TRAFFIC NOISE MODELLING CONSIDERING VARIOUS TRAFFIC COMPOSITIONS AT ROUNDABOUTS

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CERTIFICATE

I hereby certify that the work which is being presented in this thesis entitled "**TRAFFIC NOISE MODELLING CONSIDERING VARIOUS TRAFFIC COMPOSITIONS AT ROUNDABOUTS**" in partial fulfillment of the award of **Master's Degree in Production & Industrial Engineering** submitted in Mechanical Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Dr. S.P. Nigam, Visiting Professor and Mr. Daljeet Singh, Assistant Professor, Mechanical Engineering Department, Thapar University, Patiala**.

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

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ABSTRACT

The major contribution of the traffic noise, towards overall noise pollution scenario is a well known fact. Traffic noise from roundabouts creates problem for surrounding areas, especially when there is high traffic volume, heavy acceleration and small roundabouts in urban areas. Noise emanating from vehicle engines, exhausts systems and tire interaction with pavement, affect the life of nearby residents, schools, office by drowning out conversations, disrupting sleep and discouraging outdoor activities. Vehicular traffic noise problem is contributed by different class of vehicles like Cars, S.U.V., Heavy Vehicles, Three wheelers and Two wheelers. Many western countries have developed different prediction models based on L_{eq}, L_{10} and other characteristics.

The heterogeneous feature of traffic noise at roundabouts, together with the characteristics of environmental noise, with their spatial, temporal an spectral variability, makes the matter of modeling and prediction a complex and non linear problem, therefore a need is being felt to develop a traffic noise prediction model for roundabouts considering various class of vehicles suitable for Indian conditions, acceleration, deceleration and distance from road.

The present work represents a traffic prediction model taking Fountain Chowk, Thikkari Chowk, and Y.P.S. Chowk, Patiala as three roundabouts for high, medium and low traffic volume conditions respectively for representative/demonstrative site. All the measurement for noise level, traffic volume, acceleration, deceleration and distance were measured at selected points around the roundabouts at different time intervals on number of days in a random/staggered manner in order to account for statistical temporal variations in traffic flow conditions.

The noise parameters recorded are Traffic volume for each vehicle class, average acceleration and deceleration for vehicles, distance of point of measurement from road median/ roundabout and the noise descriptors recorded are Equivalent Noise Level(L_{eq}), Percentile Noise levels (L_{10} ,L_{50} and L_{90}).Effects of noise parameters on noise descriptors were also studied. To get the overall noise climate around the roundabouts, L_{eq} (Single value representing the noise

level during measurement time) and three percentile levels (L_{90} for judging and assessing the pervasive noise climate; L_{50} corresponding to average noise climate and L_{10} for maximum level of noise exposure) were studied.

A multiple regression approach has been applied for traffic noise modeling in the present study. The measured parameters were divided into four classes i.e. dependent parameters or response parameters (L_{eq}, L_{10}, L_{50} and L_{90}) and input parameters as (Vehicles volume per hour for each class, average acceleration and deceleration, distance of measurement point from road).

After carrying out the analysis the multiple R or correlation coefficient were found to be 0.84 for L_{eq}, 0.85 for L_{10}, 0.85 for L_{50}, and 0.88 for L_{90} stating that there is good correlation between the actual and the model predicted values. Also the respective R^2 values were 0.70 for L_{eq}, 0.79 for L_{10}, 0.78 for L_{50}, 0.84 for $L_{90.}$ The percentage error was found to be varying between ±3% for all the sound descriptors

Correlation test was carried out to find out the most affecting factor for a particular sound descriptor and a rank is assigned to all the factors. Negative correlation was found for road width '*l*' stating an attenuating effect between Noise level and '*l'*.

A t-test was also carried out to check for any significant difference between the measured sound level and the predicted sound level mean values. The test stated no significant difference between the measured and predicted sound levels.

Frequency analysis for 1/1 Octave band was monitored for certain days to get a feel of the dominant frequencies range. The results stated that 500 Hz., 1kHz. and 2kHz frequency components dominate in the spectrum thus causing more annoyance (1 kHz to 4 kHz). This information is quite useful and necessary for barrier design. The barrier design analysis should consider the material requirement that have more absorption coefficient to abate the peak noise level at these frequencies.

On comparison of three roundabouts weekly average traffic noise it is found that the maximum noise was found to be at Thikkari Chowk Roundabout with L_{eq} of 78.8 dB (A) , then Fountain Chowk with L_{eq} of 76.7 dB (A) and least for Y.P.S. Chowk Roundabout with L_{eq} of 73.3 dB (A). These are above the permissible values therefore mitigating measures are necessary to improve the noise climate.

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LIST OF SYMBOLS

SYMBOLS	DESCRIPTION
TTS	Temporary Threshold Shift
PTS	Permanent Threshold Shift
Hz	Hertz
f_{upper}	Frequency of Upper Limit
f_{lower}	Frequency of Lower Limit
c_{centre}	Centre Frequency
Pa	Pascal
SPL	Sound Pressure Level
SL	Sound Level
dB	Decibel
dB (A)	A-Weighted Decibel
SEL	Sound Exposure Level
L_{eq}	Equivalent Continuous Sound Level
L_{10}	10 Percentile exceeded Sound Level
L_{50}	Median value of Sound Level
L_{90}	90 Percentile exceeded Sound Level
TNI	Traffic Noise Index
NPL	Noise Pollution Level
σ	Standard deviation
Q	Traffic volume
P	Truck-Traffic Mix Ratio
V	Speed of Vehicle
a	Acceleration of Vehicle
d	Deceleration of Vehicle
l	Distance from roundabout
D_N	Observer Distance to the centre of near lanes

SYMBOLS	DESCRIPTION
D_f	Observer Distance to the centre of far lanes
D	Observer Distance
C	Number of cars
H.V.	Number of Heavy Vehicles
S.U.V.	Number of S.U.V.
T_1	Number of Three Wheelers
T_2	Number of Two Wheelers

CHAPTER - 1

INTRODUCTION

1.1 INTRODUCTION TO NOISE

In today's modern rapidly expanding environment there is a major concern of the noise. Environmental noise is an undesirable byproduct of urbanization. Although one may not notice, this unwanted or excessive sound makes a significant damage to the health of the people and has hazardous impacts on the environment. Noise is nothing but unwanted sound, a personnel definition. Noise can be defined depending upon the listener, however, several type of noise are considered to be objectionable. These types of noise are:

1) **Highway traffic noise.**
2) **Loud Machinery and tools.**
3) **Aircraft noise.**

Out of the above three, the most affecting one is the noise due to Highway traffic. In traffic noise, almost 70% of noise is contributed by vehicle noise. Vehicle noise, mainly, arises from two parameters i.e. Engine noise and Tire noise. The major concern in this work is to study the vehicular traffic noise and its prediction.

1.1.1 Harmful effects of Noise:

- Loss of hearing.
- Causes headache, nausea and general feeling of uneasiness.
- Not good for heart patients.
- Interference in worker's communication working on road leading to mistake in hearing which might result in accident.
- Leads to increased heart beat, constriction of blood vessels and dilation of pupil of the eye.

1.1.2 Useful Application of Noise

Noise though has negative impact but also has some useful effects. Some of the examples of its useful effects are:

1. **Heart beat study**: This is used by doctors, listening to the heart beats to diagnose the health of the patient.
2. **Masking effect**: If someone listens to a soft and a loud sound at the same time, he or she may not hear the soft sound. The soft sound is masked by the loud sound. The loud sound has a greater masking effect if the soft sound lies within the same frequency range, but masking also occurs when the soft sound is outside the frequency range of the loud sound. When the masking and masked sounds come at the same time, masking is simultaneous. This effect is often used in wars to befool the enemy. Also this could be used to mask an annoying sound. For example using water fountains in hotels etc. to reduce traffic noise.

1.2 FUNDAMENTALS OF NOISE

Understanding acoustics needs first the understanding of sound.

Sound is a vibratory disturbance that is produced by a moving or vibrating source. As the source moves or vibrates, surrounding atoms or molecules are temporarily displaced from their normal configuration thus forming a disturbance that moves away from the sound source.

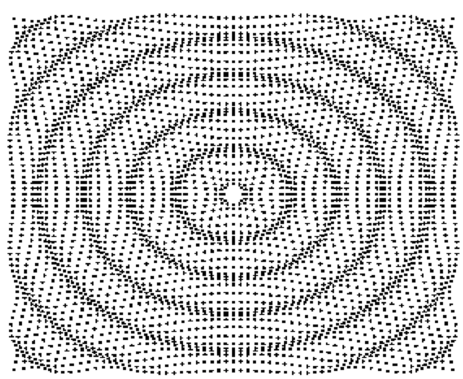


Fig.1.1 Sound waves propagate outwards as the source vibrates [38]

In the figure 1.1 it can be seen that the sphere in the middle pulsates in and out thus disturbing the molecules surrounding it and thus creating a wave pattern.

The wave pattern can easily be compared to the pattern created in water when a stone is thrown in the water.

- **Wavelength (λ):**

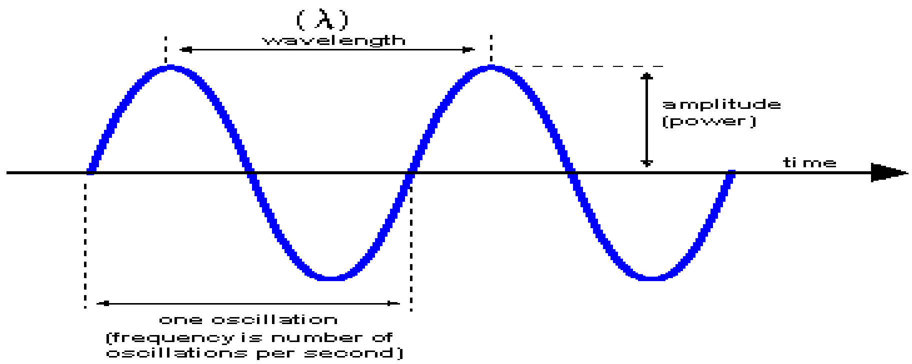


Fig.1.2 Wavelength of a sound wave [39]

The wavelength (λ) of the wave remains constant throughout its propagation provided the medium remains unchanged. It represents the repetition length of the wave.

- **Amplitude:**

Another parameter is its amplitude. The amplitude represents the strength of the wave. Greater disturbance at the source leads to greater strength of the wave and thus the amplitude will rise for the wave. For sound waves, a higher amplitude equates to higher volume

Higher the amplitude = Higher the volume

- **Frequency (f):**

Waves also have an associated frequency; Frequency abbreviated with 'f' is defined as the no. of cycles or repetitions per second.

OR

Frequency is the no. of wavelengths that pass by a stationary point in one second time

So,

Frequency (f) = (Cycles/Second) or Hertz(Hz)

$C_0 = f \lambda$

Where C_0 is the speed of sound

$C_0 = 343$ m/s = 1125 ft/s (in air at 20^0C)

The sound propagates through air particles and thus a pattern is created. The Fig. 1.3 shows the propagation of a single frequency wave in the air. The air particles are displaced as the sound waves propagates away from the source. The particles itself oscillates back and forth thus allowing the wave to travel through them.

Fig.1.3 Sound waves propagation in air through particles [40]

- Bunch up of air particles = higher amplitude area (Maximum amp.)
- Least bunch up = lower amplitude area with negative amplitude (Min. Amp.)

The audible sound range is = 20 Hz to 20 kHz

1.2.1 Physical Properties of Sound:

The amplitude of a sound wave can be quantified by measuring the associated pressure disturbance. In other words we need to measure the change in pressure from its ambient value .This change in pressure is termed as acoustic pressure. Sound can be termed in terms of physical units of pressure, Pascal (Pa.) The range of audible sound pressure variations is very wide ranging from 2 x 10^{-5} Pa (20 μPa), which is threshold of hearing (P_t) to approximately 100 Pa, the threshold of pain (P_p).

$$\text{Pascal (Pa)} = \text{N/m}^2$$

Acoustics pressure can vary in the range of 1/100 to the 100 thousands in Pascals. Because of the wide range of the amplitude encountered in measuring pressure it has become convenient to plot he pressure data on a more compact logarithmic scale. On this scale the unit is decibel (dB).

So, instead of plotting the acoustic pressure one plots the sound pressure level.

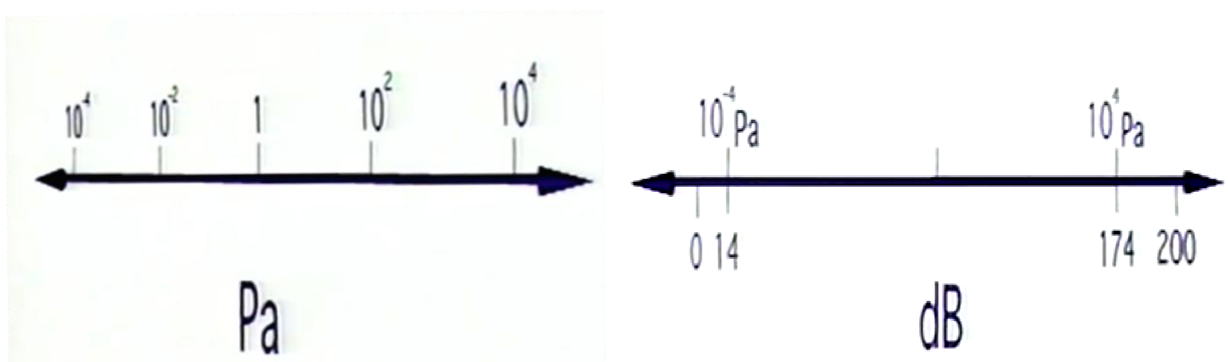


Fig. 1.4 Pascal scale and the Decibel scale [41]

The equation to find the sound pressure level (S.P.L.) is

$$\text{S.P.L} = 10 \log_{10}(p/p_{ref})^2$$

P = time averaged pressure

p_{ref} = ref. pressure value

	p_{ref} (air)	$= 20 * 10^{-6}$ Pa	=20 micro Pascal
	p_{ref} (water)	$= 1 * 10^{-6}$ Pa	=1 micro Pascal

The normal conversation S.P.L =65 dB

A lawnmower = 75 dB

A diesel truck (50 mtr. Away) = 85 dB

A jet craft at 1000 ft = 90 dB

Loud Automobile horn = 100 dB

Thresh hold value for human hearing is between 130 to 140 dB

The SPL is often abbreviated by 'L'

Table 1.1 Environmental conditions at different SPL [36]

Sound Pressure(N/m^2)	**S.P.L. (dB)**	**Conditions**
10^2	134	Threshold of pain
10	114	Loud Automobile horn (distance 1m)
1	94	Inside subway train
10^{-1}	74	Average Traffic on street corner
10^{-2}	54	Living room, Typical business office
10^{-3}	34	Library
10^{-4}	14	Broadcasting Studio
$2x10^{-5}$	0	Threshold of Hearing

1.2.2 Algorithm of sound:

As in normal addition method

80 + 80 = 160

But in the addition of S.P.L. 80 dB +80 dB ≠ 160 dB.

We can use the following expression to do so.

$$L_{\Sigma} = 10.\,\text{Log}_{10}\left(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + \cdots + 10^{\frac{L_n}{10}}\right)$$

This is done as the decibel scale is logarithmic. Therefore, one first needs to convert the each decibel value to linear scale , then add them and converted them back to the logarithmic scale.

L_1, L_2 , ... L_n represents different sound pressure levels.

So.

$$L_{\Sigma} = 10.\,\text{Log}_{10}\left(10^{\frac{80}{10}} + 10^{\frac{80}{10}}\right)$$

$$= 83.01 \text{ dB.}$$

Table 1.2 Experimental results of relation between loudness observed and S.P.L.[41]

Sound Level Change(dB)	Descriptive Change in perception
+20	Four times as loud
+10	Twice as loud
+5	Readily perceptible increase
+3	Barely perceptible increase
0	Reference
-3	Barely perceptible reduction
-5	Readily perceptible increase
-10	Half as loud
-20	One quarter as loud

1.2.3 Sound Sources:

Point source:

It is the one that is concentrated at a single point and propagates noise equally in all directions. In other words sound radiates spherically from the point source.

- The S.P.L. dips by 6 dB by doubling the distance from the point source.
- The S.P.L. dips by 3 dB by doubling the dist. when considered a line sound source.

Line source:

Line source can be considered of a no. of point sources arranged in a line. This gives us a cylindrical spreading.

So, one can consider the highway as a line source or a point depending on the density of the traffic. Individual vehicles act as a point source.

The reasons for the noise on highway due to vehicles are due to

- Engine noise
- Tire pavement interaction noise
- Exhaust noise

As highway traffic consists of various vehicles so a combination of different point sources leads to a formation of a line source of noise and thus a cylindrical spreading model could be considered and the rate of decrease of noise is -3dB per doubling of the distance between the line source and the receiver.

Traffic noise effect those who live near the road, the school, the one who work in surrounding communities, or the people who work on the highway itself,

The most obvious effects of noise due to traffic noise are

- Physical hearing damage

- Interference with other activities(Sleeping, conversation, studying....etc)
- The most dangerous is to the one working on the highway itself and are more prone to accident as they cannot hear the voice of the one who is guiding the other

1.2.4 Frequency Spectrum

A source of sound can have many different frequencies mixed. A musical tone's timbre is characterized by its harmonic spectrum. Sound in our environment that is referred to as noise includes many different frequencies. When a sound signal contains a mixture of all audible frequencies, distributed equally over the audio spectrum, it is called white noise.

A sound having one frequency component only is said to be a pure tone. Such type of sound is not common in nature, however, and the example of a pure tone is the sound produced by that of a tuning fork. Usually, Sound has components at several frequencies and the characteristics of a steady sound are determined by the pressure amplitudes at the different frequency component. Thus one can describe a steady sound by a graph of frequency against amplitude, referring to as the Frequency spectrum of the sound. Sound measuring instruments are integrally constructed to measure the frequency spectrum, but for convenience to measurement and simplicity of the instrument, the energy content is measured in a particular range of frequencies called as octave bands.

1.2.5 Frequency Analyzers:

When more detailed information about a complex sound is needed, the frequency range of 20 Hz to 20 kHz can be split into sections or bands. This is done electronically within a sound level meter. These bands usually have a bandwidth of 1/1 Octave or 1/3 Octave. More advanced instruments may be able to give a narrow band analysis of the noise data. An octave band is a frequency band where the highest frequency is twice the lowest frequency. For example, 1/1 octave filter with a centre frequency of 1 kHz has a lower frequency of 707 Hz and an upper frequency of 1.414 kHz. Any frequencies below and above these limits are rejected. A 1/3 octave has a width of 1/3 of that of an octave band.

The graphical representation of the both octave band can be seen in the figure below.

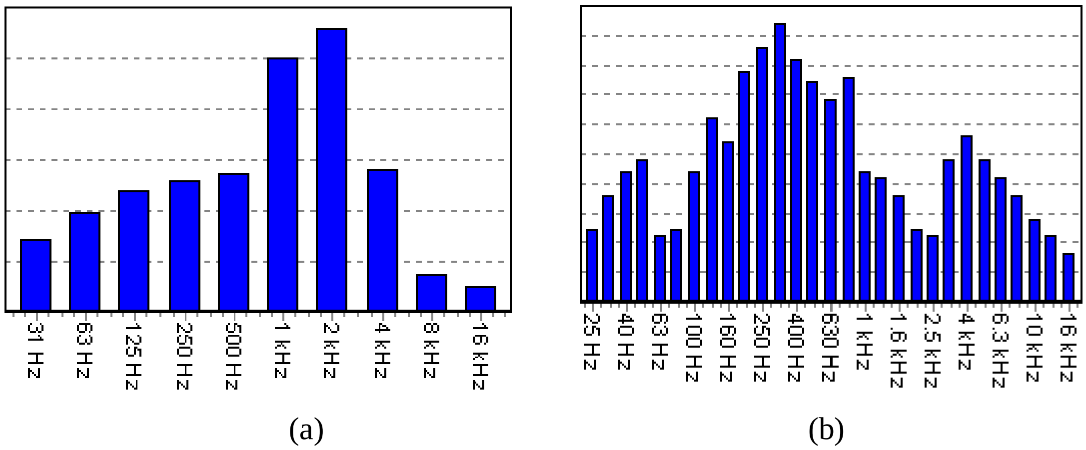


Fig. 1.5 Frequency Spectrum (a) 1/1 Octave band (b) 1/3 Octave band [42]

So, for 1/1 octave band $f_{upper} = 2f_{lower}$

for 1/3 octave band $f_{upper} = 2^{1/3}f_{lower}$

$$f_{center} = \sqrt{f_{lower}\, f_{upper}}$$

1.2.6 Loudness:

Loudness is the subjectively perceived attribute of sound which enables a listener to order their magnitude on a scale from soft to loud. It is defined as subjective intensity of sound.

Loudness Level in Phons / Sone:

A loudness of 1 sone is equivalent to the loudness of a signal at 40 phons, the loudness level of a 1 kHz tone at 40 dB SPL. But phons scale with level in dB, not with loudness, so the sone and phon scales are not proportional. Rather, the loudness in sones is, at least very nearly, a power law function of the signal intensity, with an exponent of 0.3. With this exponent, each 10 phon increase (or 10 dB at 1 kHz) produces almost exactly a doubling of the loudness in sones. This can be seen in the graph

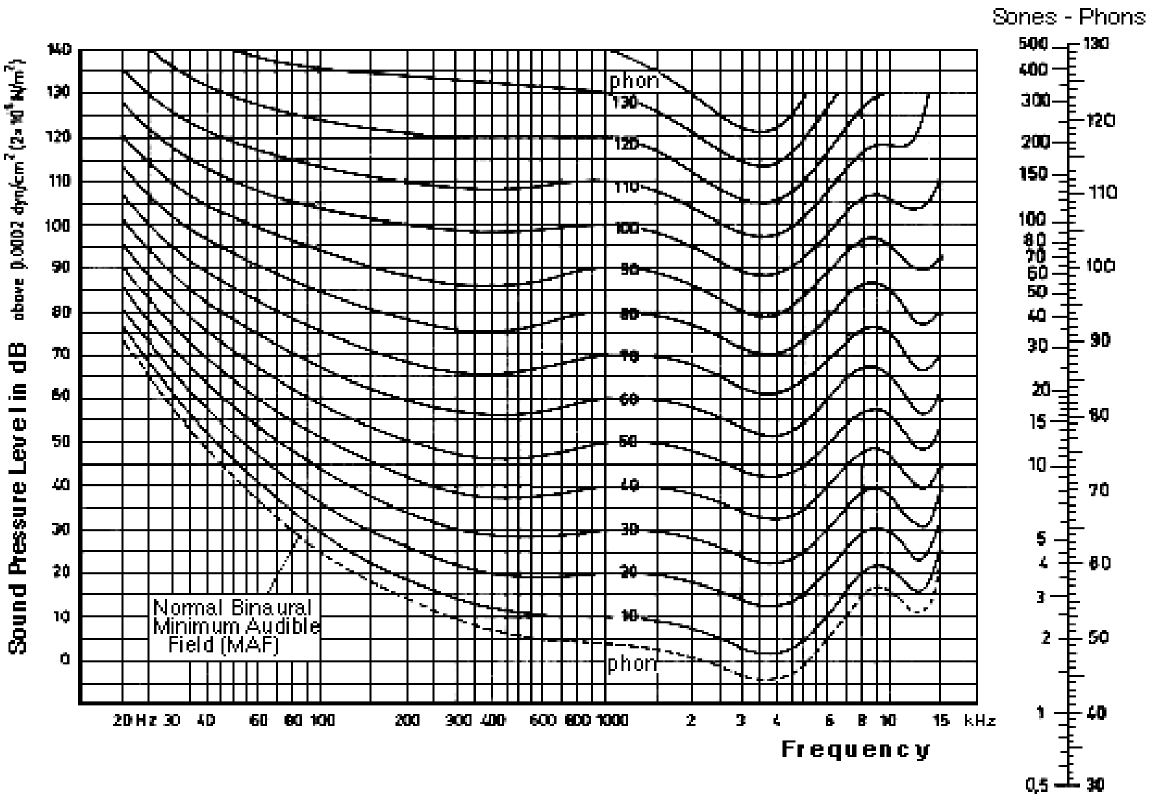
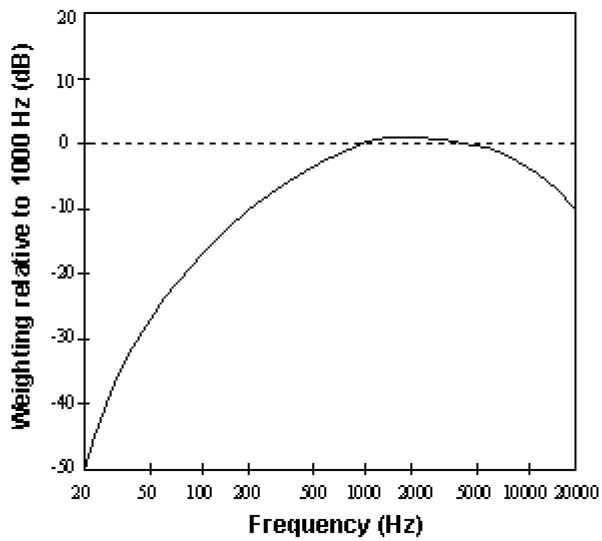


Fig. 1.6 Graph for Equal Loudness Contours [43]

1.2.7 A-Weighted Sound Level:

Human ears are most sensitive to the range of 1000 to 6300 Hz. To describe sound levels in a manner which closely approximates normal human hearing the actual sound level measurement is modified by applying “A-Weighting” to each different sound pressure level frequency. A weight is a respond function that expands the audible frequency range. Different weight is assigned to each frequency which is related to the sensitivity of the ear at that frequency. Frequencies up to lower value (20 Hz.) are weighted less. It emphasizes a

Positive adjustment for	1000 to 6,300 dB range
Negative adjustment ranges	20 to 1000 and 6,300 to above



Frequency (Hz.)	A –Weighted adjustments (dB)
31.5	-39.4
63	-26.2
125	-16.1
250	-8.6
500	-3.2
1000	0
2000	+1.2
4000	+1.0
8000	-1.1

Fig. 1.7 An 'A'-Weighted Curve and adjustment in dB [42]

So, after applying A-weight to the normal decibel value (S.P.L.) it is converted to A-weighted S.L.

dB (S.P.L.) → [A-Weighted] → dB (A) (S.L.)

This dB(A) is internationally accepted to measure the environmental noise. It follows approximately 40 phon curve. Other type of weighing curves like B and C follow more or less 70 phon and 100 phon curve respectively.

1.2.8 Background Noise:

Background noises are those noises that are due to some other conditions or parameters that are not being considered while measuring noise. For example, if it is required to measure noise on a machine than there could be other noises that could influence our results. It is important that for carrying out the noise results there should be low background noise. The back ground noise must be subtracted from total noise to obtain the sound produced by a machine alone.

