TRAFFIC NOISE MODELLING USING GENETIC ALGORITHM

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CERTIFICATE

I hereby declare that the work which is being presented in the dissertation entitled " **Traffic noise modeling using Genetic Algorithm**" in partial fulfillment of the requirement for the award of the degree of MASTER OF ENGINEERING in PRODUCTION AND INDUSTRIAL ENGINEERING submitted in Department of Mechanical Engineering, Thapar University, Patiala is an authentic record of my own work carried out from July 2011 to July 2012.

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The matter embodied in this dissertation has not been submitted in part or full to any other university or institute for the award of any other degree

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ABSTRACT

The major contribution of the traffic noise, towards overall noise pollution scenario is well known established fact. Traffic noise from highways creates problems for surrounding areas, especially when there are high traffic volumes and high speeds. Vehicular traffic noise problem is contributed by various kinds of vehicles like heavy, medium trucks/buses, automobile and two wheelers.

In India, the transportation sector is growing rapidly and number of vehicles on Indian roads is increasing at very fast rate. This has lead to overcrowded roads and noise pollution. So, a need is being felt to develop a noise prediction model suitable for Indians roads condition.

A mathematical model is developed in Patiala city (Punjab) for a site at Patiala-Chandigarh highway (10 km from Thapar University). A large number of sets of data were recorded for 15 mins duration.

The noise measurement parameters to be recorded were L_{eq} (15 min). Sound level meter (CESVA SC 310) was used for these measurements.

The Developed mathematical model which can be used for predicting L_{eq}, level included the parameters such as Total vehicle volume/hr, percentage of heavy vehicles, and average speed of vehicles.

The Noise levels Leq is used in Genetic algorithm and regression analysis for prediction. It was concluded that value of R^2 ranges from 0.88 to 0.99. The paired t-test was also carried out successfully for goodness-of-fitness.

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NOMENCLATURE

SYMBOL	DESCRIPTION
L_w	Sound Power Level in Decibel
L_i	Sound intensity level (dB)
L_p	Sound pressure level (dB)
L_{eq}	Equivalent sound level (dB)
L_X	Percentile Exceeded Sound Level
L_{dn}	Day Night Average Sound level
TNI	Traffic Noise Index
NPL	Noise Pollution Level

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CHAPTER 1

Introduction

1.1 Sound is defined as any pressure variation that the ear can detect ranging from the weakest sounds to sound levels which can damage hearing. The word noise is derived from the Latin term nausea. It has been defined as unwanted sound, a potential hazard to health and communication dumped into the environment with regard to the adverse effect it may have on unwilling ears. [17]

Noise is unwanted sound. The vibration of sound pressure waves in the air produces sound. Sound pressure levels used to measure the intensity of sound are described in terms of decibels. The decibel (dB) is a logarithmic unit, which expresses the ratio of the measured sound pressure level to a standard reference level. Sound is composed of various frequencies, but the human ear does not respond to all frequencies. Frequencies to which the human ear does not respond are filtered out when measuring highway traffic noise levels. Sound level meters are usually equipped with weighting circuits, which filter out selected frequencies. The A-scale on a sound level meter best approximates the frequency response of the human ear. Sound pressure levels measured on the A-scale of a sound meter are abbreviated dB(A). In addition to noise varying in frequency, noise intensity fluctuates with time. The most common descriptor of environmental noise in the United States of America is the equivalent (energy average) sound level. The equivalent sound level is the steady state, A-weighted sound level which contains the same amount of acoustic energy as the actual time varying, A-weighted sound level over a specified period of time (see Figure 1). If the time period is one hour, the descriptor is the hourly equivalent sound level, Leq(h), which is widely used by highway agencies as a descriptor of highway traffic noise. An additional descriptor, which is sometimes used, is the L_{10}. This is simply the A-weighted sound level that is exceeded 10 percent of the time.

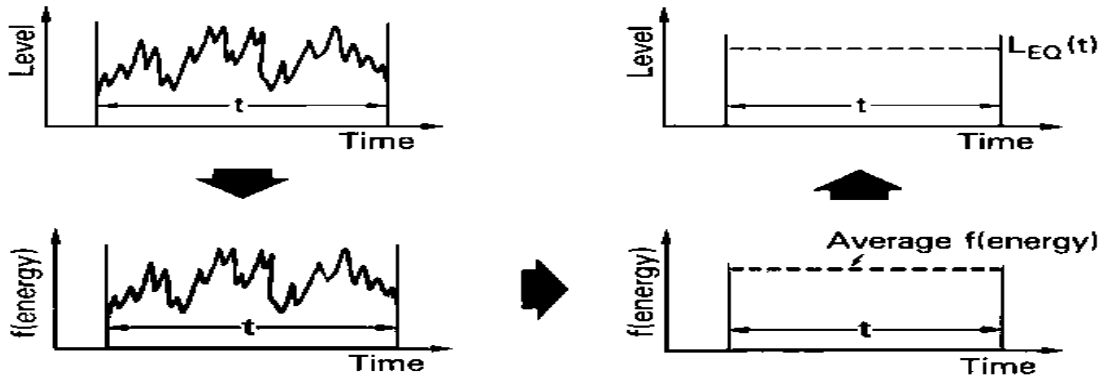

Figure 1: Conceptualizing Equivalent Sound Level, L_{eq}

1.2 CLASSIFICATION OF NOISE:

Noise may be classified as steady, non-steady or impulsive, depending upon the temporal variations in sound pressure level. The various types of noise [17]

1.2.1 Steady noise is a noise with negligibly small fluctuations of sound pressure level within the period of observation. If a slightly more precise single-number description is needed, assessment by NR (Noise Rating) curves may be used. A noise is called **non-steady** when its sound pressure levels shift significantly during the period of observation. This type of noise can be divided into intermittent noise and fluctuating noise.

1.2.2 Fluctuating noise is a noise for which the level changes continuously and to a great extent during the period of observation.

1.2.3 Tonal noise may be either continuous or fluctuating and is characterized by one or two single frequencies. This type of noise is much more annoying than broadband noise characterized by energy at many different frequencies and of the same sound pressure level as the tonal noise.

1.3 Harmful Effects

On Human Being, Animal and Property: Noise has always been with the human civilization but it was never so obvious, so intense, so varied & so pervasive as it is seen in the last of this century. Noise pollution makes men more irritable. The effect of noise pollution is multifaceted & inter related. The effects of Noise Pollution on Human Being, Animal and property are as follows:[18]

1. It decreases the efficiency of a man:- Regarding the impact of noise on human efficiency there are number of experiments which print out the fact that human efficiency increases with noise reduction. A study by Sinha & Sinha in India suggested that reducing industrial booths could improve the quality of their work. Thus human efficiency is related with noise.

2. Lack of concentration:- For better quality of work there should be concentration , Noise causes lack of concentration. In big cities, mostly all the offices are on main road. The noise of traffic or the loud speakers of different types of horns divert the attention of the people working in offices.

3. Fatigue:- Because of Noise Pollution, people cannot concentrate on their work. Thus they have to give their more time for completing the work and they feel tiring.

4. It causes Blood Pressure: - Noise Pollution causes certain diseases in human. It attacks on the person‟ s peace of mind. The noises are recognized as major contributing factors in accelerating the already existing tensions of modern living. These tensions result in certain disease like blood pressure or mental illness etc.

5. **Temporary of permanent Deafness**:- The effect of nose on audition is well recognized. Mechanics, locomotive drivers, telephone operators etc. All have their hearing. Impairment as a result of noise at the place of work. Physicist physicians & psychologists are of the view that continued exposure to noise level above. 80 to 100 db is unsafe, loud noise causes temporary or permanent deafness.

6. **Effect on vegetation:-** Poor quality of Crops:- Now is well known to all that plants are similar to human being. They are also as sensitive as man. There should be cool & peaceful environment for their better growth. Noise pollution causes poor quality of crops in a pleasant atmosphere.

7. **Effect on property:-** Loud noise is very dangerous to buildings, bridges and monuments. It creates waves which struck the walls and put the building in danger condition. It weakens the edifice of buildings.

1.4 The Decibel The decibel (dB), as used in acoustics, is a unit expressing the ratio of two quantities that are proportional to power. The decibel level is equal to 10 times the common logarithm of the power ratio;[13]

$$dB=10 \log^{P1/P2}$$

In this equation P_2 is the absolute value of the power under evaluation and P_1 is an absolute value of a power reference quantity with the same units.

When several decibel values to be added following equation should be used

$$L_{sum}= 10 \log [10^{Lp1/10}+10^{Lp2/10}+….+10^{Lp3/10}]$$

In the special case where decibel levels of equal magnitudes are to be added, the cumulative level can be determined with equation given below

$$L_{sum} = L_P + 10 \log (n)$$

Where n is the number of sources, all with magnitude Lp

Decibel Addition

As mentioned above, decibels are logarithmic units and are not added arithmetically. Table .1 provides general procedures for decibel addition. This table shows that the sound pressure level from two equal sources is 3 dB greater than the sound pressure level of just one source. So, two trucks producing 90 dB each combine to produce 93 dB, not 180 dB. In other words, a doubling of the noise source produces only a 3 dB increase in the sound pressure level. Studies have shown that this increase is barely perceptible by the human ear. [13]

Table 1 : Rules for Combining Sound Levels by "Decibel Addition"

When two decibel values differ by	Add the following amount to the higher
0 or l dB	3 Db
2 or 3 dB	2 Db
4 to 9 dB	1 dB
10 dB or more	0 Db

1.5 SOUND INTENSITY LEVEL (L_i)

- Sound intensity is sound power per unit area. Sound intensity, like sound power, is not audible. It is the sound intensity that directly relates sound power to sound pressure. Strictly speaking, sound intensity is the average flow of sound energy

through a unit area in a sound field. Sound intensity is also a vector quantity, that is, it has both a magnitude and direction. Like sound power, sound intensity is not directly measurable, but sound intensity can be obtained from sound pressure measurements.[13]

- **Definition, Sound Intensity Level.** The sound intensity level (in decibels) is defined by:

  $\mathbf{L_i = 10 \log I/I_{ref}}$

  Where I is the absolute level of the sound intensity and I_{ref} is the reference intensity. Unless otherwise stated the intensity, I, is the effective root mean square (r m s) sound intensity .

1.6 SOUND POWER LEVEL

The sound power level, L_w (or PWL), may be defined as follows:[13]

$\mathbf{L_w = 10 \log_{10}}$ **(sound intensity)/(ref.sound intensity)** (dB)

The internationally agreed reference power is 10-12 W. Again, the following convenient form is obtained when the reference sound power is introduced into the above equation:

$L_W = 10 \log_{10} W + 120$ (dB)

The lowest sound level that people of excellent hearing can discern has an acoustic sound power about 10^{-12} W, 0 dB

The loudest sound generally encountered is that of a jet aircraft with a sound power of 10^5 W, 170 dB.

1.7 Sound Sources

Sound sources can be classified as follows:

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

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

1.7.3 Plane Source: A plane source can be described as follows. If a piston source is constrained by hard walls to radiate all its power into an elemental tube to produce a plane wave, the tube will contain a quantity of energy numerically equal to the power output of the source. In the ideal situation there will be no attenuation along the tube. Plane sources are very rare and only found in duct systems.

1.8 Propagation of sound: Sound is a sequence of waves of pressure that propagates through compressible media such as air or water. (Sound can propagate through solids as well, but there are additional modes of propagation). During propagation, waves can be reflected, refracted, or attenuated by the medium.

The behavior of sound propagation is generally affected by three things [17]

- A relationship between density and pressure. This relationship, affected by temperature, determines the speed of sound within the medium.
- The propagation is also affected by the motion of the medium itself. For example, sound moving through wind. Independent of the motion of sound through the medium, if the medium is moving, the sound is further transported.
- The viscosity of the medium also affects the motion of sound waves. It determines the rate at which sound is attenuated. For many media, such as air or water, attenuation due to viscosity is negligible.

1.8.1 Sound Field Definitions [20]

1.8.1.1 Free-field = the space around the source where there are no reflections or disturbance of the sound waves

• SPL and intensity drop by 6 dB as distance from the source doubles

• SPL measurements should be made in the free-field

1.8.1.2 Near-field = the space close (the smaller of: 2x largest dimension of source or the wavelength of lowest frequency component) to the source

• SPL measurements in the near field are not reliable, because small changes in position can result in big differences in reading scan.

1.8.1.3 Reverberant field = The space around the source where reflections from walls and other objects significantly disturb the sound waves from the source

1.9 Characteristics of sound [20]

1.9.1 Loudness

At the threshold of hearing, a noise is just "loud" enough to be detected by the human ear. Above that threshold, the degree of loudness is a subjective interpretation of sound pressure level or intensity of the sound.

The loudness level of a sound is determined by adjusting the sound pressure level of a comparison pure tone of specified frequency until it is judged by normal hearing observers to be equal in loudness. Loudness level is expressed in **phons**, which have the same numerical value as the sound pressure level at 1000 Hz. Attempts have been made to introduce the **sone** as the unit of loudness designed to give scale numbers approximately proportional to the loudness, but it has not been used in the practice of noise evaluation and control[18]

1.9.2 Pitch

Pitch is the subjective response to frequency. Low frequencies are identified as "low-pitched", while high frequencies are identified as "high-pitched". As few sounds of ordinary experience are of a single frequency (for example, the quality of the sound of a musical instrument is determined by the presence of many frequencies other than the fundamental frequency), it is of interest to consider what determines the pitch of a complex note. If a sound is characterized by a series of integrally related frequencies (for example, the second lowest is twice the frequency of the lowest, the third lowest is three times the lowest, etc.), then the lowest frequency determines the pitch [19]

1.9.3 A-Weighted Sound Pressure (dBA)

A-weighted sound pressure is “corrected” to more closely resemble the hearing characteristics of the human ear. The human ear approximates the A-weighted curve in the 20 to 30 dB range. At these low sound levels, the ear has relatively poor sensitivity to low frequency sound. Table.2 shows the adjustments for A-weighted sound with the very large adjustments in the lower frequency bands. There is also Band C-weighted sound data, which is meant for louder sound levels.

These sound levels are not as common as A-weighted values. A-weighted sound criteria are most commonly used in outdoor sound evaluations. It is often used in city building codes when referencing the maximum acceptable sound pressure levels at the property line. It is popular because it is a single number that most sound meters include.

Table.2 A-Weighted Octave Band Adjustments

BAND	63	125	250	500	1000	2000	4000	8000
ADJUSTMENT	-26	-16	-9	-3	0	1	1	-1

1.9.4 Frequency Weighting [19]

The human ear is not equally sensitive to sound at different frequencies. To adequately evaluate human exposure to noise, the sound measuring system must account for this difference in sensitivities over the audible range. For this purpose, frequency weighting networks, which are really "frequency weighting filters" have been developed. These networks "weight" the contributions of the different frequencies to the **over-all sound level**, so that sound pressure levels are reduced or increased as a function of frequency before being combined together to give an overall level. Thus, whenever the weighting networks are used in a sound measuring system, the various frequencies which constitute the sound contribute differently to the evaluated over-all sound level, in accordance with the given frequency's contribution to the subjective loudness of sound, or noise. The two internationally standardised weighting networks in common use are the "A" and "C", which have been built to correlate to the frequency response of the human ear for different sound levels.

The "A" network modifies the frequency response to follow approximately the equal loudness curve of 40 phons, while the "C" network approximately follows the equal

loudness curve of 100 phons, respectively. A "B" network is also mentioned in some texts but it is no longer used in noise evaluations.

The popularity of the A network has grown in the course of time. It is a useful simple means of describing interior noise environments from the point of view of habitability, community disturbance, and also **hearing damage**, even though the C network better describes the loudness of industrial noise which contributes significantly to hearing damage. Its great attraction lies in its direct use in measures of **total noise exposure.**

When frequency weighting networks are used, the measured noise levels are designated specifically, for example, by dB(A) or dB(C).

Alternatively, the terminology A-weighted sound level in dB or C-weighted sound level in dB are often preferred.

If the noise level is measured without a "frequency-weighting" network, then the sound levels corresponding to all frequencies contribute to the total as they actually occur. This physical measurement without modification is not particularly useful for exposure evaluation and is referred to as the linear (or unweighted) sound pressure level. [19]

1.9.5 Background Noise [19]

It is important to separate the background noise from the noise produced by the source itself

- Measure SPL with source on
- Measure SPL without source
- Subtract readings
  - If less than 3 dB, questionable accuracy
  - If 3 db < ΔSPL < 10 dB, correct the reading
  - If ΔSPL > 10 dB, no correction is needed

1.9.6 Masking

Masking is the phenomenon of one sound interfering with the perception of another sound. For example, the interference of traffic noise with the use of a public telephone on a busy street corner is probably well known to everyone.

In general, it has been shown that low frequency sounds can effectively "mask" high frequency sounds even if they are of a slightly lower level. This has implications for warning sounds which should be pitched at lower frequencies than the dominant background noise,

but not at such a low frequency that the frequency response of the ear causes audibility problems. Generally frequencies between about 200 and 500 Hz are heard most easily in the presence of typical industrial background noise, but in some situations even lower frequencies are needed. If the warning sounds are modulated in both frequency and level, they are even easier to detect. [19]

1.9.7 Threshold of hearing

The response of the human ear to sound or noise depends both on the sound frequency and the sound pressure level. Given sufficient sound pressure level, a healthy, young, normal human ear is able to detect sounds with frequencies from 20 Hz to 20,000 Hz.

1.9.8 Equivalent Sound Level – L_{eq}

Very often, noise levels fluctuate or vary randomly with time, as in case with factory and community noise. The correct representation of noise level in this kind of situation is given by the equivalent continuous level, L_{eq} measured in dB (A).The L_{eq} level is a measure of the energy content of the noise over the measurement period.

Equivalent Sound Level – L_{eq} - can be expressed as

$$L_{eq} = 10 \log [(1/T) \int pA^2 \, dt/pref^2]$$

1.9.9 SOUND EXPOSURE LEVEL (SEL)

It is defined as the L_{eq} value referred for one second, is useful for comparing individual noise event of different duration.

1.9.10 NOISE DOSE [19]

The noise dose is variant of L_{eq} measurement for which the measurement time is fixed at eight hours. The only difference between noise dose and 8 hr $L_{eq\ is}$ that noise dose is expressed as a percentage of the allowable daily exposure, 100% corresponds to an L_{eq} level of 90 dB(A) for 8 hours.

1.10 SOUND LEVEL METER

Many types of measuring systems can be used for the measurement of sound depending on the purpose of the study, the characteristics of sound and the extent of information that is desired about the sound. The various elements in a measuring system are:

a. the transducer; that is, the microphone;

b. the electronic amplifier and calibrated attenuator for gain control;

c. the frequency weighting or analyzing possibilities;

d. the data storage facilities;

e. the display.

Not all elements are used in every measuring system. The microphone can, for instance, be connected to a sound level meter or directly to a magnetic tape recorder for data storage and future measurement or reference. An example of the components of the sound level meter is shown in Figure

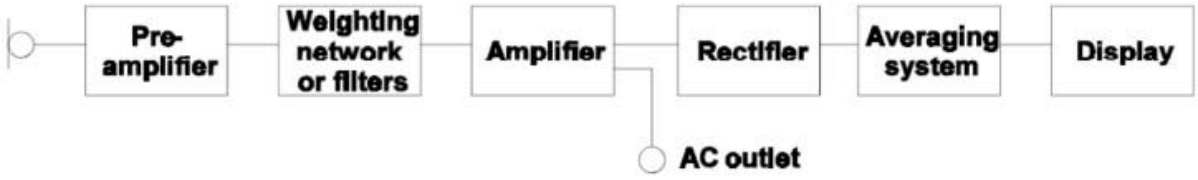

Fig.2 Sound level meter block diagram

The two main characteristics are:

1. The frequency response: that is, the deviation between the measured value and the true value as a function of the frequency. As the ear is capable of hearing sounds between 20 Hz and 20kHz, the frequency response of the sound level meter should be good, with variations smaller than 1 dB, over that range.

2. The dynamic range: that is, the range in dB over which the measured value is proportional to the true value, at a given frequency (usually 1000 Hz). This range is limited at low levels by the electrical background noise of the instrument and at high levels by the signal distortion caused by overloading the microphone or amplifiers.

1.10.1 Description

A sound level meter is an instrument designed to measure sound pressure levels. Today such instruments can be anything from simple devices with analogue filters and detectors and a moving coil meter to advanced digital analyzers. The microphone converts the sound pressure to an electrical signal, which is amplified and passes through various filters. After this the signal is squared and averaged with a detector, and the result is finally converted to decibels and shown on a display.

1.10.2 Elements of sound level meter

1. **Microphones**: Most measurement microphones generate a voltage that is proportional to the sound pressure at the microphone and is the electrical analog of sound waves impinging on the microphone"s diaphragm. The particular mechanism that converts the pressure variation into sound waves signal. Different types of microphones are
   a. Capacitor (Condenser) Microphone
   b. Pre-polarized Microphone
   c. Piezo electric Microphone
2. **Amplifier**: It amplifies the signal from microphone sufficiently to permit measurement of low SPL. It amplifies sound over a wide frequency range. It maintains the amplifications constant.
3. **Rectifier**: It rectifies the signal from analog to digital signal.
4. **Smoothing circuit**: The circuit through which the sound waves pass.
5. **Meter**

Fig.3 Sound level meter

Steps of measurement system

1. Check the sensitivity (Calibration) of the measurement system.
2. Measure the acoustical noise level
3. Apply all necessary correction to the observed measurement.
4. Make a written record of all relevant data

Out Door Measurement use of Wind screen

Wind can be significant influence on outdoor acoustical measurement.

1. Wind effects can be minimized to protect microphones
2. Wind generated noise can be reduced significantly by

1.10.3 NOISE STANDARDS IN INDIAN ROADS [4]

Noise has been recognized as one of the unwanted by products of the industrialized society along with air, water, and other pollutants. One of the earliest noise standards available is due to the occupation safety and health act (OSHA) enacted in U.S.A in 1971 which happens to be a land mark step in the direction of environment noise control.

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.

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.

The following has 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.