- If the difference between the two readings (with background noise and without background noise), is less than 3dB then the measurement should be discontinued till the difference is not greater than 3 dB.
- If the difference lies between 3 to 10 dB then the curve to correct the measured value could be used as shown in Figure 1.8
- If the difference is greater than 10 dB then the background noise could be ignored.

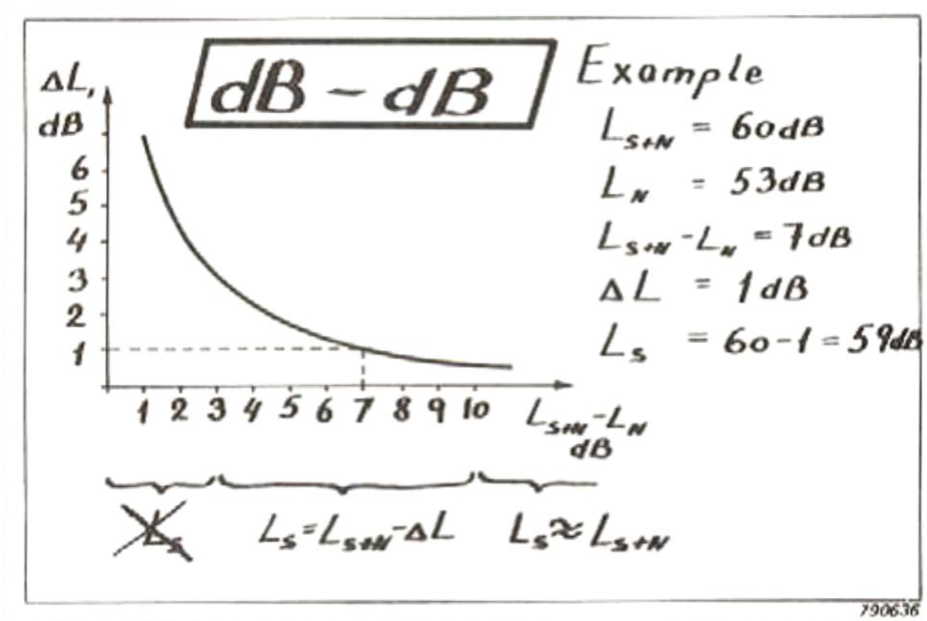


Fig. 1.8 Curve for background noise subtraction in dB [38]

1.2.9 Equivalent Sound Level (L_{eq}):

Often it is found that noise level fluctuates or varies randomly with time, as in case of road traffic noise, machine noise or community noise. The correct representation of noise level in such kind of situation is given by the equivalent continuous level (L_{eq}) that is measured in dB(A). L_{eq} is a measure of the energy content of the noise over the measurement period. It can be expressed as

$$L_{eq} = 10\ log\frac{1}{T}\int\frac{p_a^2}{p_{ref}^2}dt$$

Where,	L_{eq}	=	Equivalent sound level (dB)
	T	=	Time period(s)
	P_a	=	Sound pressure (Pa, N/m^2)
	P_{ref}	=	Reference sound pressure (20 x 10^{-6} Pa, N/m^2)

1.3 NOISE MEASUREMENT TECHNIQUES & INSTRUMENTS

Noise measuring devices typically use a sensor to receive the noise signals emanating from a source. The sensor, however, not only detects the noise from the source, but also any ambient background noise. Thus, measuring the value of the detected noise is inaccurate, as it includes the ambient background noise. Different types of instruments are available to measure sound levels and the most widely used are sound level meters.

1.3.1 Elements of sound level meter

(a) Microphone: 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 microphone are:

a. Capacitor (Condenser) Microphone

b. Pre-polarized Microphone

c. Piezoelectric Microphone

(b) 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 amplification constant.

(c) Rectifier: It rectifies the signal from analog signal to digital signal.

(d) Smoothing circuit: The circuit through which the sound waves pass.

(e) Meter: Part of the sound level meter by which observations are taken.

Fig.1.9 Sound Level Meter (CESVA SC 310)

1.3.2 Steps of Measurement System

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

Outdoor Measurement

- Wind can be significant influence on outdoor acoustical measurement
- Wind effects can be minimized to protect microphone.
- Wind generated Noise can be reduced significantly by fitting a wind screen.

Noise Measurement Procedure

- SLM should be at least at a distance of 0.5 m from the body of the observer.
- Reflections from the body of the observer can cause an error of up to 6 dB at frequencies around 400 Hz.

- SLM should be at a height of 1.2 –1.5 m from the floor level.
- Preferred position from near buildings and windows is 1 –2 m away.
- Outdoor measurements to be made at least 3.5 m away from other reflecting structures.
- Within the room measurement should be made in the Free Field zone.

1.4 NOISE ABADEMENT CRITERIA

Certain international standards for the noise abatement have been specified according to the site specific conditions and their levels. The Federal Highway Administration regulations states following noise levels for certain site conditions. These are shown in Table 1.3

Table 1.3 Noise Abatement Criteria

Activity Category	**L_{1h} dB(A)**	**1-hour 10-Percentile-exceeded level**	**Descriptions of activity category**
A	57 (exterior)	60 (exterior)	Lands on which serenity and quietness are significant.
B	67 (exterior)	70 (exterior)	Picnic areas, recreation areas, playgrounds, parks, residents, motels, hotels, libraries, churches etc.
C	72 (exterior)	75 (exterior)	Developed lands, properties or activities not in Category A or B above.
D	-	-	Undeveloped Lands
E	52 (interior)	55 (interior)	Residences, hotels, motels, public meeting rooms, schools, churches, libraries, hospitals and auditorium

CHAPTER – 2

VEHICULAR TRAFFIC NOISE

2.1 NOISES IN HIGHWAY TRAFFIC

Noise in the highway are considered to be a case of a sound source moving i.e. not stationary and if one needs to measure it with a sound measuring equipment then it is needed to consider a case in which sound level is zero when there is no traffic and increases when a vehicle passes by, reaches maximum value when it is most near to the sound receiver and then minimizes at it moves away.

It is also needed to consider various parameters that could be affecting the traffic noise like vehicle traffic flow and their proportions, vehicle speed, road width, vehicle acceleration and deceleration, in case of non uniform speed situations like intersection or roundabout. The accuracy of the model may also be increased by considering different site locations and more data set.

2.2 HIGHWAY NOISE PREDICTORS

Because of the large array of noises and the need to understand them from different perspectives there are several ways to describe noise. Many of these descriptors are available and each of these is appropriate in different conditions.

L_x – Percentile Exceeded Sound Level.

The general descriptor L_A is the one already discussed

L_A – A-Weighted Sound Level.

Some other descriptors are

Table 2.1 Descriptor and their symbols

Descriptor Symbol	Descriptor
L_{AE}	Sound Exposure Level
$L_{A(F,S)max}$	Maximum Sound Level
L_{Aeq1h}	Hourly Equivalent Sound Level(A-weighted)
L_{dn}	Day-Night Average Sound Level
L_{den}	Day-Evening-Night average
L_{10}	10 Percentile Exceeded Sound Level
L_{50}	50 Percentile Exceeded Sound Level
L_{90}	90 Percentile Exceeded Sound Level
TNI	Traffic Noise Index
NPL	Noise Pollution Level

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

$$NPL = L_{eq} + 2.56\sigma \text{ dB}$$ where σ= Standard deviation of instantaneous sound level

2.3 VEHICLE NOISE

2.3.1Characteristic

Highway traffic noise is due to the vehicles moving on the road. The highway traffic is composed of different vehicle class. These are like Light Vehicle(Bike), Medium Vehicle(Car), Heavy Vehicle(Truck/Bus), Three Wheeler(Auto) and S.U.V.

2.3.2 Vehicle Noise Sources

It is known that vehicular traffic noise is one of the major urban community annoyance sources. The one near the highways are the most affected by this. The heavy vehicles are considered to be the main offender. The reason for which there is such high annoyance due to heavy vehicles are

- Horn Blowing
- Engine Noise
- Transmission Noise
- Tyre Interaction Noise
- Exhaust Noise

Tyre interaction noise is more dominant when the vehicle is moving at high speeds, greater than ≈ 50 km/hr. At lower speeds the engine/transmission noise/exhaust noise is more dominant than the tyre interaction noise. So in urban city areas the engine noise/exhaust noise becomes the main factor of traffic noise.

2.3.3 Effect of various parameters on traffic noise

Since the vehicular traffic noise is considered to be dependent on different factors like traffic composition, Vehicle speed, Acceleration, Deceleration, Width of median etc. These factors do not remain constant. Some of the factors like distance of center lane from measuring point could be made constant by adjusting the distance between centre lane and measuring spot.

- **Traffic Parameters**: Vehicle Volume
  Vehicle Class
  Vehicle Mix Ratio
  Average Speed (*v*)
  Acceleration (*a*)
  Deceleration (*d*)
- **Roadways Characteristics:** Pavement or Road Width (*l*)
  Flow Characteristic
  Gradient
  Surface Finish
- **Observer Characteristics:** Observer Distance
  Element Size
  Shielding
  Observer Relative Height

2.4 METHODS OF PREDICTION

Several investigators have tried to formulate the equation for traffic noise with the help of a mathematical expression in terms of parameters that are affecting it. Two approaches have been used for predict the noise descriptors.

- Computerized Procedure: In this type of approach an equation can be formulated for various noise descriptors and try to find the factors that could be most significantly affecting the respective sound descriptor.
- Nomograph Procedure: In this procedure we try to predict the traffic noise model for a very high traffic volume flowing on a straight path.

2.5 NOISE BARRIERS

The term noise barrier refers to any large object that blocks the line of sight between the source and the receiver. It includes the ground itself if it protrudes upwards b/w the line of sight. Natural terrain features such as hills and dense woods as well as man made features such as walls buildings etc are example of noise barriers. This reduces the noise level at the receiver.

This reduction depends on the size of the obstruction and the frequency content of the noise source. Three possible path the sound can propagate between the noise source and the receiver are:

1. By diffraction through the barrier.
2. Reflected by the barrier.
3. Reflection from the barrier.

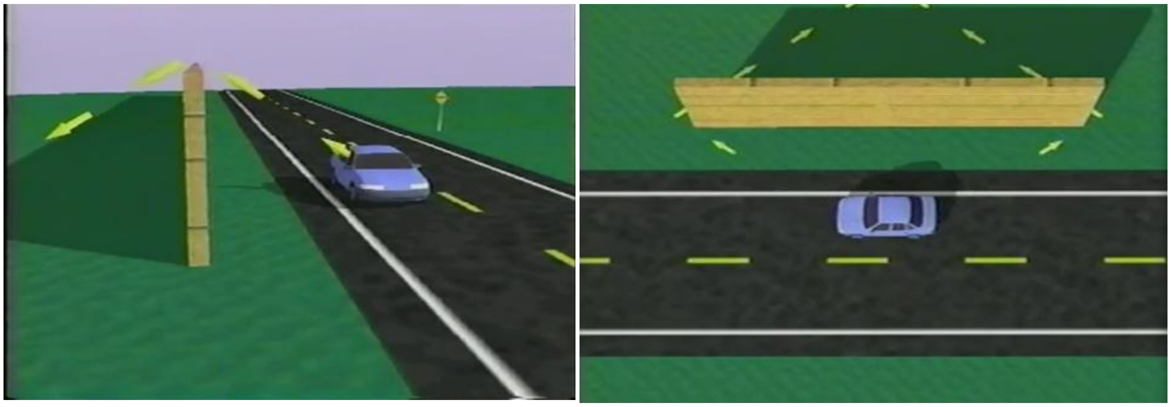


Fig. 2.1 Barrier Consideration aside a road [41]

Higher wavelength sound waves bend sharply through diffraction by the edge of the barrier.

Shorter wavelength sound waves do not bend that much by the edge of the barrier.

Diffraction also occurs around the barrier ends.

Due to barrier insertion there is a loss termed as "Barrier Insertion Loss (IL)"

$$IL = L_{before} - L_{after}$$

The other important factor is the transmission through the barrier. This relate to the transmitting of the sound through the barrier. It mainly depends on the material of the barrier used. The amount of dip in noise level for concrete is up to 30 dB for normal wall thickness.

2.6 NOISE PREDICTION MODELS

Evidence and results state that the traffic noise level is a contribution of the type of individual vehicle class and the factors such as vehicle speed, acceleration, deceleration road gradient etc. These have been developed in many countries. The model includes the prediction of various descriptors like L_{10}, L_{eq}. Countries like U.S.A., U.K, and other European Countries have developed and modified their own traffic noise models and standards. Some of the examples of these models are like F.H.W.A.(Federal Highway Administration) of U.S., C.O.R.T.N. (Calculation of road traffic noise) of U.K, A.S.J. of Japan, RLS-90 of Germany. These models have also been adopted by many other countries.

2.6.1 Use of a Traffic Noise Model:

Traffic noise prediction models are required as aids in the design of highways and other roads and sometimes in the assessment of existing or envisaged changes in traffic noise conditions. They are commonly needed to predict sound pressure levels (S.P.L.), specified in terms of L_{eq},L_{10} etc., set by government authorities.

Traffic noise prediction models are required for use by five main groups:

1. **Roadway engineers**, who check designs for compliance with statutory noise constraints and determine any need for screens or additional spacing between road and buildings.

2. **Acoustical engineers**, for fine work such as architectural and more general applications, one would wish, in addition to L_{eq}, predictions of, say, L_{max}, L_1, L_5, L_{10} and L_{90} if these could be had conveniently.

Capability is especially wanted for interrupted and complex row, for predicting the effects of various traffic light cycles, traffic routings, pedestrian crossing locations and other controls. There is a need for a convenient model to give these predictions.

3**. Expert witnesses in civil or criminal courts** or other official enquiries, whose opinion is usually required in addition to an assessment of any statutory requirements.

4. **Acoustic specialists**, who prepare the acoustic section of Environmental Impact Statements.

5**. Acoustic consultants**, engaged by clients perhaps adversely affected by road traffic noise. Such cases primarily require remedies and recommendations. Models may be used to ascertain whether measured noise is consistent with appropriate design or, in a few cases, statutory conditions.

CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

Traffic noise models are required in designing new highways and also for redesigning traffic flow in existing roads to have good and silent noise conditions. In the last few years a number of traffic noise models have been created by different researchers to estimate noise levels in various areas like highway and urban areas. Pamanikabud P. et al. [11] formulated a model of highway traffic noise based on vehicle types and class in Thailand. Li et al. [9] formulated a GIS based road traffic model for noise prediction. Calixto et al. [13] developed a statistical model to estimate road traffic noise in an urban setting in Brazil. Steele Campbell [7] reviewed various models that were developed and used like CoRTN, STAMINA, and F.H.W.A. M. Tansatchab et al. [17] developed a model's parameters including traffic volume and combination, the average spot speed of each type of vehicle and the physical conditions of the motorway in terms of right-of-way width, number of lanes, lane width, shoulder width, and median width for both roadways. Many researchers in different countries have also done modeling for roundabout. All the above mentioned and important works are discussed as follows:

Johnson D.R. et al. [1] carried out surveys for noise emission in freely flowing on sites varying from freeway to urban roads. Some of the measurements were taken with place having adjacent building rows. The survey also included the consideration of road gradient. The results stated that there was a major contribution of traffic density, composition, speed and distance from road. They formulated the prediction model for median noise level for any traffic conditions.

Lewis P.T. et al. [2] showed the results of roadside measurements of the noise emitted by vehicles accelerating from and decelerating towards roundabouts. Three rural sites were used at which speed limits of 50, 60 and 70 mph, respectively, were in operation and where the traffic was freely flowing upstream of the roundabout. The vehicles were divided into two groups: light vehicles (less than 1525 kg unladen weight) and heavy vehicles. The measured noise levels are expressed in terms of the distance of the vehicles from the roundabout. It was found that, for both accelerating and decelerating vehicles, the noise level/distance relationships were largely determined by the free flow speeds upstream of the intersection.

Lewis P.T. et al. [3] carried out a procedure for analyzing roundabout noise. Measurement of the noise from accelerating and decelerating traffic streams on the approach roads to roundabouts at a total of 70 positions at three sites were reported together with a simulation study of noise from central island traffic. The results showed that, in general, noise from the accelerating traffic streams was within ±1 dB (A) of the free flow level on the same road and that the noise from the decelerating stream was equal to or less than the free flow level. The propagation of noise from the central island was expressed in the form of a nomogram. Good agreement between predicted and measured levels was found.

Stoilova K. et al. [4] carried out the design of a control system which was able to change the green light timings as the sound levels changed on the intersection. Traffic noise level was introduced as a state variable in a dynamical optimization problem. A closed loop control system was designed which influences the green duration of the lights according to the L_{eq}. Real time considerations lead to sub-optimal control implementation. This control policy decreased the noise levels at intensive traffic intersections. The traffic lights adapted their duration according to the noise pollution.

Makarewicz R. et al. [5] carried out the study for an interrupted traffic flow by an interruption/stopping line. Freely flowing road traffic was interrupted by a stopping line. Traffic was mainly from light vehicles, because the number of trucks, buses, etc., was negligible. Vehicles were cruising or stopping, and the traffic flows in both directions was approximately equivalent. The theory discussed in the study enabled to predict the time-average sound level, L_{AT}, when the distance between the stopping line and the receiver exceeded the road width, acceleration length, and the length of the vehicle's queue. To estimate the adjustable parameters of the model, two simultaneous measurements of L_{AT} at the site of interest were required.

Chan T.M. et al. [6] formulated a simple equation by which it is possible to relate the noise level at any distance from the center of the roundabout to the noise level measured at the center of the roundabout. Although roundabouts can carry smooth traffic flow by minimizing the start–stop operations of drivers, the noise emitted from moving vehicles would definitely affect those people who live, work, or study in the vicinity. This study gave an analytical solution of the noise emitted from vehicles at roundabouts by assuming vehicles to be incoherent sources lying continuously on the roundabouts.

Steele C. [7] carried out a review study of various models being developed in the 1950s and 1960s were designed to predict a single vehicle sound pressure level, L_p at the roadside like F.H.W.A. Version 1.0, CoRTN, RLS 90,STL-86, MITHRA and ASJ model. These models assumed constant speed, the predicted levels then being expressed as functions of speed only. Later models were designed to predict L_{eq} for traffic over a chosen period under interrupted and varying flow conditions. Earlier models predicted linear levels whereas the later models predicted A-weighted levels. More recent models predicted one-third octave band spectra. Early models assumed single point sources, some assumed short line sources whereas later ones assumed double point and even with thirty-two point sources and some with different spectra. Some commonly used models were reviewed and discussed. All the models reviewed fulfilled the conditions of government regulations.

Bengang Li et al. [8] developed a road traffic noise prediction model suitable for use in China. This model was based on local environmental standards, vehicle types and traffic conditions. The model was accurate to 0.8 dB (A) at locations near the road carriage way and 2.1 dB (A) within the housing estate, which was comparable to the F.H.W.A. model. Hourly equivalent noise levels were predicted according to the following general formula:

$$\Delta L_{EQ} = \Delta L_{O,EQ} + \Delta L_v + \Delta L_Q + \Delta L_D + \Delta L_F + \Delta L_{Ground} + \Delta L_{Gradient} + \Delta L_s$$

Where

ΔL_{EQ} is A-weighted hourly energy equivalent noise level in dB (A).

$\Delta L_{O,EQ}$ is a reference emission level of vehicles.

ΔL_V is a speed adjustment.

ΔL_Q is a traffic flow adjustment.

ΔL_D is a distance adjustment.

ΔL_F is an adjustment for finite length of road segment.

ΔL_{Ground} is an adjustment for ground absorption.

$\Delta L_{Gradient}$ is an adjustment for road surface gradient.

ΔL_s is a shielding adjustment.

Rylander R. et al. [9] in this paper found the basic increase in noise level for the various categories of vehicles i.e. Light medium and heavy, when they pass over a speed breaker. To do this the plan was to first have the reading for the normal case when there was no speed breaker and second condition with speed breaker. Two different reading were found for each case and the difference b/w the two concluded which class of vehicles offered more contribution to noise while passing over a speed breaker. Maximum difference of 23 dB was found to be for light vehicles (Cars) and reason was claimed to be aggressive acceleration.

Pamanikabud et al. [10] formulated a highway traffic noise model based on vehicle types. Data was collected from highways in Thailand with free-flow traffic conditions. First data on vehicle noise was collected from individual vehicles using sound level meters placed at a reference distance. Secondly, the collected data for building the highway traffic noise model consisted of traffic noise levels, traffic volumes by vehicle classification, average speeds by vehicle type, and the geometric dimension of highway sections. The free-flow traffic noise model was generated from this database. A constant mean emission level for each type of vehicles was developed based on direct measurement of $L_{eq(10s)}$ from the real running condition of each type of vehicles using constant term from formulated equation.

Martin S.J. et al. [11] in this paper formulated mathematical model for outdoor sound propagation from road traffic. Two models were considered. In the first one the source was considered to be coherent line source. In the second model the source was considered to be incoherent line source.

Results found were:

- Median barrier 1 m in height produced consistent values of insertion loss of between 1 and 2 dB.
- Median barrier used with a roadside barrier produced further improvement in insertion loss of between 1 and 2 dB over the range of conditions considered.

Calixto A. et al. [12] carried out the studies on the roads that were transformed in to big avenues, measurement for noise level(L_x), speed(V) and vehicle flow(Q) was done for each vehicle category composition. A mathematical model was developed from the data collected and the results found were compared to the German standard RLS-90, and found acceptable. It was concluded that the mean traffic noise level was above prescribed value in these areas and were exposed to high noise levels. High correlation was fund for vehicle flow per hour and percentage of heavy vehicles for noise descriptors L_{10}, L_{50}, L_{90}.Measuring distance was taken as 25 meters.

$$L_{eq} = 7.7 \log[Q(1 + 0.095 \cdot VP)] + 43 \quad dB(A)$$

$$L_{10} = 6.2 \log[Q(1 + 0.095 \cdot VP)] \quad dB(A)$$

$$L_{90} = 10.2 \log[Q(1 + 0.050 \cdot VP)] + 27.1 \quad dB(A)$$

Anyogita S. et al. [13] studied the noise and 1/1 octave band spectrum for various categories of CNG vehicles like R.T.V., Bus, Auto rickshaw and Taxi. Various noise descriptors were analyzed for under speed and free flow speed. The results stated that equivalent sound level was maximum for R.T.V. followed by bus, a utos and then taxi. The study revealed that there was lesser noise level from CNG driven vehicles.

Lenzi A. et al. [14] analyzed the effect of traffic composition on the noise generated by vehicles on Brazilian roads. Traffic composition was defined as the percentage of heavy vehicles with respect to the total number of vehicles. A total of 149 measurements were made on three roads. For each road L_{10} and the equivalent level L_{eq} were measured. These levels were plotted against the composition of the traffic and empirical expressions were obtained with reasonably good correlation coefficients. The results were found to be greater for both descriptors L_{eq} and L_{10} compared to those of Crompton and Gilbert found for UK roads, accompanied with the explanation that difference was due to unusual acceleration, non standard exhaust pipes, horn blowing without reason.

Nicol F. [15] carried out a series of noise measurements in ‘canyon’ streets in Athens with aspect ratio (height/width) varying from 1.0 to 5.0. The main purpose of the measurements was to examine the vertical variation in noise in the canyons in order to give advice on natural ventilation potential. A simple model of the noise level was developed using a linear regression analysis. The model could be used to predict the fall-off (attenuation) of the noise level with height above street level. The attenuation was found to be a function of street width and height above the street, but the maximum level of attenuation (at the top of the canyon) was almost entirely a function of the aspect ratio except in narrow streets. Background noise (L_{90}) suffers less attenuation with height than the foreground noise (L_{10}).

M. Tansatchab et al. [16] developed a model’s parameters including traffic volume and combination, the average spot speed of each type of vehicle and the physical conditions of the motorway in terms of right-of-way width, number of lanes, lane width, shoulder width, and median width for both roadways. The noise level generated by each type of vehicle had been analyzed according to the propagation in the direction perpendicular to the centre-line of motorway. The total traffic noise was then analyzed from traffic volume of all vehicle types on both sides of roadways. Also it was found out that speed of the vehicle can also be taken out of the formula when we approach this analysis.

Sooriyaarachchi R.T. et al. [17] developed a road traffic noise prediction model for the roads of Sri Lanka. The developed model was capable of predicting the combined traffic noise generated from vehicles in highways. Traffic flow data used for constructing this model consisted of vehicle noise, vehicle class, vehicle speed and the distance from the traffic flow line was collected from several locations of the Western Province. A regression analysis was performed to have a individual basic emission noise level. TNFM-UOC simulator software was used for the development of the simulation and the GUI. The predictions made by the model were found to be within ±11dBA accuracy with respect to the actual experimental observations.

Chevallier et al. [18] developed a dynamic macroscopic model for unsignalized intersections which accounts for time-limited disruptions in the minor stream flow, even in free-flow conditions when the average flow demand was satisfied. It introduced a fictitious traffic light to represent an average alternating sequence of available and busy time periods for insertion depending on the major stream flow. Two allocation schemes of the total outflow during green periods were developed to model the influence or non-influence of the minor stream over the major stream flow. The model developed could be used for more than two traffic flow stream mixing. Moreover, the model predicts accurate average vehicle delay and queue length estimates compared to theoretical and empirical data. It had three easy parameters t_m (the inverse of the major road capacity), t_f (the insertion time) and μ (the dynamic capacity ratio) that could be easily calibrated and simulated. These could also be used for roundabout.

Cohn F. et al. [19] investigated the accuracy of the two simulation software, FHWA TNM (Version 2.5) and HNP (Version 1.0). The accuracy was found to be more in HNP as the error was found to be within 0.5 dB (A) whereas in TNM the error was found to be 2.0 dB(A).The reason was found to be the improved ground reflection deployed in HNP. While the TNM is supposed to give better results in case where there is no barrier. The data was collected for point source. The results thus finally state that FHWA TNM (2.5) over predicts the noise level.

Makarewicz et al. [20] carried out the study for replacement of a classical road intersection by a roundabout, under certain conditions, which produced a traffic noise decrease. These conditions were expressed in terms of the roundabout speed and the receiver location. The A-weighted sound exposure level was used to describe noise reduction. The $\Delta L<0$, when the roundabout traffic speed V_R was less than the critical speed V_*. The model presented in this study was based on the assumptions that traffic flow is identical in all possible directions, with only one category of vehicles(Automobiles), each automobile stopped at the center of the road intersection, there was a constant deceleration and acceleration rate. During deceleration and acceleration, the A-weighted sound power is a cubic function (αV^3) and a linear function (αV) respectively, of the point sourced automobile speed.

Qudais et al. [21] developed a statistical model for $L_{eq,}$ L_{max}, $L_{min.}$in terms of traffic volume, composition of traffic, traffic speed, horn using effect, number of lanes, width of lanes, approach width, road slope, and pavement surface texture. The parameters affecting each noise level were selected based on correlation matrices, scatter plots, and statistical t-test. The best factor was found to be the traffic volume. Predicted maximum noise level was found to be significantly affected by the number of heavy vehicle in the traffic stream in addition to the horn effect. Their model developed ha a R^2 value of 0.88 which was able to explain the variation well in the noise level variation.