Group 1	Industrial Noise Automobiles Noise Domestic Appliances Noise Public Address System Noise
Group 2	Aircraft Noise Railway Noise Construction Noise Noise from Crackers

Table 3. Sources of noise

Vehicle category	Maximum permissible sound level in dB(A)			
	1992	**1999**	**2002**	**2003**
A) Two wheelers				
Displacement upto 125cc	80	80	75	75
Displacement up to 125cc-250cc			77	77
Displacement up to 125cc-250cc			80	80
B) Three wheeler	80	80	77	77
C) Passengers Cars	82	79	74	75
D) Commercial vehicles				
Light wt up to 4 tonnes	85	82	77	80
Light wt up to 4-12 tonnes	89	86	80	83
Light wt more than 12 tonnes	91	88	82	85

Table 4.Permissible sound levels for automotive vehicles in India

1.10.4 TYPICAL TRAFFIC NOISE LEVELS

- Areas with heavy traffic or close to blaring loud speaker: 80-105 dB(A)
- Areas with over flying aircrafts: 90-100 dB(A)
- At railway stations, traffic junctions , busy markets: 70-90 dB(A)
- Residential areas close to traffic, industries and markets: 60-80 dB(A)
- Residential areas away from heavy traffic roads or other noisy sources: 40-60 dB(A)

Chapter 2

TRAFFIC NOISE

2.1 Introduction

With urbanization and corresponding increase in number of vehicles in metropolitan cities, the pollution is increasing at an alarming rate. Main areas of concern are related to air and noise pollution. More than 70% of total noise in our environment is due to vehicular noise. Noise levels are showing an alarming rise and in fact level exceeds the prescribed levels in most of the areas. Investigation in several countries in the past decades have shown that noise has adverse effect on human health, living in close proximity to busy road highway [4]

To create a healthy and noise pollution free environment a noise prediction model is needed so that the noise level along a busy highway can be predicted and investigated in advance during the planning and design process. A mathematical model for road traffic noise in urban situation making use of grid coordinates in order to measure the noise due to direct propagation, diffraction and deflection was developed (Clayden et al. 1974). Bodsworth and Lawrence investigated the contribution of heavy vehicles such as trucks and buses on the noise profile of traffic stream to urban traffic noise by showing that number of heavy vehicles play a major role in road traffic noise (Bodsworth and Lawrence 1978). A computer model for predicting noise levels generated by urban road traffic under interrupted flow conditions was developed (Radwan and Oldham 1987). Applicability of autoregressive integrated moving averages (ARIMA) modeling, a special class of time series techniques for the development forecast models of road traffic noise was investigated by Kumar and Jain in Delhi city (Kumar and Jain 1999).Traffic composition is defined as the percentage of heavy vehicles with respect to the total number of vehicles by investigating the annoyance from road traffic noise (Ouis 2001). Filho et al. investigated the effect of traffic composition on the noise generated by Brazilian roads (Filho et al. 2004). A motor traffic noise model based on the perpendicular propagation analysis technique (direction perpendicular to the centerline of motorways carriageway) is found performed well in a statistical goodness of fit test against the field data (Tansatcha et al. 2005).

2.2 TRAFFIC NOISE DESCRIPTORS [18]

2.2.1 Equivalent continuous (A-Weighted) Sound level, L_{eq}:

Equivalent continuous (A-Weighted) sound level is defined as the steady sound level that contains the same amount of acoustic energy as a fluctuating level over the prescribed period of time. Common prescribed periods are one hour , 24 hour, and day time and night time.

L_{eq}
$=10\log_{10}(1/T)_0\int^{T}[P/P_{ref}]^2$

T= Total measurement time

P= A-weighted instantaneous acoustic pressure

P_{ref} = Reference acoustic pressure=20μPa

2.2.2 Sound Exposure Level (SEL), L_{AE}: That constant level in dB(A) which, lasting for one second, has the same amount of acoustic energy as a given A-weighted noise event.

2.2.3 Day-Night Average Sound Level (DNL), L_{DN}: A 24-hour equivalent continuous level in dB(A) where 10 dB is added to nighttime noise levels from 2200 hours to 0700 hours.

2.2.4 Community Noise Equivalent Level (CNEL), L_{DEN}: A 24-hour equivalent continuous level in dB(A) where 5 dB is added to evening noise levels from 1900 hours to 2200 hours and 10 dB is added to nighttime noise levels from 2200 hours to 0700 hours.

2.2.5 Percentile Level, L_X: That noise level in dB(A) exceeded for N% of the measurement time T.

Percentile Exceeded Sound level:

L_{10} = 10 Percentile exceeded sound level

L_{90} = 90 Percentile exceeded sound level

L_{50} = 50 Percentile exceeded sound level

2.2.6 Noise Pollution Level (NPL), L_{NP}: 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

$L_{NP} = Leq, + 2{,}56\sigma dB$

Where σ is the standard deviation of the dB(A) levels.

2.2.7 Perceived Noise Level, L_{PN}: A complex rating based on one-third octave band data used to certify aircraft types for flyover noise. An approximation is given by adding 13(± 3) dB to the measured A-weighted noise level.

2.2.8 Effective Perceived Noise Level, L_{EPN}: This is the result of applying tone and duration

corrections to the perceived Noise Level based on one-third octave band data.

2.2.9 Noise Exposure Forecast, N_{EF}: A complex criteria for predicting future noise impact of airports. The computation considers the effective perceived noise level of each type of aircraft, flight profile, number of flights, time of day, etc. Generally used in plots of equal NEF contours around airports for zoning control.

2.3 Vehicle Categories [15]

For the purpose of highway traffic noise analyses, motor vehicles fall into one of five categories:

1. Automobiles - vehicles with two axles and four tires;
2. Medium trucks - all cargo vehicles with two axles and six tires;
3. Heavy trucks - all cargo vehicles with three or more axles;
4. Buses - all vehicles designed to carry more than nine passengers; and
5. Motorcycles – all vehicles with two or three tires and an open-air driver/passenger compartment

The emission levels of all five-vehicle types increase as a function of the logarithm of their speed. In other words, the highway traffic noise levels increases with increasing speed for all five vehicle types.

2.4 Variables Affecting Highway Traffic Noise

The level of highway traffic noise primarily depends on three things:[18]

1. The volume of the traffic,
2. The speed of the traffic, and
3. The number of trucks in the flow of the traffic.

Generally, heavier traffic volumes, higher speeds, and greater numbers of trucks increase the loudness of highway traffic noise. Vehicle noise is primarily a combination of the noises produced by the engine, exhaust, and tires. Defective mufflers or other faulty equipment on vehicles can increase the loudness of highway traffic noise. Any condition (such as a steep incline) that causes heavy laboring of motor vehicle engines will also increase highway traffic noise levels.

Additionally, other, more complicated factors affect the loudness of highway traffic noise. For example, as a person moves away from a highway, distance, terrain, vegetation, and natural and manmade obstacles reduce highway traffic noise levels. Highway traffic noise is

not usually a serious problem for people who live more than 500 feet from heavily traveled freeways or more than 100 to 200 feet from lightly traveled roads. In quiet settings, however, such as rural areas, people notice highway traffic noise over greater distances. Pavement type can also affect noise generated at the tire/pavement interface [14]

2.5 Vehicle Noise Characteristics [19]

Highway traffic consists of a large collection of vehicles of different types, makes and models. The relative proportion (mix) of which depends on the type of highway and the time of day, among other factors. In the assessment of highway noise by calculation it is convenient to assume that there are two main categories of vehicles. They are

- **Automobiles**
- **Heavy trucks/buses**

Automobiles are defined as transport vehicle with Gross Vehicle Wight Ratings (GVWR) of less than 4536 kg (includes the matadors, cars and three wheelers).Heavy trucks are defined as transport vehicle with Gross Vehicle Weight Ratings (GVWR) of more than 4536 kg. (Includes buses and heavy trucks)

2.6 Vehicle Noise Sources [19]

The noise produced by a vehicle is dependent on the mode of operation of the vehicle. Truck noise can be considered to be produced by two major sources. They are:

(1) **Power plant and transmission noise source**

(2) **Running gear noise sources** Power plant and transmission noise source includes engine, exhaust, intake, cooling system and drive train noise.

Running gear noise source includes the tire-road interaction, differential and propulsion shaft noise etc. Noise from the power plant increase as engine speed increases while noise from tire increases as vehicle speed increases. Truck tends to operate at a nominally constant engine speed, so that engine and exhaust noise do not vary appreciably with vehicle speed. Therefore, at lower highway speeds the engine-exhaust noise is dominant, while at higher vehicle speeds tire-pavement interaction becomes the dominant source of noise.

2.7 EFFECTS OF VARIOUS FACTORS ON TRAFFIC NOISE

Rapidly changing population patterns on the national scene and developed public expectancy

in terms of environmental effects have generated the requirement to furnish environmental impact statement is the noise that my result from the traffic noise is more complicated due to the facts that highways are not flat, straight or free from natural terrain variation. The factors like vehicle speed, density, traffic mix, width of median and number of lanes are not constant. Therefore, for traffic noise each of these parameters is taken into account.[13]. Traffic noise depends on the following factors

1. **Traffic Parameters**
   (i) Vehicle volume
   (ii) Vehicle mix
   (iii) Average speed
2. **Roadways characteristics**
   (i) Pavement width
   (ii) Flow characteristics
   (iii) Gradient
   (iv) Surface finish
3. **Observer characteristics**
   (i) Observer distance
   (ii) Element size
   (iii) Shielding
   (iv) Observer relative height

2.8 TRAFFIC PARAMETERS [13]

2.8.1 Traffic Volume, Q

The noise level near the highway depends on the number of vehicles. The noise level increases with an increase in traffic volume.

Traffic volume is defined as the total number of vehicles flowing per hour. The numbers of vehicles passing through a fixed point on the road are to be counted. The traffic volume may be sub grouped into heavy vehicles and automobiles for duration of fifteen minutes. Several

such samples are to be taken in different time slots ranging from 9.00 A.M. to 5.00 P.M.

2.8.2 Vehicle Mix

Studies have indicated that trucks and buses contribute more noise to the environment as compared to the automobile .Traffic is a mix of both of these categories and the ratio is computed in term of percentage. It has been observed that for very values of this ratio, traffic noise is controlled by automobile traffic whereas an increase in the ratio will increase the noise level

2.8.3 Average speed

In a study of urban traffic it was observed that for vehicles traveling within a limited range of road speeds, the noise produced is related to the engine which in turn varies with each vehicle type. It was further observed that, although the main body of traffic stream was travelling at a particular road speed, many vehicles were either accelerating or decelerating when passing the measurement position.

Thus, it was concluded that the inclusion of a term for average road speed for vehicles in the urban area becomes meaningless. However the effect of average road speed on noise levels has been elaborated upon in coming section

2.9 Roadway Characteristics [1]

Flow characteristics

The fundamental law of traffic flow states that

Flow (vehicles/hr)= Concentration(vehicles/mix) x Speed (mph)

In practice, when the number of vehicles on the road is not sufficiently large to influence the choice of driving speeds, it is found that, although individual vehicles can cover a wide of speeds, the majority have a narrow speed distribution, with effectively contant average value so that is directly proportional to concentration. The inverse of concentration is the spacing of successive vehicles, known as headway.

At distances greater than about a quarter of the vehicles headway, mean sound level decreases basically at rate of 3 dB per doubling of distances and increases 3 dB per doubling of flow. Close to the roadway, over distances that are small compared to vehicle headway, mean sound level is independent of distances but increase 6 dB per doubling of flow, while maximum sound level decrease 6 dB per doubling of distances but is independent of flow

2.9.1 Gradient[3]

The effect of gradient on traffic noise is complex because the multiple sources that constitute motor vehicular noise vary in many and sometimes opposite ways e.g. for an upgrade condition, engine noise of heavy truck increases significantly [3]. At the same time the speed drops and so does tire noise. Therefore, to determine the effect of gradient, tire noise has to be separated from other noise sources. On the other hand, gradient has little influence on the noise of automobiles. The positive adjustment to account for the increased noise of trucks on gradients is showing in following table

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

Table 5. Adjustment to trucks noise levels for various road gradients

2.10 Observer Characteristics

2.10.1 Equivalent Distance from Roadways, D_E

Traffic noise diminishes from the source at the rate of 3 to 4.5 dB (A) per doubling of distance on ground cover. Noise levels are computed on the basis of a single equivalent lane located at

$D_E = \sqrt{D_N D_F}$ in meters

Where, D_N and D_F are observer distance to the Centre of the near and far lanes respectively.

2.10.2 Shielding

Three types of shielding namely barriers, structures and plantation are considered. The attenuation effect of a solid, acoustically opaque roadside barrier is quite pronounced (up to 15 d B A) but if the entire roadway element under consideration is not shielded, its effectiveness is reduced. The presence of buildings or structures can have an attenuating effect of 3 to 5 d B per row of houses and this attenuation should not exceed a maximum of 10 dB. Plantation, like bushes, trees and similar foliage can attenuate sound only if the

growth is dense enough and depth of the foliage is great. A design value of 5 d B reduction for every 100ft of depth may be used.[19]

2.10.3 Observer relative height

The vertical displacement of an at gated roadway to a position below (depressed) or above (elevated) ground level provides a certain degree of acoustic shielding of the vehicular noise sources from the observation position .On the basis of Galloway" s measurement for the above case, Maekawa"s curves were modified to represent adequately the acoustical performance of the respective geometries as regards automobile traffic noise.[16]

CHAPTER 3

LITERATURE REVIEW

A lot of time and effort has been devoted to analyze and predict road traffic noise and develop certain mathematical models. The recognition of road traffic noise as one of the main sources of environmental pollution has led to develop models that enable to predict noise level from fundamental variables. Traffic noise prediction models are required as aids for designing roads and highways. From a long time, work is continued in this field. Some important works are as follows

Johnson and Saunders [1] described road side surveys of the noise emitted by freely flowing traffic on sites ranging from motorways to urban roads. Sites were generally unobstructed but a few tests were made in places with buildings adjacent to the roadway. The survey also included measurements on two sites involving road gradients. The results provide an indication of present day traffic noise conditions against which future comparisons may be made and also show how basic variables such as traffic density, speed and composition, and distance from roadside affect the observed patterns of noise. Agreement between the experimental data and theoretical analysis of simplified traffic flow forms the basis of a method for predicting the median Sound level produced under any given set of traffic conditions. The reliability of the method, provided that due allowance is made for possible ground attenuation effects, is demonstrated using the results of the survey.

Masaru, K et al. [2] have given a scale model for noise reduction by an acoustic barrier of a straight line source. From the experimental results a curve can be deduced which shows a relation between sound attenuation and Fresnel number

Bolt Berank, et al. [3] developed noise model for free flowing traffic. They have shown that,

1) Propagation loss varies from 3 dB per doubling of distance to 4.5 dB per doubling of distances depending on the ground cover.

2) The truck noise is omni directional of 0° to 45° in the plane normal to the vehicle motion.

3) The noise is correlated with number of axles and speed of the truck.

Bjorkman M [4] reviewed certain field investigations which have shown that the correlation between the extent of annoyance due to road traffic noise and the noise dose expressed in Leq is rather poor. A higher correlation was found when the expression of the noise dose was based upon the maximum noise level (MNL) from the single noisiest event. To determine the relation between Leq and MNL according to different principles, 24-h measurements were made for a period of 5 days in 18 streets with various types of traffic noise exposure. Analyses were made of the variation in MNL during different times of day and of the correlation between MNL during different times of day and of the correlation between MNL and other noise indices. Leq, and MNL during day, evening and night were not related. It is suggested that investigations be performed focusing on the extent of annoyance in streets with similar Leq values where the MNL for day, evening and night is different.

Kumar Krishan et al [5] carried out a survey of traffic noise in the city of Delhi in order to examine the nature and levels of noise inside various types of vehicle. The study involved measurements of average A weighted levels and power spectra of noise inside buses, auto-rickshaws, cars and trucks from which L10, L50, L90 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 fall four types of vehicle exhibit rather similar behavior.

Campbell Steele [6] has presented a review of various traffic noise prediction models in the 1950s and 1960s were designed to predict a single Vehicle sound pressure level Lp at the roadside. These models were based on constant speed experiments, the predicted levels then being expressed as functions of speed, and with zero acceleration. Later models were not intended to predict single vehicle levels but to predict the equivalent continuous level L_{eq} for traffic over a chosen period. Still later models predicted L_{eq} under interrupted and varying flow conditions. Early models predicted linear levels whereas the later models predicted A-weighted levels. Several more recent models predict one-third octave and spectra. Early models assumed single point sources, some assumed short line sources, later ones double point, and even one with thirty-two point sources; some with different spectra. Six commonly used models and others under development were reviewed

Bengang Li et al [7] have developed suitable road traffic noise prediction model for use in China. This model is based on local environmental standards, vehicle types and traffic conditions. The model was accurate to 0.8 dBA at locations near the road carriage way and 2.1 dBA within the housing estate, which is comparable to the FHWA model. An integrated noise-GIS system was developed to provide general functions for noise modeling and an additional tool for noise design, Application of this system offered improvements in the efficiency and accuracy of traffic noise assessment and noise design.

Calixto Alfredo et al [8] discussed a study of the problem of traffic noise on roads which have been transformed into big avenues in the city of Curitiba. Noise levels are measured and the impacts suffered by the community documented. Around the main roads inside the urban perimeter of Curitiba, simultaneous measurements were done regarding noise levels, vehicle flow and traffic composition and thus some mathematical models have been developed in order to estimate those sound pressure levels. The measured levels compared with the calculated ones obtained from the mathematical model and the German Standard RLS-90 as well. The validity of the mathematical models was confirmed, as well as the applicability of the calculation method adopted by the German Standard RLS-90. Finally, the mean traffic noise levels around those roads and the noise limits of the municipal law 8583/1995 were examined and it was confirmed that people living or working in these areas are exposed to noise levels beyond the legislated norms.

O.Gundogdu et al [9] investigated the effect of traffic composition on the noise pollution in a small city Erzurum, located in eastern Turkey, where the population is about 400,000. Manual noise measurements and vehicle counts were performed at the four heaviest traffic points in the city for a period of 12 h. Using the information on vehicle composition and the maximum legal noise emissions of each type of vehicles, two prediction models based on genetic algorithms have been developed that can be used as tools for in-city traffic flow redesign.

Banerjee D et al [10] evaluates factors that significantly influence the equivalent road traffic noise level, L_{eq} and develops models for the industrial town of Asansol, India. The study shows that L_{eq} values are mainly influenced by the hourly traffic volume. Day time data reveals a stronger relationship than night data. Principal component analysis was also used to identify dominating variables affects L_{eq}.

Banerjee et al [11] presented the objectives of the study were to monitor and assess the road traffic noise in its spatial temporal aspect in an urban area. The paper discusses the observations, results and their interpretation based on the study. Noise recordings from site, collected from April 2006 to March 2006, were used for statistical analysis and generation of various noise indices. Noise maps were also created for impact analysis and formulation of Noise Risk Zones. Mean L_{dn} value ranged between 55.1 and 87.3 dB (A). Day time L_{eq} level ranged between 51.2 and 89.0 dB (A), where it ranged between 43.5 and 81.9 dB (A) during night. The study reveals that present noise level in all the locations exceeds the limit prescribed by CPCB. Based on the finding it can be said that the population in this industrial town are exposed to significantly high noise level, which is caused mostly due to road traffic.

Pamanikabuda et al [12] presented a report to build a highway traffic noise simulation model for free-flow traffic conditions in Thailand employing a technique utilizing individual vehicular noise modeling based on the equivalent sound level over 20 s (L_{eq} 20 s). This L_{eq} 20 s technique provides a more accurate measurement of noise energy from each type of vehicle under real running conditions. The coefficient of propagation and ground effect for this model was then estimated using a trial-and-error method, and applied to the highway traffic noise simulation model. This newly developed highway traffic noise model was tested for its goodness-of-fit to field observations. The test shows that this new model provides good predictions for highway noise conditions in Thailand. The concepts and techniques that are modeled and tested in this study can also be applied for prediction of traffic noise for local conditions in other countries.

Dae Seung Cho [13] presented an investigation on the effects of vehicles and pavement surface types on noise at the Korea Highway Corporation"s Test Road along the southbound side of the Jungbu Inland Expressway, South Korea. The study was conducted in 2005 and 2006 through field measurements at nine surface sections of asphalt concrete and Portland cement concrete pavements using eleven vehicles. For the road noise analysis, the sound power levels (PWLs) of combined noise (e.g., tire/pavement interaction noise and power- train noise together) and tire/pavement interaction noise using various vehicles were

calculated based on the novel close proximity (NCPX) and pass-by methods. Then, the characteristics of the PWLs were evaluated according to surface type, vehicle type, and vehicle speed. The results show that the PWLs of vehicles are diversely affected by vehicle speed and the condition of the road surface.

Claudio guarnaccia [14] presented a study on acoustical noise produced by vehicular traffic depends on many parameters, including the geometry and the general features of the road. The presence of a conflicting point, i.e. an intersection, strongly affects and modifies the simulation strategy of noise in urban environments that is usually performed with statistical models tuned on experimental data related to standard condition (free flow traffic, intermediate vehicular volumes, etc.). In this paper, the author presents the analysis of an intersection case study in proximity of Salerno University, performed by means of experimental measurements and software simulations. The chosen area presents interesting features because of the priority rights on the principal road and because of the relevant amount of vehicles and buses, mainly due to the University students and personnel that transit in the intersection, especially during rush hours.

S. Rahmani et al [15] developed two models for predicting in-city road-traffic noise pollution of Mashhad has been obtained. Traffic volume, composition, and speed have been chosen as model" s parameters. Vehicles were classified into light cars and medium and heavy trucks. Reference emission level of each group was determined experimentally based on perpendicular propagation from central lane of traffic road. Simultaneous measurements of noise level and vehicle flow and composition were done. Two mathematical models have been proposed by the use of genetic algorithms which can be used for calculating L_{eq}. These models have been validated against noise data. Subsequently, measured traffic noise has been compared with calculated Ones, using developed models, and a relatively good agreement has been obtained among them. The models are found accurate within ±1% and can be used for flat road noise prediction.

Gordon and Galloway et al [16] have predicted a relation for mean noise level with randomly spaced vehicles by developing the Monte Carlo simulation model. Instantaneous noise levels are computed for a succession of random vehicle distribution. Propagation loss and complex road geometry are included.

CHAPTER 4

Genetic Algorithm

4.1. Introduction

Noise contamination owing to transportation in cities is one of the most important environmental health consequences that must be solved. Traffic noise is one of the significant sources of the noise in cities compared to the other sources such as industrial noise, airport noise and community noise. It will be a larger and serious social problem in the future if effective precautions are not taken accordingly. Investigations in different countries in the past several decades have shown that noise affect different activities badly and cause sleep disturbances and a poorer life quality. Therefore, there is an essential need to control the noise induced by transportation in cities.[15]

Traffic noise can be either measured or predicted in the case of noise pollution management. Since the noise measurements are complicated and time consuming, and moreover impossible at the design stage, traffic noise prediction models are required means in designing new highways and other roads or redesigning traffic flow in existing roads to have comfortable traffic noise conditions. In the last few years, a number of prediction tools have been created to estimate noise levels in several countries. For instance, GIS based road traffic noise prediction model was developed for use in China by Li et al. [7]. Calixto et al. [8] from Brazil developed a statistical model to estimate road traffic noise in an urban setting. A detailed discussion on some early and six recent traffic noise prediction models (such as FHWA and STAMINA used in United States and CoRTN in United Kingdom) can be found in the review by Steele [6]. Commonly used variables taken into account in the course of prediction tool development were traffic flow in terms of vehicle per hour, traffic speed, traffic composition by heavy truck percentage, road gradient, road surface, etc. The present study was conducted initially to determine the noise level on Patiala – Chandigarh Highway and rate its seriousness. Subsequently, a simple yet useful prediction method was developed to estimate the noise, giving a special emphasis to the contributions of the type of vehicles in the total pollution. Genetic algorithms (GA) were used in the optimization of the objective functions minimizing the squared error between the observed

and computed data.[9]

4.2 Genetic Algorithm

Genetic algorithms, mostly referred to as GAs, are one of the optimization methods finding wide application in optimization problems. Genetic algorithm searches stochastically through the real space of problem by generating some of the potential solutions, which is named as initial population. This method is one kind of evolution-based systems that measures the fitness of each individual in population, and then selects the fittest individuals until reproducing the intermediate population. Recombinant genetic operators affect some individuals in this population and produce the next population for the new generation. The GA could optimize linear and nonlinear objective functions by exploring the space
of problem and exponentially exploiting promising areas through selection, crossover, and mutation operations applied to individuals in the population [15]. In evolution language, the individual is named as chromosome and every variable in each individual is termed as the gene. A common GA that is used for optimization problems contains the following steps [15]:

Step 1. Initialization: Initial population is randomly generated in the feasible space and design variable domain as defined chromosomes. Because of simplicity of Gaussian uniform distribution, it is used as an usual method for creating the initial population. Moreover, the population size must be set by user.[15]

Step 2. Representation: Now, each chromosome should be represented in binary codes (0 and 1) or float numbers. However, the more natural representations are further efficient and produce better candidates for problem solutions, but the type of representation depends on problem and varies from a case to another. For the float representation, each variable belongs to each gene of chromosome, but in binary form, each variable is represented by several genes dependant on required precision and domain of each variable. (1)

Step 3. Evaluation: From the stochastic viewpoint, the fitness function, which evaluates each individual in population set, is independent of the GA operations while depending on minimization, and maximization problem could map the population into specified form .

Step 4. Selection: There are different types of selection process for the GA, which is categorized as roulette wheel selection, scaling techniques, tournament and ranking selections

. In the roulette wheel after calculation of a cumulative probability (qi) for each individual (*vi*), random numbers from the domain [0, 1] are generated. Since each random number is located between two consequent cumulative probabilities, the greater one is selected for new population. Unlike the roulette wheel, the tournament selection is used for minimizing. This type of selection randomly chooses two chromosomes from the population, selects the better one, and sends into the sampling pool. Till the completion of the population size of individuals in sampling pool, this method repeats. The stochastic uniform selection function, as scaling technique, lays out a line in which each parent corresponds to a section of the line of length proportional to its scaled value. The algorithm moves along the line in steps of equal size. At each step, the algorithm allocates a parent from the section it lands on. The first step is a uniform random number less than the step size. However, in all selection methods one or several individuals with the best fitness value(s) should be kept as elitism(s) and should be copied without change in next generation.

Step 5. Genetic operation: Crossover and mutation are two essential parts of genetic operation. By using crossover probability (pc), two individuals as parents for mating pool are selected and their two new children are produced while one chromosome randomly by mutation probability (pm) undergoes mutation to produce new one. For the binary system, the uniform mutation and single or two-point crossover are defined. Moreover, for the float representation, the arithmetic crossover, scattered crossover, single or two-point crossover, intermediate crossover, and Heuristic crossover with uniform mutation, non-uniform mutation, multi non- uniform mutation, and boundary mutation are also used.

Step 6. Termination: There are several strategies to stop the GA, which the most prevalent one is the maximum number of generations. Improvement of solutions from one generation to the next and limitation of time and fitness value are other stopping criteria.
Based on the advantages and limitations of genetic algorithm, it could be realized when genetic algorithm should be applied for optimization problems.

Parallelism (solve the problem by several chromosomes), wide solution space, complexity of fitness function, discover the global optimum, using as multi-objective function, without gradient complexity and just using function evaluations the GA is easily modified for different problems. Moreover it handles noisy functions well and is resistant to becoming trapped in local optima. But it should be considered that the GA has some limitations like

identifying fitness function, definition of representation, premature convergence, problem of choosing the various parameters like the size of the population, mutation rate, cross over rate, the selection method and number of elites and sometimes needs to be coupled with a local search technique [15]

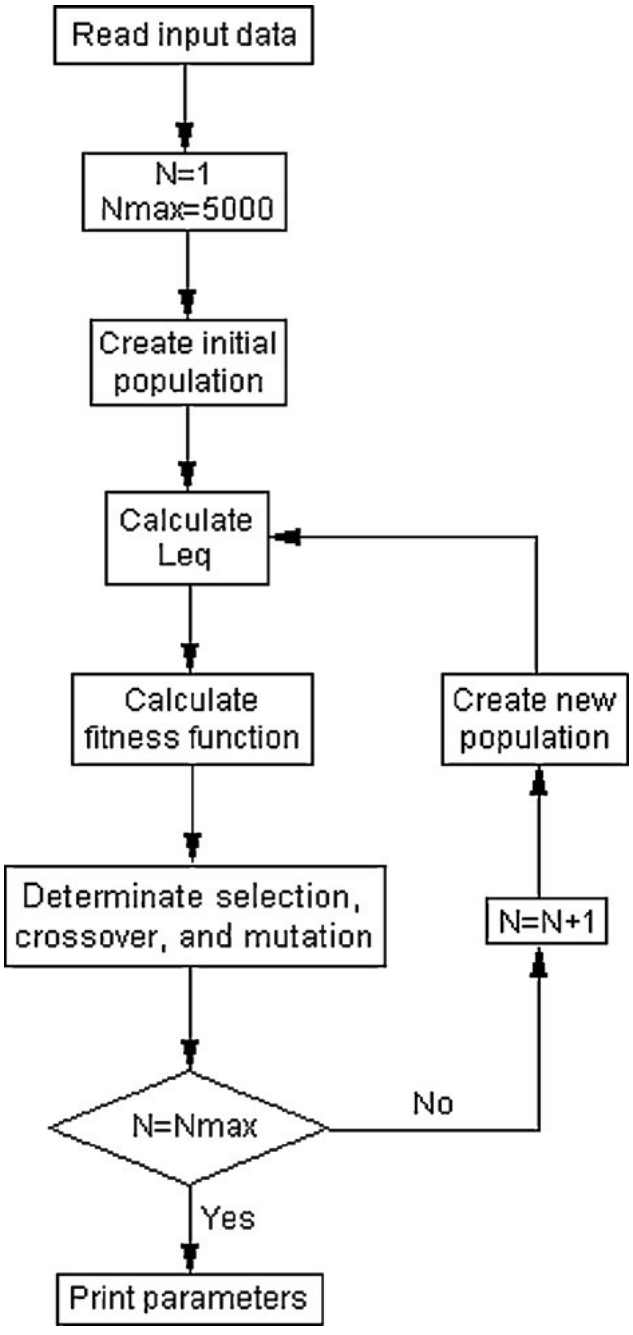

Fig 4 Flow chart of used GA program. [9]

CHAPTER 5
EXPERIMENTAL INVESTIGATION

5.1 NATURE OF PROBLEM

Traffic noise prediction models are required as aids in the design of roads and sometimes used in the assessment of existing or envisaged changes in traffic noise conditions. They are commonly needed to predict sound pressure levels, specified in terms of L_{eq} . For Traffic modeling model based on Genetic Algorithm is developed for experimental data from variables such as traffic flow, speed of vehicles etc. A survey of the area revealed that major contribution to the noise is from traffic with substantially high percentage of heavy vehicles. The average speed of the vehicles was found within range of 60-80 km/h. The noise was aggravated by the indiscriminate horn blowing, rapid acceleration and old vehicles which produces more noise due to their ill fated condition.

5.2 SITE SELECTION

To develop mathematical model for predicting the traffic noise, the first task was site selection. So, according to surveys of different areas and nature of noise problem , a two lane straight patch where continuous flow of vehicles occurs, without any obstruction like traffic signal etc was selected at Patiala – Chandigarh Highway (10 km from Thapar University), Patiala. This is the two lane straight patch with continuous flow of vehicles, a reasonably flat open area, free from large reflecting surfaces, such as parked vehicles, signs, buildings and any obstructions like traffic signal lights etc.

5.3 SITE LAYOUT

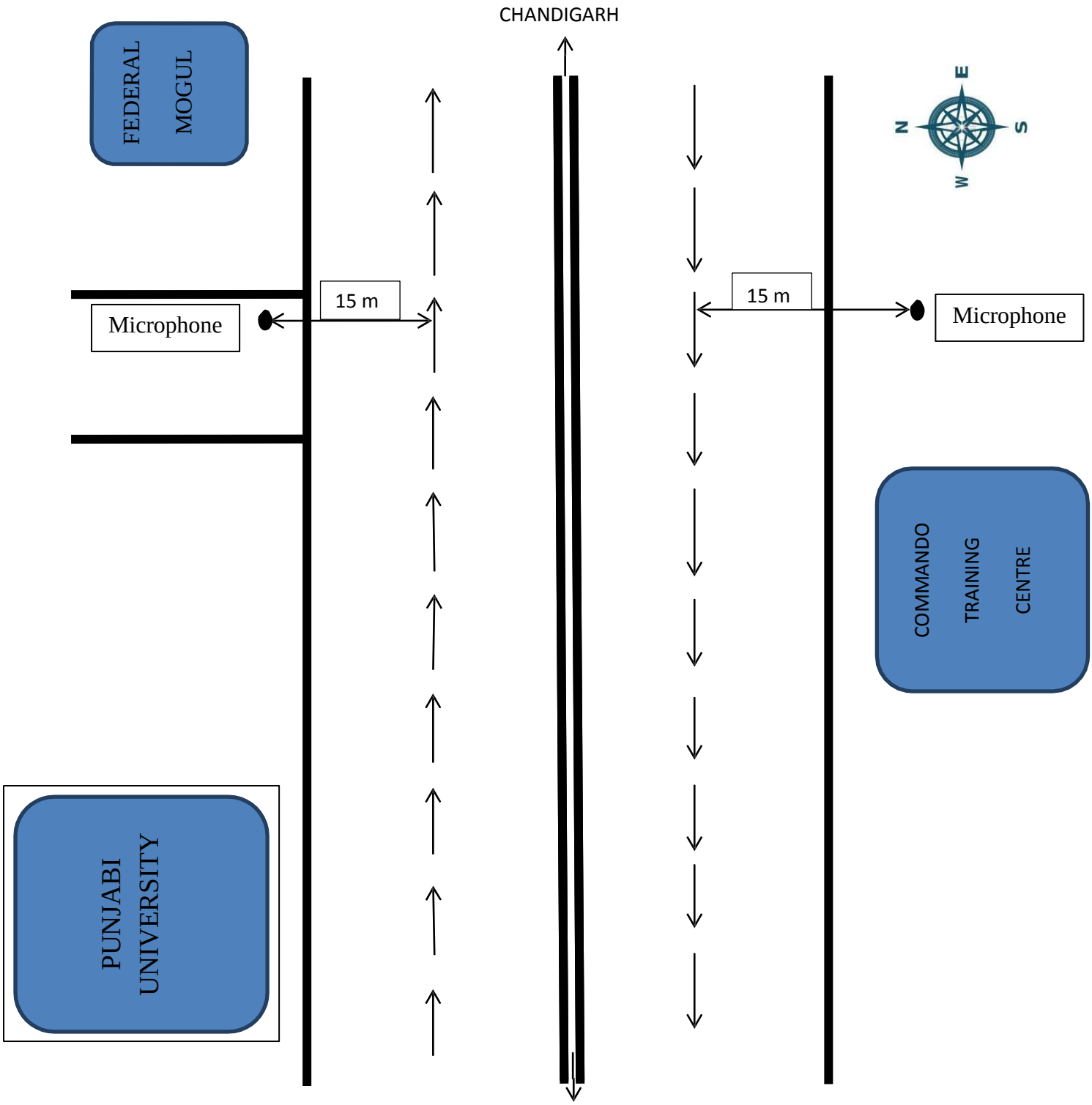

Fig.5 Site layout

5.4 Definition of problem

Today, because of the rapid development in the transportation sector, the number of vehicles on the Indian roads is increasing at a very fast rate. This leads to overcrowded roads and noise pollution that generate environment problem which inflicts serious damage to the health of human beings and lowers their labor productivity. Therefore, the control of traffic noise has become a matter of major concern for communities trying to maintain a satisfactory environment in which to live and work. So for the control of the traffic noise, first it should be fully understood. It is basically generated because of two major sources

· **Power plant and transmission noise source (**includes engine, exhaust, intake, cooling system and drive train noise.)

· **Running gear noise sources (**includes the tire-road interaction, differential and propulsion shaft noise etc.)

Several factors like type of roads, vehicle type, traffic mix, driving behavior, traffic flow, percentage of heavy vehicle, average speed, Pavement width, Surface finish, Observer distance, Shielding and many more which contribute their effect to the traffic noise. No comparable advances have been made in many countries based on different highway noise descriptors and traffic noise parameters, but the highway noise descriptors, L_{eq} (in North America, Continental Europe is increasingly being used for quantitative assessment of nuisance associated with traffic noise. Further these models are unreliable for predicting highway noise in India because of different traffic condition and traffic characteristics.

This study is thus aimed to develop a more relevant and accurate free-flow traffic noise prediction model for highway in India, taking Patiala (Punjab) city as a representative city, based on Leq and as noise descriptors and traffic flow, percentage of heavy vehicle, average speed as traffic noise parameters. A large number of sets of data were recorded for 1 hr. duration on different dates and timings in a random or staggered manner in order to account for statistical temporal variations in traffic flow characteristics. To fulfill the above objective, Genetic algorithm approach has been applied for traffic noise modeling in the present study. The measured parameter is L_{eq} (output parameters) and input parameters (vehicle volume/hr., percentage of heavy vehicles and average vehicle speed) and further the input parameters are randomly distributed for initialization to evaluate fitness function. The prediction capability of G.A was checked for the given testing set of input parameters. A comparison is also made between experimental and G.A output parameters.

5.5 Methodology

The methods described here concern only open field measurements, the main goal of which is to measure, at a certain number of points in a given area, the noise levels due to road traffic.

Measurements are made mainly for the following reasons:

1. To determine noise levels in an area so as to identify undesired situations,
2. To compare background variations in noise levels,
3. To compare noise levels before and after road construction
4. To estimate the effectiveness of the anti noise measures implemented

Location, measurement times, and the methods selected depend on purpose and scope e.g , when a large must be evaluated , the selection of measurement durations and survey points greatly affects the significance of the result obtained.

Noise measurement is a difficult process, and so some precautions must be taken for the precision and reliability of the measurements. These precautions are as follow:

- Using proper testing procedures and methods
- Checking instruments regularly
- Calibrating instruments before and after use
- Making sure that instruments are not affected by weather conditions
- Recording weather conditions during testing (wind speed, humidity etc) with a view to accepting or rejecting the results.
- Avoid making measurements under exceptional conditions(rains, snow . fog)

The “A” Weighting network which is now used almost exclusively is designed to follow the response of the human ear at low sound levels. For traffic noise measurements at a suitable site systematic noise monitoring was done during May 2012 - June 2012 using Sound Level Meter (Cesva SC-310).The sound level meter has been suitably calibrated. The microphone mounted on a tripod has been suitably level with air bubble. The SLM was mounted at a

height of 1.2 meter above the ground level and was located a distance of 15 m from the center of the road lane. Continuous data was recorded with Sound Level Meter during daytime from 9.00 A.M to 5.00 P.M at the selected site. The noise descriptors L_{eq}, is measured for 15 min. duration in dB (A) weighting with slow response. Besides noise monitoring vehicles counts and vehicle speed, temperature were also measured continuously.

Fig 6: Sound level meter with screens and tripod

5.6 SOUND LEVEL METER

For accurate data, the sound level meter should be kept at a constant calibration.

The sound level meter consists of the following elements:

1. Transducer to sense the sound wave pressure and convert it into electrical voltage.
2. An input amplifier to raise the electrical signal.
3. A calibrated attenuator to adjust the amplification.
4. An indicating meter to display the measured level.

5. Weighting network to modify the frequency characterization of the instrument response.
6. An output amplifier and calibrated output attenuator.
7. Wind screen.

5.6.1 Measurement of L_{eq}(15 min) hourly

To determine the distribution of noise level the L_{eq} . The following steps may be employed. Step 1 Place the sound level meter near the highway.

Once the instrument is placed on the tripod then it is reset. Other parameters are initializes in the instrument as follow

Time weighting - „Slow"

Frequency weighting - „A"

Displayed parameters - L_{10},L_{50},L_{90},L_{eq},L_{max},L_{min} Step

2 Attach the wind screen to microphone

Step 3 Mount the sound level meter on the tripod

Step 4 Set the preset time for 15 min

After the time period of 15 min is over, the readings of L_{eq} are taken from the sound level meter

Measurements

Data was measured at the selected site as per the described procedure.

Measured Parameters are:

Traffic volume

Traffic volume (number of vehicles passed during the measurement interval) was measured during the measurement period. Vehicles are categorized into 7 different types (Appendix-A) taking into account the Indian conditions.

Measurements for the 15 min. interval were repeated on different dates and timings in order to account for statistical temporal variations in traffic flow characteristics and hourly data for Leq has been calculated by taking the average of 4 readings of 15 minutes period and for traffic flow by addition of these 4 readings.

Average speed of vehicles

Average speed of vehicles was also measured with manual method by measuring the time taken by the vehicle to travel 100m distance.