Can et al. [22] did the study to test different traffic and noise source representations for L_{Aeq} and statistical levels estimation for a 10 minute period. Tests on four scenarios that reflect urban traffic conditions were carried on which showed an individualized representation of vehicles with a macroscopic behavior rule is sufficient for noise descriptors estimation. High levels of noise were estimated at intersections. The results were obtained for having same emission law for each vehicle. They also further included the effect of gear ratio effect and classes of vehicles. The model though did not have the inclusion of heavy vehicles.

Banerjee D. et al. [23] did the study that found the effect of various factors such as vehicular speed, percentage of heavy vehicles, road width, open space, and built-up area; residential area that significantly influenced the equivalent road traffic noise level, L_{eq} and developed models for the industrial town of Asansol, India. The study also found that L_{eq} level was mainly influenced by the hourly traffic volume. The day time volume data had a large relationship with noise level, as compared to the night time volume data. Also regression equations were found and correlation coefficients were found to have a picture of relationship between factors. The R^2_{adj} value were found to be 0.88 for $L_{eq\text{-}Day}$ and 0.72 for $L_{eq\text{-}Night}$.

Rajakumara H.N. et al. [24] developed a model for interrupted traffic flow, which included the effect of acceleration and deceleration. The both effect were found separately. The model was built for a site selected in Bangalore. Sixteen points were selected for this effect to take into account. Based on these two effects, two different models were developed for regression analysis for acceleration and deceleration lanes. They also included the effect of near side and far side lane effect into a single factor as D_g (Geometric Mean of road section). The background noise was not taken into account, acoustic condition were also neglected. The noise level was measured as L_{eq}. Also the equivalent traffic volume and equivalent speed were found by having a correlation effect of each class vehicle with their noise emissions. The R^2 values obtained were 0.82 for acceleration model and 0.73 for deceleration model. The t-stat value was also found within the t-critical values.

Chevallier E. et al. [25] carried out the study in which they had considered of taking a site having intersection and then converting that intersection into a roundabout. The model assumes three different approaches for this and compares them i.e. (a) Static noise models considering free flow and constant speed with uniform distribution of vehicles, (b) Analytical model which assumes noise models assume that all vehicles are isolated from one another and (c) Micro simulation model which considered the hypothesis of no interaction between vehicles and fully capture traffic flow effects such as queue evolution. The third one gave the best results and the difference was found to be of 2.5 dB (A) for converting a intersection into roundabout.

Guarnaccia et al. [26] carried out the noise study at an intersection point in proximity of Salerno University. Acoustical noise produced by vehicular traffic depended on many parameters, including the geometry and the general features of the road. The presence of a conflicting point, i.e. an intersection, strongly affected the simulation strategy of noise that is usually performed with statistical models tuned on experimental data related to standard condition (free flow traffic, intermediate vehicular volumes, etc). The study was done by means of experimental measurements and software simulations. The aid of predictive software was highlighted, together with the shortcomings of a simulation strategy that does not take into account traffic dynamics. The error was found to be of 1.3 dB (A) between the experimental and simulate model.

Parida M. et al. [27] assessed the impact of traffic noise on residents and road users. The analysis was done by applying the F.H.W.A. model on the Moolchand Flyover, Delhi section considered. All the vehicles/Vehicles population was divided into 7 different classes. Noise level was predicted for each vehicle class from the following formulae:

$$L_{eq(ij)} = L_0 + A_{vs(ij)} + A_{Di} + A_g + A_B + A_F + A_S$$

$L_{eq(ij)}$ = Values are summed logarithmically to give equivalent noise due to traffic at the receiver

L_0 = Basic noise levels

$A_{vs(ij)}$ = Volume/speed (flow adjustment)

A_{Di} = Distance adjustment

A_g = Ground adjustment

$A_{B(iij)}$ = Barrier adjustment

A_F = Finite segment adjustment

A_S = Shielding adjustment for buildings

It is found that the observed value is always higher than the predicted value during monitoring hour. It is concluded that traffic noise caused by heavy traffic flow condition on the main BRTS corridor is significant and exceeding the national CPCB standards and thus a 2.5 meter corridor was required to satisfy CPCB standard.

Chi-wing Law et al. [28] through this 3D modeling method gave a new way of traffic noise modeling. After so much dramatic enhancement of computation power, rapid development in Geographic Information System (GIS), three-dimensional (3D) computer graphic and virtual reality technology; and the wide availability of digital topographic and mapping data have facilitated the substantial advancement in road traffic noise assessments and data presentation in Hong Kong. Traditional earlier available noise modeling tools are incapable of handling the complex topography, building geometry and noise screening structures of Hong Kong. It was basically an integration of 3D presentation tools integrating noise modeling, GIS and computer graphics. This is basically to have picture model of noise information to the community, be it for public education, engagement or consultation; and recent advances in the availability of such information interactively, and in a user-friendly manner, through the internet.

Montella A. et al. [29] investigated by means of a driving simulator experiment, driver's behaviour in terms of speed, deceleration, and lateral position on major approaches of rural intersections in relation to different perceptual cues. Ten different design conditions with and without speed-reducing treatments along the approach to the intersection were tested. Twentythree drivers drove a test route two times and data from the second drive were used for comparison. Three different data analysis techniques were used: (a) cluster analysis of speed and lateral position data, (b) statistical tests of speed and lateral position data, and (c) categorical analysis of deceleration behaviour patterns. These measures, in comparison to the base intersection, produced a significant speed reduction starting from 250 m before the intersection in the range of 13 and 23 km/h, a significant change in the deceleration behavior with a reduction in the proportion of drivers which did not deceleration and a shift away from the intersection of the deceleration beginning.

Bueno et al. [30] analyzed the influence of the surface temperature on the acoustical behaviour of a asphalt pavement. The sound levels emitted by the interaction between a reference tire and the asphalt pavement at different surface temperatures were measured. Speed was taken to be constant as 50 km/h for the testing purpose. The results shows that increasing pavement temperature leads to a reduction in the close proximity sound levels assessed at a rate of 0.06 dB(A)/^{0}C. It was also found that the friction and adhesion between tire and pavement in the contact patch could be affected by the variation of the surface temperature. As the tire temp rises and the pavement temperature rises then the noise level could further increase significantly.

Zhao Jianqiang et al. [31] in this paper developed a traffic noise model for non-straight roads such as flyovers, following the modeling process of the Federal Highway Administration's (F.H.W.A.) traffic-noise model. The traffic-noise levels predicted using the approximate and the F.H.W.A. models were compared through an example and were shown to differ only very marginally. The developed model and the FHWA model were applied to predict the traffic noise of non-straight roads for a comparison. The results indicate that the difference obtained from the two models is minor. It is also observed that the result of the two model shows least difference when the width (Δx) a small section of path considered as straight is taken as for 2km section, Δx was taken as 10 mtr and max dB(A) difference b/w the two model result was 0.1 dB(A). For the same distance 2km road and an elevated bridge (9 mtr. high) the max. Diff was found to be .4 dB(A). Receiver was kept at 20 mtr away from the road centerline.

Coensel et al. [32] found that a little scientific research has been spent on the effects of synchronized traffic lights on emissions. They did a computational study in which a microscopic traffic simulation model (Paramics) is combined with sub models for the emission of noise and air pollutants using simulation software. Through the simulation they investigated the influence of traffic intensity, signal coordination schemes and signal parameters on the noise, carbon dioxide, nitrogen oxides and particulate matter emissions on a road equipped with a series of traffic lights. It was found that the introduction of a green wave could potentially lower the emissions of the considered air pollutants by 10% to 40% in the best conditions, depending on traffic flow and signal timing settings. S.P.L. was found to decrease by up to 1 dB(A) near the traffic signals, but to increase by up to 1.5 dB(A) in between intersections. Traffic intensity was found to be having the largest influence on emissions, while the traffic cycle time did not have a significant effect on emissions. Also it was stated that by having a perfect green wave we can have more road capacity.

Tripathi V. [33] proposed the model for the generation of levels of noise for Indian traffic conditions and to measure the effectiveness of this model from the data collected at NH-58 (Dehradun Roorkee Highway). Results compared to Calixto model by having the R^2 value and the correlation between the actual measured and predicted values from models. The R^2 value for the model developed was 0.85 and efficiency of the model was 99.63 %.

Calvo et al. [34] analyzed the average behavior of a sample of vehicles and drivers in real urban traffic conditions to produce an average behavior for a ‘‘standard driver’’ and an ‘‘aggressive driver’’. The drivers experience did not have any appreciable impact on noise generated. Engine noise was significantly greater, however, for aggressive driving, and especially so for gasoline vehicles because they tend to be able to go faster and accelerate more rapidly, but under analogous conditions, engine noise is always greater for diesel vehicles than for gasoline. At low and medium engine speeds, gasoline vehicles also produce less noise than diesel ones.

Subramani T.et al. [35] carried out the study at Coimbatore city (Tamil Nadu) in which they formulated a L_{eq} equation having consideration of various parameters such as number of vehicles (Q), Vehicle speed (V), Atmospheric temperature (Ta), Surface temperature (Ts), and Relative humidity (H). There was a positive correlation between L_{eq} and Q and V and H individually.

Also there was a negative correlation between L_{eq} and surface temperature and road temperature. The R^2 value for the model was found to 0.583. Also they conducted a t-test for the sample mean. The null hypothesis was found to be accepted with mean difference to be zero.

3.2 GAPS AND CONCLUSION

Through the literature survey it is found that a large no. of models have been developed for various road conditions. It has been seen that different countries have different models for the traffic noise to meet the requirements of government regulations and designers. A review of six traffic noise emission models i.e. FHWA highway traffic noise prediction model, FHWA traffic model version 1.0, CORTN model, RLS 90 and ASJ model has been done. Also a lot of models have been developed for Highways considering various parameters and tried to implement on real road conditions. All the models discussed here have acoustic energy descriptors usually explicit as L_{eq} or in some cases as L_{10}.

It has been found that a research has not been done for the optimization of the available models for the Indian road conditions. Also a study for development of a roundabout traffic noise model has not been done for the Indian road conditions. So an effort should be made by conducting a study considering various parameters such as traffic volume and its composition, vehicle acceleration and deceleration, road width etc.

CHAPTER – 4

EXPERIMENTAL INVESTIGATION

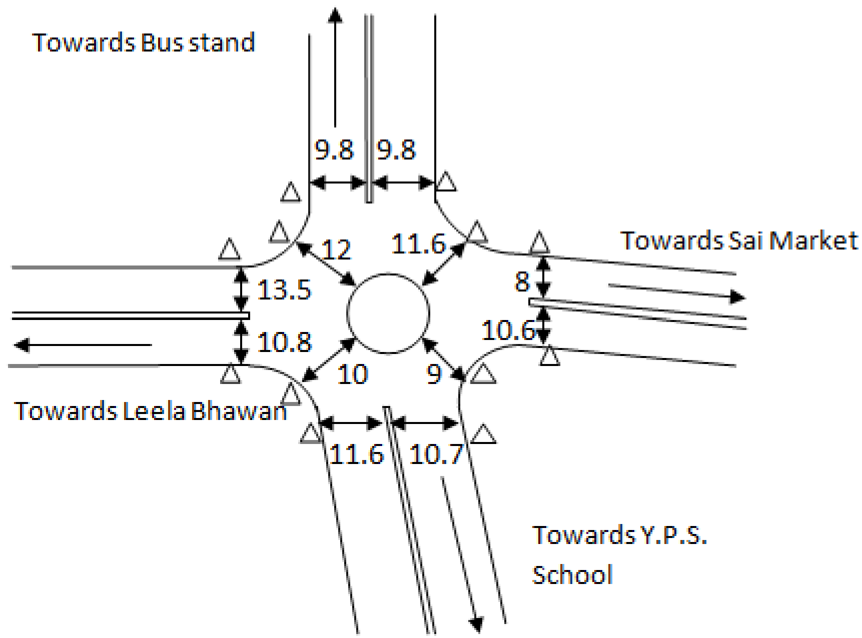
Traffic noise models are required to predict the noise produced under given road conditions. These can be used to design the roads for the changing traffic conditions in urban as well as highway road. Thus, it is commonly needed to predict various sound descriptors such as L_{eq}, L_{10}, L_{90}. Numbers of models in different countries have been developed using regression analysis and other statistical tools from the collected data. A survey of the site location revealed that the different traffic composition i.e. class of the vehicle, its acceleration and deceleration play a role in traffic noise. The vehicle composition was found to be much higher for medium vehicles and two wheelers. The average acceleration was found to be varying between 0.15to3.45m/sec^2 and deceleration for traffic was found to be varying between 0.1 to 4.43 m/sec^2.Traffic noise was exacerbated sometimes by air pressure horns at corners and excessive acceleration at the time of overtaking.

4.1 SITE SELECTION

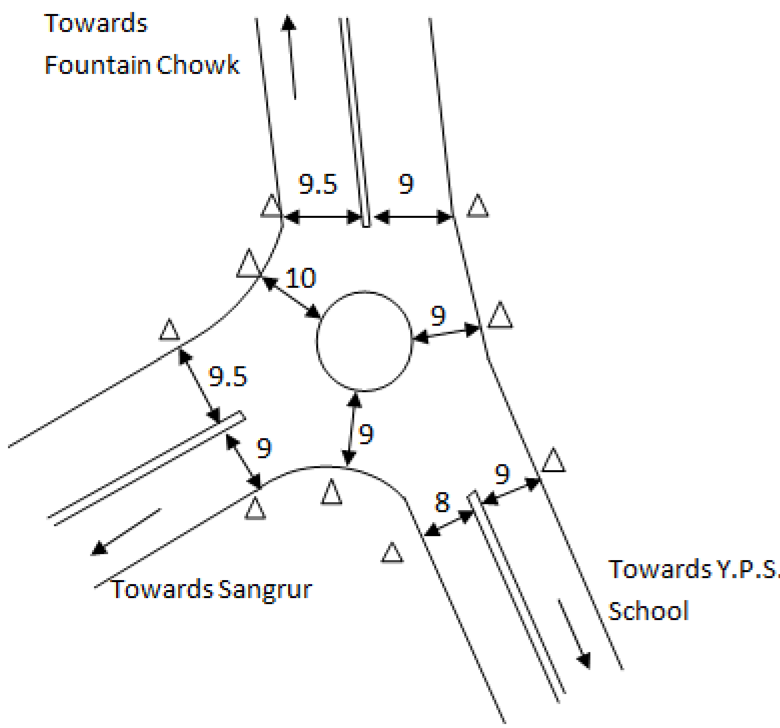
To predict the traffic noise for a roundabout, the very first task was to select the round about having all the wings approximate equal. Three roundabouts were chosen having three different types of traffic condition i.e. medium, high and low traffic volume. These three roundabouts selected were Fountain Chowk, Thikkari Chowk and Y.P.S. Chowk, Patiala, respectively. Microphone was placed at a height of 1.2 meter and at a distance '*l*' meter from the centre of the divider (Road width). The microphone was placed at various locations around the roundabout.

The locations where readings were taken are marked by **'**Δ**'** around the roundabout, as shown in Figure 4.1

(a) Sketch For Fountain Chowk:



(b) Sketch For Thikkari Chowk :



(c) Sketch For Y.P.S. Chowk :

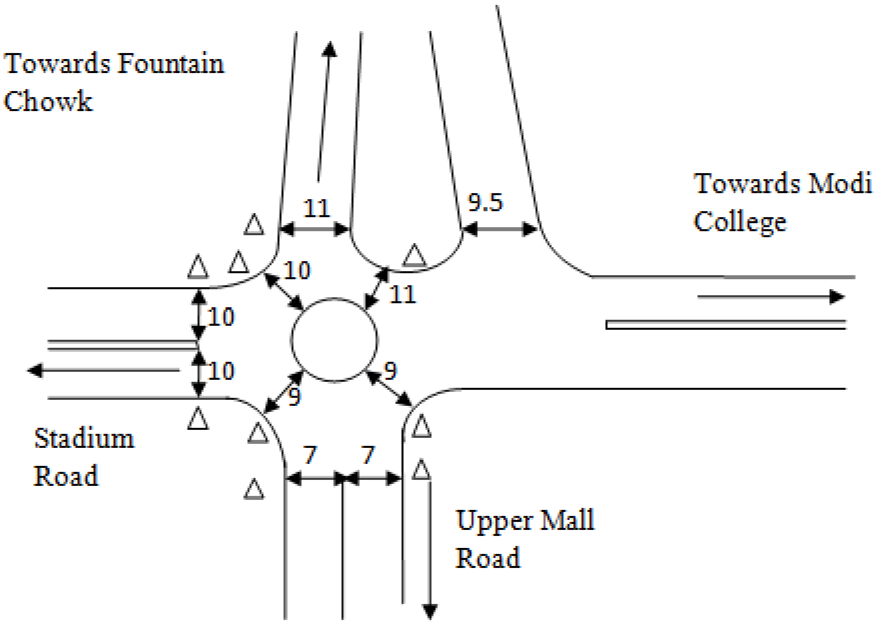


Fig. 4.1 Site map for roundabout: (a) Fountain chowk (b) Thikkari Chowk (c) Y.P.S. Chowk

Table 4.1 Roundabout Diameters.

Site	Roundabout Diameter
(A) Fountain Chowk	≅ 9 Meter
(B) Thikkari Chowk	≅ 13 Meter
(C) Y.P.S. Chowk	≅ 8 Meter

4.2 METHODOLOGY

The very first step is to define the problem. The L_{eq}, L_{10}, L_{50}, L_{90} sound levels are to be collected for 1 hour duration. The number of vehicles in each class is to be noted separately that pass a given location. The values for acceleration and deceleration on an average are to be measured for each hour. There would be some unexpected noise like from horns but the sound generated by the vehicles will be steady. The site selected for the measurement around the roundabout are such that the role of acceleration and deceleration can be studied. Thus having all the independent parameters a prediction model could be formulated.

4.3 MEASUREMENT PROCEDURE

For traffic noise problem it is useful to have the continuous equivalent sound level L_{eq}, 10 percentile exceeded sound level L_{10}, 50 percentile exceeded sound level L_{50},90 percentile exceeded sound level L_{90}.Such data is collected using a sound level meter (CESVA SC-310). The acceleration (a) and deceleration (d) values were calculated by taking readings of speed at the point of measurement and 60 meter before the roundabout using the radar gun. Also the time measured to cover the 60 meter distance was measured. Equations of motion could be used to find the acceleration and deceleration values.

$$a \ or \ d = \frac{2(s - u.t)}{t^2} \quad m/sec^2$$

The sound level meter should be calibrated correctly using the calibrator before using it to check and correct any errors. The tripod must be correctly leveled at a height of 1.2 meter from the ground level or pavement level.

The road width (l) is also to be measured corresponding to the point of placing the microphone using measuring tape.

The noise measurements recorded are L_{eq}, L_{10}, L_{50} and L_{90}.

4.4 MEASUREMENTS

Readings for the data were recorded. The vehicle count was also done during the measurement period. Vehicles are divided in to five categories according to the Indian conditions. A large number of

1-hour measurements were taken for each location on different days in random manner in order to account for temporal variations in traffic flow characteristics.

Fig. 4.2 Sound Level Meter on a tripod with windscreen.

Table 4.2 List of parameters and symbol

Parameter	**Symbol**
Car	C
Heavy Vehicle	H.V.
S.U.V.	S
Three Wheeler	T_1
Two Wheeler	T_2
Acceleration	a
Deceleration	d
Road width	l

CHAPTER – 5

RESULTS AND DISCUSSIONS

5.1 TRAFFIC NOISE MODELING

Traffic noise modeling has many uses like prediction of noise exposure along roadways, assessing the effect of road change, change of different parameters and the performance of noise barriers if applied on a road side. The basic elements of traffic noise modeling consist of the source creating noise and its propagation through air and its attenuation between the source and the receiver. Typical source inputs to the traffic noise are somehow related to the volume of each vehicle class as noise varies from class to class and the acceleration and deceleration values, operating mode of the vehicle and the section of roadway within the line of sight to the receiver position. The propagation of sound includes the acoustic character of the ground, number of lanes, site geometry and barriers/building rows if present between the source and receiver. Most models also take into account the type of pavement in regard to the tyre-pavement interaction noise, the wind and temperature conditions and interrupted flows.

In traffic noise modeling there are certain assumptions about the height of the source vehicle producing noise, the vertical distribution of source strength on vehicles in operating mode. There should also be the knowledge about the barrier effectiveness, if present.

Step 1

Collect the data showing corresponding values and variables. (APPENDIX - A)

Step 2

Plot the graphs between each noise descriptor (L_{eq} $L_{10,}$ $L_{50,}$ L_{90}) and the variables considered.

From the scatter diagram one can have a visualization of nature of each relationship. (Fig 5.5- Fig 5.36)

Step 3

The curve fitting can be obtained by doing multiple regression analysis in "Microsoft Excel" "JMP Pro" and "SPSS". By regression analysis [48] a mathematical equation can be developed.

The output of the regression from the computer is shown in APPENDIX-B TO E.

The Graphs for individual roundabout varying various sound level with days passage is also drawn in Figures (5.1 – 5.3)

Also a correlation test is also done to have a comparison that which parameter considered is having more impact on a particular sound descriptor. Output for the correlation is shown in Table (5.2-5.5).

A t paired test is also done to check the goodness of fit for $\alpha = 0.05$. Output of the t test for each predictor is shown in Tables (5.6-5.9)

Graphs for various sound descriptors have been plotted for various parameters considered. Graphs can be seen in Figure (5.10- 5.39)

Frequency analysis is also done for the traffic noise and the graphs for 1/1 Octave band are shown in the Figures (5.40 – 5.43).

Site: Fountain Chowk Roundabout, Thikkari Chowk Roundabout, Y.P.S. Roundabout.

Measurement Period: 1 Hour

Microphone at 10 meter from the centre of the lane and at a height of 1.0 meter

Temperature (Range): 25-35 ^{0}C

Humidity (Range): 11-34%

Summary:

(A) Duration of data collection – 135 Hours

(B) No. of Days – 24Days

(C) Dates – 12th March to 17th March, 2013 - Fountain Chowk Roundabout
18th March to 24th March, 2013 - Thikkari Chowk Roundabout
25th March to 2nd April, 2013 - Y.P.S. Chowk Roundabout

(D) Duration - 9:00 A.M. to 1:00 P.M. and 2:00P.M. to 5:00 P.M.

(E) Critical Observations: On Sundays and holidays the vehicle composition has decreased thus leading to the lower value of L_{10} and L_{eq}. In some cases there is excessive increase of $L_{10(1sec)}$ to 109 dB(A) because of some old used three wheelers and blowing of Air pressure horns from bus nearby the sound level meter.

(F) Traffic Volume is found to be varying throughout the day, having maximum composition during early and late hours i.e. from 9:00A.M. to 11:00A.M. and 4:00P.M. to 6:00P.M.

(G) Vehicular composition for cars and two wheelers is found to be very high as compared to the other vehicle categories throughout the day.

(H) The data for actual data being measured from the three sites are shown in APPENDIX-A.

5.1.1 REGRESSION ANALYSES FOR EQUIVALENT SOUND LEVEL (L_{eq})

The first step after collecting data for all the three roundabouts the next is to develop a model from it. A regression analysis has been done to formulate an equation for each roundabout's equivalent sound level that could be applied to predict it. The respective equations are as shown below.

For Fountain Chowk Roundabout

$$L_{eq} = 89.26 - 5.59Log(C) + 1.23Log(S.U.V.) + 3.73Log(H.V.) + 0.41Log(T_1) + 1.35Log(T_2) + 0.06a^2 - 0.27d^2 - 0.75l \quad (5.1)$$

For Thikkari Chowk Roundabout

$$L_{eq} = 79.45 + 0.91Log(C) - 0.98Log(S.U.V.) + 4.3Log(H.V.) + 1.62Log(T_1) + 1.79Log(T_2) + 0.33a^2 + 0.04d^2 - 1.87l \quad (5.2)$$

For Y.P.S. Chowk Roundabout

$$L_{eq} = 37.41 + 4.17Log(C) + 2.71Log(S.U.V.) + 1.25Log(H.V.) + 1.16Log(T_1) + 1.58Log(T_2) + 0.03a^2 - 0.02(d^2 + l) \quad (5.3)$$

From the above equations it is found that the individual model formed had an error of -4.06 to 4.41% for Fountain Chowk Roundabout, -4.27 to 2.83 % for Thikkari Chowk Roundabout, -3.76 to 4.7% for Y.P.S. Chowk Roundabout between the predicted and the measured value. Though the percentage error for the readings was found to be within ±5% but the R^2 values were found to be 0.46, 0.63, 0.56 for the respective roundabouts, but was only applicable to the respective roundabouts as it was not able to cope up with the changing conditions of a different roundabout. So, an equation is developed that could be applied to all the three roundabouts and could give more accurate model. This is done by combining the data for the three roundabouts, performing multiple regression analysis and forming a single equation that could be applied to all the three roundabouts. The R^2 value for the combined data is 0.70 and error was found to be varying within -3.2 to 3.4%. The analysis also depicts a picture of the factors that affect most the equivalent sound level. The data for the regression output can be seen in APPENDIX-B

Regression output

Multiple R	0.84
R^2	0.70
Adj. R^2	0.69
Standard Error	1.79
Confidence Level	95%
P-Value of F-Significance	0.000
F-Value	38.37
No. of observations	135

Variables	Coefficients	Standard Error	t Stat	P-value
Intercept	59.44	2.94	20.22	**0.00**
Log(C)	-1.57	1.73	-0.91	0.37
Log(S)	2.88	1.22	2.37	**0.02**
Log(H.V.)	2.39	0.59	4.07	**0.00**
Log(T_1)	1.91	0.77	2.49	**0.01**
Log(T_2)	3.39	1.69	2.01	**0.04**
a^2	0.11	0.05	2.04	**0.04**
d^2	-0.04	0.03	-1.27	0.21
l	-0.45	0.13	-3.45	**0.00**

Equation for L_{eq}:

$$L_{eq} = 59.44 - 1.57\text{Log(C)} + 2.88\text{Log(S)} + 2.39\text{Log(H.V.)} + 1.91\text{Log}(T_1) + 3.39\text{Log}(T_2) + 0.11\,a^2 - .04\,d^2 - 0\,.45l \quad (5.4)$$

Summary:

- From the regression results it is found that the model has the various parameters considered, out of which the six parameters i.e. Log (S), Log (H.V.), Log (T_1), Log (T_2), a^2 and l are very highly impacting the L_{eq} as the p-value for them lies below 0.05 and thus are very highly significant.
- The overall p-value (0.000) for the model is also very low (< 0.05) thus the model is significant for 95% confidence level.
- The R^2 value (0.70) for the model is also closer to 1 and the model is able to explain the variations well.

5.1.2 REGRESSION ANALYSES FOR 10 PERCENTILE EXCEEDED SOUND LEVEL (L_{10})

L_{10} sound levels are recorded to get a picture of factors that affect most the maximum noise levels of sound exposure on a roundabout. A regression analysis has been done to formulate an equation for each roundabout's L_{10} sound level that could be applied to predict it. The respective equations are as shown below.