Noise descriptors (L_{eq},) The noise descriptors L_{eq}, is displayed on the SLM screen and were recorded in SLM memory

Site: Patiala-Chandigarh (Both Lanes)

Measurement period: 1 hour

Microphone at 15m from centre of the lane & at height of 1.2 m

Table 6 Measured Values

Time	Traffic Vol. Q (Veh/h)	Heavy vehicles P (%)	Avg. vehicle speed V (km/h)	Sound pressure level dB (A) L_{eq}
Monday 28/5/12				
10:00 to 11:00	1308	28.5	42.9	74.5
11:15 to 12:15	1413	31.7	48.1	75.9
12:30 to 13:30	1391	32.2	51.5	76.1
13:40 to 14:40	1400	31.4	49.7	75.9
15:00 to 16:00	1419	31.9	50.4	76.4
16:10 to 17:10	1442	32.8	50.7	76.4
Tuesday 29/5/12				
9:30 to 10:30	1378	32.4	50.7	75.9
10:40 to 11:40	1483	32.4	53.7	77.4
12:00 to 13:00	1512	35.2	57.8	77.8
13:15 to 14:15	1621	36.4	61.5	79.1
14:30 to 15:30	1589	39.1	60.9	78.9
15:40 to 16:40	1564	38.7	60.7	78.7
Wednesday 30/5/12				
10:00 to 11:00	1318	26.1	45.3	74.9
11:15 to 12:15	1403	31.4	49.5	76.4
12:30 to13:30	1446	33.8	52.5	76.9
13:40 to 14:40	1505	35.6	53.3	77.3
15:00 to 16:00	1403	30.1	49.1	75.9
16:15 to 17:15	1554	37.3	58.4	78.1
Thursday 31/5/12				
10:00 to 11:00	1420	32.9	51.9	76.1
11:15 to 12:15	1468	33.9	50.4	76.7
12:30 to13:30	1480	32.9	52.7	77.2
13:40 to 14:40	1532	37.5	58.2	78.3
15:00 to 16:00	1543	35.6	56.5	78.5
16:15 to 17:15	1605	39.9	60.2	79.2
Friday 1/6/12				
10:00 to 11:00	1363	28.7	46.5	75.7
11:10 to 12:10	1483	32.8	52.8	77.3
12:15 to 13:15	1480	31.4	53.6	76.9
13:20 to 14:20	1502	34.9	55.8	77.9
14:45 to 15:45	1556	34.4	56.2	78.1
16:00 to 17:00	1496	36.7	53.2	77.5

Time	Traffic Vol. Q (Veh/h)	Heavy vehicles P (%)	Avg. vehicle speed V (km/h)	Sound pressure level dB (A) L_{eq}
Saturday 2/6/12				
9:30 to 10:30	1425	33.6	50.6	76.4
10:40 to 11:40	1603	39.5	60.8	79
12:00 to 13:00	1343	29.3	47.5	75.3
13:15 to 14:15	1622	39.9	60.1	79.3
14:20 to 15:20	1483	36.8	56.2	77.6
15:30 to 16:30	1722	42.5	65.1	80.7
Monday 4/6/12				
10:00 to 11:00	1587	38.2	59.8	78.5
11:15 to 12:15	1502	35.8	57.8	77.7
12:30 to13:30	1549	35.3	54.9	77.9
13:40 to 14:40	1352	29.5	46.2	75.4
15:00 to 16:00	1488	32.4	53.6	76.9
16:15 to 17:15	1472	33.8	53.8	77.2
17:30 to 18:30	1657	40.4	61.6	79.7
Tuesday 5/6/12				
9:30 to 10:30	1465	32.2	53.3	77.1
10:40 to 11:40	1450	31.2	51.3	76.8
12:00 to 13:00	1550	37.6	56.2	78.1
13:15 to 14:15	1563	37.5	57.4	78.5
14:30 to 15:30	1681	43.5	66.6	80.6
15:40 to 16:40	1623	39.4	61.5	79.4
16:50 to 17:50	1646	39.9	62.3	80.1
Wed 6/6/12				
9:00 to 10:00	1352	29.7	48.6	75.4
10:10 to 11:10	1500	34.1	53.3	77.2
11:20 to 12:20	1545	35.3	58.5	78.2
13:30 to 14:30	1578	38.3	59.8	79.0
14:45 to 15:45	1615	36.8	59.7	79.1
16:00 to 17:00	1650	39.2	64.3	80.1
17:10 to 18:10	1610	39.1	60.8	79.4
Thursday 7/6/12				
10:00 to 11:00	1479	31.6	52.9	76.9
11:15 to 12:15	1579	36.3	59.3	78.5
12:30 to13:30	1506	34.7	53.7	77.6
13:40 to 14:40	1521	37.6	57.1	78.1
15:00 to 16:00	1554	37.1	57.4	78.5
16:15 to 17:15	1531	37.4	58.6	78.3
17:30 to 18:30	1609	37.4	60.3	79.3

Time	Traffic Vol. Q (Veh/h)	Heavy vehicles P (%)	Avg. vehicle speed V (km/h)	Sound pressure level dB (A) L_{eq}
Friday 8/6/12				
9:30 to 10:30	1336	29.6	46.6	75.3
10:40 to 11:40	1367	28.7	48.5	75.8
12:00 to 13:00	1456	33.6	51.3	76.9
13:15 to 14:15	1443	31.3	49.7	76.3
14:20 to 15:20	1609	40.4	62.2	79.4
15:30 to 16:30	1484	35.1	52.4	77.2
Sat 9/6/12				
10:00 to 11:00	1408	33.1	49.7	76.3
11:15 to 12:15	1670	40.1	63.9	80.1
12:30 to13:30	1609	38.9	62.4	79.5
13:40 to 14:40	1368	29.2	49.6	75.7
15:00 to 16:00	1479	33.2	54.5	77.1
16:15 to 17:15	1500	34.4	54.4	77.8
17:30 to 18:30	1535	36.7	55.5	78.2
Monday 11/6/12				
10:00 to 11:00	1348	29.9	47.1	75.5
11:15 to 12:15	1481	34.5	51.9	77.1
12:30 to13:30	1502	34.6	56.6	77.5
13:40 to 14:40	1563	37.2	55.1	78.1
15:00 to 16:00	1573	35.5	56.5	78.5
16:15 to 17:15	1543	35.7	57.8	78.2
Tuesday 12/6/12				
10:00 to 11:00	1513	36.7	54.7	77.9
11:15 to 12:15	1430	30.9	50.1	76.4
12:30 to13:30	1573	35.8	58.9	78.3
13:40 to 14:40	1363	31.9	47.8	75.8
15:00 to 16:00	1442	34.7	53.8	76.8
16:15 to 17:15	1538	34.5	58.2	78.1
Wed 13/6/12				
9:30 to 10:30	1392	31.5	48.1	75.9
10:40 to 11:40	1474	31.1	51.8	76.9
12:00 to 13:00	1442	32.5	52.7	76.5
13:15 to 14:15	1475	33.6	54.9	77.5
14:20 to 15:20	1527	33.9	56.3	77.8
15:30 to 16:30	1529	34.7	57.7	78.2
16:40 to 17:40	1691	39.7	65.2	80.1

Time	Traffic Vol. Q (Veh/h)	Heavy vehicles P (%)	Avg. vehicle speed V (km/h)	Sound pressure level dB (A) L_{eq}
Thursday 14/6/12				
9:00 to 10:00	1471	33.5	53.5	76.9
10:10 to 11:10	1413	29.9	48.3	76.1
11:20 to 12:20	1509	33.3	53.6	77.7
13:30 to 14:30	1566	37.7	56.1	78.2
14:45 to 15:45	1540	35.2	57.8	77.8
16:00 to 17:00	1497	34.9	56.2	77.7
17:10 to 18:10	1679	41.1	64.9	80.1
Friday 15/6/12				
9:00 to 10:00	1443	32.9	48.6	76.3
10:10 to 11:10	1405	32.1	51.8	76.4
11:20 to 12:20	1519	34.9	57.6	78.1
13:30 to 14:30	1518	36.1	55.5	77.7
14:45 to 15:45	1530	34.6	54.6	77.8
16:00 to 17:00	1518	35.7	58.5	78.1
17:10 to 18:10	1451	32.4	51.3	76.8
Sat 16/6/12				
9:00 to 10:00	1551	36.6	57.7	78.1
10:10 to 11:10	1509	35.9	57.4	77.8
11:20 to 12:20	1447	33.9	50.3	76.5
13:30 to 14:30	1517	37.8	57.2	78.0
14:45 to 15:45	1518	34.3	57.2	77.9

Summary

Temperature (range): 32-43° C

(A) Duration of data collection- 28/05/2012 to 16/06/2012
(B) No. of days ------ 18
(C) 5 hours per day (total days) -------1
(D) 6 hours per day (total days) -------9
(E) 7 hours per day (total days) ------ 8
(F) Total data collection hours ------115

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 Mathematical modeling

General equation for calculation and prediction of hourly equivalent noise level was proposed as below:

$L_{eq}= P_1(p,q,v)+P_2$

Where P_1 and P_2 are constant and can be calculated from Genetic algorithm code.

Where P is % of heavy vehicles, q is traffic flow per hour, V is average vehicle speed L_{eq} is A-weighted hourly equivalent noise level (dB)A,

To find out values of $P_1$and P_2 the above linear equations are used. The optimized values were found as from the genetic algorithm code in MATLAB [20] using a population size with a string length of 115.

Simulation

Using MATLAB software, a computer program based on GA has been written for optimizing models proposed. The objective function, by GA literature fitness function, was the minimization of mean square error:

$$\mathrm{E} = \sum_{i=1}^{n} (L_i - L_{eq,i})^2$$

Where L_i and $L_{eq,i}$ are measured and calculated noise levels.

Following is the G.A Code by which the values of P_1 and P_2 are found

```
load('noise_data')

%////////////// for p ////////////////////////////////
combine=[v leq];
% p1=0.3714;
% p2=64.66;
% for i=1:length(combine)
%     leq new=p(i) * p1 + p2;
%     combine(i,3)=leq_new;
```

```
%     diff_leq=combine(i,2)-combine(i,3);
%     combine(i,4)=diff_leq;
% end
%////////////////////////////////////////////////////////
xq=combine(:,2);
yq=p;
all_pts=[xq yq];
%/////////////// implimenting ga for predicting p1 and p2/////
chromosomes=1000;
generations=10000;
%////////////// randomly initilizing chromosomes ////////////
current_pts1=randint(1,chromosomes,[round(min(xq))    round(max(xq))]);
current_pts2=randint(1,chromosomes,[round(min(xq))    round(max(xq))]);

last_dist=inf;
for i=1:generations
    dist_mat=[];
    for k=1:length(current_pts1)
        current_pt1=current_pts1(k);
        current_pt2=current_pts2(k);

        current_p1=[current_pt1 min(yq)];
        current_p2=[current_pt2 max(yq)];

        m=(current_p1(1)-current_pt2(1))/(current_p1(2)-current_p2(2));
        A=1;
        B=-1 * m;
        C=(m*current_p2(2))-current_p2(1);

        distance=0;
        for j=1:length(all_pts)
            d=abs((A*all_pts(j,1) + B*all_pts(j,2) + C))/sqrt(A.^2 +B.^2);
            distance=distance+d;
        end
        dist_mat=[dist_mat;current_p1  current_p2 distance];

    end
    dist_mat=sortrows(dist_mat,5);
    if(last_dist>dist_mat(1,5))
        dummy=dist_mat(1:length(dist_mat)/2,:);
        dist_mat((length(dist_mat)/2)+1:end,:)=dummy;

        last_gud_pts=dist_mat(1:(length(dist_mat)/2),:);
        last_dist=dist_mat(1,5)
    else
        dist_mat((length(dist_mat)/2)+1:end,:)=last_gud_pts;
    end
combine_pt1=[dist_mat(1,1) dist_mat(1,3)];
        combine_pt2=[dist_mat(1,2) dist_mat(1,4)];

        figure(1)
        plot(xq,yq,'*r')

title(strcat('generation:',num2str(i),'____P1:',num2str(m),'_____P2:',num
2str(-1 * C)))
       % axis([0 100 0 100]);
        hold on;

        line(combine_pt1,combine_pt2)
        p1=m;
```

```
        p2=-1 * C;
        min_vi=min(v);
        max_vi=max(v);
        leq_min=p1*min_vi+p2;
        leq_max=p1*max_vi+p2;

        combine_pt1=[leq_min leq_max];
        combine_pt2=[min_vi max_vi];
         line(combine_pt1,combine_pt2)

        hold off
        drawnow

        a=randint(chromosomes,1,[-10 10]);
        b=randint(chromosomes,1,[-10 10]);
        if(i<500)
            a=a/100;
            b=b/100;
        elseif(i>500 && i<1000)
            a=a/1000;
            b=b/1000;
        else
            a=a/100000;
            b=b/100000;
        end
        current_pts1=dist_mat(:,1)+a;
        current_pts2=dist_mat(:,3)+b;

%         p1=1/m
%         p2=min(yq)-(current_pt1/m)

        p1_1=m
        p2_1=current_pt1-(m*min(yq))
end
```

From above code the values of P_1 and P_2 were found and substituted in equation 1,2,3 for p,q,v respectively.

$L_{eq}=P_1(p)+P_2$.....(1) where$P_1=0.36894$ and $P_2=64.7949$
$L_{eq}=P_1(q)+P_2$.....(2) where $P_1=0.014508$ and $P_2=55.785$
$L_{eq}=P_1(v)+ P_2$.....(3) where $P_1=0.25454$ and $P_2=63.5801$

Therefore, the equation formed after substituting the above values are given below.

$L_{eq}= 0.36894(p) + 64.7949$
$L_{eq}=0.014508(q) + 55.785$
$L_{eq}=0.25454(v) + 63.5801$

6.2 REGRESSION ANALYSIS OF DATA

Very often in practice a relationship is found to exist between two or more variables. When this relationship is to be expressed in mathematical form by determining an equation connecting the variables, following steps are followed:

Step 1

Collect the data showing corresponding values of variables in tables 6

Step 2

Plot the graphs

L_{eq} Vs P, L_{eq} Vs V, L_{eq} Vs Q , L_{eq} Vs Log V, L_{eq} Vs Log P, L_{eq} Vs Log Q, L_{eq} Vs $\sqrt[3]{P}$, L_{eq} Vs $\sqrt{v}$

From the scatter diagram it is possible to visualize a nature of relationship between variables shown in Fig (7-14)

Step 3

The problem of curve fitting can be carried out using multiple linear regression analysis by software method using 'StatPro'. By regression analysis mathematical equation for L_{eq} can be developed. Computer output of regression analysis is shown in Tables (7-15).

A t-paired test is also applied to test the model for goodness of fit. Output for t-test is also shown in Tables (7-15).

The results obtained by G.A programming and regression analysis are compared in the table below.

Table.7 Genetic algorithm output & Regression analysis output with Q as an independent variable

Sr No.	Measured L_{eq}(dB)A	Predicted L_{eq} with G.A (dB)A	% Error	Predicted L_{eq} with Regression(dB)A	% Error
1.	74.5	74.8	-0.3	74.7	-0.2
2.	75.9	76.3	-0.4	76.3	-0.4
3.	76.1	76.0	0.1	75.9	0.2
4.	75.9	76.1	-0.2	76.1	-0.2
5.	76.4	76.4	0.0	76.3	0.1
6.	76.4	76.7	-0.3	76.7	-0.3
7.	75.9	75.8	0.1	75.7	0.2
8.	77.4	77.3	0.1	77.3	0.1
9.	77.8	77.7	0.1	77.7	0.1
10.	79.1	79.3	-0.2	79.3	-0.2
11.	78.9	78.8	0.1	78.9	0.0
12.	78.7	78.5	0.2	78.5	0.2
13.	74.9	74.9	0.0	74.8	0.1
14.	76.4	76.1	0.3	76.1	0.3
15.	76.9	76.8	0.1	76.7	0.2
16.	77.3	77.6	-0.3	77.6	-0.3
17.	75.9	76.1	-0.2	76.1	-0.2
18.	78.1	78.3	-0.2	78.3	-0.2
19.	76.1	76.4	-0.3	76.4	-0.3
20.	76.7	77.1	-0.4	77.1	-0.4
21.	77.2	77.3	-0.1	77.2	0.0
22.	78.3	78.0	0.3	78.0	0.3
23.	78.5	78.2	0.3	78.2	0.3
24.	79.2	79.1	0.1	79.1	0.1
25.	75.7	75.6	0.1	75.5	0.2
26.	77.3	77.3	0.0	77.3	0.0
27.	76.9	77.3	-0.4	77.2	-0.3
28.	77.9	77.6	0.3	77.6	0.3
29.	78.1	78.4	-0.3	78.4	-0.3
30.	77.5	77.5	0.0	77.5	0.0
31.	76.4	76.5	-0.1	76.4	0.0
32.	79	79.0	0.0	79.1	-0.1
33.	75.3	75.3	0.0	75.2	0.1
34.	79.3	79.3	0.0	79.3	0.0
35.	77.6	77.3	0.3	77.3	0.3
36.	80.7	80.8	-0.1	80.8	-0.1
37.	78.5	78.8	-0.3	78.8	-0.3
38.	77.7	77.6	0.1	77.6	0.1
39.	77.9	78.3	-0.4	78.3	-0.4
40.	75.4	75.4	0.0	75.3	0.1
41.	76.9	77.4	-0.5	77.4	-0.5
42.	77.2	77.1	0.1	77.1	0.1

43.	79.7	79.8	-0.1	79.9	-0.2
44.	77.1	77.0	0.1	77.0	0.1
45.	76.8	76.8	0.0	76.8	0.0
46.	78.1	78.3	-0.2	78.3	-0.2
47.	78.5	78.5	0.0	78.5	0.0
48.	80.6	80.2	0.4	80.2	0.4
49.	79.4	79.3	0.1	79.4	0.0
50.	80.1	79.7	0.4	79.7	0.4
51.	75.4	75.4	0.0	75.3	0.1
52.	77.2	77.5	-0.3	77.5	-0.3
53.	78.2	78.2	0.0	78.2	0.0
54.	79	78.7	0.3	78.7	0.3
55.	79.1	79.2	-0.1	79.2	-0.1
56.	80.1	79.7	0.4	79.8	0.3
57.	79.4	79.1	0.3	79.2	0.2
58.	76.9	77.2	-0.3	77.2	-0.3
59.	78.5	78.7	-0.2	78.7	-0.2
60.	77.6	77.6	0.0	77.6	0.0
61.	78.1	77.9	0.2	77.8	0.3
62.	78.5	78.3	0.2	78.3	0.2
63.	78.3	78.0	0.3	78.0	0.3
64.	79.3	79.1	0.2	79.1	0.2
65.	75.3	75.2	0.1	75.1	0.2
66.	75.8	75.6	0.2	75.6	0.2
67.	76.9	76.9	0.0	76.9	0.0
68.	76.3	76.7	-0.4	76.7	-0.4
69.	79.4	79.1	0.3	79.1	0.3
70.	77.2	77.3	-0.1	77.3	-0.1
71.	76.3	76.2	0.1	76.2	0.1
72.	80.1	80.0	0.1	80.0	0.1
73.	79.5	79.1	0.4	79.1	0.4
74.	75.7	75.6	0.1	75.6	0.1
75.	77.1	77.2	-0.1	77.2	-0.1
76.	77.8	77.5	0.3	77.5	0.3
77.	78.2	78.1	0.1	78.1	0.1
78.	75.5	75.3	0.2	75.3	0.2
79.	77.1	77.3	-0.2	77.3	-0.2
80.	77.5	77.6	-0.1	77.6	-0.1
81.	78.1	78.5	-0.4	78.5	-0.4
82.	78.5	78.6	-0.1	78.6	-0.1
83.	78.2	78.2	0.0	78.2	0.0
84.	77.9	77.7	0.2	77.7	0.2
85.	76.4	76.5	-0.1	76.5	-0.1
86.	78.3	78.6	-0.3	78.6	-0.3
87.	75.8	75.6	0.2	75.5	0.3
88.	76.8	76.7	0.1	76.7	0.1
89.	78.1	78.1	0.0	78.1	0.0
90.	75.9	76.0	-0.1	75.9	0.0
91.	76.9	77.2	-0.3	77.2	-0.3
92.	76.5	76.7	-0.2	76.7	-0.2
93.	77.5	77.2	0.3	77.2	0.3

94.	77.8	77.9	-0.1	77.9	-0.1
95.	78.2	78.0	0.2	78.0	0.2
96.	80.1	80.3	-0.2	80.4	-0.3
97.	76.9	77.1	-0.2	77.1	-0.2
98.	76.1	76.3	-0.2	76.3	-0.2
99.	77.7	77.7	0.0	77.7	0.0
100.	78.2	78.5	-0.3	78.5	-0.3
101.	77.8	78.1	-0.3	78.1	-0.3
102.	77.7	77.5	0.2	77.5	0.2
103.	80.1	80.1	0.0	80.2	-0.1
104.	76.3	76.7	-0.4	76.7	-0.4
105.	76.4	76.2	0.2	76.1	0.3
106.	78.1	77.8	0.3	77.8	0.3
107.	77.7	77.8	-0.1	77.8	-0.1
108.	77.8	78.0	-0.2	78.0	-0.2
109.	78.1	77.8	0.3	77.8	0.3
110.	76.8	76.8	0.0	76.8	0.0
111.	78.1	78.3	-0.2	78.3	-0.2
112.	77.8	77.7	0.1	77.7	0.1
113.	76.5	76.8	-0.3	76.8	-0.3
114.	78	77.8	0.2	77.8	0.2
115.	77.9	77.8	0.1	77.8	0.1

The following are the linear equation for L_{eq} with q as an independent variable

Regression equation	**L_{eq}=55.376+0.014772(q)**
G.A equation	**L_{eq}=55.785+0.014508(q)**

The results of the t-test are given in the table below:

t-Test: Paired Two Sample for Means For G.A output		
	L_{eq} (dB)A	**G.A Output**
Mean	77.56869565	77.5789176
Variance	1.743221968	1.634264722
Observations	115	115
Pearson Correlation	0.985925376	
Hypothesized Mean Difference	0	
df	114	
t Stat	-0.493845517	
P(T<=t) one-tail	0.311182722	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	0.622365445	
t Critical two-tail	1.980992234	

t-Test: Paired Two Sample for Means For Regression output		
	L_{eq} (dB)A	Regression output
Mean	77.56869565	77.56869565
Variance	1.743221968	1.694496906
Observations	115	115
Pearson Correlation	0.985925376	
Hypothesized Mean Difference	0	
df	114	
t Stat	-6.00337E-14	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	1	
t Critical two-tail	1.980992234	

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.985925376
R Square	0.972048848
Adjusted R Square	0.971801493
Standard Error	0.221712105
Observations	115
	Coefficients
Intercept	55.3767954
q	0.014772933

Table 8. Genetic algorithm output & Regression analysis output with "P" as an independent variable.

Sr No.	Measured L_{eq}(dB)A	Predicted L_{eq} with G.A (dB)A	% Error	Predicted L_{eq} with Regression(dB)A	% Error
1.	74.5	75.3	-1.1	76.4	-0.5
2.	75.9	76.5	-0.8	76.6	-0.5
3.	76.1	76.7	-0.8	76.3	-0.4
4.	75.9	76.4	-0.6	76.5	-0.1
5.	76.4	76.6	-0.2	76.9	-0.5
6.	76.4	76.9	-0.6	76.7	-0.8
7.	75.9	76.7	-1.1	76.7	0.7
8.	77.4	76.7	0.8	77.7	0.1
9.	77.8	77.8	0.0	78.2	0.9
10.	79.1	78.2	1.1	79.2	-0.3
11.	78.9	79.2	-0.4	79.0	-0.3
12.	78.7	79.1	-0.5	74.4	0.5
13.	74.9	74.4	0.6	76.3	0.1
14.	76.4	76.4	0.0	77.2	-0.3
15.	76.9	77.3	-0.5	77.9	-0.6
16.	77.3	77.9	-0.8	75.9	0.0
17.	75.9	75.9	0.0	78.5	-0.4
18.	78.1	78.6	-0.6	76.9	-0.8
19.	76.1	76.9	-1.1	77.3	-0.6
20.	76.7	77.3	-0.8	76.9	0.3
21.	77.2	76.9	0.3	78.6	-0.3
22.	78.3	78.6	-0.4	77.9	0.6
23.	78.5	77.9	0.7	79.5	-0.3
24.	79.2	79.5	-0.4	75.3	0.4
25.	75.7	75.4	0.4	76.9	0.4
26.	77.3	76.9	0.5	76.3	0.6
27.	76.9	76.4	0.7	77.6	0.3
28.	77.9	77.7	0.3	77.4	0.7
29.	78.1	77.5	0.8	78.3	-0.8
30.	77.5	78.3	-1.1	77.1	-0.7
31.	76.4	77.2	-1.0	79.3	-0.3
32.	79	79.4	-0.5	75.6	-0.3
33.	75.3	75.6	-0.4	79.5	-0.2
34.	79.3	79.5	-0.3	78.3	-0.7
35.	77.6	78.4	-1.0	80.4	0.3
36.	80.7	80.5	0.3	78.8	-0.3
37.	78.5	78.9	-0.5	78.0	-0.3
38.	77.7	78.0	-0.4	77.8	0.1
39.	77.9	77.8	0.1	75.6	-0.2
40.	75.4	75.7	-0.4	76.7	0.2
41.	76.9	76.7	0.2	77.2	0.0
42.	77.2	77.3	-0.1	79.7	0.0
43.	79.7	79.7	0.0	76.6	0.5
44.	77.1	76.7	0.6	76.3	0.5
45.	76.8	76.3	0.6	78.6	-0.5

46.	78.1	78.7	-0.7	78.6	-0.1
47.	78.5	78.6	-0.2	80.8	-0.2
48.	80.6	80.8	-0.3	79.3	0.1
49.	79.4	79.3	0.1	79.5	0.6
50.	80.1	79.5	0.7	75.7	-0.3
51.	75.4	75.8	-0.5	77.3	-0.1
52.	77.2	77.4	-0.2	77.8	0.4
53.	78.2	77.8	0.5	78.9	0.1
54.	79	78.9	0.1	78.3	0.8
55.	79.1	78.4	0.9	79.2	0.9
56.	80.1	79.3	1.1	79.2	0.2
57.	79.4	79.2	0.2	76.4	0.5
58.	76.9	76.5	0.6	78.1	0.4
59.	78.5	78.2	0.4	77.6	0.0
60.	77.6	77.6	0.0	78.6	-0.5
61.	78.1	78.7	-0.7	78.4	0.1
62.	78.5	78.5	0.0	78.5	-0.2
63.	78.3	78.6	-0.4	78.5	0.8
64.	79.3	78.6	0.9	75.7	-0.4
65.	75.3	75.7	-0.6	75.3	0.5
66.	75.8	75.4	0.5	77.1	-0.2
67.	76.9	77.2	-0.4	76.3	0.0
68.	76.3	76.3	-0.1	79.7	-0.3
69.	79.4	79.7	-0.4	77.7	-0.5
70.	77.2	77.7	-0.7	77.0	-0.7
71.	76.3	77.0	-0.9	79.5	0.6
72.	80.1	79.6	0.6	79.1	0.4
73.	79.5	79.1	0.4	75.5	0.2
74.	75.7	75.6	0.2	77.0	0.1
75.	77.1	77.0	0.1	77.4	0.4
76.	77.8	77.5	0.4	78.3	-0.1
77.	78.2	78.3	-0.2	75.8	-0.3
78.	75.5	75.8	-0.4	77.5	-0.4
79.	77.1	77.5	-0.5	77.5	0.0
80.	77.5	77.6	-0.1	78.5	-0.4
81.	78.1	78.5	-0.5	77.8	0.7
82.	78.5	77.9	0.8	77.9	0.3
83.	78.2	78.0	0.3	78.3	-0.4
84.	77.9	78.3	-0.6	76.2	0.2
85.	76.4	76.2	0.3	78.0	0.3
86.	78.3	78.0	0.4	76.5	-0.7
87.	75.8	76.6	-1.0	77.6	-0.8
88.	76.8	77.6	-1.0	77.5	0.6
89.	78.1	77.5	0.7	76.4	-0.5
90.	75.9	76.4	-0.7	76.2	0.7
91.	76.9	76.3	0.8	76.7	-0.2
92.	76.5	76.8	-0.4	77.1	0.4
93.	77.5	77.2	0.4	77.3	0.5
94.	77.8	77.3	0.6	77.6	0.6
95.	78.2	77.6	0.8	79.4	0.7

96.	80.1	79.4	0.8	77.1	-0.2
97.	76.9	77.2	-0.3	75.8	0.3
98.	76.1	75.8	0.4	77.0	0.7
99.	77.7	77.1	0.8	78.7	-0.5
100.	78.2	78.7	-0.6	77.7	0.1
101.	77.8	77.8	0.0	77.6	0.1
102.	78.2	77.6	0.8	79.9	0.2
103.	80.1	79.4	0.8	76.9	-0.6
104	76.9	77.2	-0.3	76.6	-0.2
105.	76.1	75.8	0.4	77.6	0.5
106.	77.7	77.1	0.8	78.1	-0.4
107.	78.2	78.7	-0.6	77.5	0.3
108.	77.8	77.8	0.0	77.9	0.2
109.	77.7	77.7	0.0	76.7	0.1
110.	80.1	80.0	0.2	78.3	-0.2
111.	76.3	76.9	-0.8	78.0	-0.2
112.	76.4	76.6	-0.3	77.3	-0.8
113.	78.1	77.7	0.5	78.7	-0.7
114.	77.7	78.1	-0.5	77.4	0.5
115.	77.8	77.6	0.3	75.2	0.5

The following are the linear equation for L_{eq} with p as an independent variable.

Regression equation	**L_{eq}=64.6249+0.37236(p)**
G.A equation	**L_{eq}=64.7949+0.36894(p)**

The results of the t-test are given in the table below:

t-Test: Paired Two Sample for Means for G.A output		
	L_{eq}(dB)A	**G.A Output**
Mean	77.59561404	77.63983737
Variance	1.674582363	1.474748305
Observations	114	114
Pearson Correlation	0.937477883	
Hypothesized Mean Difference	0	
df	113	
t Stat	-1.048368044	
P(T<=t) one-tail	0.148353099	
t Critical one-tail	1.658450217	
P(T<=t) two-tail	0.296706197	
t Critical two-tail	1.981180296	

t-Test: Paired Two Sample for Means for regression output		
	L_{eq}(dB)A	**Regression output**
Mean	77.5687	77.57510747
Variance	1.743222	1.507181249
Observations	115	115
Pearson Correlation	0.147501	
Hypothesized Mean Difference	0	
df	114	
t Stat	-0.0413	
P(T<=t) one-tail	0.483566	
t Critical one-tail	1.65833	
P(T<=t) two-tail	0.967132	
t Critical two-tail	1.980992	

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.939045
R Square	0.881806
Adjusted R Square	0.88076
Standard Error	0.455918
Observations	115
	Coefficients
Intercept	64.62492
p	0.372366

Table.9 Genetic algorithm output & Regression analysis output with "V" as an independent variable.

Sr No.	Measured L_{eq}(dB)A	Predicted L_{eq} with G.A (dB)A	% Error	Predicted L_{eq} with Regression(dB)A	% Error
1.	74.5	74.5	0.0	74.4	0.1
2.	75.9	75.8	0.1	75.8	0.1
3.	76.1	76.7	-0.8	76.7	-0.6
4.	75.9	76.2	-0.4	76.2	-0.3
5.	76.4	76.4	0.0	76.4	0.0
6.	76.4	76.5	-0.1	76.5	-0.1
7.	75.9	76.5	-0.8	76.5	-0.6
8.	77.4	77.2	0.2	77.2	0.2
9.	77.8	78.3	-0.6	78.3	-0.5
10.	79.1	79.2	-0.2	79.3	-0.2
11.	78.9	79.1	-0.2	79.1	-0.2
12.	78.7	79.0	-0.4	79.1	-0.4
13.	74.9	75.1	-0.3	75.0	-0.1
14.	76.4	76.2	0.3	76.1	0.3
15.	76.9	76.9	-0.1	76.9	0.0
16.	77.3	77.1	0.2	77.1	0.2
17.	75.9	76.1	-0.2	76.0	-0.1
18.	78.1	78.4	-0.4	78.5	-0.4
19.	76.1	76.8	-0.9	76.8	-0.7
20.	76.7	76.4	0.4	76.4	0.3
21.	77.2	77.0	0.3	77.0	0.2
22.	78.3	78.4	-0.1	78.4	-0.1
23.	78.5	78.0	0.7	78.0	0.5
24.	79.2	78.9	0.4	78.9	0.3
25.	75.7	75.4	0.4	75.4	0.3
26.	77.3	77.0	0.4	77.0	0.3
27.	76.9	77.2	-0.4	77.2	-0.3
28.	77.9	77.8	0.1	77.8	0.1
29.	78.1	77.9	0.3	77.9	0.2
30.	77.5	77.1	0.5	77.1	0.4
31.	76.4	76.5	-0.1	76.4	0.0
32.	79	79.1	-0.1	79.1	-0.1
33.	75.3	75.7	-0.5	75.6	-0.3
34.	79.3	78.9	0.5	78.9	0.4
35.	77.6	77.9	-0.4	77.9	-0.3
36.	80.7	80.2	0.7	80.2	0.5
37.	78.5	78.8	-0.4	78.8	-0.3
38.	77.7	78.3	-0.8	78.3	-0.6
39.	77.9	77.6	0.4	77.6	0.3
40.	75.4	75.3	0.1	75.3	0.1
41.	76.9	77.2	-0.4	77.2	-0.3
42.	77.2	77.3	-0.1	77.3	-0.1
43.	79.7	79.3	0.6	79.3	0.4
44.	77.1	77.1	-0.1	77.1	0.0
45.	76.8	76.6	0.2	76.6	0.2
46.	78.1	77.9	0.3	77.9	0.2
47.	78.5	78.2	0.4	78.2	0.3
48.	80.6	80.5	0.1	80.6	0.0
49.	79.4	79.2	0.2	79.3	0.1

50.	80.1	79.4	0.8	79.5	0.6
51.	75.4	76.0	-0.7	75.9	-0.5
52.	77.2	77.1	0.1	77.1	0.1
53.	78.2	78.5	-0.3	78.5	-0.3
54.	79	78.8	0.3	78.8	0.2
55.	79.1	78.8	0.4	78.8	0.3
56.	80.1	79.9	0.2	80.0	0.1
57.	79.4	79.1	0.4	79.1	0.3
58.	76.9	77.0	-0.2	77.0	-0.1
59.	78.5	78.7	-0.2	78.7	-0.2
60.	77.6	77.2	0.5	77.2	0.4
61.	78.1	78.1	0.0	78.1	0.0
62.	78.5	78.2	0.4	78.2	0.3
63.	78.3	78.5	-0.3	78.5	-0.2
64.	79.3	78.9	0.5	79.0	0.3
65.	75.3	75.4	-0.2	75.4	-0.1
66.	75.8	75.9	-0.2	75.9	-0.1
67.	76.9	76.6	0.3	76.6	0.3
68.	76.3	76.2	0.1	76.2	0.1
69.	79.4	79.4	0.0	79.5	-0.1
70.	77.2	76.9	0.4	76.9	0.3
71.	76.3	76.2	0.1	76.2	0.1
72.	80.1	79.8	0.3	79.9	0.2
73.	79.5	79.5	0.0	79.5	0.0
74.	75.7	76.2	-0.7	76.2	-0.5
75.	77.1	77.5	-0.5	77.5	-0.4
76.	77.8	77.4	0.5	77.4	0.4
77.	78.2	77.7	0.6	77.7	0.5
78.	75.5	75.6	-0.1	75.5	0.0
79.	77.1	76.8	0.4	76.8	0.3
80.	77.5	78.0	-0.6	78.0	-0.5
81.	78.1	77.6	0.6	77.6	0.5
82.	78.5	78.0	0.7	78.0	0.5
83.	78.2	78.3	-0.1	78.3	-0.1
84.	77.9	77.5	0.5	77.5	0.4
85.	76.4	76.3	0.1	76.3	0.1
86.	78.3	78.6	-0.3	78.6	-0.3
87.	75.8	75.7	0.1	75.7	0.1
88.	76.8	77.3	-0.6	77.3	-0.5
89.	78.1	78.4	-0.4	78.4	-0.3
90.	75.9	75.8	0.1	75.8	0.1
91.	76.9	76.8	0.2	76.7	0.2
92.	76.5	77.0	-0.6	77.0	-0.5
93.	77.5	77.6	-0.1	77.6	-0.1
94.	77.8	77.9	-0.1	77.9	-0.1
95.	78.2	78.3	-0.1	78.3	-0.1
96.	80.1	80.2	-0.1	80.2	-0.1
97.	76.9	77.2	-0.4	77.2	-0.3
98.	76.1	75.9	0.3	75.8	0.3
99.	77.7	77.2	0.6	77.2	0.5
100.	78.2	77.9	0.4	77.9	0.3
101.	77.8	78.3	-0.6	78.3	-0.5

102.	77.7	77.9	-0.2	77.9	-0.2
103.	80.1	80.1	0.0	80.2	-0.1
104.	76.3	76.0	0.5	75.9	0.4
105.	76.4	76.8	-0.5	76.7	-0.3
106.	78.1	78.2	-0.2	78.3	-0.2
107.	77.7	77.7	0.0	77.7	0.0
108.	77.8	77.5	0.4	77.5	0.3
109.	78.1	78.5	-0.5	78.5	-0.4
110.	76.8	76.6	0.2	76.6	0.2
111.	78.1	78.3	-0.2	78.3	-0.2
112.	77.8	78.2	-0.5	78.2	-0.4
113.	76.5	76.4	0.2	76.4	0.1
114.	78	78.1	-0.2	78.2	-0.2
115.	77.9	78.1	-0.3	78.2	-0.3

The following are the linear equation for L_{eq} with v as an independent variable.

Regression equation	**L_{eq}=63.1957+0.26155(v)**
G.A Equation	**L_{eq}=63.5801+0.25454(v)**

The results of the t-test are given in the table below.

t-Test: Paired Two Sample for Means For G.A output		
	L_{eq} (dB)A	**G.A Output**
Mean	77.5687	77.56785
Variance	1.743222	1.563992
Observations	115	115
Pearson Correlation	0.973284	
Hypothesized Mean Difference	0	
df	114	
t Stat	0.029805	
P(T<=t) one-tail	0.488137	
t Critical one-tail	1.65833	
P(T<=t) two-tail	0.976275	
t Critical two-tail	1.980992	

t-Test: Paired Two Sample for Means for Regression output		
	L_{eq} (dB)A	Regression output
Mean	77.56869565	77.56869565
Variance	1.743221968	1.651324023
Observations	115	115
Pearson Correlation	0.973284494	
Hypothesized Mean Difference	0	
df	114	
t Stat	1.83598E-13	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	1	
t Critical two-tail	1.980992234	

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.973284494
R Square	0.947282706
Adjusted R Square	0.946816181
Standard Error	0.30448514
Observations	115
	Coefficients
Intercept	63.19572133
v	0.261550106

Table.10 Regression analysis output with P, Q, V as independent variables.

Sr. No	q	p	v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
1.	1308	28.5	42.9	74.5	74.6	-0.1
2.	1413	31.7	48.1	75.9	76.1	-0.2
3.	1391	32.2	51.5	76.1	76.2	-0.1
4.	1400	31.4	49.7	75.9	76.1	-0.2
5.	1419	31.9	50.4	76.4	76.3	0.1
6.	1442	32.8	50.7	76.4	76.6	-0.3
7.	1378	32.4	50.7	75.9	76.0	-0.1
8.	1483	32.4	53.7	77.4	77.2	0.3
9.	1512	35.2	57.8	77.8	77.9	-0.1
10.	1621	36.4	61.5	79.1	79.2	-0.2
11.	1589	39.1	60.9	78.9	79.0	-0.1
12.	1564	38.7	60.7	78.7	78.8	-0.1
13.	1318	26.1	45.3	74.9	74.8	0.2
14.	1403	31.4	49.5	76.4	76.1	0.4
15.	1446	33.8	52.5	76.9	76.8	0.1
16.	1505	35.6	53.3	77.3	77.5	-0.2
17.	1403	30.1	49.1	75.9	76.0	-0.1
18.	1554	37.3	58.4	78.1	78.4	-0.4
19.	1420	32.9	51.9	76.1	76.5	-0.5
20.	1468	33.9	50.4	76.7	76.9	-0.2
21.	1480	32.9	52.7	77.2	77.1	0.1
22.	1532	37.5	58.2	78.3	78.2	0.1
23.	1543	35.6	56.5	78.5	78.1	0.5
24.	1605	39.9	60.2	79.2	79.1	0.1
25.	1363	28.7	46.5	75.7	75.4	0.4
26.	1483	32.8	52.8	77.3	77.1	0.2
27.	1480	31.4	53.6	76.9	77.1	-0.3
28.	1502	34.9	55.8	77.9	77.6	0.3
29.	1556	34.4	56.2	78.1	78.1	0.0
30.	1496	36.7	53.2	77.5	77.4	0.1
31.	1425	33.6	50.6	76.4	76.5	-0.1
32.	1603	39.5	60.8	79	79.1	-0.2
33.	1343	29.3	47.5	75.3	75.3	0.0
34.	1622	39.9	60.1	79.3	79.3	0.0
35.	1483	36.8	56.2	77.6	77.6	0.0
36.	1722	42.5	65.1	80.7	80.7	0.0
37.	1587	38.2	59.8	78.5	78.9	-0.5
38.	1502	35.8	57.8	77.7	77.8	-0.2
39.	1549	35.3	54.9	77.9	78.0	-0.1
40.	1352	29.5	46.2	75.4	75.3	0.1
41.	1488	32.4	53.6	76.9	77.2	-0.4
42.	1472	33.8	53.8	77.2	77.2	0.0
43.	1657	40.4	61.6	79.7	79.7	0.0
44.	1465	32.2	53.3	77.1	77.0	0.1
45.	1450	31.2	51.3	76.8	76.7	0.2
46.	1550	37.6	56.2	78.1	78.2	-0.1
47.	1563	37.5	57.4	78.5	78.4	0.1
48.	1681	43.5	66.6	80.6	80.5	0.1
49.	1623	39.4	61.5	79.4	79.4	0.0
50.	1646	39.9	62.3	80.1	79.7	0.5

Sr. No.	q	p	v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
51.	1352	29.7	48.6	75.4	75.5	-0.1
52.	1500	34.1	53.3	77.2	77.4	-0.2
53.	1545	35.3	58.5	78.2	78.3	-0.1
54.	1578	38.3	59.8	79	78.8	0.3
55.	1615	36.8	59.7	79.1	79.1	0.1
56.	1650	39.2	64.3	80.1	79.8	0.3
57.	1610	39.1	60.8	79.4	79.2	0.3
58.	1479	31.6	52.9	76.9	77.1	-0.2
59.	1579	36.3	59.3	78.5	78.7	-0.2
60.	1506	34.7	53.7	77.6	77.5	0.1
61.	1521	37.6	57.1	78.1	78.0	0.1
62.	1554	37.1	57.4	78.5	78.3	0.2
63.	1531	37.4	58.6	78.3	78.2	0.1
64.	1609	37.4	60.3	79.3	79.1	0.3
65.	1336	29.6	46.6	75.3	75.2	0.2
66.	1367	28.7	48.5	75.8	75.6	0.3
67.	1456	33.6	51.3	76.9	76.8	0.1
68.	1443	31.3	49.7	76.3	76.5	-0.2
69.	1609	40.4	62.2	79.4	79.4	0.1
70.	1484	35.1	52.4	77.2	77.2	0.0
71.	1408	33.1	49.7	76.3	76.2	0.1
72.	1670	40.1	63.9	80.1	80.0	0.1
73.	1609	38.9	62.4	79.5	79.3	0.2
74.	1368	29.2	49.6	75.7	75.7	0.0
75.	1479	33.2	54.5	77.1	77.3	-0.2
76.	1500	34.4	54.4	77.8	77.5	0.4
77.	1535	36.7	55.5	78.2	78.0	0.3
78.	1348	29.9	47.1	75.5	75.3	0.2
79.	1481	34.5	51.9	77.1	77.1	0.0
80.	1502	34.6	56.6	77.5	77.7	-0.3
81.	1563	37.2	55.1	78.1	78.2	-0.2
82.	1573	35.5	56.5	78.5	78.4	0.2
83.	1543	35.7	57.8	78.2	78.2	0.0
84.	1513	36.7	54.7	77.9	77.7	0.2
85.	1430	30.9	50.1	76.4	76.4	0.0
86.	1573	35.8	58.9	78.3	78.6	-0.3
87.	1363	31.9	47.8	75.8	75.6	0.2
88.	1442	34.7	53.8	76.8	76.9	-0.2
89.	1538	34.5	58.2	78.1	78.1	-0.1
90.	1392	31.5	48.1	75.9	75.9	0.0
91.	1474	31.1	51.8	76.9	76.9	0.0
92.	1442	32.5	52.7	76.5	76.8	-0.3
93.	1475	33.6	54.9	77.5	77.3	0.3
94.	1527	33.9	56.3	77.8	77.9	-0.1
95.	1529	34.7	57.7	78.2	78.0	0.2
96.	1691	39.7	65.2	80.1	80.3	-0.3
97.	1471	33.5	53.5	76.9	77.1	-0.3
98.	1413	29.9	48.3	76.1	76.0	0.1
99.	1509	33.3	53.6	77.7	77.5	0.3
100.	1566	37.7	56.1	78.2	78.4	-0.2

Sr. No	q	p	v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
101.	1540	35.2	57.8	77.8	78.2	-0.5
102.	1497	34.9	56.2	77.7	77.6	0.1
103.	1679	41.1	64.9	80.1	80.2	-0.2
104.	1443	32.9	48.6	76.3	76.4	-0.2
105.	1405	32.1	51.8	76.4	76.3	0.1
106.	1519	34.9	57.6	78.1	77.9	0.2
107.	1518	36.1	55.5	77.7	77.8	-0.1
108.	1530	34.6	54.6	77.8	77.8	0.0
109.	1518	35.7	58.5	78.1	78.0	0.1
110.	1451	32.4	51.3	76.8	76.7	0.1
111.	1551	36.6	57.7	78.1	78.3	-0.3
112.	1509	35.9	57.4	77.8	77.9	-0.1
113.	1447	33.9	50.3	76.5	76.7	-0.2
114.	1517	37.8	57.2	78	78.0	0.0
115.	1518	34.3	57.2	77.9	77.9	0.0

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.991820125
R Square	0.983707161
Adjusted R Square	0.983266814
Standard Error	0.170791268
Observations	115
	Coefficients
Intercept	58.20538125
q	0.008903009
p	0.041010377
v	0.083046511

The equation for L_{eq} with p and v as independent variables formed with regression analysis.