For Fountain Chowk Roundabout

$$L_{10} = 111.67 - 3.31Log(C) - 0.56Log(S.U.V.) + 2.04Log(H.V.) - 0.30Log(T_1) - 4.59Log(T_2) - 0.18a^2 - 0.11 d^2 - 0.68l \quad (5.5)$$

For Thikkari Chowk Roundabout

$$L_{10} = 76.72 + 1.8Log(C) - 2.3Log(S.U.V.) + 1.34Log(H.V.) + 3.32Log(T_1) - 0.72Log(T_2) + 0.15a^2 + 0.10d^2 - 0.74l \quad (5.6)$$

For Y.P.S. Chowk Roundabout

$$L_{10} = 72.45 + 1.78Log(C) + 0.75Log(S.U.V.) + 0.63Log(H.V.) + 0.17Log(T_1) + 0.09(Log(T_2) - d^2) + 0.08a^2 - 0.51l \quad (5.7)$$

From the above equations it is found that the individual model formed had a maximum error of -3.8 to 3.93% for Fountain Chowk Roundabout, -2.68 to 4.07 % for Thikkari Roundabout, -2.86 to 2.09% for Y.P.S. Chowk Roundabout between the predicted and the measured value. Though the percentage error for the readings was found to be within ±4% but the R^2 values were found to be 0.58, 0.51, 0.67 for the respective roundabouts, but was only applicable to the respective roundabouts as it was not able to cope up with the changing conditions of a different roundabout. So, an equation is developed that could be applied to all the three roundabouts and could give more accurate model. This is done by combining the data for the three roundabouts, performing multiple regression analysis and forming a single equation that could be applied to all the three roundabouts. . The R^2 value for the combined data is 0.79 and error was found to be varying within -3.6 to 3.2%. The analysis also depicts a picture of the factors that affect most the 10 percentile exceeded noise levels. The data for the regression output can be seen in APPENDIX-C

Regression output

Multiple R	0.89
R^2	0.79
Adj. R^2	0.78
Standard Error	1.62
Confidence Level	95%
P-Value of F-Significance	0.000
F-Value	41.07
No. of observations	135

Variables	Coefficients	Standard Error	t Stat	P-value
Intercept	62.07	2.65	23.39	**0.00**
Log(C)	0.17	1.56	0.11	0.91
Log(S)	0.66	1.10	0.60	0.55
Log(H.V.)	1.23	0.53	2.32	**0.02**
Log(T_1)	4.23	0.69	6.13	**0.00**
Log(T_2)	1.49	1.52	0.98	0.33
a^2	0.03	0.05	0.71	0.48
d^2	-0.02	0.03	-0.56	0.57
l	-0.24	0.12	-2.04	**0.04**

Equation for L_{10}:

$$L_{10} = 62.07 + 0.17Log(C) + 0.66Log(S) + 1.23Log(H.V.) + 4.23Log(T_1) + 1.49Log(T_2) + 0.03a^2 - 0.02d^2 - 0.24l \quad (5.8)$$

Summary:

- From the regression results it is found that the model has the various parameters considered, out of which the three parameters i.e. Log(H.V.), Log(T_1) and l are very highly impacting L_{10} as the p- value for them lies below 0.05 and thus are very highly significant.
- The overall p-value (0.000) for the model is also very low (< 0.05) thus the model is significant for 95% confidence level.
- The R^2 value (0.79) for the model is also very much closer to 1 and the model is able to explain the variations well.

5.1.3 REGRESSION ANALYSIS FOR AVERAGE SOUND LEVEL (L_{50})

L_{50} sound levels are recorded to get a picture of factors that affect the average noise levels of sound exposure on a roundabout. A regression analysis has been done to formulate an equation for each roundabout's L_{50} sound level that could be applied to predict it. The respective equations are as shown below.

For Fountain Chowk Roundabout

$$L_{50} = 105.38 - 2.1\text{Log(C)} - 0.66\text{Log(S.U.V.)} + 2.24\text{Log(H.V.)} - 1.43\text{Log}(T_1) - 4.61\text{Log}(T_2) - 0.13(a^2 + d^2) - 0.75l \quad (5.9)$$

For Thikkari Chowk Roundabout

$$L_{50} = 63.42 - 0.24\text{Log(C)} - 1.04\text{Log(S.U.V.)} + 2.07\text{Log(H.V.)} + 0.85\text{Log}(T_1) + 1.11\text{Log}(T_2) + 0.05a^2 + 0.02d^2 + 0.34l \quad (5.10)$$

For Y.P.S. Chowk Roundabout

$$L_{50} = 61.52 + 2.9\text{Log(C)} + 1.18\text{Log(S.U.V.)} + 0.95\text{Log(H.V.)} + 0.26\text{Log}(T_1) - 1.05\text{Log}(T_2) + 0.05a^2 - 0.03d^2 - 0.23l \quad (5.11)$$

From the above equations it is found that the individual model formed had a maximum error of -2.99 to 2.98% for Fountain Roundabout, -2.93 to 2.88 % for Thikkari Roundabout, -2.59 to 2.03% for Y.P.S. Chowk Roundabout between the predicted and the measured value. Though the percentage error for the readings was found to be within ±3% but the R^2 values were found to be 0.68, 0.40, 0.48 for the respective roundabouts, but was only applicable to the respective roundabouts as it was not able to cope up with the changing conditions of a different roundabout. So, an equation is developed that could be applied to all the three roundabouts and could give more accurate model. This is done by combining the data for the three roundabouts, performing multiple regression analysis and forming a single equation that could be applied to all the three roundabouts. The R^2 value for the combined data is 0.78 and error was found to be varying within -4 to 3.35%. The analysis also depicts a picture of the factors that affect most the affect the average noise levels. The data for the regression output can be seen in APPENDIX-D

Regression output

Multiple R	0.85
R^2	0.78
Adj. R^2	0.77
Standard Error	1.58
Confidence Level	95%
P-Value of F-Significance	0.000
F-Value	41.59
No. of observations	135

Variables	Coefficients	Standard Error	t Stat	P-value
Intercept	51.59	2.60	19.84	**0.00**
Log(C)	1.12	1.53	0.73	0.46
Log(S)	0.84	1.08	0.78	0.44
Log(H.V.)	0.86	0.52	1.65	0.10
$\text{Log}(T_1)$	4.02	0.68	5.94	**0.00**
$\text{Log}(T_2)$	1.47	1.49	0.98	0.33
a^2	0.01	0.05	0.23	0.82
d^2	0.01	0.03	0.51	0.61
l	-0.05	0.11	-0.41	0.68

Equation for L_{50}:

$$L_{50} = 51.59 + 1.12\text{Log(C)} + 0.84\text{Log(S)} + 0.86\text{Log(H.V.)} + 4.02\text{Log}(T_1) + 1.47\text{Log}(T_2) - 0.01\,(a^2 + d^2) - 0.05l \quad (5.12)$$

Summary:

- From the regression results it is found that the model has the various parameters considered, out of which one parameter i.e. Log (T_1) is very highly impacting the L_{50} as the p-value for it lies below 0.05 and thus is very highly significant.
- The overall p-value (0.000) for the model is also very low (< 0.05) thus the model is significant for 95% confidence level.
- The R^2 value (0.78) for the model is also very much closer to 1 and the model is able to explain the variations well.

5.1.4 REGRESSION ANALYSIS FOR 90 PERCENTILE EXCEEDED SOUND LEVEL (L_{90})

L_{90} sound levels are recorded to get a picture of factors that affect the pervasive or background noise levels of sound exposure on a roundabout. A regression analysis has been done to formulate an equation for each roundabout's L_{90} sound level that could be applied to predict it. The respective equations are as shown below.

For Fountain Chowk Roundabout

$$L_{90} = 85.16 + 0.36Log(C) - 0.29Log(S.U.V.) + 1.34Log(H.V.) - 0.90Log(T_1) - 2.98Log(T_2) + 0.27a^2 - 0.09d^2 - 0.46l \quad (5.13)$$

For Thikkari Chowk Roundabout

$$L_{90} = 55.04 + 0.01Log(C) - 2.36Log(S.U.V.) + 0.98Log(H.V.) + 1.61Log(T_1) + 1.21Log(T_2) + 0.35a^2 - 1.03l \quad (5.14)$$

For Y.P.S. Chowk Roundabout

$$L_{90} = 37.41 + 4.17Log(C) + 2.71Log(S.U.V.) + 1.25Log(H.V.) + 1.16Log(T_1) + 1.58Log(T_2) + 0.03a^2 - 0.02(d^2 + l) \quad (5.15)$$

From the above equations it is found that the individual model formed had a maximum error of -3.28 to 2.93% for Fountain Roundabout, -4.68 to 3.58 % for Thikkari Roundabout, -2.7 to 3.66% for Y.P.S. Chowk Roundabout between the predicted and the measured value. Though the percentage error for the readings was found to be within ±5% but the R^2 values were found to be 0.60, 0.29, 0.61 for the respective roundabouts, but was only applicable to the respective roundabouts as it was not able to cope up with the changing conditions of a different roundabout. So, an equation is developed that could be applied to all the three roundabouts and could give more accurate model. This is done by combining the data for the three roundabouts, performing multiple regression analysis and forming a single equation that could be applied to all the three roundabouts. . The R^2 value for the combined data is .84 and error was found to be varying within -3.31 to 3.25%. The analysis also depicts a picture of the factors that affect most the affect the pervasive noise level climate. The data for the regression output can be seen in APPENDIX-E

Regression output

Multiple R	0.87
R^2	0.84
Adj. R^2	0.83
Standard Error	1.71
Confidence Level	95%
P-Value of F-Significance	0.000
F-Value	52.35
No. of observations	135

Variables	Coefficients	Standard Error	t Stat	P-value
Intercept	34.53	2.81	12.30	**0.00**
Log(C)	3.06	1.66	1.85	**0.05**
Log(S)	1.18	1.16	1.01	0.31
Log(H.V.)	0.65	0.56	1.16	0.25
Log(T_1)	3.47	0.73	4.75	**0.00**
Log(T_2)	3.41	1.61	2.11	**0.04**
a^2	-0.01	0.05	-0.15	0.88
d^2	0.02	0.03	0.63	0.53
l	0.13	0.12	1.03	0.30

Equation for L_{90}:

$$L_{90} = 34.53 + 3.06\text{Log}(C) + 1.18\text{Log}(S) + 0.65\ \text{Log}(H.V.) + 3.47\text{Log}(T_1) + 3.41\text{Log}(T_2) – 0.01\ a^2 - 0.02\ d^2 + 0.13l \qquad (5.16)$$

Summary:

- From the regression results it is found that the model has the various parameters considered, out of which the three parameters i.e. Log(C), Log(T_1) and Log(T_2) are very highly impacting the L_{90} as the p- value for them lies below 0.05 and thus are very highly significant.
- The overall p-value (0.000) for the model is also very low (< 0.05) thus the model is significant for 95% confidence level.
- The R^2 value (0.84) for the model is also very much closer to 1 and the model is able to explain the variations well.

From the regression analysis it is found that there are certain parameters that affect the particular sound level. These factors are identified by their corresponding *p*-value. If the p-value lies below 0.05 then that factor is considered to be highly significant, but it cannot be said that other factors that do not have p-value less than 0.05 do not have any effect on the noise descriptors as they do have some impact on them though not significant. Thus those parameters cannot be neglected from the equation. If it is tried to exclude those parameters then the correlation between the predicted and the measured values loses its significance.

The output for multiple regression results showings error and predicted sound level for all descriptors are shown in APPENDIX-B TO APPENDIX-E.

5.1.5 COMPARISON OF NOISE LEVELS ON THREE ROUNDABOUTS

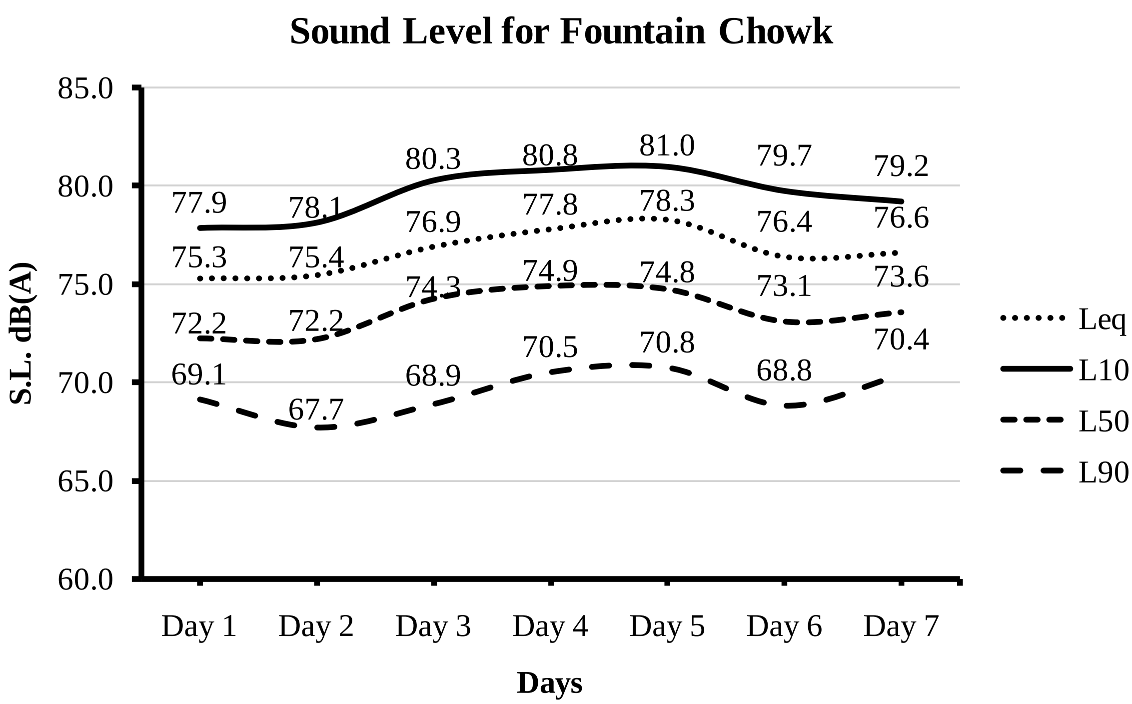


Figure 5.1 Sound levels for each day at Fountain Chowk Roundabout

A graph is plotted for different sound levels being observed for each day on an average for the Fountain Chowk Roundabout. From the graph it is found that the maximum sound levels were found to be varying between 77.9 and 81 dB (A). The equivalent sound level was found to be varying between 75.3 to 78.3 dB(A). The average sound level was found to be varying between 72.2 to 74.9 dB (A). The pervasive noise level was found to be varying between 67.7 to 70.8 dB (A).

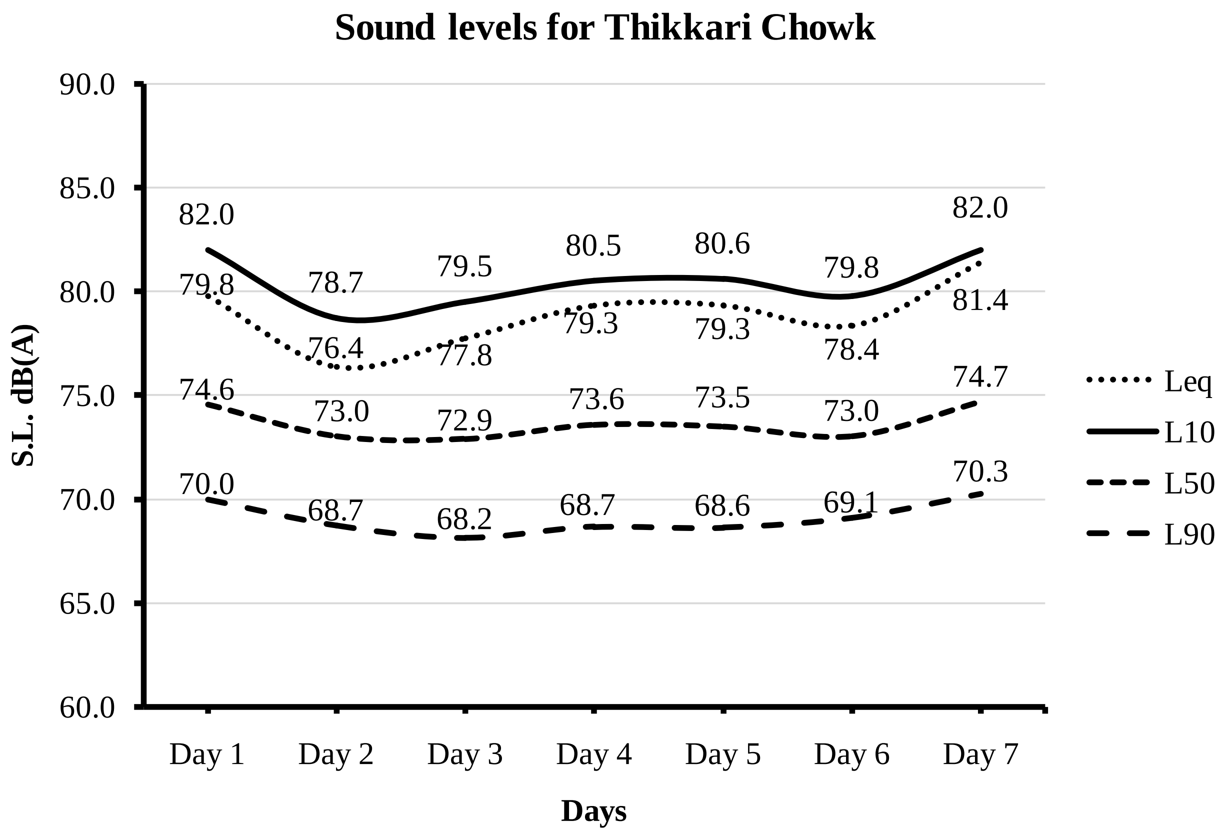


Figure 5.2 Sound levels for each day at Thikkari Chowk Roundabout

A graph is plotted for different sound levels being observed for each day on an average for the Thikkari Chowk Roundabout. From the graph it is found that the maximum sound levels were found to be varying between 78.7 and 82 dB (A). The equivalent sound level was found to be varying between 76.4 to 81.4 dB (A). The average sound level was found to be varying between 72.9 to 74.7 dB (A). The pervasive noise level was found to be varying between 68.2 to 70.3 dB(A).

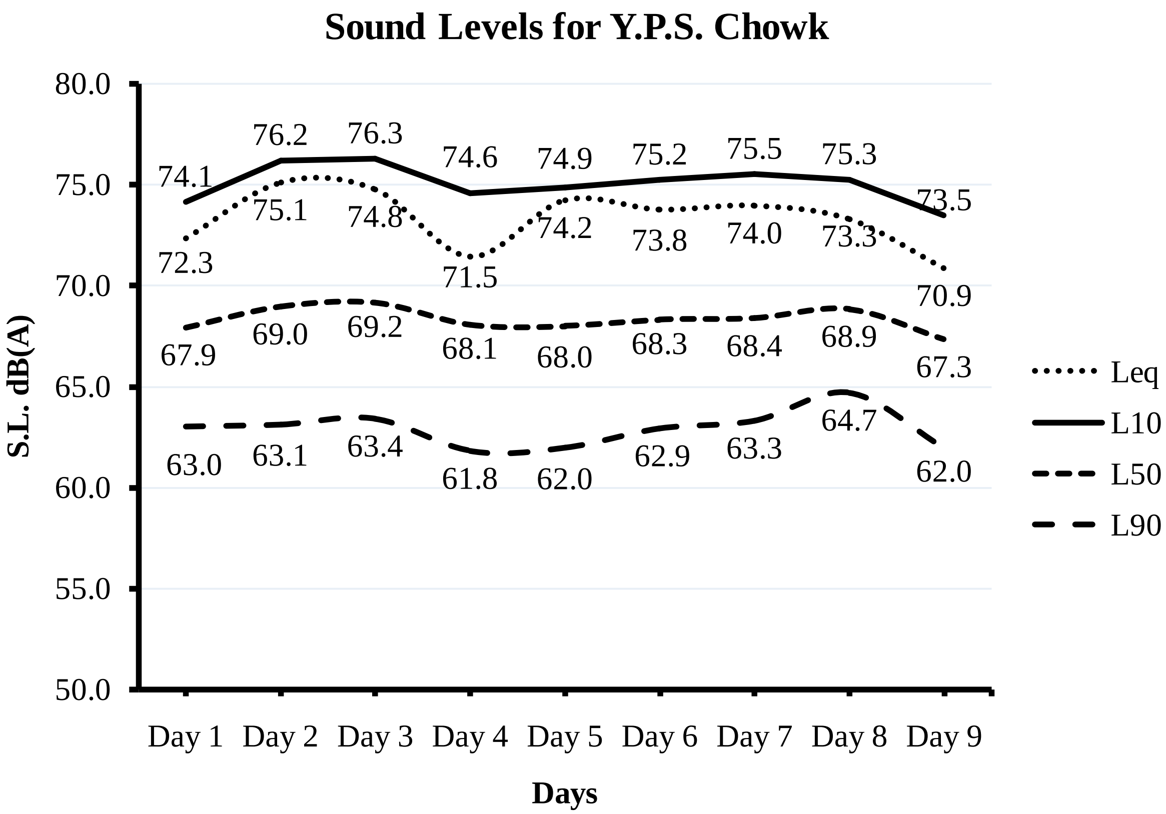


Figure 5.3 Sound levels for each day at Thikkari Chowk Roundabout

A graph is plotted for different sound levels being observed for each day on an average for the Y.P.S. Chowk Roundabout. From the graph it is found that the maximum sound levels were found to be varying between 73.5 and 76.3 dB(A). The equivalent sound level was found to be varying between 70.9 to 75.1 dB(A). The average sound level was found to be varying between 67.3 to 69.2 dB(A). The pervasive noise level was found to be varying between 61.8 to 64.7 dB(A).

Table 5.1 Weekly Average Sound Levels for Roundabouts

Site	L_{eq}	L_{10}	L_{50}	L_{90}
Fountain Chowk	76.7	79.6	73.6	69.4
Thikkari Chowk	78.8	80.4	73.6	69.1
Y.P.S. Chowk	73.3	75.0	68.3	62.9

From the weekly average sound levels for the three roundabouts it is found that the Thikkari Chowk Roundabout had the maximum Equivalent Sound Level of 78.8 dB (A), followed by Fountain Chowk with an Equivalent Sound Level of 76.7 dB (A) and then Y.P.S. Chowk with an Equivalent Sound Level of 73.3 dB (A). The same pattern followed for ten percentile exceeded sound level (L_{10}) with maximum of 80.4 dB (A) for Thikkari Chowk Roundabout and minimum for Y.P.S. Chowk Roundabout. The average sound level (L_{50}) was found to be same for Fountain Chowk Roundabout and Thikkari Chowk Roundabout of 73.6 dB (A) and minimum for Y.P.S. Chowk Roundabout. The background Sound Level was found to be maximum for Fountain Chowk of 69.4 dB (A) and minimum for Y.P.S. Chowk of 62.9 dB (A).

The noise levels were found to be greater than the Indian C.P.C.B. Standards for all the three roundabouts. So measures need to be taken to mitigate the traffic noise levels by constructing barriers around the roundabout.

Table 5.2 CPCB Ambient Noise Standards (India) [27]

S.No.	**Area**	**Leq dB (A)**	
		Day Time	**Night Time**
1	Industrial Area	75	70
2	Commercial Areas	**65**	55
3	Residential Area	55	45
4	Silence Zone	50	40

5.2 CORRELATION TEST

By correlation analysis it is found that which factor has the most and which one has least effect on the different statistical sound parameters. A rank has been assigned to have a picture of which factor is affecting most a particular sound descriptor. A correlation coefficient greater than 0.5 to 1 is considered to be good.

A) Correlation test for L_{eq}:

Table 5.3 Correlation Output for L_{eq}

Factors	L_{eq} Correlation Coefficients	Rank
Three Wheelers	0.722	1
H.V.	0.706	2
Two wheeler	0.683	3
S.U.V.	0.670	4
Car	0.635	5
Acceleration ‘*a*’	0.405	6
Deceleration ‘*d*’	0.015	7
Distance ‘*l*’	-0.032	8

From the correlation test it is found that the Equivalent Sound Level (L_{eq}) and all the various factors except Acceleration, Deceleration and Distance have a very good + ve Correlation. This means that the L_{eq} value will increase significantly with the increase in the parameter’s magnitude having correlation coefficient between 0.5 to 1.

B) Correlation test for L_{10}:

Table 5.4 Correlation Output for L_{10}

Factors	L_{10} Correlation Coefficients	Rank
Three Wheeler	0.821	1
H.V.	0.680	2
Two Wheeler	0.663	3
S.U.V.	0.601	4
Car	0.598	5
Acceleration ‘*a*’	0.345	6
Deceleration ‘*d*’	0.116	7
Distance ‘*l*’	-0.220	8

From the correlation test it is found that the Maximum Sound Level (L_{10}) and all the various factors except Acceleration, Deceleration and Distance have a very good + ve Correlation. This means that the L_{10} value will increase significantly with the increase in the parameter's magnitude having correlation coefficient between 0.5 to 1.

C) Correlation test for L_{50}:

Table 5.5 Correlation Output for L_{50}

Factors	L_{50} Correlation Coefficients	Rank
Three Wheeler	0.830	1
Car	0.725	2
Two Wheeler	0.732	3
S.U.V.	0.692	4
H.V.	0.671	5
Acceleration '*a*'	0.280	6
Deceleration '*d*'	0.176	7
Distance '*l*'	-0.107	8

From the correlation test it is found that the Average Sound Level (L_{50}) and all the various factors except Acceleration and Deceleration and Distance have a very good + ve Correlation. This means that the L_{50} value will increase significantly with the increase in the parameter's magnitude having correlation coefficient between 0.5 to 1.

D) Correlation test for L_{90}:

Table 5.6 Correlation Output for L_{90}

Factors	L_{90} Correlation Coefficients	Rank
Three wheelers	0.818	1
Car	0.807	2
Tw0 Wheeler	0.790	3
S.U.V.	0.746	4
H.V.	0.667	5
Acceleration '*a*'	0.224	6
Deceleration '*d*'	0.164	7
Distance '*l*'	-0.008	8

From the correlation test it is found that the pervasive noise level (L_{90}) and the various factors except acceleration and deceleration have a very good + ve Correlation. This means that the L_{eq} value will increase significantly with the increase in the parameter's magnitude having correlation coefficient between 0.5 to 1.

It is also seen that there is a negative correlation between L_{eq}, L_{10}, L_{50}, L_{90} and the distance '*l*', stating that as the distance between the center lane and the point of microphone placement increases the sound level dips.

Some parameters that do not have good correlation coefficient between 0.5 to 1 cannot be neglected as they do have some impact on the sound level and thus always maintain their significance as though they have low correlation coefficient but they do have some impact on noise levels.

5.3 T-TEST:

T-Test for various Statistical Sound Predictors: For comparing the sound level in both cases a 2t-test is performed.

(A) For L_{eq}:

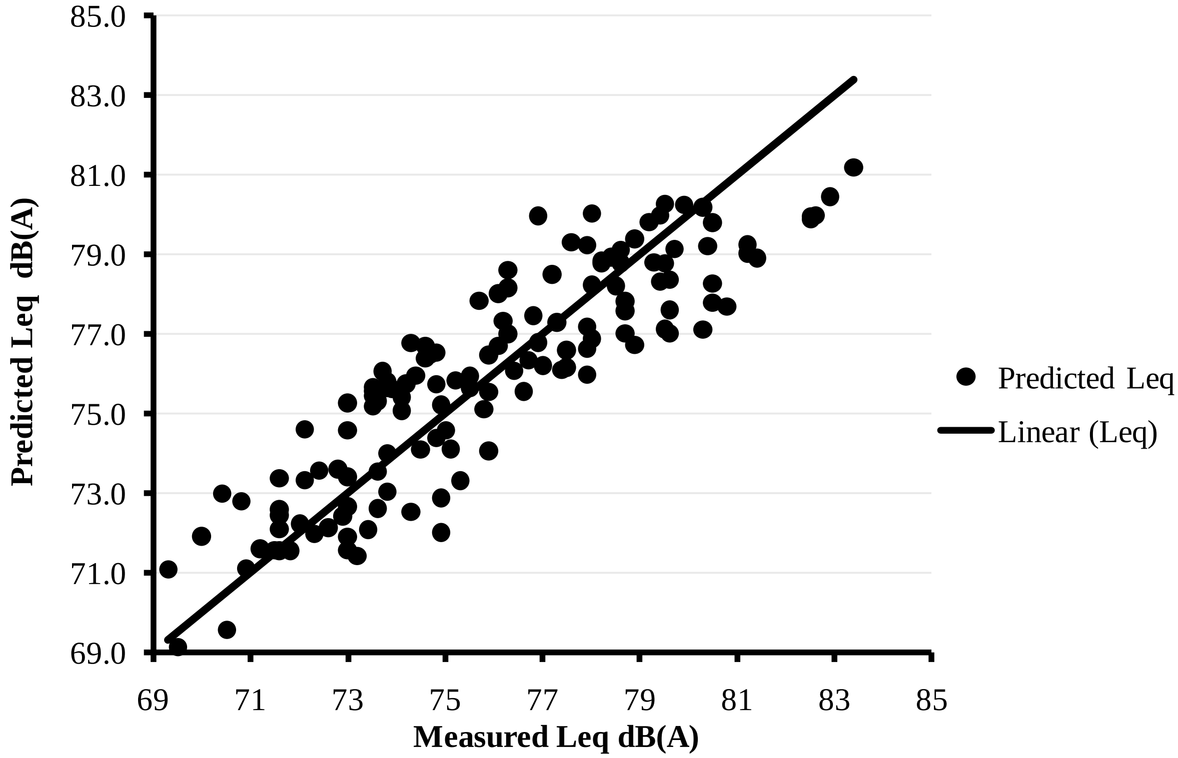


Fig. 5.4 Predicted L_{eq} vs. Measured L_{eq}

Table 5.7 T-test output for L_{eq}

	L_{eq}	**Predicted L_{eq}**
Mean	76.487 dB	77.137 dB
Variance	5.301	1.458
Observations	25	25
df	24	
t-Statistical	**-0.34**	
P(T<=t) two-tail	0.739	
t-Critical two-tail	**2.069**	

Since calculated 't' (t-statistical) is less than the tabulated 't' (t-critical), therefore H_0 is accepted at 5% level of significance having α=.05 and it may be concluded that there is no significant difference between 'L_{eq}' and 'Predicted L_{eq}'.

(B) For L_{10}:

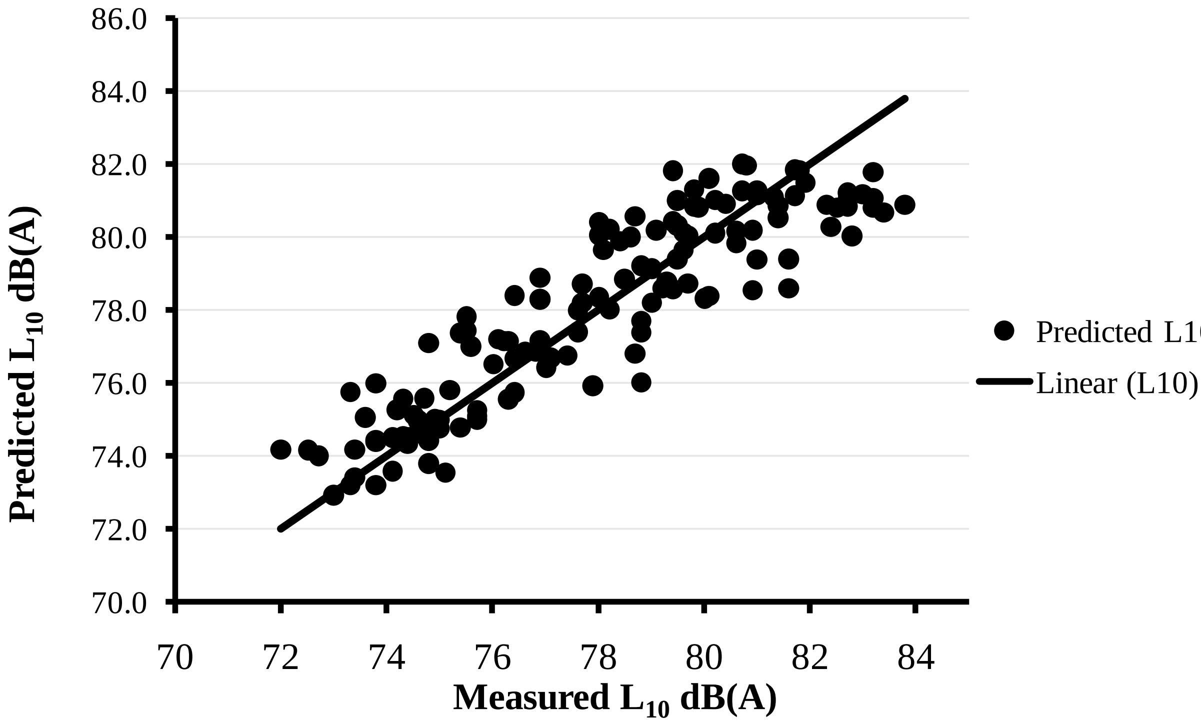


Fig. 5.5 Predicted L_{10} vs Measured L_{10}

Table 5.8 T-test output for L_{10}

	L_{10}	Predicted L_{10}
Mean	80.005 dB	80.021 dB
Variance	1.4282	3.6574
Observations	25	25
df	24	
t-Statistical	**0.133**	
P(T<=t) two-tail	0.895	
t-Critical two-tail	**2.068**	

Since calculated 't' (t-statistical) is less than the tabulated 't' (t-critical), therefore H_0 is accepted at 5% level of significance having α=.05 and it may be concluded that there is no significant difference between 'L_{10}' and 'Predicted L_{10}'.

(C) For L_{50}:

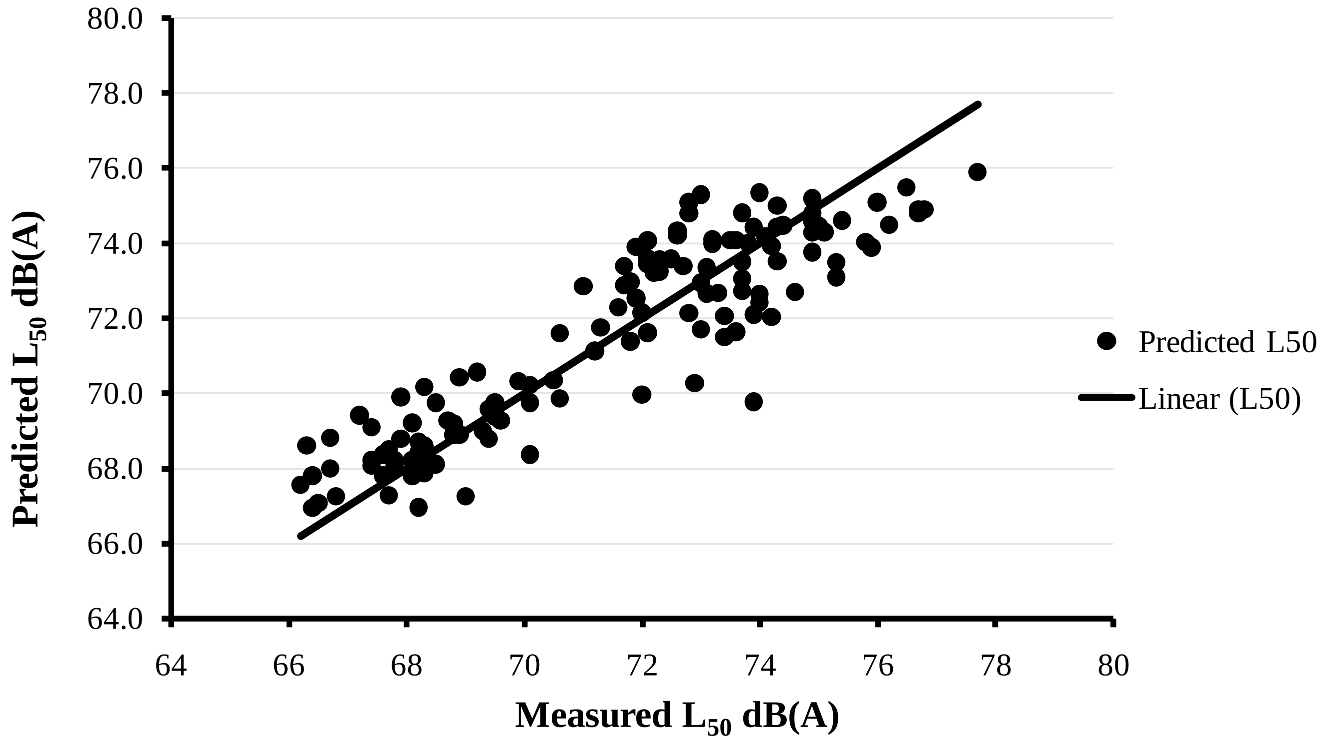


Fig. 5.6 Predicted L_{50} vs Measured L_{50}

Table 5.9 T-test output for L_{50}

	L_{50}	**Predicted L_{50}**
Mean	73.387 dB	73.45 dB
Variance	1.545	2.9191
Observations	25	25
df	24	
t-Statistical	**-0.26**	
P(T<=t) two-tail	0.796	
t-Critical two-tail	**2.068**	

Since calculated 't' (t-statistical) is less than the tabulated 't' (t-critical), therefore H_0 is accepted at 5% level of significance having α=.05 and it may be concluded that there is no significant difference between 'L_{50}' and 'Predicted L_{50}'.

(D) For L_{90}:

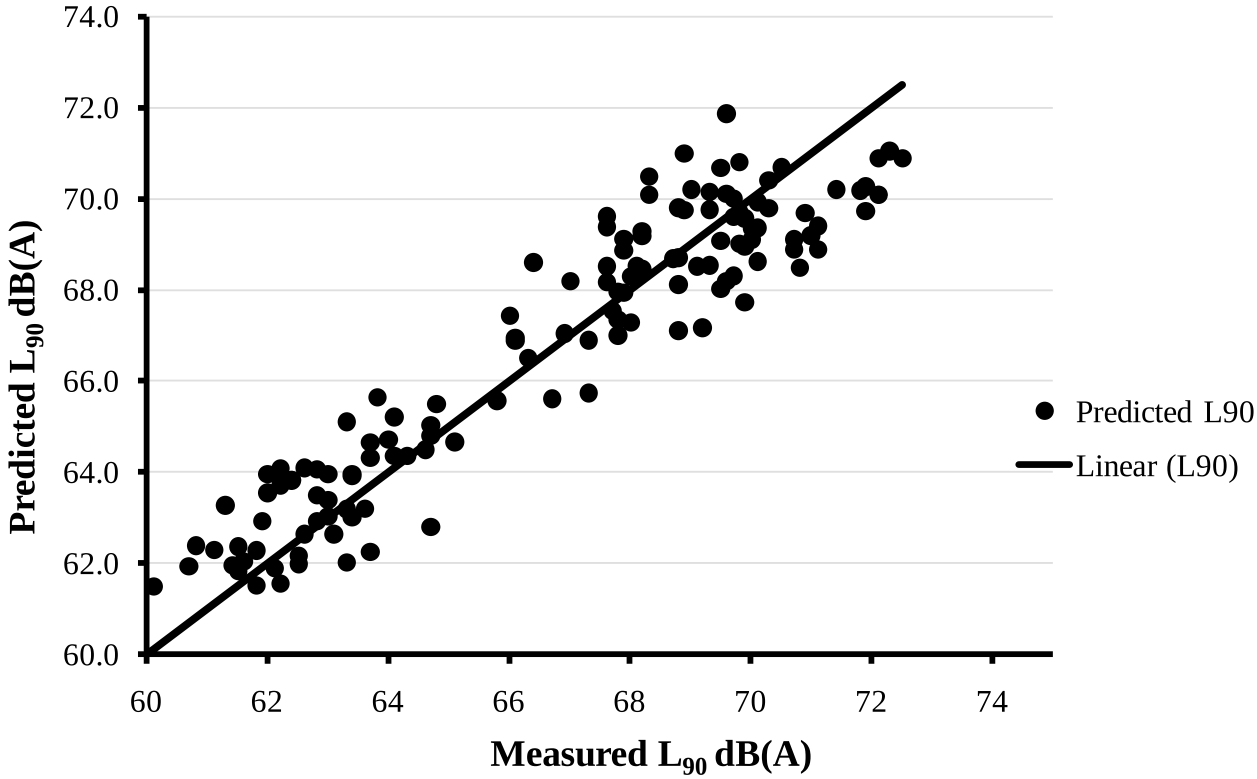


Fig. 5.7 Predicted L_{90} vs Measured L_{90}

Table 5.10 T-test output for L_{90}

	L_{90}	Predicted L_{90}
Mean	68.812 dB	68.735 dB
Variance	3.043	2.180
Observations	25	25
df	24	
t-Statistical	**-0.275**	
P(T<=t) two-tail	0.785	
t-Critical two-tail	**2.064**	

Since calculated 't' (t-statistical) is less than the tabulated 't' (t-critical), therefore H_0 is accepted at 5% level of significance having α=.05 and it may be concluded that there is no significant difference between 'L_{90}' and 'Predicted L_{90}'.

Result Summary:

To perform t-test it is first needed to assume the Null Hypothesis (H_0) and Alternate Hypothesis (H_1). 25 Samples were taken and t-test was done on them.

Let, Mean value for measured $L_x = \mu_1$

Mean value for predicted $L_x = \mu_2$ where $L_x = L_{eq}, L_{10}, L_{50}, L_{90}$ for each test.

So , assume hypothesis $H_0 : \mu_1 = \mu_2$ (Null Hypothesis)

$H_1 : \mu_1 \neq \mu_2$ (Alternate Hypothesis)

It is found that in all the cases the calculated t value 't-stat' was less than or between the tabulated t value 't-critical'. So the null hypothesis is accepted. This means that the mean value of the predicted and measured values of Sound Level is same.

The table for each test sample chosen is shown in APPENDIX-F

Graphs for L_{eq}

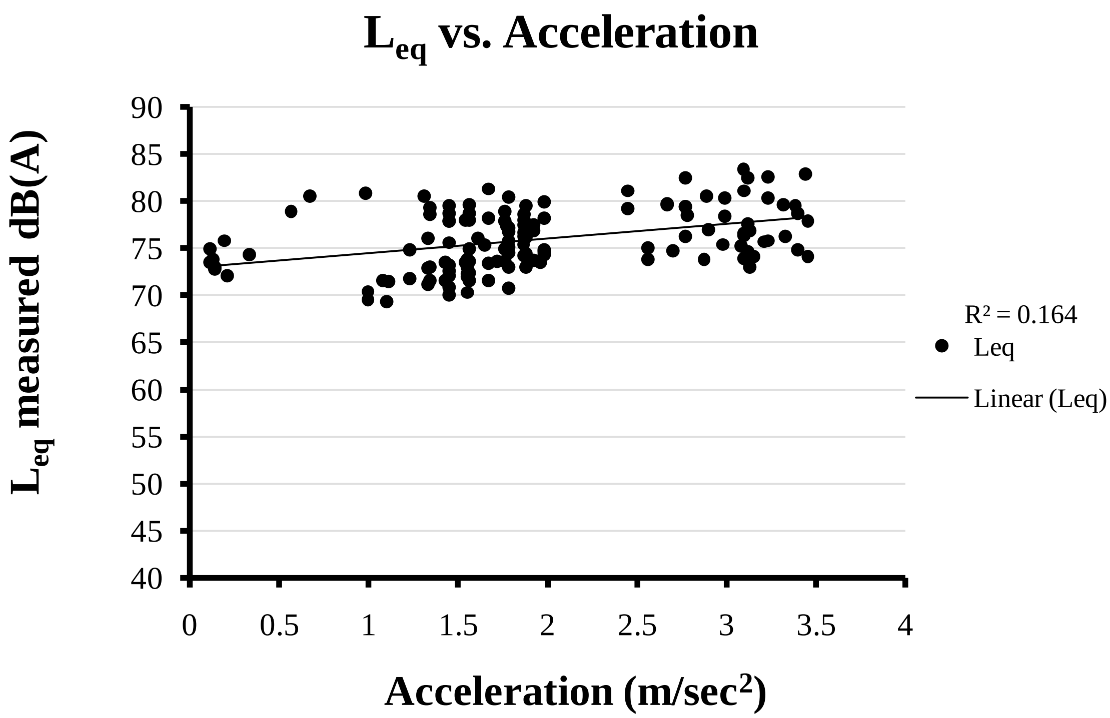


Fig. 5.8 L_{eq} vs Acceleration (m/sec^2)

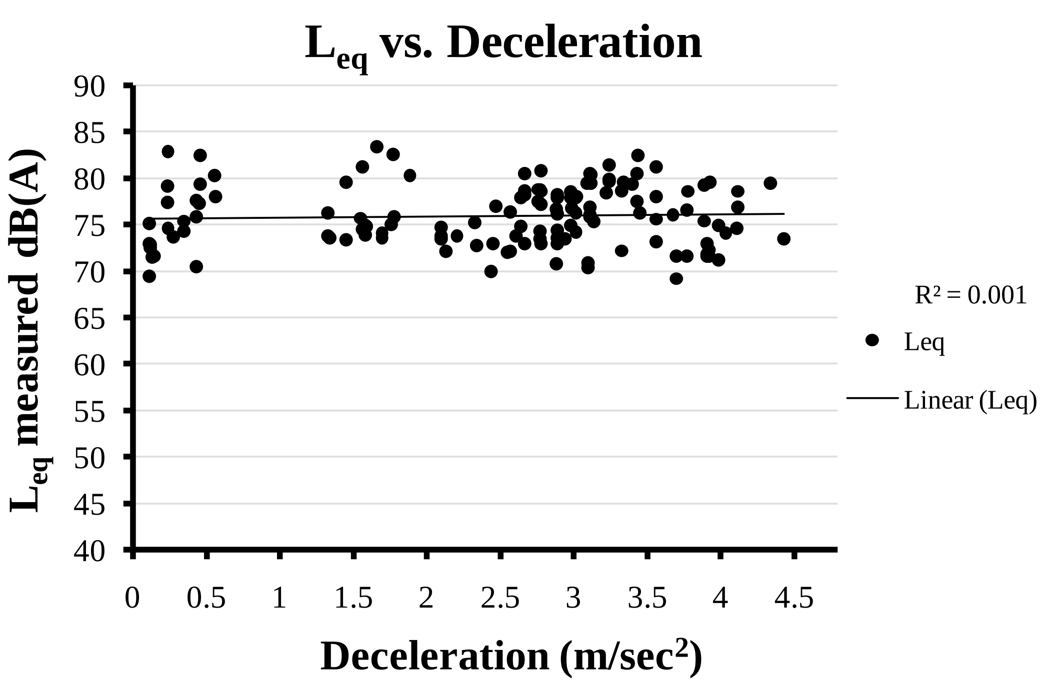


Fig. 5.9 L_{eq} vs Deceleration (m/sec^2)

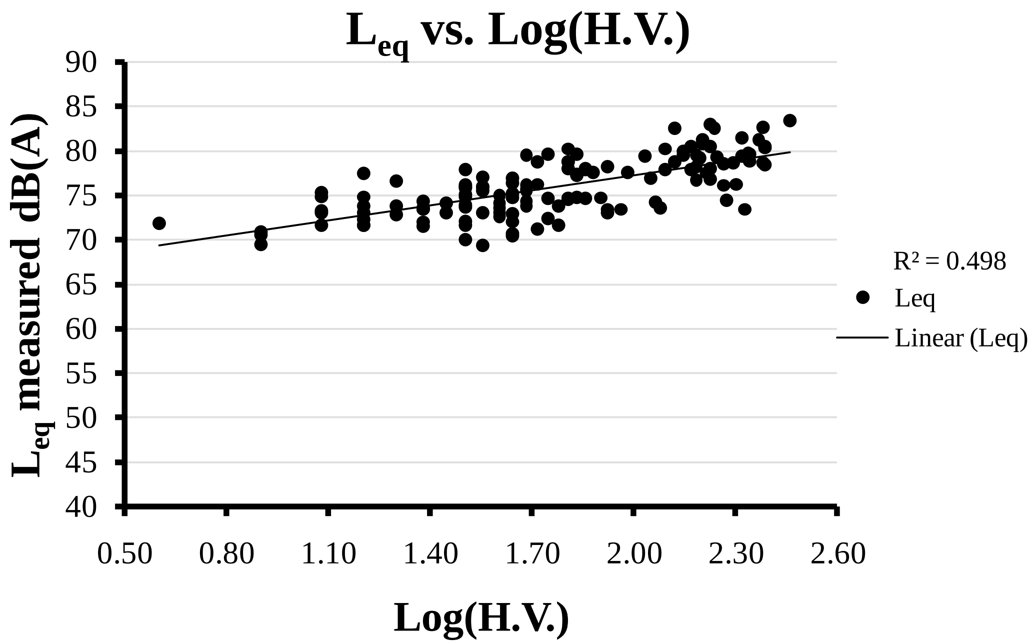


Fig. 5.10 L_{eq} vs Log_{10}(H.V.)

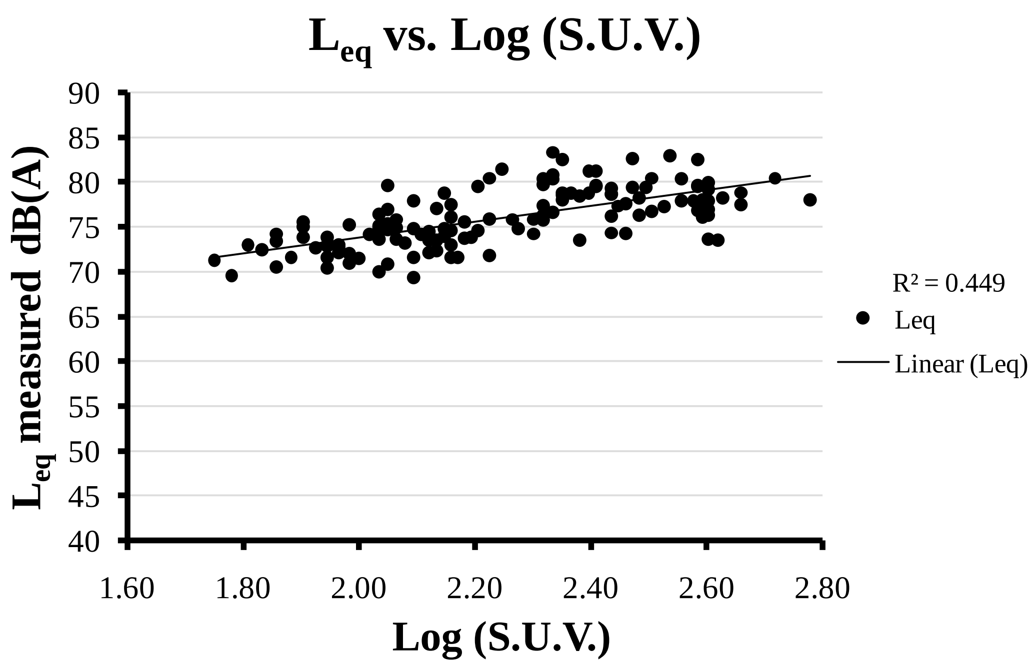


Fig. 5.11 L_{eq} vs Log_{10}(S.U.V.)