L_{eq}= 58.205+(0.00890)q+(0.04101)p+(0.08304)v

The results of the t-test are given in the table below.

t-Test: Paired Two Sample for Means		
	L_{eq}(dB)A	**Predicted L_{eq}(dB)A**
Mean	77.56869565	77.56869565
Variance	1.743221968	1.714819933
Observations	115	115
Pearson Correlation	0.991820125	
Hypothesized Mean Difference	0	
df	114	
t Stat	-2.20168E-13	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	1	
t Critical two-tail	1.980992234	

Table.11 Regression analysis output with Log P, Log Q, Log V as independent variables.

Sr.No	Log v	Log q	Log p	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
1.	1.63	3.12	1.45	74.5	74.4	0.1
2.	1.68	3.15	1.5	75.9	76.0	-0.1
3.	1.71	3.14	1.51	76.1	76.1	0.0
4.	1.7	3.15	1.5	75.9	76.2	-0.3
5.	1.7	3.15	1.5	76.4	76.2	0.2
6.	1.71	3.16	1.52	76.4	76.7	-0.3
7.	1.71	3.14	1.51	75.9	76.1	-0.2
8.	1.73	3.17	1.51	77.4	77.2	0.2
9.	1.76	3.18	1.55	77.8	77.9	-0.1
10.	1.79	3.21	1.56	79.1	79.2	-0.1
11.	1.78	3.2	1.59	78.9	78.9	0.0
12.	1.78	3.19	1.59	78.7	78.6	0.1
13.	1.66	3.12	1.42	74.9	74.6	0.3
14.	1.69	3.15	1.5	76.4	76.1	0.3
15.	1.72	3.16	1.53	76.9	76.9	0.0
16.	1.73	3.18	1.55	77.3	77.6	-0.3
17.	1.69	3.15	1.48	75.9	76.1	-0.2
18.	1.77	3.19	1.57	78.1	78.4	-0.3
19.	1.72	3.15	1.52	76.1	76.5	-0.4
20.	1.7	3.17	1.53	76.7	77.0	-0.3
21.	1.72	3.17	1.52	77.2	77.1	0.1
22.	1.76	3.19	1.57	78.3	78.3	0.0
23.	1.75	3.19	1.55	78.5	78.1	0.4
24.	1.78	3.21	1.6	79.2	79.2	0.0
25.	1.67	3.13	1.46	75.7	75.2	0.5
26.	1.72	3.17	1.52	77.3	77.1	0.2
27.	1.73	3.17	1.5	76.9	77.1	-0.2
28.	1.75	3.18	1.54	77.9	77.8	0.1
29.	1.75	3.19	1.54	78.1	78.1	0.0
30.	1.73	3.17	1.56	77.5	77.4	0.1
31.	1.7	3.15	1.53	76.4	76.4	0.0
32.	1.78	3.2	1.6	79	78.9	0.1
33.	1.68	3.13	1.47	75.3	75.3	0.0
34.	1.78	3.21	1.6	79.3	79.2	0.1
35.	1.75	3.17	1.57	77.6	77.6	0.0
36.	1.81	3.24	1.63	80.7	80.6	0.1
37.	1.78	3.2	1.58	78.5	78.9	-0.4
38.	1.76	3.18	1.55	77.7	77.9	-0.2
39.	1.74	3.19	1.55	77.9	78.0	-0.1
40.	1.66	3.13	1.47	75.4	75.1	0.3
41.	1.73	3.17	1.51	76.9	77.2	-0.3
42.	1.73	3.17	1.53	77.2	77.3	-0.1
43.	1.79	3.22	1.61	79.7	79.7	0.0
44.	1.73	3.17	1.51	77.1	77.2	-0.1
45.	1.71	3.16	1.49	76.8	76.6	0.2
46.	1.75	3.19	1.58	78.1	78.3	-0.2

Sr.No	Log v	Log q	Log p	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
47.	1.76	3.19	1.57	78.5	78.3	0.2
48.	1.82	3.23	1.64	80.6	80.4	0.2
49.	1.79	3.21	1.6	79.4	79.3	0.1
50.	1.79	3.22	1.6	80.1	79.6	0.5
51.	1.69	3.13	1.47	75.4	75.4	0.0
52.	1.73	3.18	1.53	77.2	77.6	-0.4
53.	1.77	3.19	1.55	78.2	78.3	-0.1
54.	1.78	3.2	1.58	79	78.9	0.1
55.	1.78	3.21	1.57	79.1	79.1	0.0
56.	1.81	3.22	1.59	80.1	79.8	0.3
57.	1.78	3.21	1.59	79.4	79.2	0.2
58.	1.72	3.17	1.5	76.9	77.0	-0.1
59.	1.77	3.2	1.56	78.5	78.7	-0.2
60.	1.73	3.18	1.54	77.6	77.6	0.0
61.	1.76	3.18	1.58	78.1	78.1	0.0
62.	1.76	3.19	1.57	78.5	78.3	0.2
63.	1.77	3.18	1.57	78.3	78.1	0.2
64.	1.78	3.21	1.57	79.3	79.1	0.2
65.	1.67	3.13	1.47	75.3	75.2	0.1
66.	1.69	3.14	1.46	75.8	75.7	0.1
67.	1.71	3.16	1.53	76.9	76.8	0.1
68.	1.7	3.16	1.5	76.3	76.5	-0.2
69.	1.79	3.21	1.61	79.4	79.4	0.0
70.	1.72	3.17	1.55	77.2	77.2	0.0
71.	1.7	3.15	1.52	76.3	76.3	0.0
72.	1.81	3.22	1.6	80.1	79.8	0.3
73.	1.8	3.21	1.59	79.5	79.4	0.1
74.	1.7	3.14	1.47	75.7	75.8	-0.1
75.	1.74	3.17	1.52	77.1	77.3	-0.2
76.	1.74	3.18	1.54	77.8	77.7	0.1
77.	1.74	3.19	1.56	78.2	78.1	0.1
78.	1.67	3.13	1.48	75.5	75.3	0.2
79.	1.72	3.17	1.54	77.1	77.2	-0.1
80.	1.75	3.18	1.54	77.5	77.8	-0.3
81.	1.74	3.19	1.57	78.1	78.1	0.0
82.	1.75	3.2	1.55	78.5	78.4	0.1
83.	1.76	3.19	1.55	78.2	78.2	0.0
84.	1.74	3.18	1.56	77.9	77.8	0.1
85.	1.7	3.16	1.49	76.4	76.5	-0.1
86.	1.77	3.2	1.55	78.3	78.6	-0.3
87.	1.68	3.13	1.5	75.8	75.4	0.4
88.	1.73	3.16	1.54	76.8	77.0	-0.2
89.	1.76	3.19	1.54	78.1	78.2	-0.1
90.	1.68	3.14	1.5	75.9	75.7	0.2
91.	1.71	3.17	1.49	76.9	76.9	0.0
92.	1.72	3.16	1.51	76.5	76.8	-0.3
93.	1.74	3.17	1.53	77.5	77.4	0.1
94.	1.75	3.18	1.53	77.8	77.7	0.1

Sr.No	Log v	Log q	Log p	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
95.	1.76	3.18	1.54	78.2	77.9	0.3
96.	1.81	3.23	1.6	80.1	80.1	0.0
97.	1.73	3.17	1.53	76.9	77.3	-0.4
98.	1.68	3.15	1.48	76.1	76.0	0.1
99.	1.73	3.18	1.52	77.7	77.5	0.2
100.	1.75	3.19	1.58	78.2	78.3	-0.1
101.	1.76	3.19	1.55	77.8	78.2	-0.4
102.	1.75	3.18	1.54	77.7	77.8	-0.1
103.	1.81	3.23	1.61	80.1	80.2	-0.1
104.	1.69	3.16	1.52	76.3	76.5	-0.2
105.	1.71	3.15	1.51	76.4	76.4	0.0
106.	1.76	3.18	1.54	78.1	77.9	0.2
107.	1.74	3.18	1.56	77.7	77.8	-0.1
108.	1.74	3.18	1.54	77.8	77.7	0.1
109.	1.77	3.18	1.55	78.1	78.0	0.1
110.	1.71	3.16	1.51	76.8	76.7	0.1
111.	1.76	3.19	1.56	78.1	78.3	-0.2
112.	1.76	3.18	1.56	77.8	78.0	-0.2
113.	1.7	3.16	1.53	76.5	76.7	-0.2
114.	1.76	3.18	1.58	78	78.1	-0.1
115.	1.76	3.18	1.54	77.9	77.9	0.0

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.989074
R Square	0.978268
Adjusted R Square	0.97768
Standard Error	0.197252
Observations	115
	Coefficients
Intercept	-41.3388
Log v	9.64751
Log q	30.08054
Log p	4.279093

The equation for L_{eq} with Log v, Log q , Log p as independent variables formed with regression analysis.

L_{eq}= (9.64751) Log v + (30.08054) Log q + (4.27902)Log p- 41.3388

The results of the t-test are given in the table below.

t-Test: Paired Two Sample for Means		
	L_{eq} (dB)A	**Predicted L_{eq} (dB)A**
Mean	77.56869565	77.56869565
Variance	1.743221968	1.705337546
Observations	115	115
Pearson Correlation	0.989074105	
Hypothesized Mean Difference	0	
df	114	
t Stat	3.19992E-13	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	1	
t Critical two-tail	1.980992234	

Table.12 Regression analysis output with P, Log Q, V as independent variables.

Sr.No	p	Log q	v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
1.	28.5	3.12	42.9	74.5	74.6	-0.1
2.	31.7	3.15	48.1	75.9	76.1	-0.2
3.	32.2	3.14	51.5	76.1	76.1	0.0
4.	31.4	3.15	49.7	75.9	76.2	-0.3
5.	31.9	3.15	50.4	76.4	76.3	0.1
6.	32.8	3.16	50.7	76.4	76.6	-0.2
7.	32.4	3.14	50.7	75.9	76.1	-0.2
8.	32.4	3.17	53.7	77.4	77.1	0.3
9.	35.2	3.18	57.8	77.8	77.9	-0.1
10.	36.4	3.21	61.5	79.1	79.2	-0.1
11.	39.1	3.2	60.9	78.9	79.0	-0.1
12.	38.7	3.19	60.7	78.7	78.7	0.0
13.	26.1	3.12	45.3	74.9	74.7	0.2
14.	31.4	3.15	49.5	76.4	76.2	0.2
15.	33.8	3.16	52.5	76.9	76.8	0.1
16.	35.6	3.18	53.3	77.3	77.6	-0.3
17.	30.1	3.15	49.1	75.9	76.1	-0.2
18.	37.3	3.19	58.4	78.1	78.4	-0.3
19.	32.9	3.15	51.9	76.1	76.5	-0.4
20.	33.9	3.17	50.4	76.7	76.9	-0.2
21.	32.9	3.17	52.7	77.2	77.1	0.1
22.	37.5	3.19	58.2	78.3	78.4	-0.1
23.	35.6	3.19	56.5	78.5	78.1	0.4
24.	39.9	3.21	60.2	79.2	79.2	0.0
25.	28.7	3.13	46.5	75.7	75.2	0.5
26.	32.8	3.17	52.8	77.3	77.1	0.2
27.	31.4	3.17	53.6	76.9	77.1	-0.2
28.	34.9	3.18	55.8	77.9	77.7	0.2
29.	34.4	3.19	56.2	78.1	78.0	0.1
30.	36.7	3.17	53.2	77.5	77.4	0.1
31.	33.6	3.15	50.6	76.4	76.4	0.0
32.	39.5	3.2	60.8	79	79.0	0.0
33.	29.3	3.13	47.5	75.3	75.3	0.0
34.	39.9	3.21	60.1	79.3	79.2	0.1
35.	36.8	3.17	56.2	77.6	77.6	0.0
36.	42.5	3.24	65.1	80.7	80.6	0.1
37.	38.2	3.2	59.8	78.5	78.8	-0.3
38.	35.8	3.18	57.8	77.7	78.0	-0.3
39.	35.3	3.19	54.9	77.9	78.0	-0.1
40.	29.5	3.13	46.2	75.4	75.2	0.2
41.	32.4	3.17	53.6	76.9	77.1	-0.2
42.	33.8	3.17	53.8	77.2	77.2	0.0
43.	40.4	3.22	61.6	79.7	79.7	0.0
44.	32.2	3.17	53.3	77.1	77.1	0.0
45.	31.2	3.16	51.3	76.8	76.6	0.2
46.	37.6	3.19	56.2	78.1	78.2	-0.1

Sr.No	p	Log q	v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
47.	37.5	3.19	57.4	78.5	78.3	0.2
48.	43.5	3.23	66.6	80.6	80.6	0.0
49.	39.4	3.21	61.5	79.4	79.3	0.1
50.	39.9	3.22	62.3	80.1	79.7	0.4
51.	29.7	3.13	48.6	75.4	75.5	-0.1
52.	34.1	3.18	53.3	77.2	77.5	-0.3
53.	35.3	3.19	58.5	78.2	78.3	-0.1
54.	38.3	3.2	59.8	79	78.8	0.2
55.	36.8	3.21	59.7	79.1	79.0	0.1
56.	39.2	3.22	64.3	80.1	79.8	0.3
57.	39.1	3.21	60.8	79.4	79.3	0.1
58.	31.6	3.17	52.9	76.9	77.0	-0.1
59.	36.3	3.2	59.3	78.5	78.7	-0.2
60.	34.7	3.18	53.7	77.6	77.6	0.0
61.	37.6	3.18	57.1	78.1	78.0	0.1
62.	37.1	3.19	57.4	78.5	78.3	0.2
63.	37.4	3.18	58.6	78.3	78.1	0.2
64.	37.4	3.21	60.3	79.3	79.1	0.2
65.	29.6	3.13	46.6	75.3	75.3	0.0
66.	28.7	3.14	48.5	75.8	75.7	0.1
67.	33.6	3.16	51.3	76.9	76.7	0.2
68.	31.3	3.16	49.7	76.3	76.5	-0.2
69.	40.4	3.21	62.2	79.4	79.5	-0.1
70.	35.1	3.17	52.4	77.2	77.2	0.0
71.	33.1	3.15	49.7	76.3	76.3	0.0
72.	40.1	3.22	63.9	80.1	79.9	0.2
73.	38.9	3.21	62.4	79.5	79.4	0.1
74.	29.2	3.14	49.6	75.7	75.8	-0.1
75.	33.2	3.17	54.5	77.1	77.3	-0.2
76.	34.4	3.18	54.4	77.8	77.6	0.2
77.	36.7	3.19	55.5	78.2	78.1	0.1
78.	29.9	3.13	47.1	75.5	75.3	0.2
79.	34.5	3.17	51.9	77.1	77.1	0.0
80.	34.6	3.18	56.6	77.5	77.8	-0.3
81.	37.2	3.19	55.1	78.1	78.1	0.0
82.	35.5	3.2	56.5	78.5	78.4	0.1
83.	35.7	3.19	57.8	78.2	78.2	0.0
84.	36.7	3.18	54.7	77.9	77.8	0.1
85.	30.9	3.16	50.1	76.4	76.5	-0.1
86.	35.8	3.2	58.9	78.3	78.6	-0.3
87.	31.9	3.13	47.8	75.8	75.5	0.3
88.	34.7	3.16	53.8	76.8	77.0	-0.2
89.	34.5	3.19	58.2	78.1	78.2	-0.1
90.	31.5	3.14	48.1	75.9	75.8	0.1
91.	31.1	3.17	51.8	76.9	76.9	0.0
92.	32.5	3.16	52.7	76.5	76.8	-0.3
93.	33.6	3.17	54.9	77.5	77.3	0.2
94.	33.9	3.18	56.3	77.8	77.7	0.1

Sr.No	p	Log q	v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
95.	34.7	3.18	57.7	78.2	77.9	0.3
96.	39.7	3.23	65.2	80.1	80.2	-0.1
97.	33.5	3.17	53.5	76.9	77.2	-0.3
98.	29.9	3.15	48.3	76.1	76.0	0.1
99.	33.3	3.18	53.6	77.7	77.5	0.2
100.	37.7	3.19	56.1	78.2	78.2	0.0
101.	35.2	3.19	57.8	77.8	78.2	-0.4
102.	34.9	3.18	56.2	77.7	77.8	-0.1
103.	41.1	3.23	64.9	80.1	80.3	-0.2
104.	32.9	3.16	48.6	76.3	76.5	-0.2
105.	32.1	3.15	51.8	76.4	76.4	0.0
106.	34.9	3.18	57.6	78.1	77.9	0.2
107.	36.1	3.18	55.5	77.7	77.8	-0.1
108.	34.6	3.18	54.6	77.8	77.6	0.2
109.	35.7	3.18	58.5	78.1	78.0	0.1
110.	32.4	3.16	51.3	76.8	76.7	0.1
111.	36.6	3.19	57.7	78.1	78.3	-0.2
112.	35.9	3.18	57.4	77.8	77.9	-0.1
113.	33.9	3.16	50.3	76.5	76.7	-0.2
114.	37.8	3.18	57.2	78	78.0	0.0
115.	34.3	3.18	57.2	77.9	77.8	0.0

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.99061673
R Square	0.9813215
Adjusted R Square	0.98081667
Standard Error	0.18286825
Observations	115
	Coefficients
Intercept	-15.431199
p	0.05895596
v	0.08831047
Log q	27.1051073

The equation for L_{eq} with p, v, Log q , as independent variables formed with regression analysis.

L_{eq}= (0.05895)p+(0.08831)v+(27.10510)Logq-15.431199

The results of the t-test are given in the table below.

t-Test: Paired Two Sample for Means		
	L_{eq} (dB)A	**Predicted L_{eq} (dB)A**
Mean	77.56869565	77.56873007
Variance	1.743221968	1.71067993
Observations	115	115
Pearson Correlation	0.990617961	
Hypothesized Mean Difference	0	
df	114	
t Stat	-0.002045468	
P(T<=t) one-tail	0.499185765	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	0.998371529	
t Critical two-tail	1.980992234	

Table.13 Regression analysis output with P, Log Q, Log V as independent variables.

Sr.No	p	Log q	Log v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
1.	28.5	3.12	1.63	74.5	74.5	0.0
2.	31.7	3.15	1.68	75.9	76.1	-0.2
3.	32.2	3.14	1.71	76.1	76.1	0.0
4.	31.4	3.15	1.7	75.9	76.2	-0.3
5.	31.9	3.15	1.7	76.4	76.3	0.1
6.	32.8	3.16	1.71	76.4	76.7	-0.3
7.	32.4	3.14	1.71	75.9	76.1	-0.2
8.	32.4	3.17	1.73	77.4	77.1	0.3
9.	35.2	3.18	1.76	77.8	77.9	-0.1
10.	36.4	3.21	1.79	79.1	79.1	0.0
11.	39.1	3.2	1.78	78.9	78.9	0.0
12.	38.7	3.19	1.78	78.7	78.6	0.1
13.	26.1	3.12	1.66	74.9	74.6	0.3
14.	31.4	3.15	1.69	76.4	76.1	0.3
15.	33.8	3.16	1.72	76.9	76.9	0.0
16.	35.6	3.18	1.73	77.3	77.7	-0.4
17.	30.1	3.15	1.69	75.9	76.0	-0.1
18.	37.3	3.19	1.77	78.1	78.4	-0.3
19.	32.9	3.15	1.72	76.1	76.5	-0.4
20.	33.9	3.17	1.7	76.7	77.0	-0.3
21.	32.9	3.17	1.72	77.2	77.1	0.1
22.	37.5	3.19	1.76	78.3	78.3	0.0
23.	35.6	3.19	1.75	78.5	78.1	0.4
24.	39.9	3.21	1.78	79.2	79.3	-0.1
25.	28.7	3.13	1.67	75.7	75.2	0.5
26.	32.8	3.17	1.72	77.3	77.1	0.2
27.	31.4	3.17	1.73	76.9	77.1	-0.2
28.	34.9	3.18	1.75	77.9	77.8	0.1
29.	34.4	3.19	1.75	78.1	78.0	0.1
30.	36.7	3.17	1.73	77.5	77.4	0.1
31.	33.6	3.15	1.7	76.4	76.4	0.0
32.	39.5	3.2	1.78	79	79.0	0.0
33.	29.3	3.13	1.68	75.3	75.3	0.0
34.	39.9	3.21	1.78	79.3	79.3	0.0
35.	36.8	3.17	1.75	77.6	77.6	0.0
36.	42.5	3.24	1.81	80.7	80.6	0.1
37.	38.2	3.2	1.78	78.5	78.9	-0.4
38.	35.8	3.18	1.76	77.7	77.9	-0.2
39.	35.3	3.19	1.74	77.9	78.0	-0.1
40.	29.5	3.13	1.66	75.4	75.1	0.3
41.	32.4	3.17	1.73	76.9	77.1	-0.2
42.	33.8	3.17	1.73	77.2	77.2	0.0
43.	40.4	3.22	1.79	79.7	79.7	0.0
44.	32.2	3.17	1.73	77.1	77.1	0.0
45.	31.2	3.16	1.71	76.8	76.6	0.2
46.	37.6	3.19	1.75	78.1	78.3	-0.2