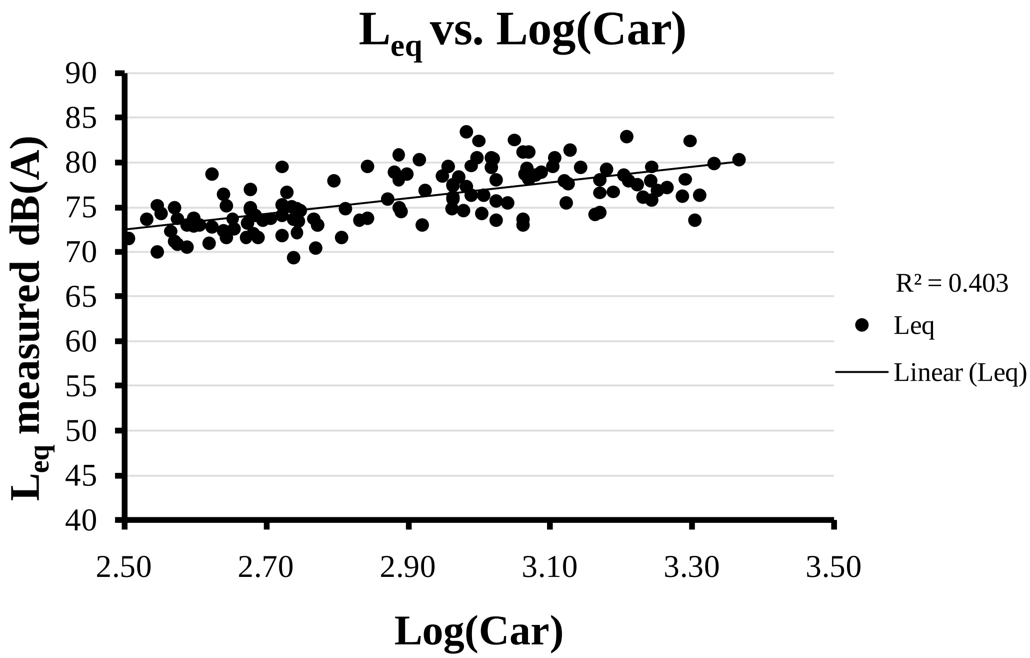


Fig. 5.12 Graph for L_{eq} vs Log_{10}(Car)

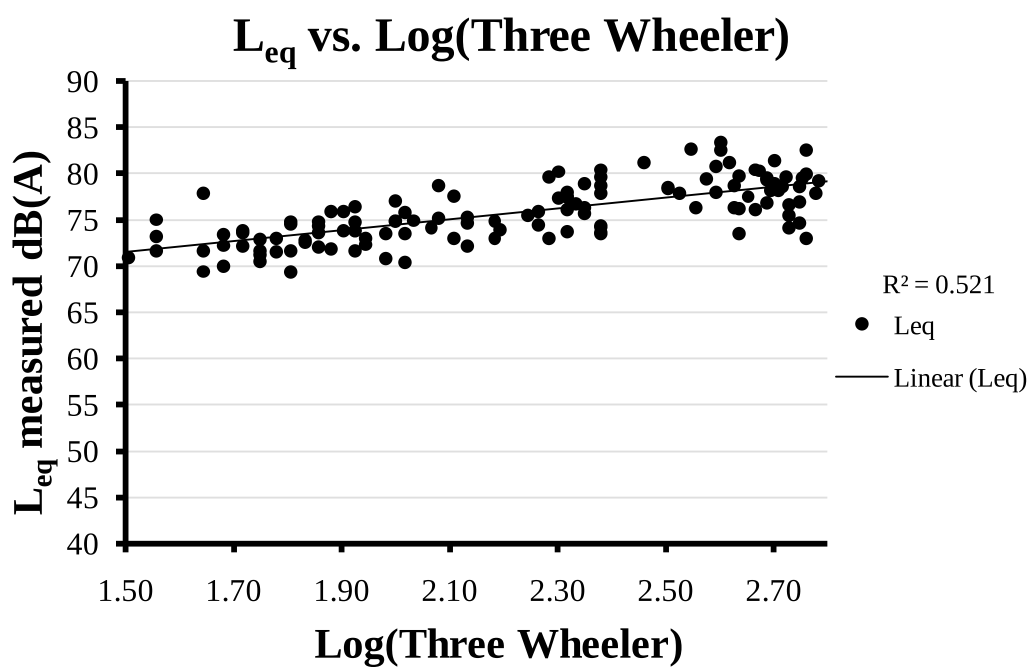


Fig. 5.13 L_{eq} vs Log_{10}(Three Wheelers)

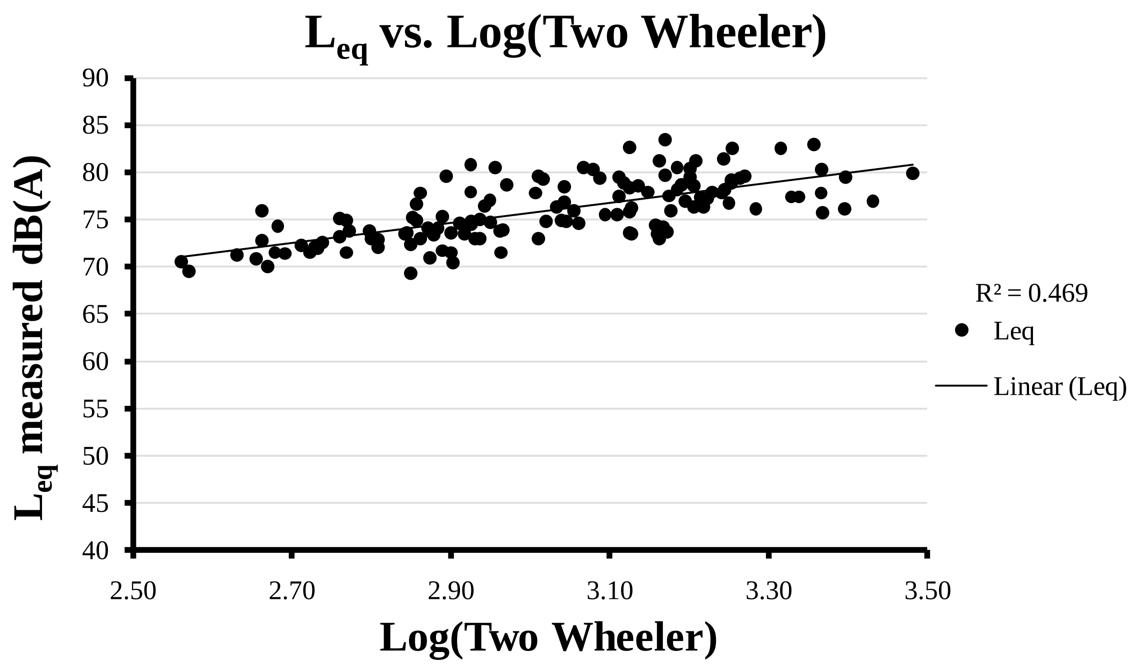


Fig. 5.14 L_{eq} vs Log_{10}(Two Wheelers)

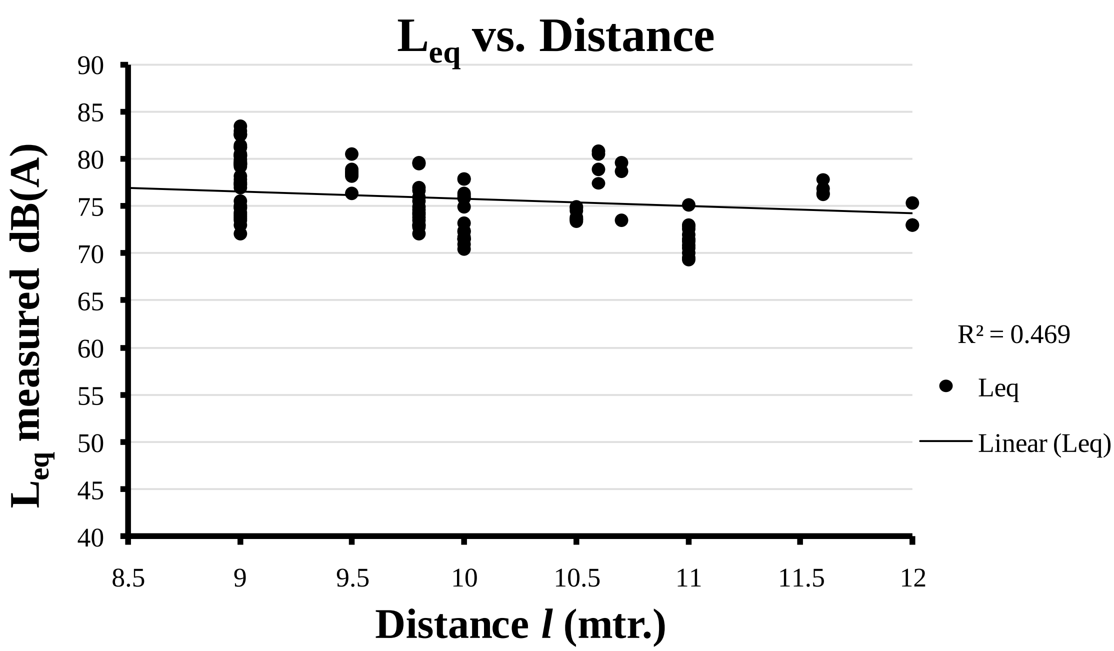


Fig. 5.15 L_{eq} vs Distance *l* (mtr.)

Graph Interpretation for L_{eq}:

From the graph plotted it is found that on an average increase in acceleration of 1m/sec^2 there was an increase of 2dB (A). However deceleration had no significant effect on the sound level. There was an increase of 7dB (A) as the no. of heavy vehicles varied from 10 to 100 vehicle/hour. The sound level increased by 5 dB (A) as the vehicle no. of S.U.V. varied from 100 to 400 vehicle/hour. The sound level showed an increment in 5dB (A) as the number of cars varied from 500 to 2000 vehicles/hour. The sound level increased by 5 dB (A) if the no. of three wheelers varied from 50 to 300 vehicles/hour. The sound level showed an increment of 6dB (A) as the no. of two wheelers varied from 500 to 1500 vehicle/hour. There was a negative relation between sound level and the distance from the roundabout. The sound level dips for roundabout by 2.5 dB (A) as the distance between roundabout varied from 9 mtr to 12mtr. So it can be said that the equivalent sound level was affected by all the parameters but deceleration played not any important role.

Graphs for L_{10}

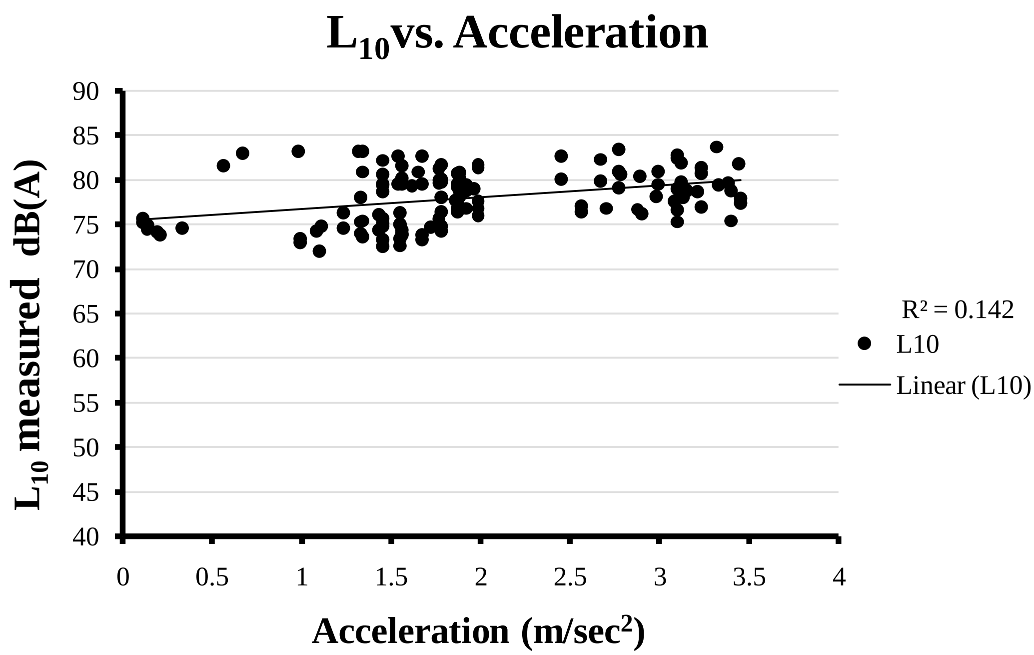


Fig. 5.16 L_{10} vs Acceleration (m/sec^2)

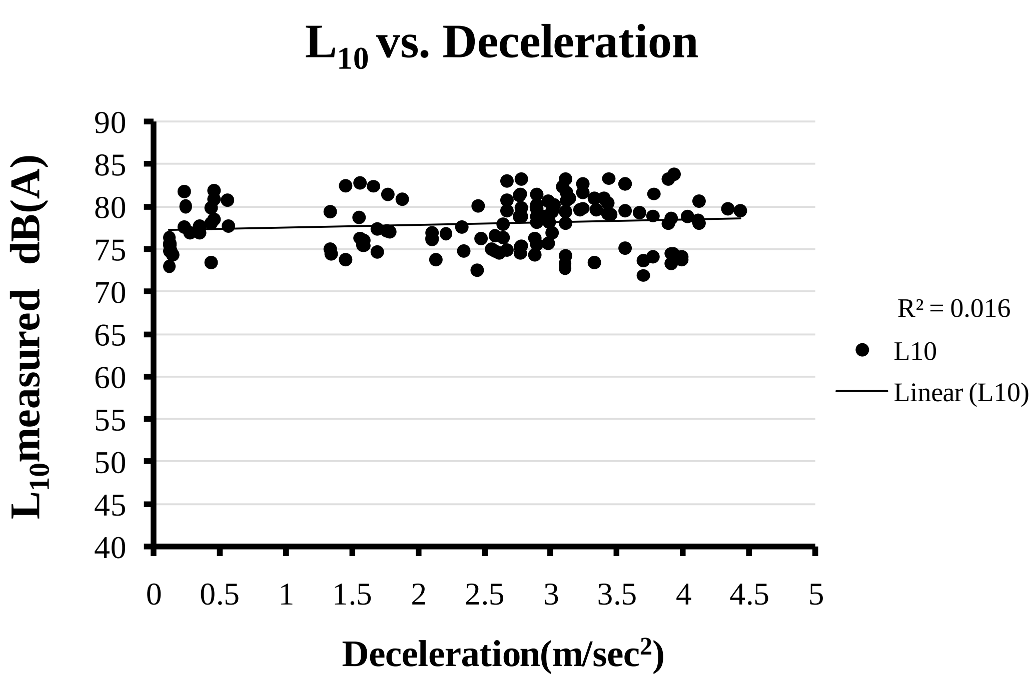


Fig. 5.17 L_{10} vs Deceleration (m/Sec^2)

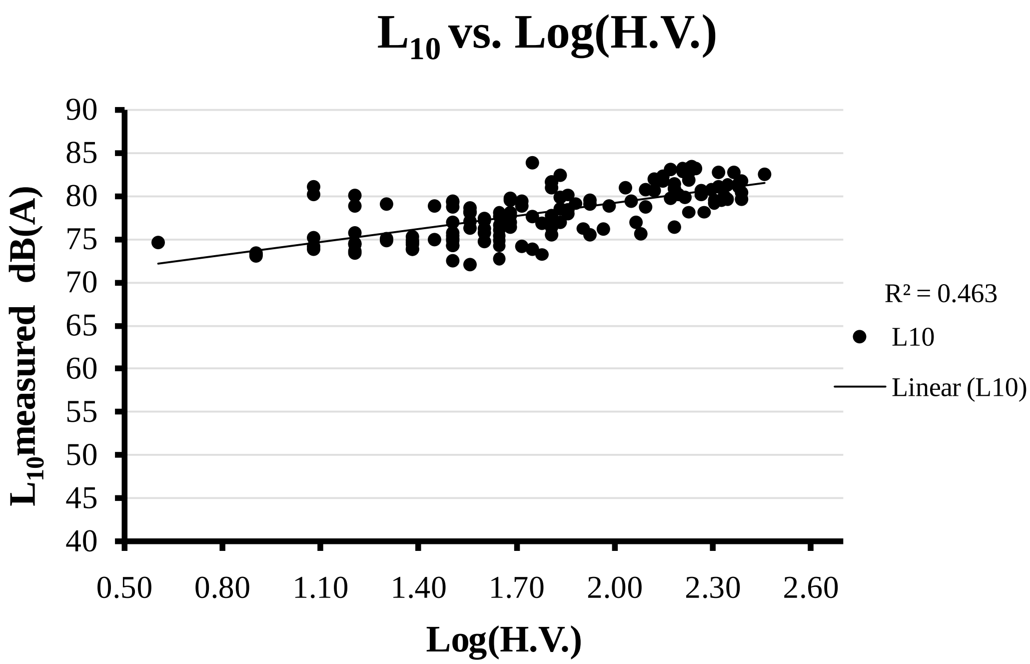


Fig. 5.18 L_{10} vs Log_{10} (H.V.)

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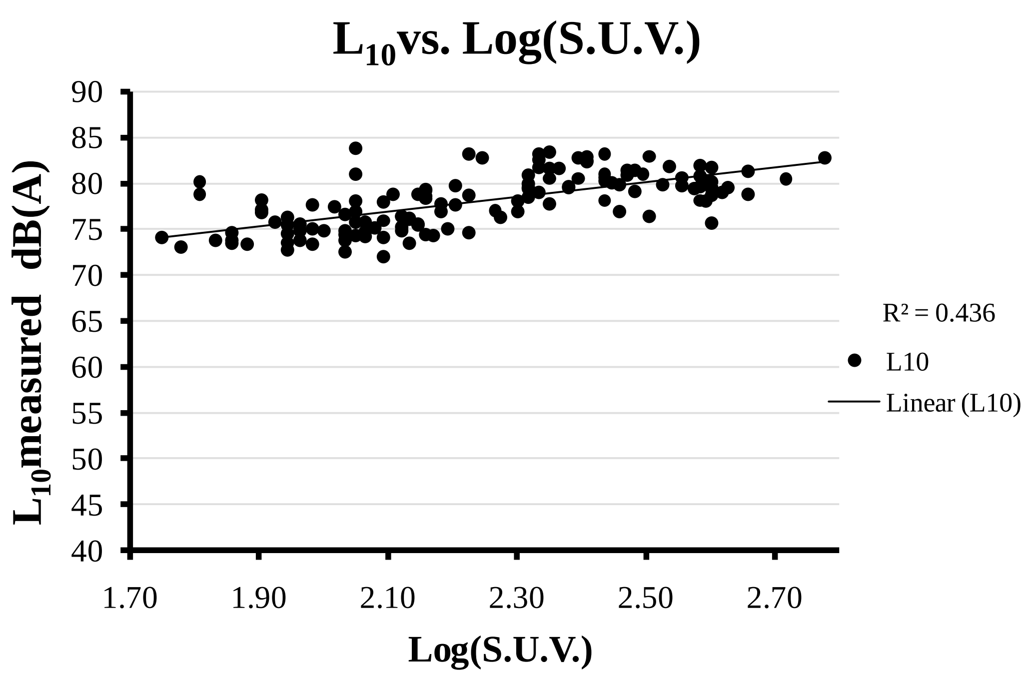


Fig. 5.19 L_{10} vs Log_{10}(S.U.V.)

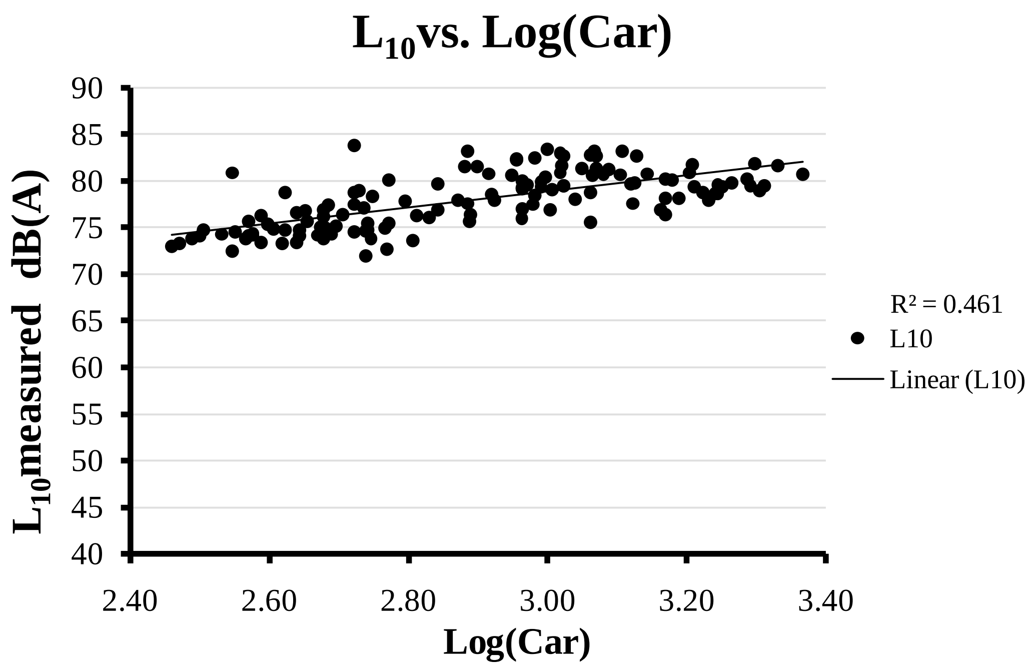


Fig. 5.20 L_{10} vs Log_{10}(Car)

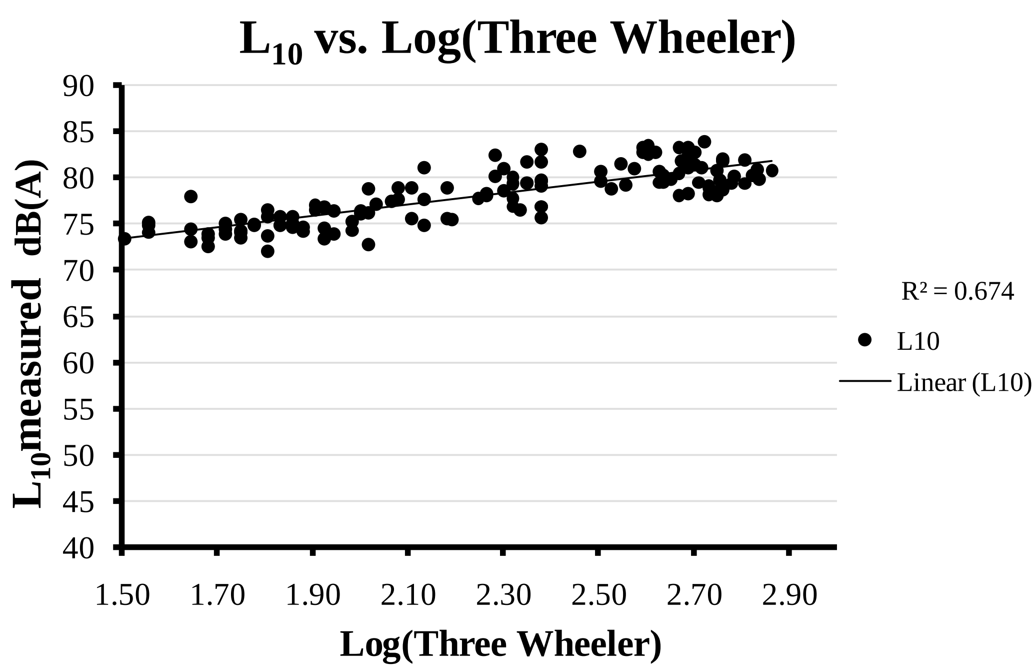


Fig. 5.21 L_{10} vs Log_{10}(Three Wheelers)

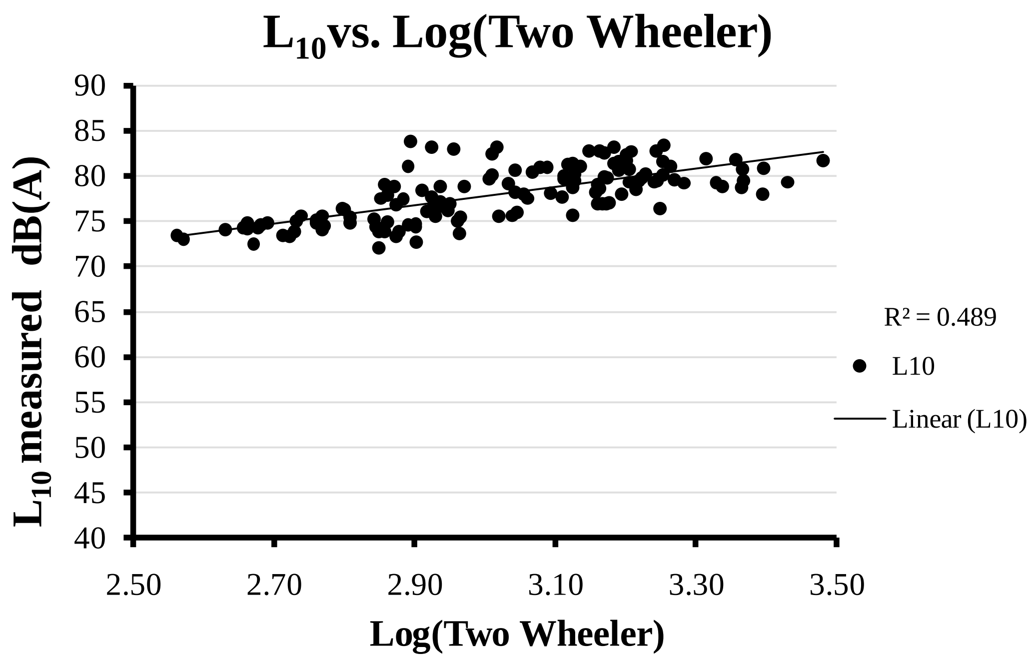


Fig. 5.22 L_{10} vs Log_{10}(Two Wheelers)

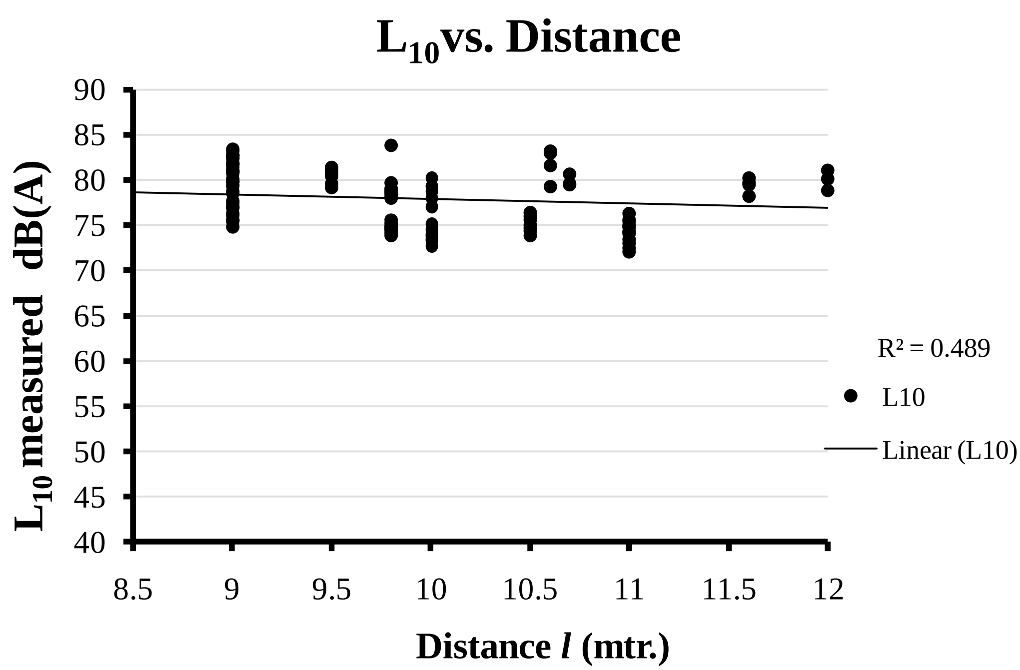


Fig. 5.23 L_{10} vs Distance *l* (mtr.)

Graph Interpretation for L_{10}:

From the graph plotted it is found that on an average increase in acceleration of 1m/sec^2 there was an increase of 2dB (A). When the deceleration increased by 3m/sec^2 the sound level increased by 1 dB (A). There was an increase of 5.5 dB (A) as the no. of heavy vehicles varied from 10 to 100 vehicles/hour. The sound level increased by 5 dB (A) as the vehicle no. of S.U.V. varied from 100 to 400 vehicle/hour. The sound level showed an increment in 5.5 dB (A) as the number of cars varied from 500 to 2000 vehicles/hour. The sound level increased by 4.5 dB (A) if the no. of three wheelers varied from 50 to 300 vehicles/hour. The sound level showed an increment of 4.5 dB (A) as the no. of two wheelers varied from 500 to 1500 vehicle/hour. There was a negative relation between sound level and the distance from the roundabout. The sound level dips for roundabout by 2 dB (A) as the distance between roundabout varied from 9 mtr to 12mtr.

Graphs for L_{50}

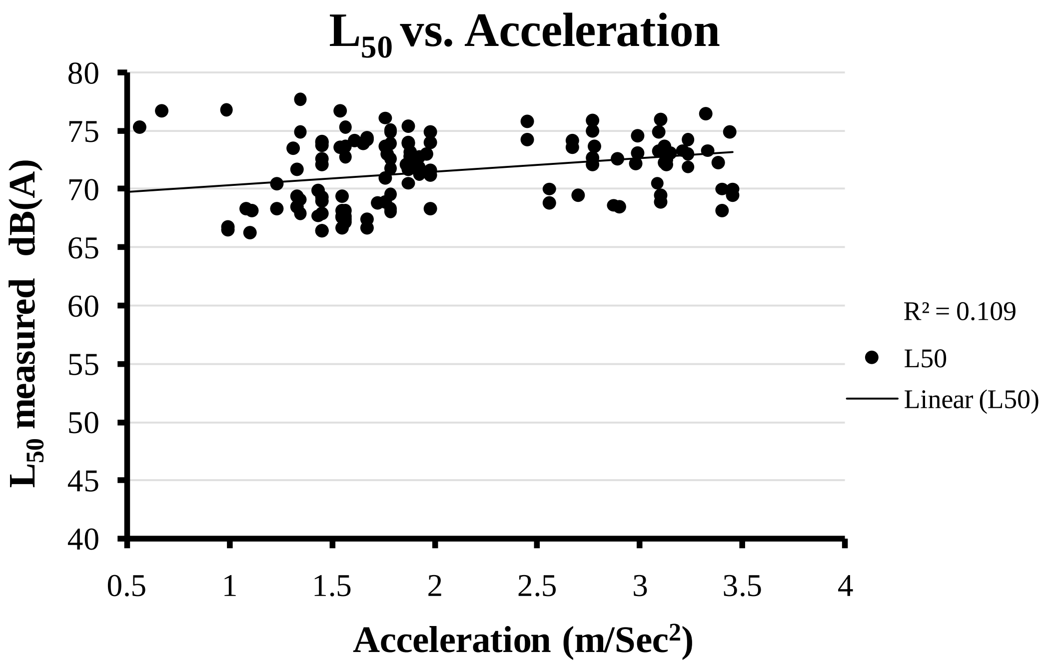


Fig. 5.24 L_{50} vs Acceleration (m/sec^2)

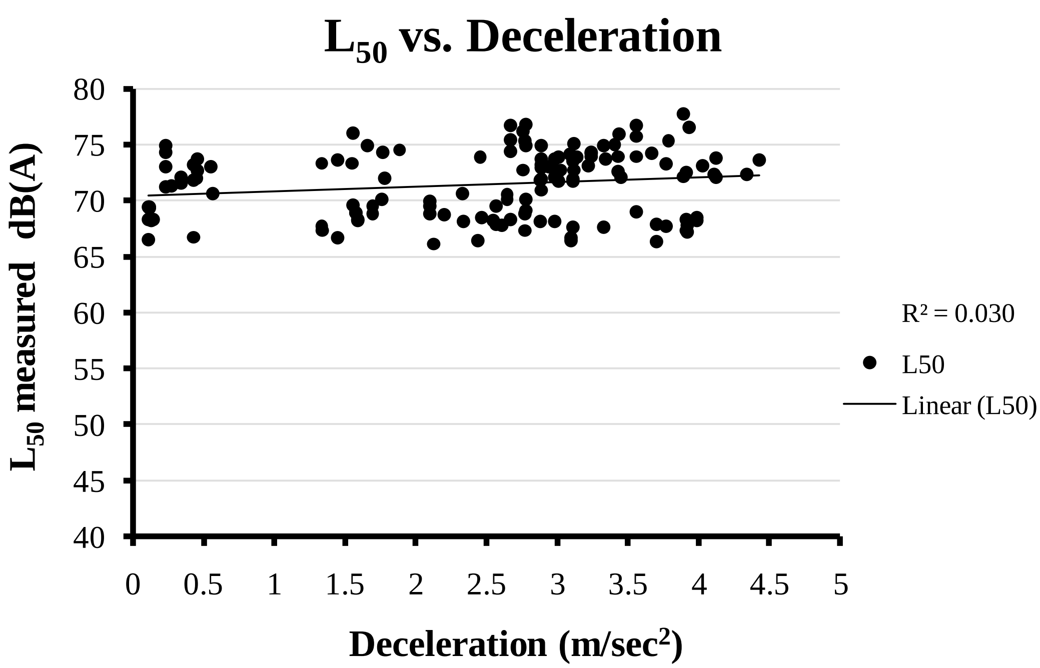


Fig. 5.25 L_{50} vs Deceleration (m/sec^2)

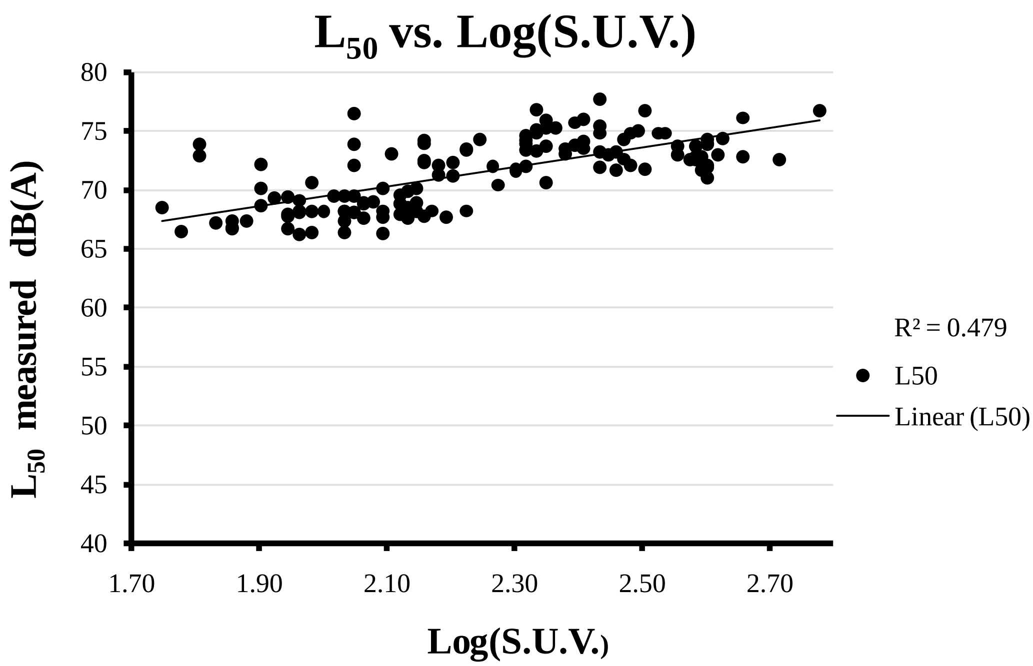


Fig. 5.26 L_{50} vs Log_{10}(S.U.V.)

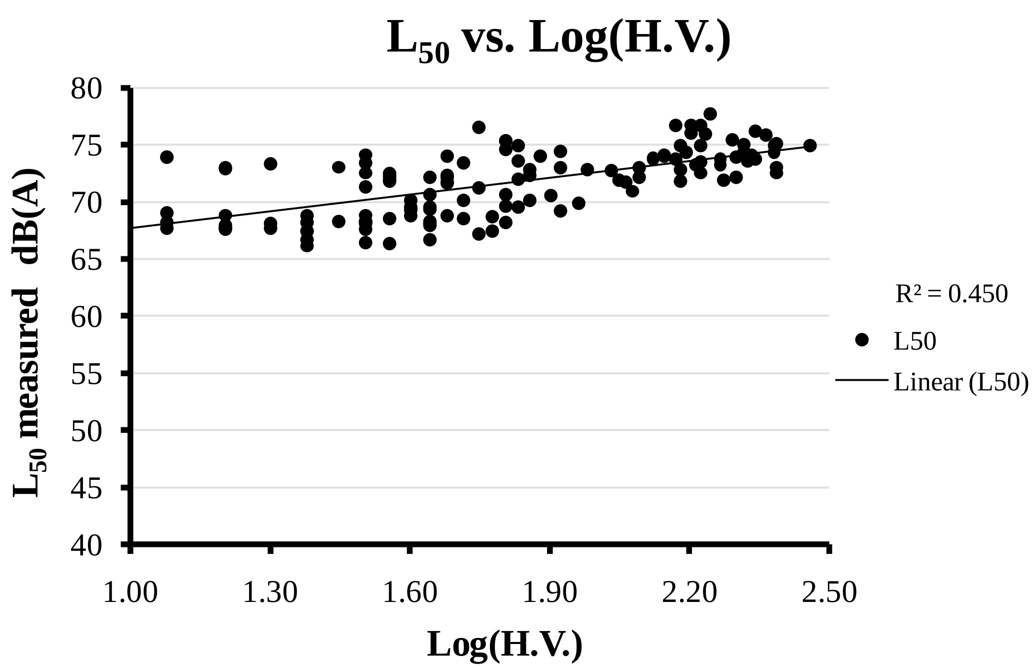


Fig. 5.27 L_{50} vs Log_{10}(H.V.)

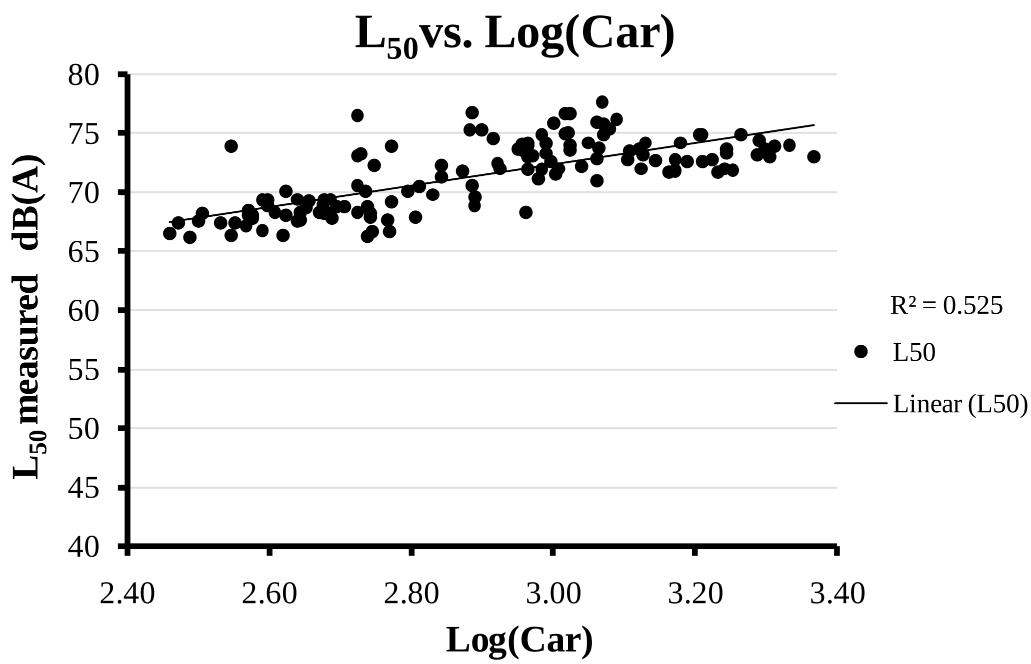


Fig. 5.28 L_{50}vs Log_{10}(Car)

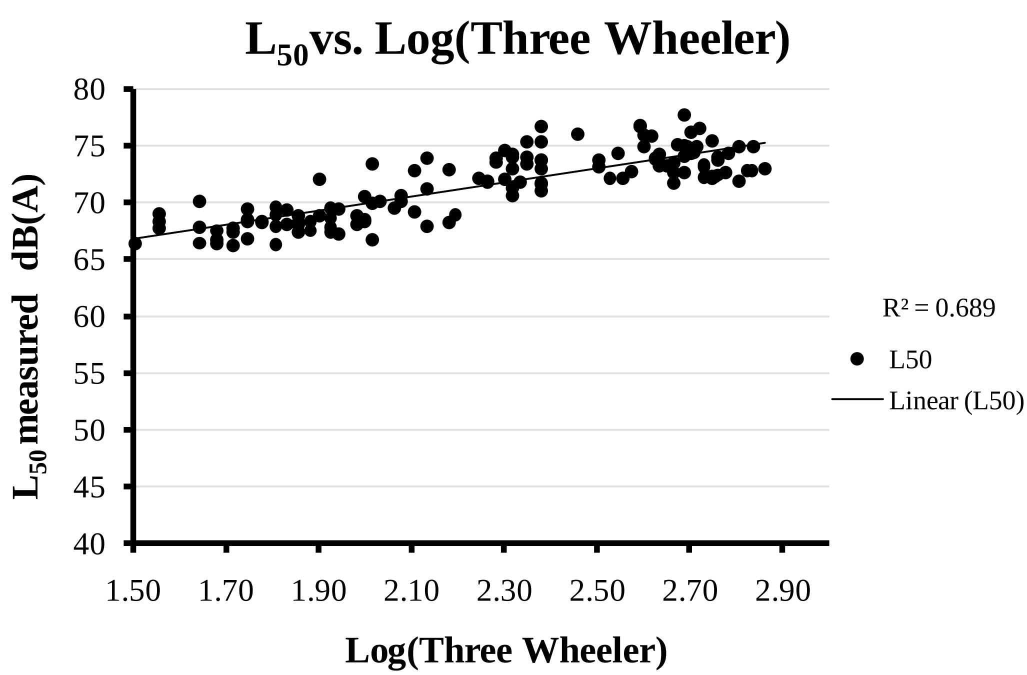


Fig. 5.29 L_{50} vs Log_{10}(Three Wheelers)

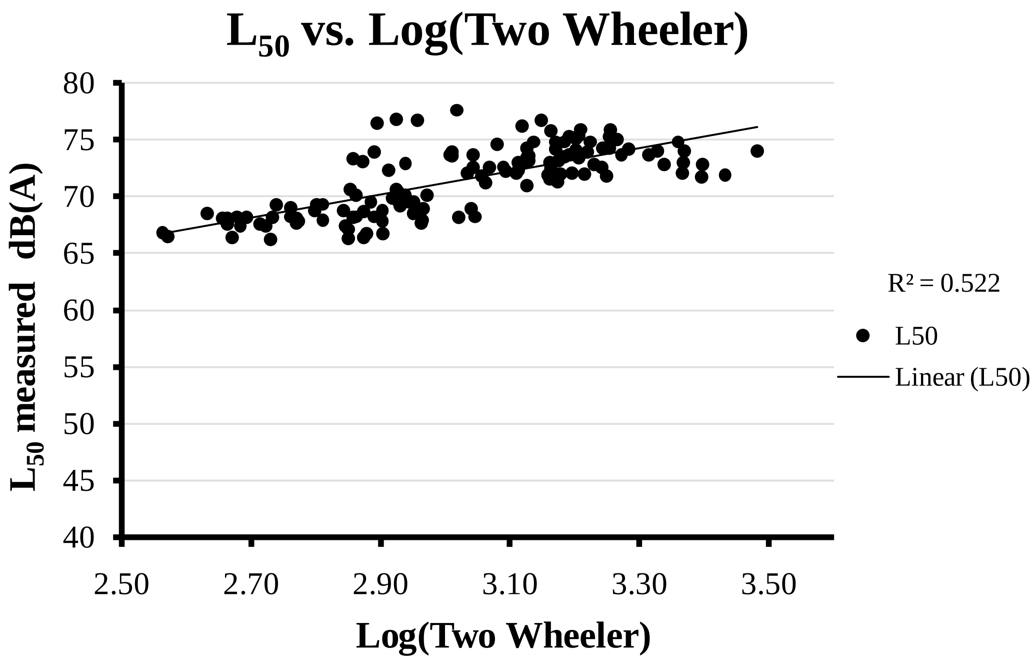


Fig. 5.30 L_{50}vs Log_{10}(Two Wheelers)

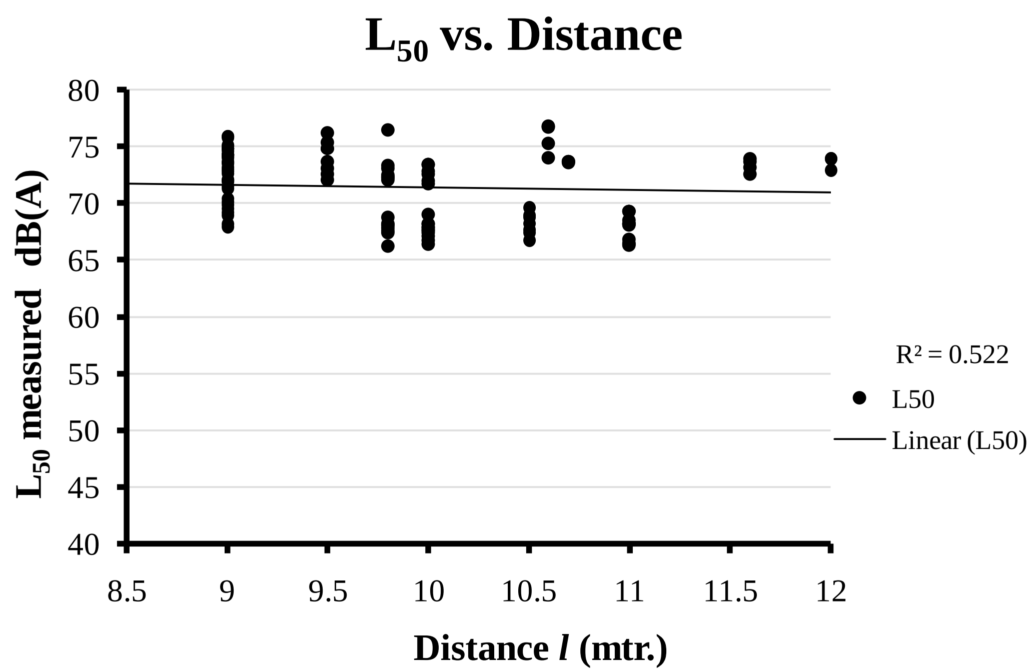


Fig. 5.31 L_{50} vs Distance *l* (mtr.)

Graph Interpretation for L_{50}:

From the graph plotted it is found that on an average increase in acceleration of 1m/sec^2 there was an increase of 1.5 dB (A). When the deceleration increased by 3m/sec^2 the sound level increased by 1.5 dB (A). There was an increase of 5.5 dB (A) as the no. of heavy vehicles varied from 10 to 100 vehicles/hour. The sound level increased by 5.5 dB (A) as the vehicle no. of S.U.V. varied from 100 to 400 vehicle/hour. The sound level showed an increment in 5.25 dB (A) as the number of cars varied from 500 to 2000 vehicles/hour. The sound level increased by 5 dB (A) if the no. of three wheelers varied from 50 to 300 vehicles/hour. The sound level showed an increment of 4.25 dB (A) as the no. of two wheelers varied from 500 to 1500 vehicle/hour. There was a negative relation between sound level and the distance from the roundabout. The sound level dips for roundabout by 0.5 dB (A) as the distance between roundabout varied from 9 mtr to 12mtr.

Graphs for L_{90}

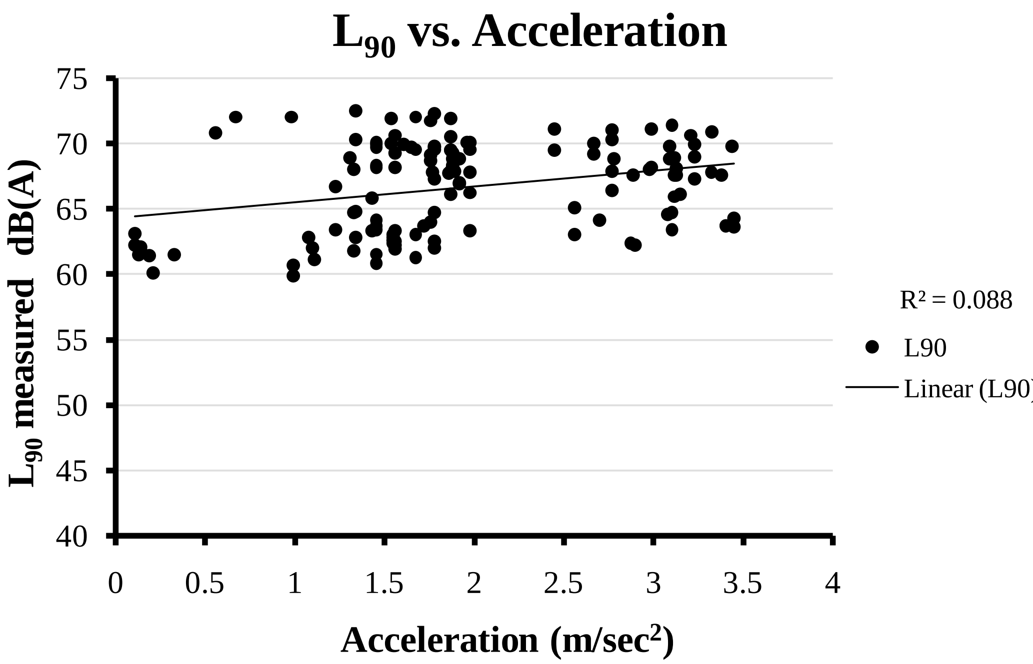


Fig. 5.32 L_{90} vs Acceleration (m/sec^2)

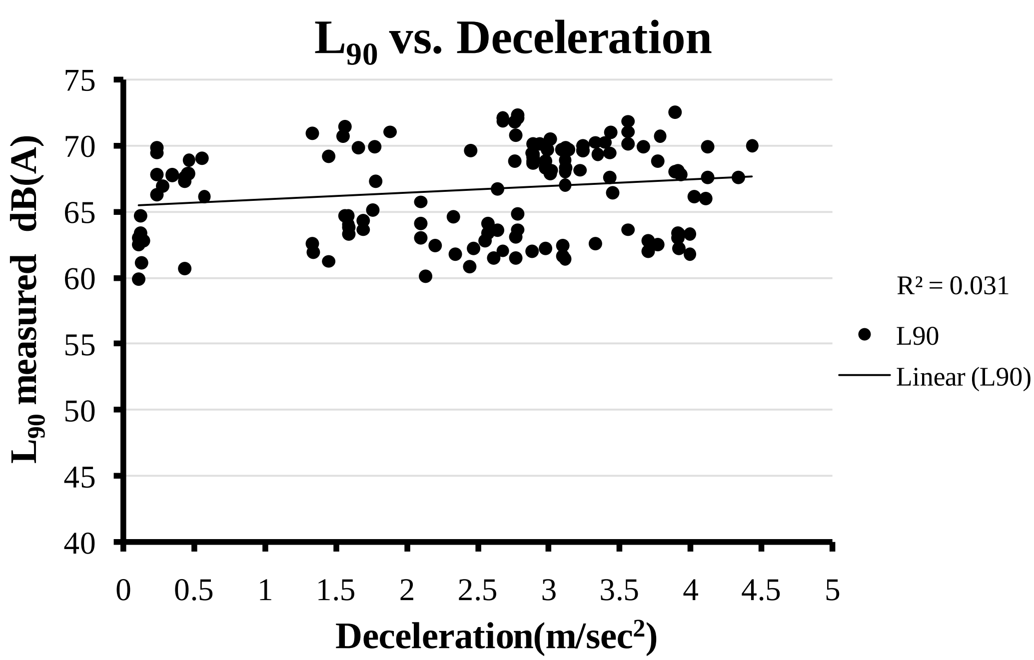


Fig. 5.33 L_{90} vs Deceleration (m/sec^2)

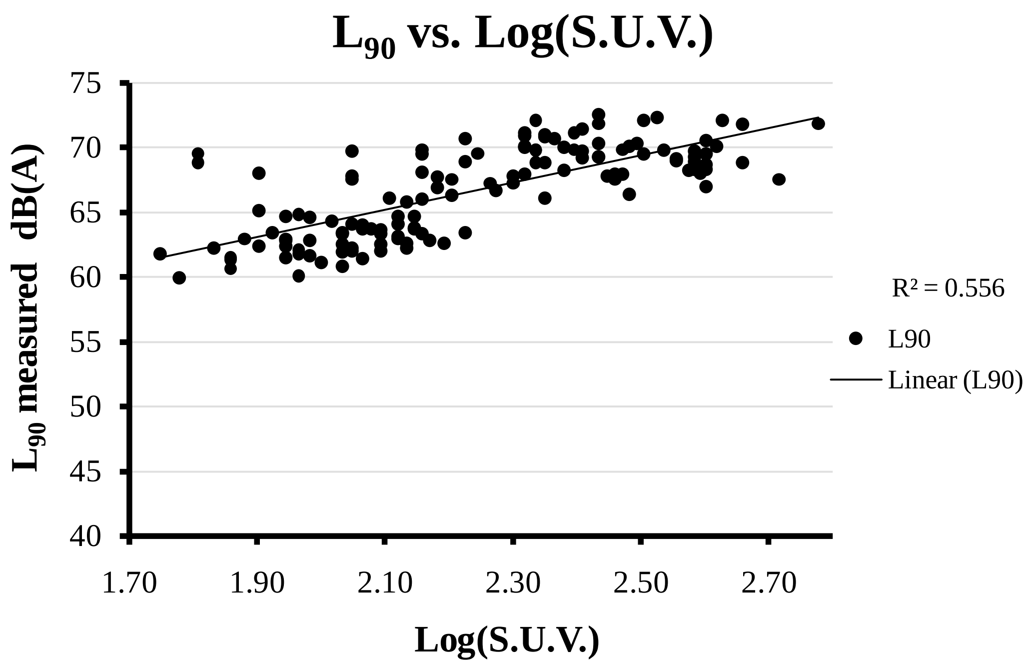


Fig. 5.34 L_{90} vs Log_{10}(S.U.V.)

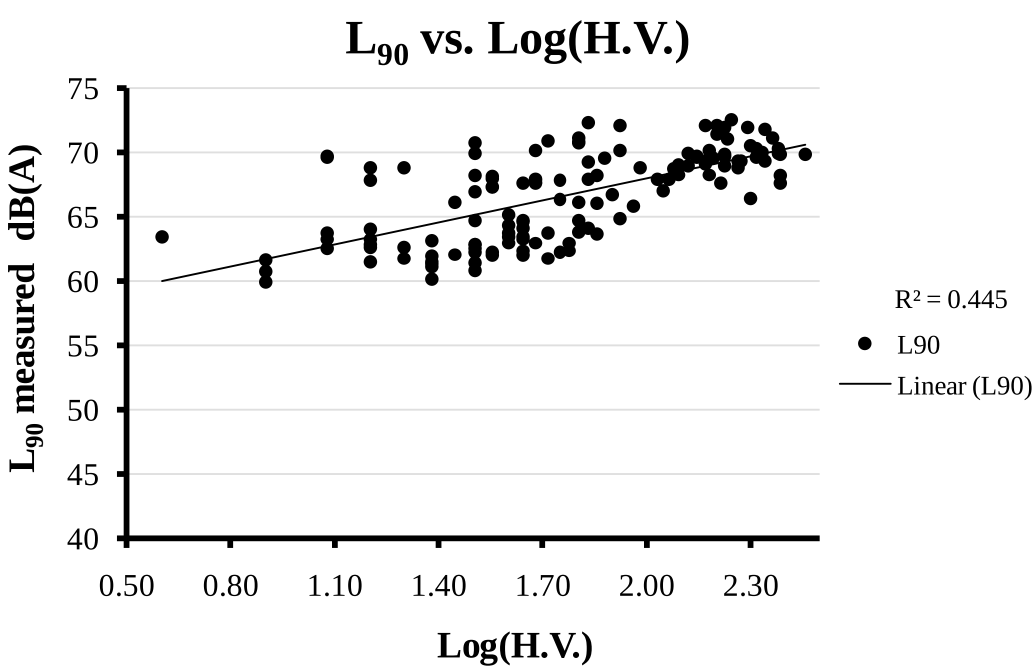


Fig.5.35 L_{90} vs Log_{10}(H.V.)