Sr.No	p	Log q	Log v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
47.	37.5	3.19	1.76	78.5	78.3	0.2
48.	43.5	3.23	1.82	80.6	80.5	0.1
49.	39.4	3.21	1.79	79.4	79.3	0.1
50.	39.9	3.22	1.79	80.1	79.7	0.4
51.	29.7	3.13	1.69	75.4	75.4	0.0
52.	34.1	3.18	1.73	77.2	77.6	-0.4
53.	35.3	3.19	1.77	78.2	78.3	-0.1
54.	38.3	3.2	1.78	79	78.9	0.1
55.	36.8	3.21	1.78	79.1	79.1	0.0
56.	39.2	3.22	1.81	80.1	79.8	0.3
57.	39.1	3.21	1.78	79.4	79.2	0.2
58.	31.6	3.17	1.72	76.9	77.0	-0.1
59.	36.3	3.2	1.77	78.5	78.6	-0.1
60.	34.7	3.18	1.73	77.6	77.6	0.0
61.	37.6	3.18	1.76	78.1	78.1	0.0
62.	37.1	3.19	1.76	78.5	78.3	0.2
63.	37.4	3.18	1.77	78.3	78.1	0.2
64.	37.4	3.21	1.78	79.3	79.1	0.2
65.	29.6	3.13	1.67	75.3	75.2	0.1
66.	28.7	3.14	1.69	75.8	75.7	0.1
67.	33.6	3.16	1.71	76.9	76.8	0.1
68.	31.3	3.16	1.7	76.3	76.5	-0.2
69.	40.4	3.21	1.79	79.4	79.4	0.0
70.	35.1	3.17	1.72	77.2	77.2	0.0
71.	33.1	3.15	1.7	76.3	76.3	0.0
72.	40.1	3.22	1.81	80.1	79.9	0.2
73.	38.9	3.21	1.8	79.5	79.4	0.1
74.	29.2	3.14	1.7	75.7	75.8	-0.1
75.	33.2	3.17	1.74	77.1	77.3	-0.2
76.	34.4	3.18	1.74	77.8	77.7	0.1
77.	36.7	3.19	1.74	78.2	78.1	0.1
78.	29.9	3.13	1.67	75.5	75.3	0.2
79.	34.5	3.17	1.72	77.1	77.2	-0.1
80.	34.6	3.18	1.75	77.5	77.8	-0.3
81.	37.2	3.19	1.74	78.1	78.1	0.0
82.	35.5	3.2	1.75	78.5	78.4	0.1
83.	35.7	3.19	1.76	78.2	78.2	0.0
84.	36.7	3.18	1.74	77.9	77.8	0.1
85.	30.9	3.16	1.7	76.4	76.5	-0.1
86.	35.8	3.2	1.77	78.3	78.6	-0.3
87.	31.9	3.13	1.68	75.8	75.5	0.3
88.	34.7	3.16	1.73	76.8	77.0	-0.2
89.	34.5	3.19	1.76	78.1	78.1	0.0
90.	31.5	3.14	1.68	75.9	75.8	0.1
91.	31.1	3.17	1.71	76.9	76.9	0.0
92.	32.5	3.16	1.72	76.5	76.8	-0.3
93.	33.6	3.17	1.74	77.5	77.3	0.2
94.	33.9	3.18	1.75	77.8	77.7	0.1

Sr.No	p	Log q	Log v	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
95.	34.7	3.18	1.76	78.2	77.9	0.3
96.	39.7	3.23	1.81	80.1	80.1	0.0
97.	33.5	3.17	1.73	76.9	77.2	-0.3
98.	29.9	3.15	1.68	76.1	75.9	0.2
99.	33.3	3.18	1.73	77.7	77.5	0.2
100.	37.7	3.19	1.75	78.2	78.3	-0.1
101.	35.2	3.19	1.76	77.8	78.2	-0.4
102.	34.9	3.18	1.75	77.7	77.8	-0.1
103.	41.1	3.23	1.81	80.1	80.2	-0.1
104.	32.9	3.16	1.69	76.3	76.5	-0.2
105.	32.1	3.15	1.71	76.4	76.4	0.0
106.	34.9	3.18	1.76	78.1	77.9	0.2
107.	36.1	3.18	1.74	77.7	77.8	-0.1
108.	34.6	3.18	1.74	77.8	77.7	0.1
109.	35.7	3.18	1.77	78.1	78.0	0.1
110.	32.4	3.16	1.71	76.8	76.7	0.1
111.	36.6	3.19	1.76	78.1	78.3	-0.2
112.	35.9	3.18	1.76	77.8	77.9	-0.1
113.	33.9	3.16	1.7	76.5	76.7	-0.2
114.	37.8	3.18	1.76	78	78.1	-0.1
115.	34.3	3.18	1.76	77.9	77.8	0.0

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.989720783
R Square	0.979547229
Adjusted R Square	0.978994451
Standard Error	0.191356562
Observations	115
	Coefficients
Intercept	-33.24526383
p	0.066247216
Log v	9.25155034
Log q	29.09826348

The equation for L_{eq} with p, Log v, Log q , as independent variables formed with regression analysis.

L_{eq}=(0.06624)p+(9.25155)Log v +(29.09826)Log q- 33.24526

The results of the t-test are given in the table below.

t-Test: Paired Two Sample for Means		
	L_{eq} (dB)A	**Predicted L_{eq} (dB)A**
Mean	77.56869565	77.56871465
Variance	1.743221968	1.707578771
Observations	115	115
Pearson Correlation	0.989721413	
Hypothesized Mean Difference	0	
df	114	
t Stat	-0.001078749	
P(T<=t) one-tail	0.499570584	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	0.999141169	
t Critical two-tail	1.980992234	

Table.14 Regression analysis output with "Log v, p, √V as independent variables

Sr.No	P	Log q	√V	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
1.	28.5	3.12	6.55	74.5	74.4	0.1
2.	31.7	3.15	6.94	75.9	76.1	-0.2
3.	32.2	3.14	7.18	76.1	76.2	-0.1
4.	31.4	3.15	7.05	75.9	76.1	-0.2
5.	31.9	3.15	7.10	76.4	76.3	0.1
6.	32.8	3.16	7.12	76.4	76.6	-0.2
7.	32.4	3.14	7.12	75.9	76.0	-0.1
8.	32.4	3.17	7.33	77.4	77.2	0.2
9.	35.2	3.18	7.60	77.8	77.9	-0.1
10.	36.4	3.21	7.84	79.1	79.2	-0.1
11.	39.1	3.2	7.80	78.9	79.0	-0.1
12.	38.7	3.19	7.79	78.7	78.8	-0.1
13.	26.1	3.12	6.73	74.9	74.7	0.2
14.	31.4	3.15	7.04	76.4	76.1	0.3
15.	33.8	3.16	7.25	76.9	76.9	0.0
16.	35.6	3.18	7.30	77.3	77.5	-0.2
17.	30.1	3.15	7.01	75.9	76.0	-0.1
18.	37.3	3.19	7.64	78.1	78.4	-0.3
19.	32.9	3.15	7.20	76.1	76.5	-0.4
20.	33.9	3.17	7.10	76.7	76.9	-0.2
21.	32.9	3.17	7.26	77.2	77.1	0.1
22.	37.5	3.19	7.63	78.3	78.2	0.1
23.	35.6	3.19	7.52	78.5	78.1	0.4
24.	39.9	3.21	7.76	79.2	79.1	0.1
25.	28.7	3.13	6.82	75.7	75.3	0.4
26.	32.8	3.17	7.27	77.3	77.2	0.1
27.	31.4	3.17	7.32	76.9	77.1	-0.2
28.	34.9	3.18	7.47	77.9	77.7	0.2
29.	34.4	3.19	7.50	78.1	78.1	0.0
30.	36.7	3.17	7.29	77.5	77.5	0.0
31.	33.6	3.15	7.11	76.4	76.5	-0.1
32.	39.5	3.2	7.80	79	79.1	-0.1
33.	29.3	3.13	6.89	75.3	75.2	0.1
34.	39.9	3.21	7.75	79.3	79.3	0.0
35.	36.8	3.17	7.50	77.6	77.6	0.0
36.	42.5	3.24	8.07	80.7	80.5	0.2
37.	38.2	3.2	7.73	78.5	78.9	-0.4
38.	35.8	3.18	7.60	77.7	77.9	-0.2
39.	35.3	3.19	7.41	77.9	78.0	-0.1
40.	29.5	3.13	6.80	75.4	75.2	0.2
41.	32.4	3.17	7.32	76.9	77.3	-0.4
42.	33.8	3.17	7.33	77.2	77.2	0.0
43.	40.4	3.22	7.85	79.7	79.7	0.0
44.	32.2	3.17	7.30	77.1	77.0	0.1
45.	31.2	3.16	7.16	76.8	76.7	0.1
46.	37.6	3.19	7.50	78.1	78.2	-0.1

Sr.No	p	Log q	√V	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
47.	37.5	3.19	7.58	78.5	78.4	0.1
48.	43.5	3.23	8.16	80.6	80.4	0.2
49.	39.4	3.21	7.84	79.4	79.4	0.0
50.	39.9	3.22	7.89	80.1	79.6	0.5
51.	29.7	3.13	6.97	75.4	75.5	-0.1
52.	34.1	3.18	7.30	77.2	77.4	-0.2
53.	35.3	3.19	7.65	78.2	78.3	-0.1
54.	38.3	3.2	7.73	79	78.8	0.2
55.	36.8	3.21	7.73	79.1	79.0	0.1
56.	39.2	3.22	8.02	80.1	79.8	0.3
57.	39.1	3.21	7.80	79.4	79.2	0.2
58.	31.6	3.17	7.27	76.9	77.1	-0.2
59.	36.3	3.2	7.70	78.5	78.7	-0.2
60.	34.7	3.18	7.33	77.6	77.5	0.1
61.	37.6	3.18	7.56	78.1	78.1	0.0
62.	37.1	3.19	7.58	78.5	78.4	0.1
63.	37.4	3.18	7.66	78.3	78.3	0.0
64.	37.4	3.21	7.77	79.3	79.1	0.2
65.	29.6	3.13	6.83	75.3	75.1	0.2
66.	28.7	3.14	6.96	75.8	75.5	0.3
67.	33.6	3.16	7.16	76.9	76.8	0.1
68.	31.3	3.16	7.05	76.3	76.5	-0.2
69.	40.4	3.21	7.89	79.4	79.3	0.1
70.	35.1	3.17	7.24	77.2	77.2	0.0
71.	33.1	3.15	7.05	76.3	76.2	0.1
72.	40.1	3.22	7.99	80.1	79.9	0.2
73.	38.9	3.21	7.90	79.5	79.3	0.2
74.	29.2	3.14	7.04	75.7	75.7	0.0
75.	33.2	3.17	7.38	77.1	77.3	-0.2
76.	34.4	3.18	7.38	77.8	77.5	0.3
77.	36.7	3.19	7.45	78.2	78.0	0.2
78.	29.9	3.13	6.86	75.5	75.3	0.2
79.	34.5	3.17	7.20	77.1	77.1	0.0
80.	34.6	3.18	7.52	77.5	77.7	-0.2
81.	37.2	3.19	7.42	78.1	78.2	-0.1
82.	35.5	3.2	7.52	78.5	78.4	0.1
83.	35.7	3.19	7.60	78.2	78.2	0.0
84.	36.7	3.18	7.40	77.9	77.8	0.1
85.	30.9	3.16	7.08	76.4	76.4	0.0
86.	35.8	3.2	7.67	78.3	78.6	-0.3
87.	31.9	3.13	6.91	75.8	75.6	0.2
88.	34.7	3.16	7.33	76.8	77.0	-0.2
89.	34.5	3.19	7.63	78.1	78.2	-0.1
90.	31.5	3.14	6.94	75.9	75.9	0.0
91.	31.1	3.17	7.20	76.9	76.9	0.0
92.	32.5	3.16	7.26	76.5	76.8	-0.3
93.	33.6	3.17	7.41	77.5	77.3	0.2
94.	33.9	3.18	7.50	77.8	77.9	-0.1

Sr.No	p	Log q	√V	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
95.	34.7	3.18	7.60	78.2	78.1	0.1
96.	39.7	3.23	8.07	80.1	80.2	-0.1
97.	33.5	3.17	7.31	76.9	77.1	-0.2
98.	29.9	3.15	6.95	76.1	76.0	0.1
99.	33.3	3.18	7.32	77.7	77.5	0.2
100.	37.7	3.19	7.49	78.2	78.4	-0.2
101.	35.2	3.19	7.60	77.8	78.2	-0.4
102.	34.9	3.18	7.50	77.7	77.7	0.0
103.	41.1	3.23	8.06	80.1	80.1	0.0
104.	32.9	3.16	6.97	76.3	76.4	-0.1
105.	32.1	3.15	7.20	76.4	76.3	0.1
106.	34.9	3.18	7.59	78.1	78.0	0.1
107.	36.1	3.18	7.45	77.7	77.8	-0.1
108.	34.6	3.18	7.39	77.8	77.8	0.0
109.	35.7	3.18	7.65	78.1	78.1	0.0
110.	32.4	3.16	7.16	76.8	76.7	0.1
111.	36.6	3.19	7.60	78.1	78.3	-0.2
112.	35.9	3.18	7.58	77.8	77.9	-0.1
113.	33.9	3.16	7.09	76.5	76.7	-0.2
114.	37.8	3.18	7.56	78	78.1	-0.1
115.	34.3	3.18	7.56	77.9	77.9	0.0

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.990869565
R Square	0.981822494
Adjusted R Square	0.98133121
Standard Error	0.180399126
Observations	115
	Coefficients
Intercept	-28.21131058
Log q	29.90743385
√V	1.241195575
P	0.046102265

The equation for L_{eq} with Log q, √v , p as independent variables formed with regression analysis.

L_{eq}=(29.90743)Log q + (1.24119) √v + (0.04610)p-28.21131

The results of the t-test are given in the table below.

t-Test: Paired Two Sample for Means		
	L_{eq} (dB)A	**Predicted L_{eq} (dB)A**
Mean	77.56869565	77.56869565
Variance	1.743221968	1.71153454
Observations	115	115
Pearson Correlation	0.990869565	
Hypothesized Mean Difference	0	
df	114	
t Stat	-9.82656E-13	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	1	
t Critical two-tail	1.980992234	

Table.15 Regression analysis output with Log v, $\sqrt[3]{P}$, $\sqrt{V}$ as independent variables.

Sr.No	$\sqrt[3]{P}$	Log q	$\sqrt{V}$	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
1.	3.05	3.12	6.55	74.5	74.4	0.1
2.	3.16	3.15	6.94	75.9	76.1	-0.2
3.	3.18	3.14	7.18	76.1	76.2	-0.1
4.	3.15	3.15	7.05	75.9	76.1	-0.2
5.	3.17	3.15	7.10	76.4	76.3	0.1
6.	3.20	3.16	7.12	76.4	76.6	-0.2
7.	3.19	3.14	7.12	75.9	76.0	-0.1
8.	3.19	3.17	7.33	77.4	77.2	0.2
9.	3.28	3.18	7.60	77.8	77.9	-0.1
10.	3.31	3.21	7.84	79.1	79.2	-0.1
11.	3.39	3.2	7.80	78.9	79.0	-0.1
12.	3.38	3.19	7.79	78.7	78.8	-0.1
13.	2.97	3.12	6.73	74.9	74.6	0.3
14.	3.15	3.15	7.04	76.4	76.1	0.3
15.	3.23	3.16	7.25	76.9	76.9	0.0
16.	3.29	3.18	7.30	77.3	77.5	-0.2
17.	3.11	3.15	7.01	75.9	76.0	-0.1
18.	3.34	3.19	7.64	78.1	78.4	-0.3
19.	3.20	3.15	7.20	76.1	76.5	-0.4
20.	3.24	3.17	7.10	76.7	76.9	-0.2
21.	3.20	3.17	7.26	77.2	77.1	0.1
22.	3.35	3.19	7.63	78.3	78.2	0.1
23.	3.29	3.19	7.52	78.5	78.1	0.4
24.	3.42	3.21	7.76	79.2	79.1	0.1
25.	3.06	3.13	6.82	75.7	75.3	0.4
26.	3.20	3.17	7.27	77.3	77.2	0.1
27.	3.15	3.17	7.32	76.9	77.2	-0.3
28.	3.27	3.18	7.47	77.9	77.7	0.2
29.	3.25	3.19	7.50	78.1	78.2	-0.1
30.	3.32	3.17	7.29	77.5	77.5	0.0
31.	3.23	3.15	7.11	76.4	76.5	-0.1
32.	3.41	3.2	7.80	79	79.1	-0.1
33.	3.08	3.13	6.89	75.3	75.2	0.1
34.	3.42	3.21	7.75	79.3	79.2	0.1
35.	3.33	3.17	7.50	77.6	77.6	0.0
36.	3.49	3.24	8.07	80.7	80.5	0.2
37.	3.37	3.2	7.73	78.5	78.9	-0.4
38.	3.30	3.18	7.60	77.7	77.9	-0.2
39.	3.28	3.19	7.41	77.9	78.0	-0.1
40.	3.09	3.13	6.80	75.4	75.2	0.2
41.	3.19	3.17	7.32	76.9	77.3	-0.4
42.	3.23	3.17	7.33	77.2	77.2	0.0
43.	3.43	3.22	7.85	79.7	79.7	0.0
44.	3.18	3.17	7.30	77.1	77.0	0.1
45.	3.15	3.16	7.16	76.8	76.7	0.1
46.	3.35	3.19	7.50	78.1	78.2	-0.1

Sr.No	$\sqrt[3]{P}$	Log q	$\sqrt{V}$	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
47.	3.35	3.19	7.58	78.5	78.4	0.1
48.	3.52	3.23	8.16	80.6	80.4	0.2
49.	3.40	3.21	7.84	79.4	79.3	0.1
50.	3.42	3.22	7.89	80.1	79.6	0.5
51.	3.10	3.13	6.97	75.4	75.4	0.0
52.	3.24	3.18	7.30	77.2	77.4	-0.2
53.	3.28	3.19	7.65	78.2	78.3	-0.1
54.	3.37	3.2	7.73	79	78.8	0.2
55.	3.33	3.21	7.73	79.1	79.0	0.1
56.	3.40	3.22	8.02	80.1	79.8	0.3
57.	3.39	3.21	7.80	79.4	79.2	0.2
58.	3.16	3.17	7.27	76.9	77.1	-0.2
59.	3.31	3.2	7.70	78.5	78.7	-0.2
60.	3.26	3.18	7.33	77.6	77.5	0.1
61.	3.35	3.18	7.56	78.1	78.1	0.0
62.	3.34	3.19	7.58	78.5	78.3	0.2
63.	3.34	3.18	7.66	78.3	78.3	0.0
64.	3.34	3.21	7.77	79.3	79.1	0.2
65.	3.09	3.13	6.83	75.3	75.1	0.2
66.	3.06	3.14	6.96	75.8	75.5	0.3
67.	3.23	3.16	7.16	76.9	76.8	0.1
68.	3.15	3.16	7.05	76.3	76.5	-0.2
69.	3.43	3.21	7.89	79.4	79.3	0.1
70.	3.27	3.17	7.24	77.2	77.2	0.0
71.	3.21	3.15	7.05	76.3	76.2	0.1
72.	3.42	3.22	7.99	80.1	79.9	0.2
73.	3.39	3.21	7.90	79.5	79.3	0.2
74.	3.08	3.14	7.04	75.7	75.7	0.0
75.	3.21	3.17	7.38	77.1	77.3	-0.2
76.	3.25	3.18	7.38	77.8	77.5	0.3
77.	3.32	3.19	7.45	78.2	78.0	0.2
78.	3.10	3.13	6.86	75.5	75.3	0.2
79.	3.26	3.17	7.20	77.1	77.1	0.0
80.	3.26	3.18	7.52	77.5	77.7	-0.2
81.	3.34	3.19	7.42	78.1	78.2	-0.1
82.	3.29	3.2	7.52	78.5	78.4	0.1
83.	3.29	3.19	7.60	78.2	78.2	0.0
84.	3.32	3.18	7.40	77.9	77.8	0.1
85.	3.14	3.16	7.08	76.4	76.4	0.0
86.	3.30	3.2	7.67	78.3	78.6	-0.3
87.	3.17	3.13	6.91	75.8	75.6	0.2
88.	3.26	3.16	7.33	76.8	77.0	-0.2
89.	3.26	3.19	7.63	78.1	78.2	-0.1
90.	3.16	3.14	6.94	75.9	75.9	0.0
91.	3.14	3.17	7.20	76.9	76.9	0.0
92.	3.19	3.16	7.26	76.5	76.8	-0.3
93.	3.23	3.17	7.41	77.5	77.3	0.2
94.	3.24	3.18	7.50	77.8	77.9	-0.1

Sr.No	$\sqrt[3]{P}$	Log q	$\sqrt{V}$	Measured L_{eq} (dB)A	Predicted L_{eq} (dB)A	%Error
95.	3.26	3.18	7.60	78.2	78.1	0.1
96.	3.41	3.23	8.07	80.1	80.2	-0.1
97.	3.22	3.17	7.31	76.9	77.2	-0.3
98.	3.10	3.15	6.95	76.1	76.0	0.1
99.	3.22	3.18	7.32	77.7	77.5	0.2
100.	3.35	3.19	7.49	78.2	78.4	-0.2
101.	3.28	3.19	7.60	77.8	78.2	-0.4
102.	3.27	3.18	7.50	77.7	77.7	0.0
103.	3.45	3.23	8.06	80.1	80.1	0.0
104.	3.20	3.16	6.97	76.3	76.4	-0.1
105.	3.18	3.15	7.20	76.4	76.3	0.1
106.	3.27	3.18	7.59	78.1	78.0	0.1
107.	3.30	3.18	7.45	77.7	77.8	-0.1
108.	3.26	3.18	7.39	77.8	77.8	0.0
109.	3.29	3.18	7.65	78.1	78.1	0.0
110.	3.19	3.16	7.16	76.8	76.7	0.1
111.	3.32	3.19	7.60	78.1	78.3	-0.2
112.	3.30	3.18	7.58	77.8	77.9	-0.1
113.	3.24	3.16	7.09	76.5	76.7	-0.2
114.	3.36	3.18	7.56	78	78.0	0.0
115.	3.25	3.18	7.56	77.9	77.9	0.0

The result of regression analysis is given in the table below.

Regression Statistics	
Multiple R	0.990639601
R Square	0.98136682
Adjusted R Square	0.98086322
Standard Error	0.182646256
Observations	115
	Coefficients
Intercept	-32.19993126
$\sqrt[3]{P}$	1.26289812
Log q	30.29910393
√V	1.27222973

The equation for L_{eq} with Log q, √v, $\sqrt[3]{P}$ as independent variables formed with regression analysis.

L_{eq}=(30.29910)Log q + (1.27222) √v +(1.26289) $\sqrt[3]{P}$ – 32.19993

The results of the t-test are given in the table below.

t-Test: Paired Two Sample for Means		
	L_{eq} (dB)A	**Predicted L_{eq}(dB)A**
Mean	77.56869565	77.56869565
Variance	1.743221968	1.710740199
Observations	115	115
Pearson Correlation	0.990639601	
Hypothesized Mean Difference	0	
df	114	
t Stat	-1.86761E-12	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.65832997	
P(T<=t) two-tail	1	
t Critical two-tail	1.980992234	

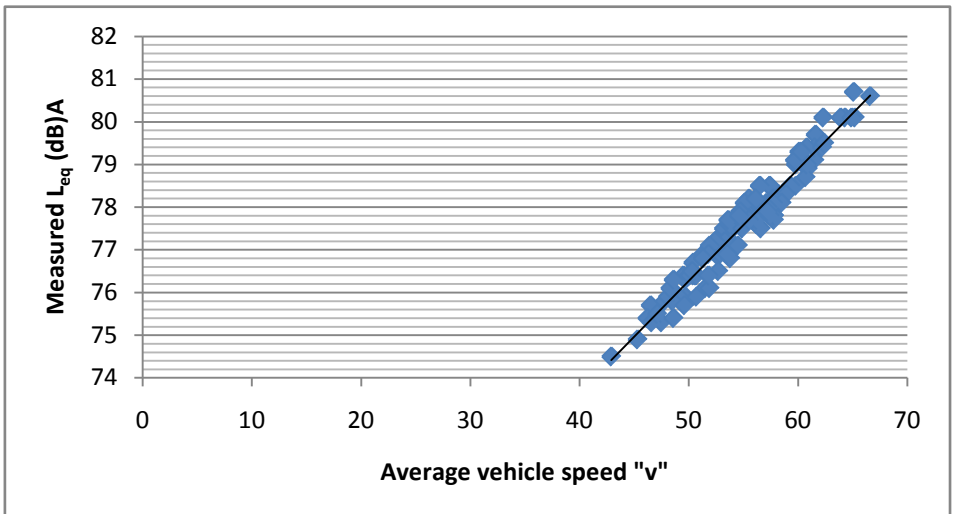

Fig. 7. Average vehicle speed "V" V/s Measured L_{eq} (dB)A

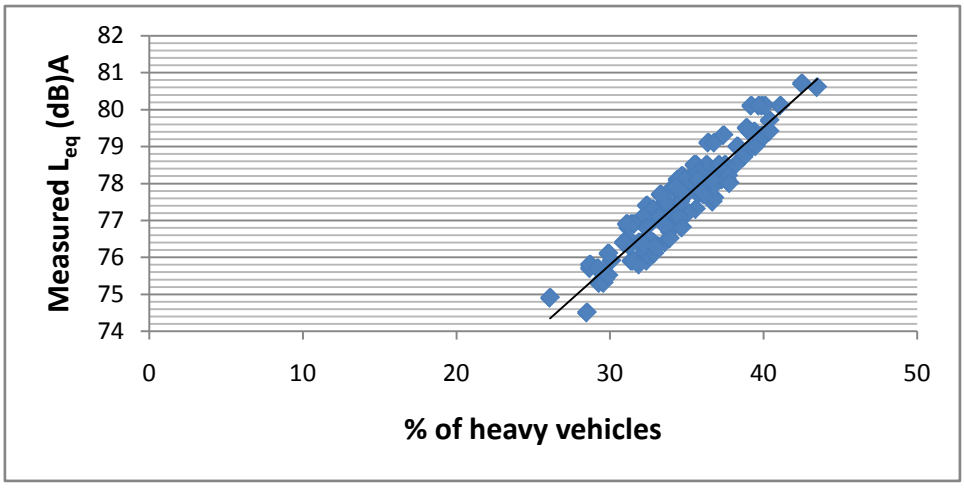

Fig. 8. % of heavy vehicles "P" V/s Measured L_{eq} (dB)A

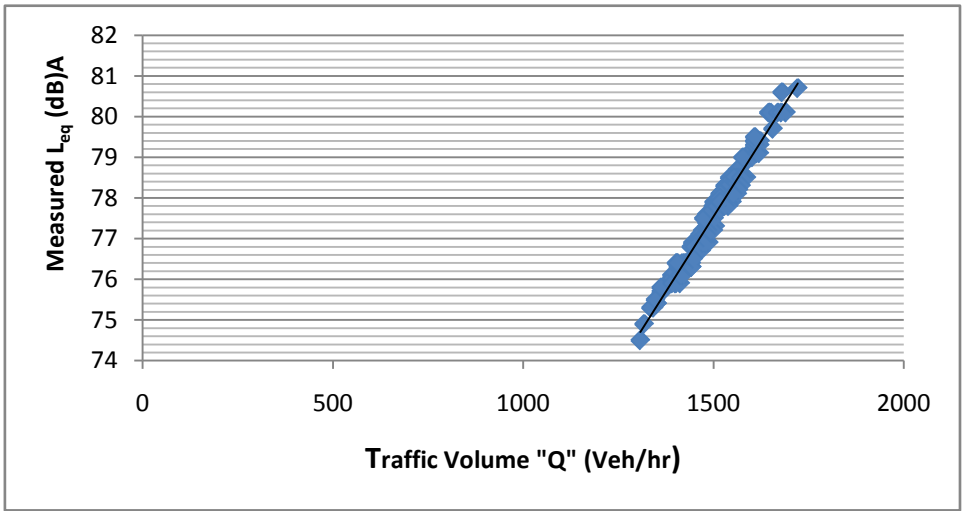

Fig. 9. Traffic volume "Q" V/s Measured L_{eq} (dB)A

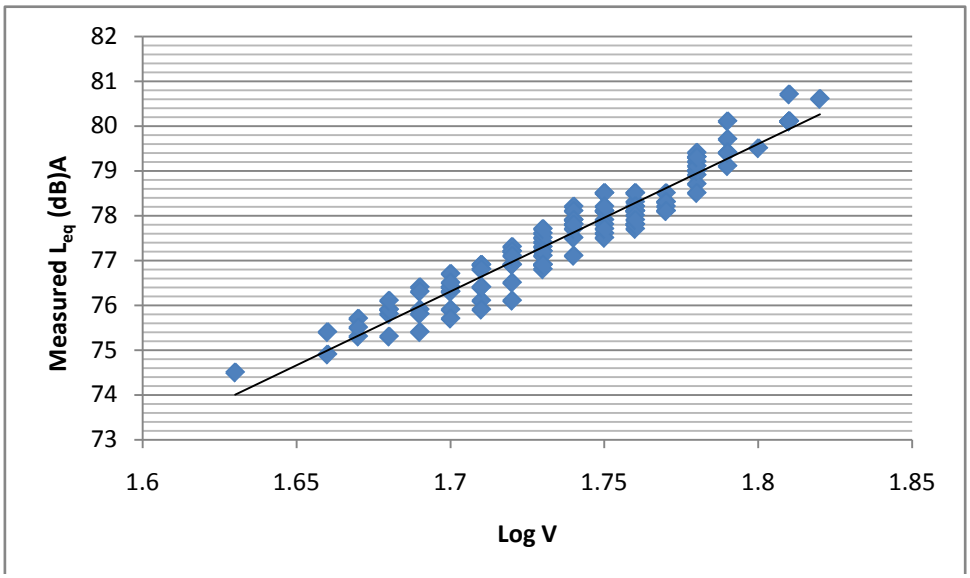

Fig. 10. Log V V/s Measured L_{eq} (dB)A

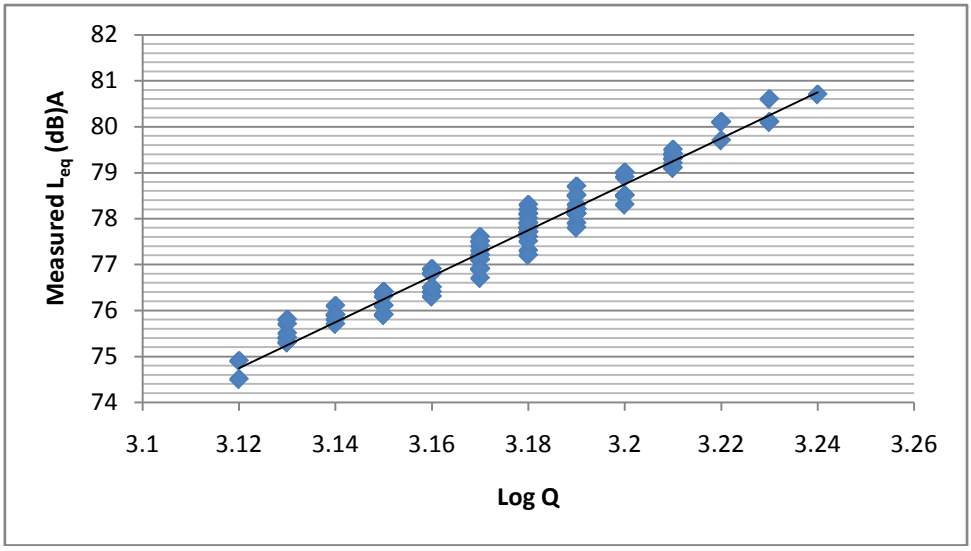

Fig. 11. Log Q V/s Measured L_{eq} (dB)A

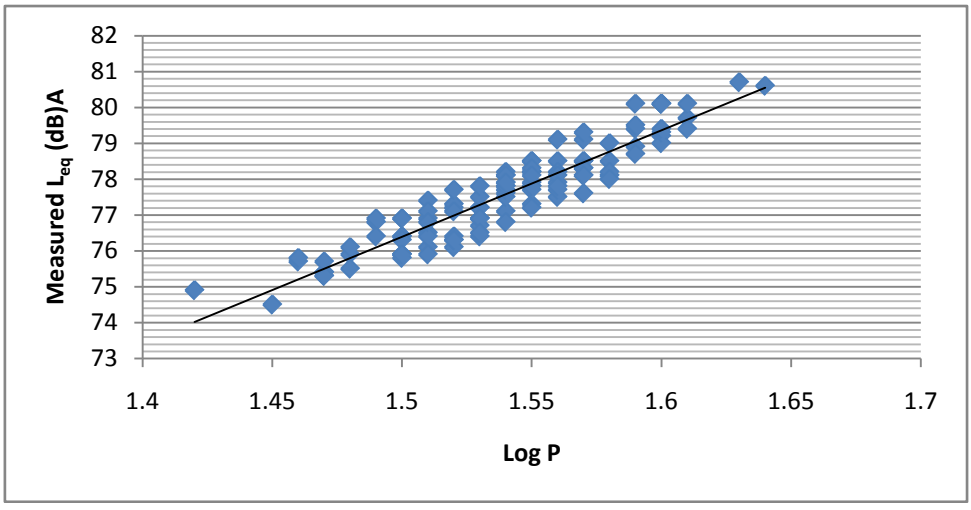

Fig. 12. Log P V/s Measured L_{eq} (dB)A

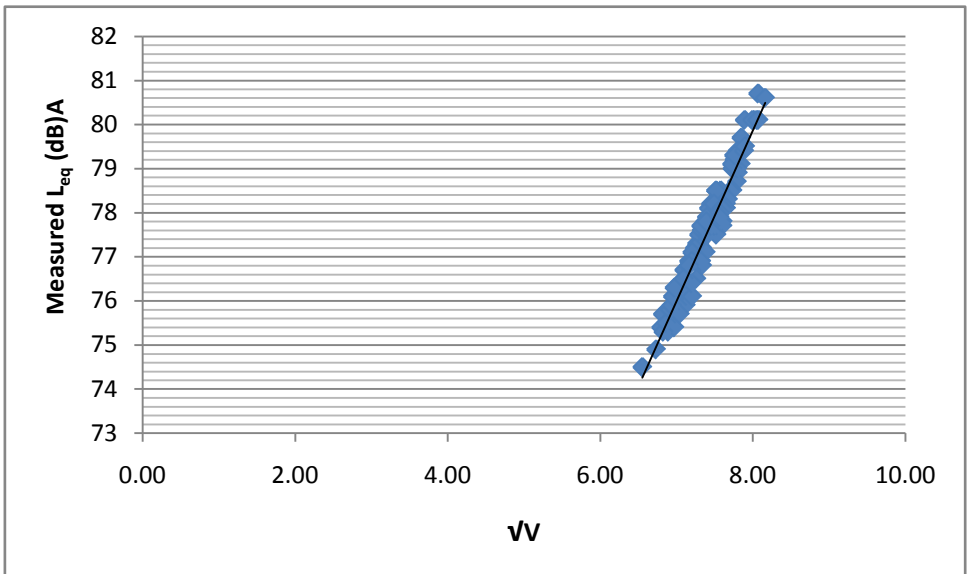

Fig. 13. √V V/s Measured L_{eq} (dB)A

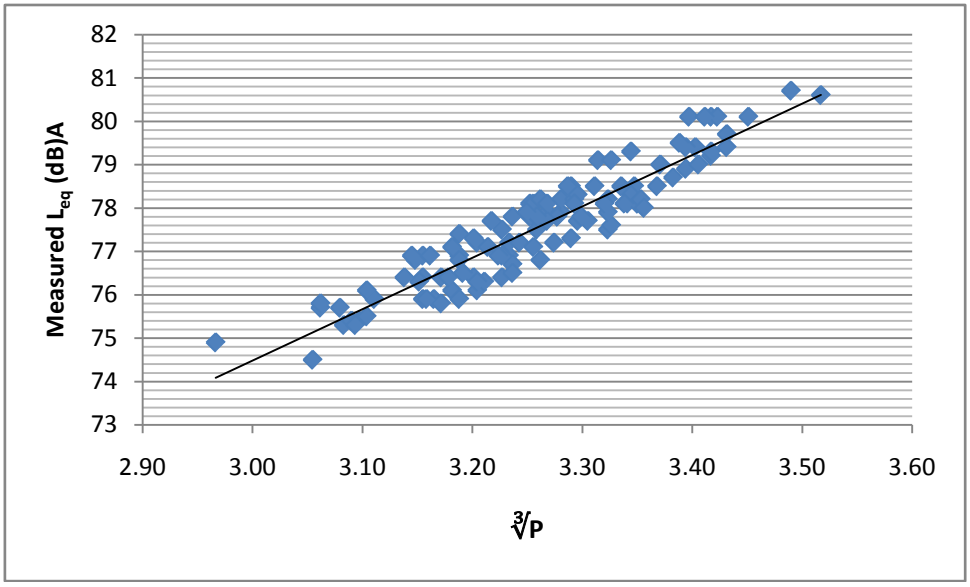

Fig. 14. $\sqrt[3]{P}$ V/s Measured L_{eq} (dB)A

6.2 Summary of the results

Following are the findings from the above result

1. Equation for L_{eq} with Q as an independent variable with Genetic Algorithm:
   L_{eq}=0.014508(q) + 55.785

2. Equation for L_{eq} with Q as an independent variable with regression analysis:
   L_{eq}=55.376+0.014772(q)

3. Equation for L_{eq} with P as an independent variable with Genetic Algorithm:
   L_{eq}=64.7949+0.36894(p)

4. Equation for L_{eq} with P as an independent variable with regression analysis:
   L_{eq}=64.6249+0.37236(p)

5. Equation for L_{eq} with V as an independent variable with Genetic Algorithm:
   L_{eq}=63.5801+0.25454(v)

6. Equation for L_{eq} with V as an independent variable with regression analysis:
   L_{eq}=63.1957+0.26155(v)

7. Equation for L_{eq} with P,Q,V as independent variables with regression analysis:
   L_{eq}= 58.205+(0.00890)q+(0.04101)p+(0.08304)v

8. Equation for L_{eq} with Log P, Log Q, Log V as a independent variables with regression analysis:
   L_{eq}= (9.64751) Log v+(30.08054) Log q+(4.27902)Log p - 41.3388

9. Equation for L_{eq} with P, Log Q, V as independent variables with regression analysis:
   L_{eq}= (0.05895)p+(0.08831)v+(27.10510)Log q - 15.431199

10. Equation for L_{eq} with P, Log Q, Log V as independent variables with regression analysis:
    L_{eq}=(0.06624)p+(9.25155)Log v +(29.09826)Log q- 33.24526

11. Equation for L_{eq} with P, Log Q, $\sqrt{V}$ as independent variables with regression analysis:
    L_{eq}=(29.90743)Log q + (1.24119) $\sqrt{V}$ + (0.04610)p-28.21131

12. Equation for L_{eq} with $\sqrt[3]{P}$, Log Q, $\sqrt{V}$ as independent variables with regression analysis:
    L_{eq}=(30.29910)Log q + (1.27222) $\sqrt{V}$ +(1.26289) $\sqrt[3]{P}$ – 32.19993

13 L_{eq} level varied from 74.5 dB (A) to 80.7 dB (A).

14 Traffic volume varied from 1308 Veh/hr to 1722 Veh/hr.

15 Average vehicle speed varied from 42.9 km/h to 66.6 km/h.

16 The percentage of heavy vehicles varied from 26.1% to 43.5%

17 In Regression Analysis, the value of R^2 varied from 0.88 to 0.99 along with different independent variables

18. Percentage Error varied from-

a) -0.5 to 0.4 for L_{eq} with "Q" as an independent variable with Genetic algorithm (Table 7)

b) -0.5 to 0.4 for L_{eq} with "Q" as an independent variable with regression analysis (Table 7)

c) -1.1 to 1.1 for L_{eq} with "P" as an independent variable with Genetic algorithm (Table 8)

d) -0.5 to 0.5 for L_{eq} with "p" as an independent variable with regression analysis (Table 8)

e) -0.9 to 0.8 for L_{eq} with "v" as an independent variable with Genetic algorithm (Table 9)

f) -0.7 to 0.6 for L_{eq} with "p" as an independent variable with regression analysis (Table 9)

g) -0.1 to 0.5 for Leq with P, Q,V as independent variables with regression analysis (Table 10)

h) -0.4 to 0.5 for L_{eq} with Log P, Log Q, Log V as independent variables with regression analysis (Table 11)

i) -0.4 to 0.5 for L_{eq} with P, Log Q, V as independent variables with regression analysis (Table.12)

j) -0.4 to 0.5 for L_{eq} with P, Log Q, Log V as independent variables with regression analysis (Table.13)

k) -0.4 to 0.5 for L_{eq} with P, Log Q, $\sqrt{V}$ as independent variables with regression analysis (Table.14)

l) -0.4 to 0.5 for L_{eq} with $\sqrt[3]{P}$, Log Q, $\sqrt{V}$ as independent variables with regression analysis (Table.15)

19. A t-paired test for means was also applied to the models for goodness-of-fit. Value of t-critical was found to be greater than t-statistics, which was found to be successful for the null hypothesis assumed.

CHAPTER-7

CONCLUSION AND SCOPE OF FUTURE WORK

Traffic situation, vehicle standards and conditions, and environmental conditions offer unique challenges in utilizing models for purpose of road-traffic noise prediction. The objectives of this study were to determine the noise pollution level in the city and the development of a traffic noise level prediction model that can be used for the purpose of traffic noise level reduction by redesigning its flow or other means. The measurements show that there is a serious noise pollution problem due to traffic in the city which is not in the acceptable range.

Appropriate precautions, such as banning the use of horns in city and prohibiting noisy vehicles from the traffic, should be taken immediately. During the measurements, it was observed that the maximum levels were produced by the heavy vehicles which are used as the main transportation means. Therefore, it can be further suggested to take precautions towards particularly noisy vehicles. Genetic Algorithm model and model based on regression analysis have been developed based on three variables, namely, average speed of vehicles, Traffic flow, and percentage of heavy vehicles

In present work, data was collected on noise generating parameters and then was applied to predict the vehicular traffic noise, and to suggest suitable models based on Indian conditions. Using Genetic algorithm and regression analysis from the present study following conclusions are drawn:

1. The programming code using Genetic algorithm is prepared for single variable. It is shown that how G.A programming can be used to predict traffic noise levels. The same has been done using regression analysis also, and it is observed that for simple problem, regression analysis can give reasonably accurate results and is found to be convenient and faster

2. R^2 value ranges from 0.88 to 0.99 for different equations of L_{eq} for the data of 18 days for 115 hours. The R^2 value of 0.88 to 0.99 indicates a very good correlation between the observed and predicted data sets.

3. The paired t- test was also carried out to provide the statistical test for the differences between the predicted results from the model and the measured result from the field. The null hypothesis was zero, that is the mean value of the differences between pairs of measured Noise and predicted Noise is equal to zero. The results from paired t- test at a significance level of 5 % show that the critical value is greater than t–statistics, so the null hypothesis is accepted, that is the mean value of difference between measured and predicted Noise level is zero.
4. The scatter plots of L_{eq} vs P,Q,V, Log Q, Log P, Log V, $\sqrt{V}$, $\sqrt[3]{P}$ were plotted which shows the dependence of L_{eq} on the different parameters.

Future Scope:

1. Measured values can be taken over wide range of time period to cover the fluctuations in readings for different timings

2. Measurement can be taken at different locations on the same highway

3. Vehicle speed was measured manually, but more accurate data can be obtained by using a radar gun.

4. Indiscriminate and heavy horn blowing causes high values of L_{max} and consequently affects L_{eq} hence, a thorough study of this aspect could be made and corrections, if any, be incorporated.

5. A Traffic counter can be used instead of manual method (i.e tally charts)

6. Observer distance, pavement width, surface finish etc. can be included in the prediction model and it may give better results.

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APPENDIX-A

CALCULATION FOR TRAFFIC VOLUME

Date.....

Site: ……..

Vehicle Type	Tally Chart			
Heavy truck (Single-unit truck with 10 wheels)				
Medium truck (Single-unit truck with 6 wheels)				
Buses				
Cars				
Tractors				
3 Wheelers				
2-wheelers (Motor Cycles, Scooters, Mopeds etc.)				

APPENDIX-B

Site: ……..

Measurement period: 15 min.

Sound level meter (Microphone):

Distance from Centre of the road (meter)……

Height from level of the road (meter) ……..

Temperature: …….^{0}C

S.No	Date & Time	Sound pressure level dB (A) Leq
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

APPENDIX-C

OBSERVATION/CALCULATION FOR AVERAGE SPEED

Distance travelled (meters).....

Time in seconds……..

Date/Time	Heavy truck (Single unit truck with 10 wheels)	Medium truck (Single unit truck with 6 wheels)	Buses	Cars	Tractors	3 Wheelers	2-wheelers (Motor Cycles, Scooters, Mopeds etc.)