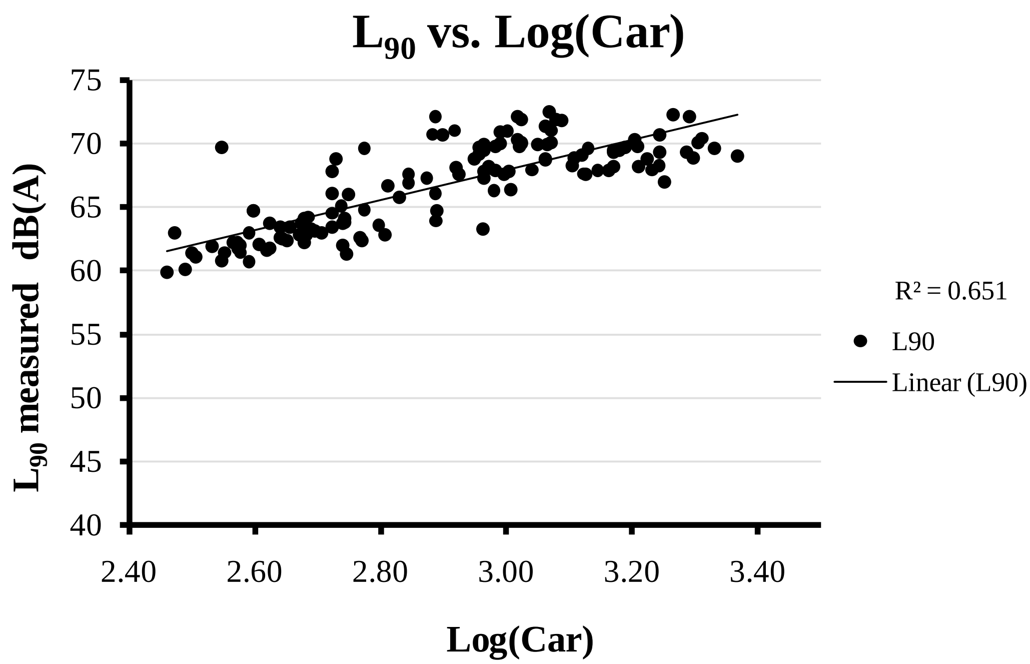


Fig. 5.36 L_{90} vs Log_{10}(Car)

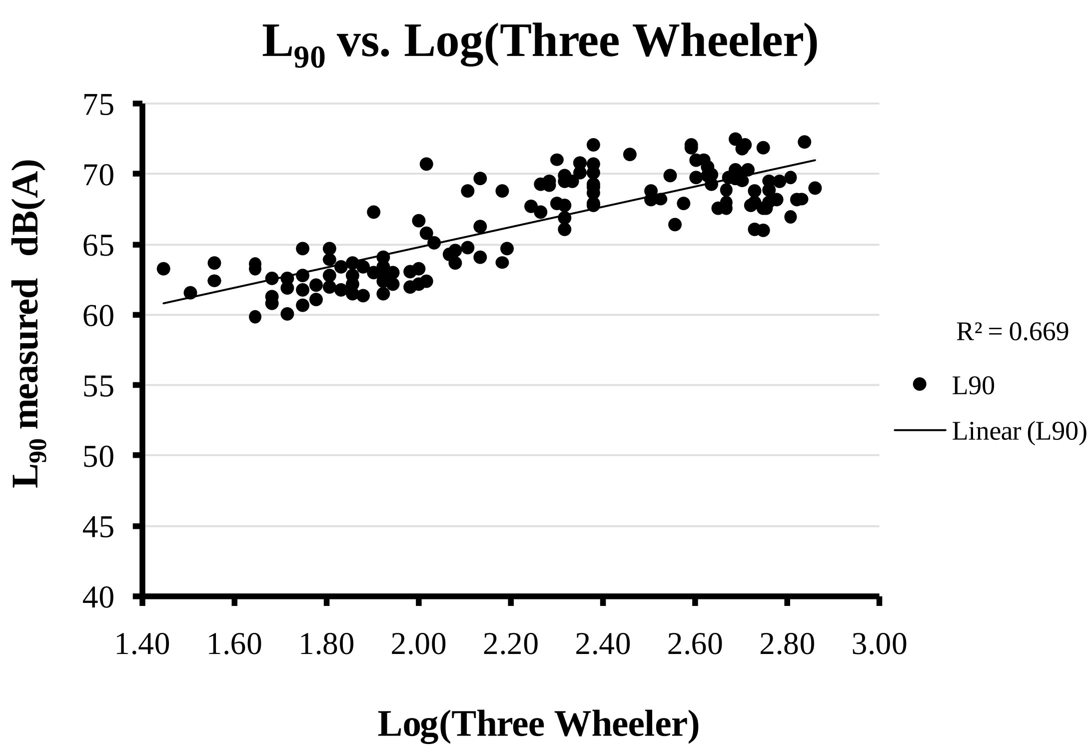


Fig. 5.37 L_{90} vs Log_{10}(Three Wheelers)

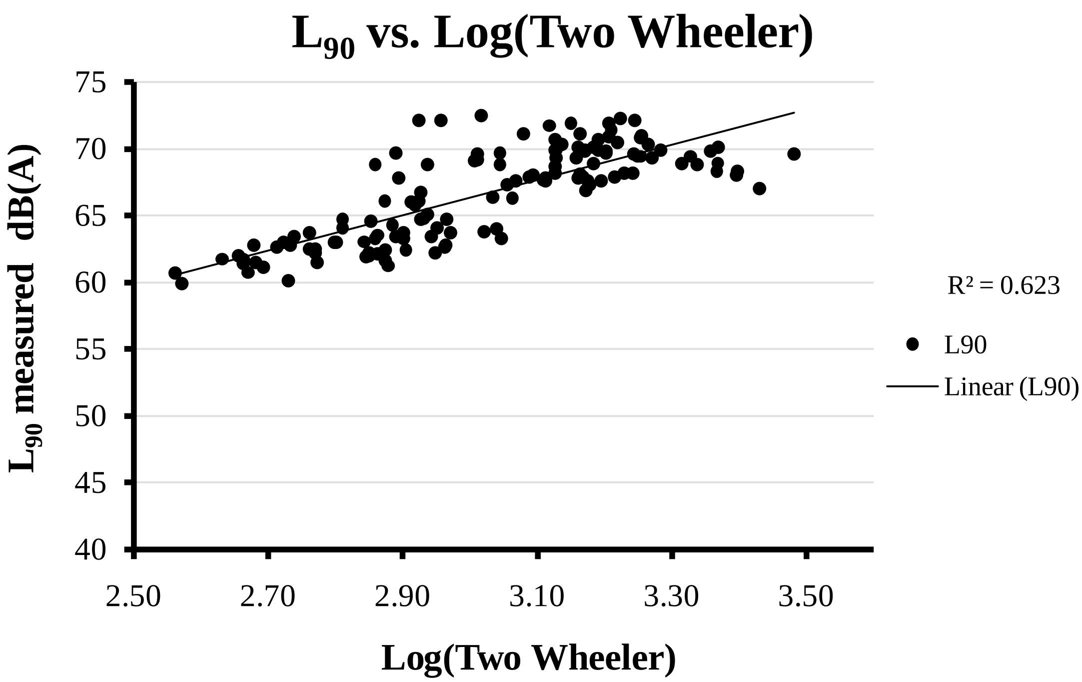


Fig. 5.38 L_{90} vs Log_{10}(Two Wheelers)

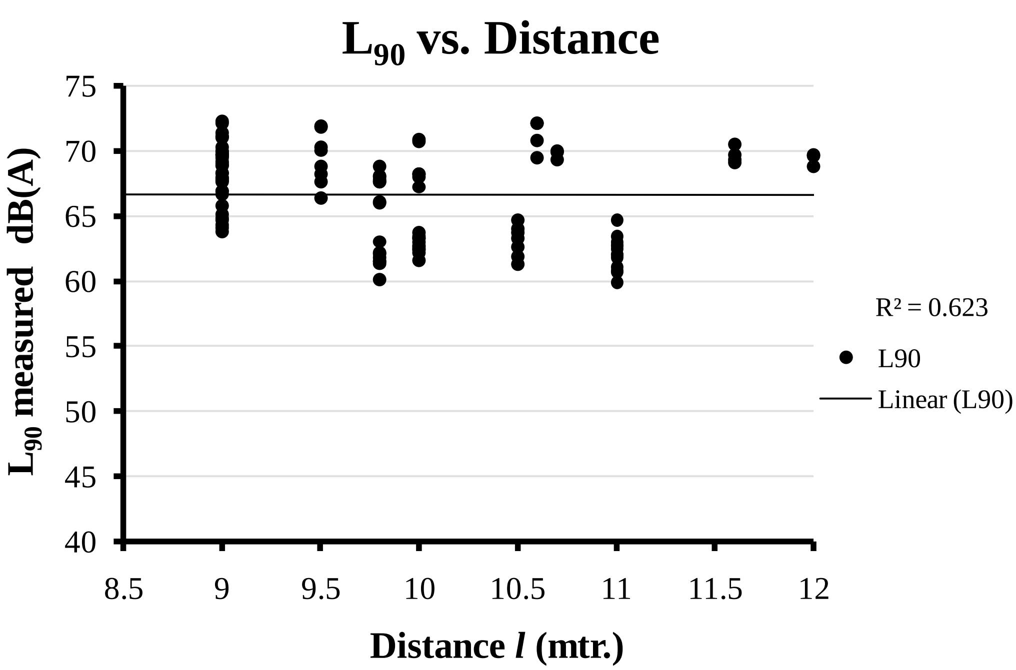


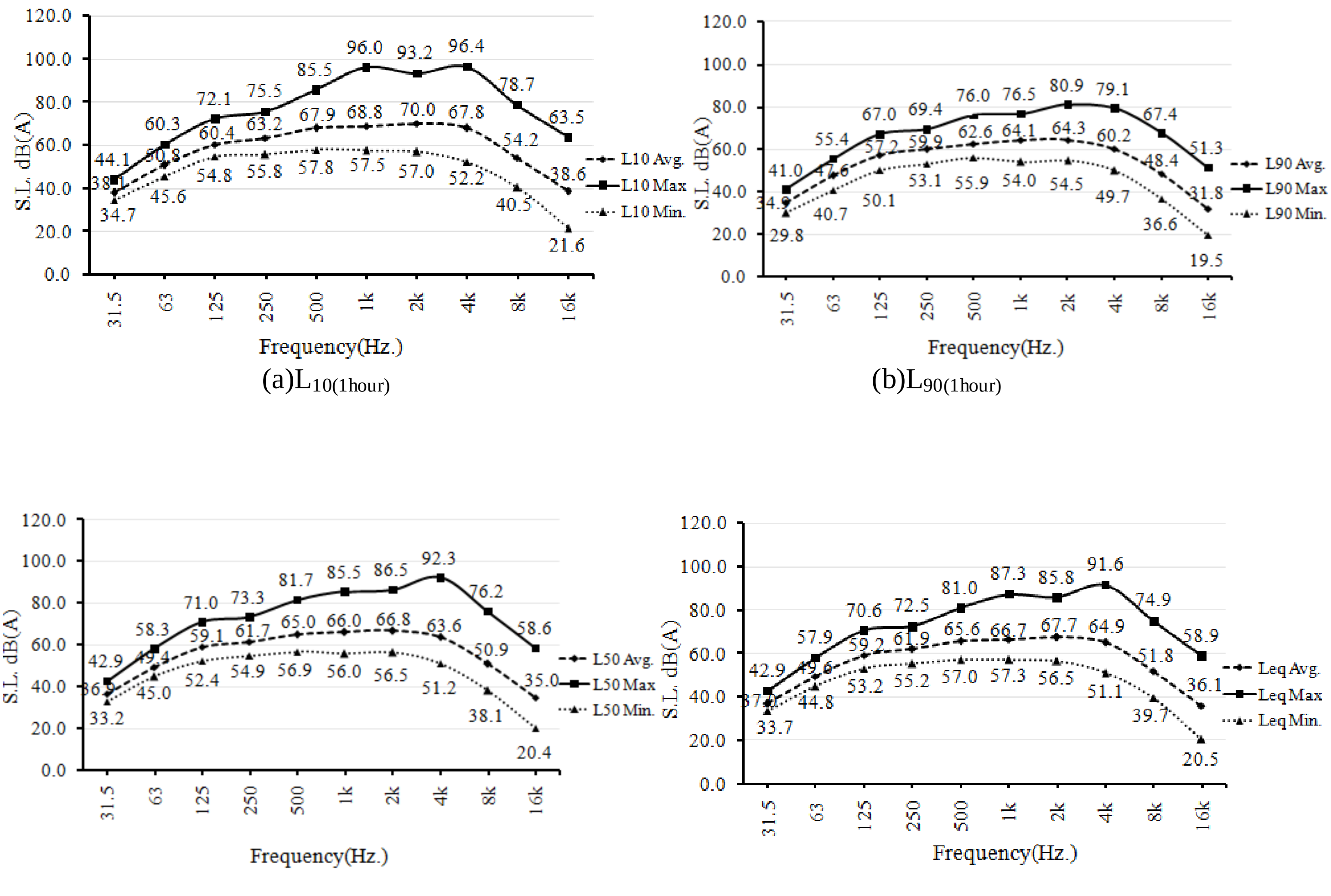
Fig. 5.39 L_{90} vs Distance *l* (mtr)

Graph Interpretation for L_{90}:

From the graph plotted it is found that on an average increase in acceleration of 1m/sec^2 there was an increase of 1 dB (A). When the deceleration increased by 3m/sec^2 the sound level increased by 1.5 dB (A). There was an increase of 5 dB (A) as the no. of heavy vehicles varied from 10 to 100 vehicles/hour. The sound level increased by 5 dB (A) as the vehicle no. of S.U.V. varied from 100 to 400 vehicle/hour. The sound level showed an increment in 8 dB (A) as the number of cars varied from 500 to 2000 vehicles/hour. The sound level increased by 5.5 dB (A) if the no. of three wheelers varied from 50 to 300 vehicles/hour. The sound level showed an increment of 6 dB (A) as the no. of two wheelers varied from 500 to 1500 vehicle/hour. There was no significant decrease in sound level as the distance between roundabout and measuring point varied from 9 mtr to 12mtr.

5.4 FREQUENCY ANALYSIS:

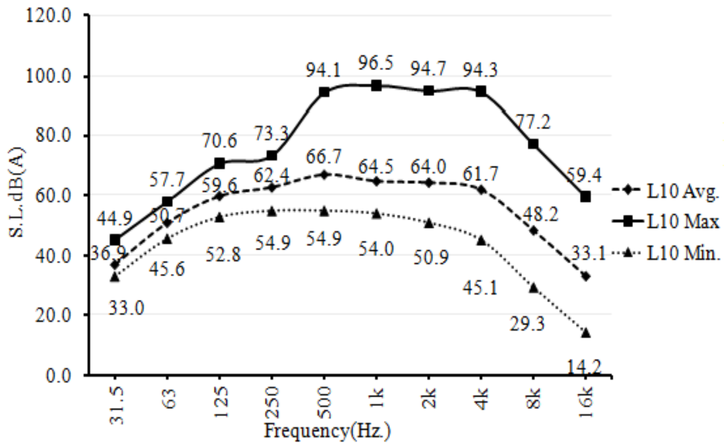
Frequency analysis has been done for 1/1 Octave band for roundabout traffic noise throughout a day. The data collected for each frequency is then averaged and A-weight to each frequency band is applied. This results in a frequency spectrum that would be useful for traffic noise analysis for barrier design to reduce annoyance effect in surrounding areas. and material suggestion that could be used in barrier to mitigate the traffic noise level.



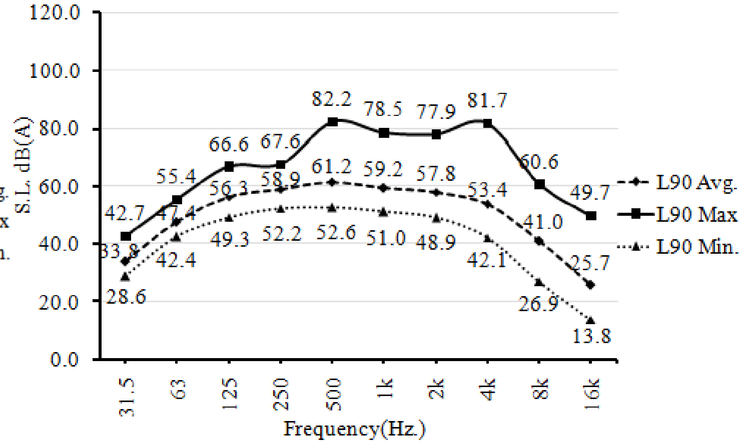
(a)$L_{10(1hour)}$ (b)$L_{90(1hour)}$

(c) $L_{50(1hour)}$ (d) $L_{eq(1hour)}$

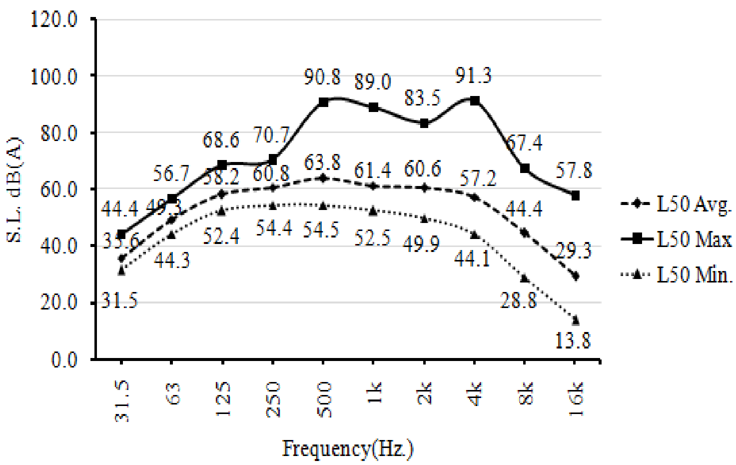
Fig. 5.40 Sound Level vs. Frequency 1/1 octave band.(Day 1)



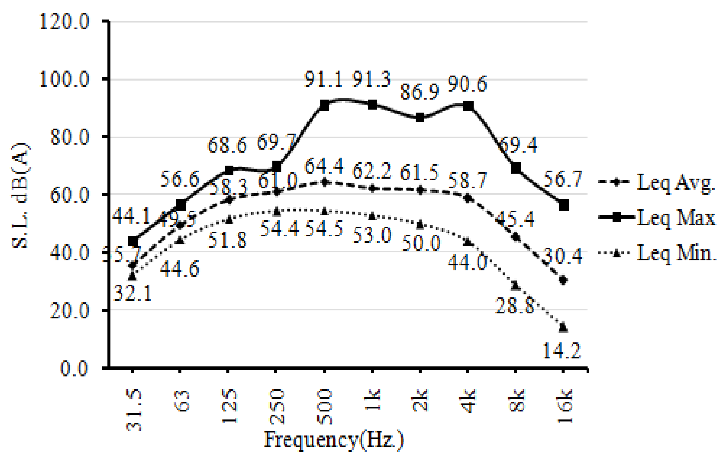
(a) $L_{10(1hour)}$



(b) $L_{90(1hour)}$

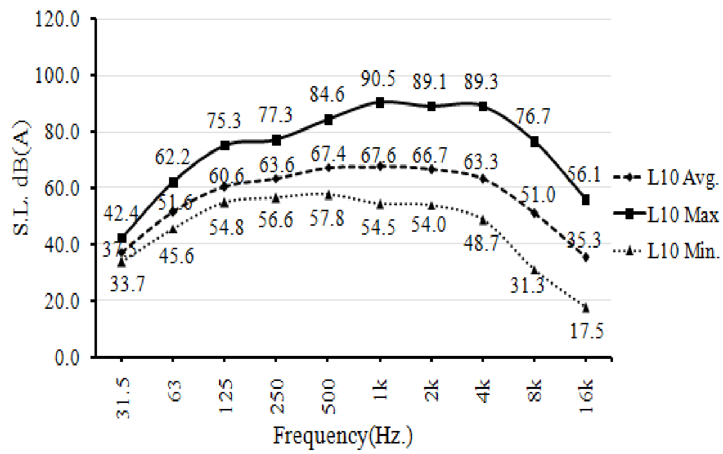


(c) $L_{50(1hour)}$

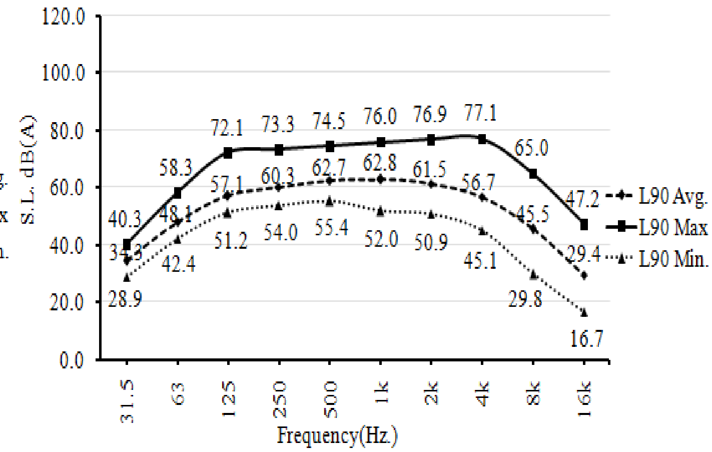


(d) $L_{eq(1hour)}$

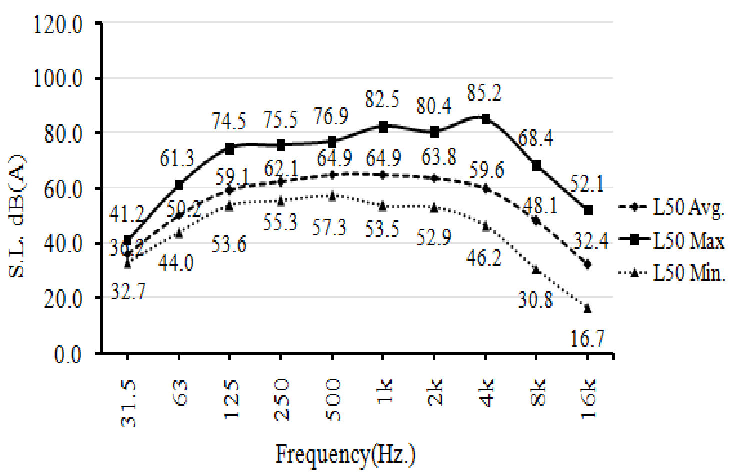
Fig. 5.41 Sound Level vs. Frequency 1/1 octave band (Day 2)



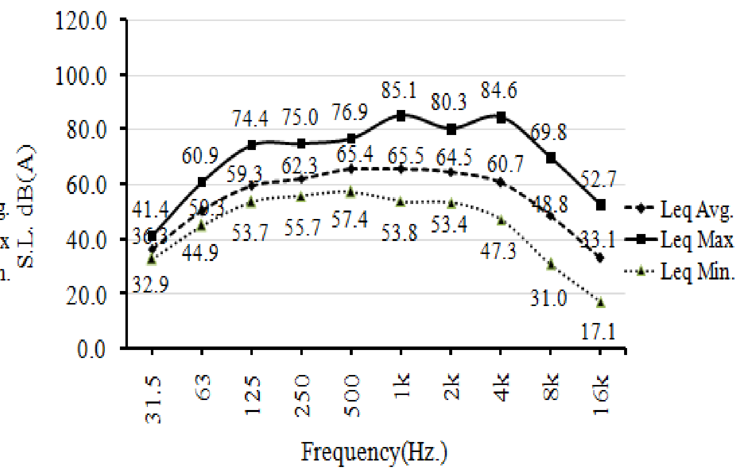
(a) $L_{10(1hour)}$



(b) $L_{90(1hour)}$

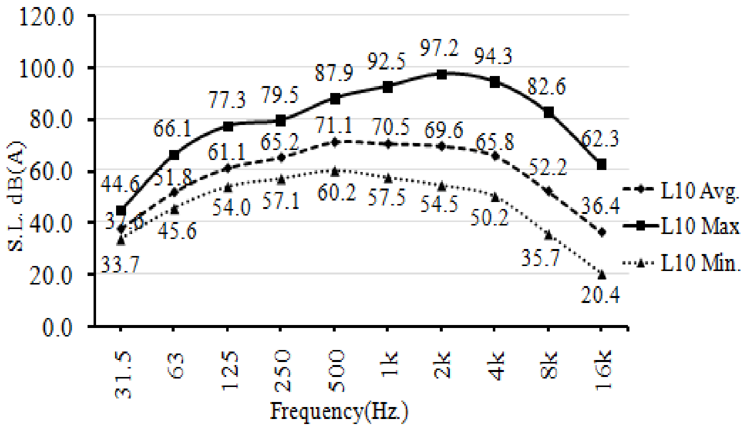


(c) $L_{50(1hour)}$

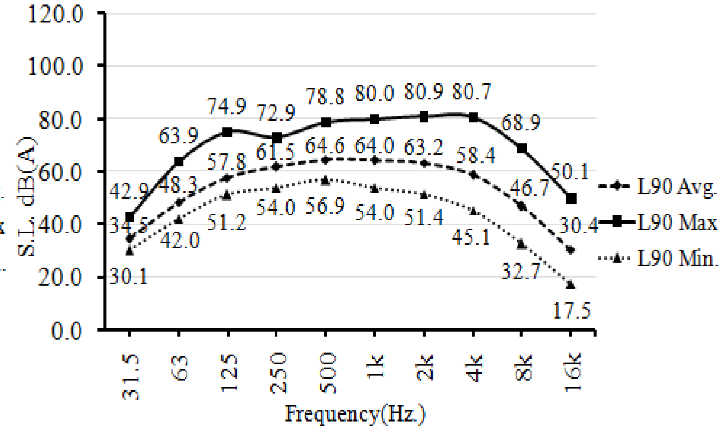


(d) $L_{eq(1hour)}$

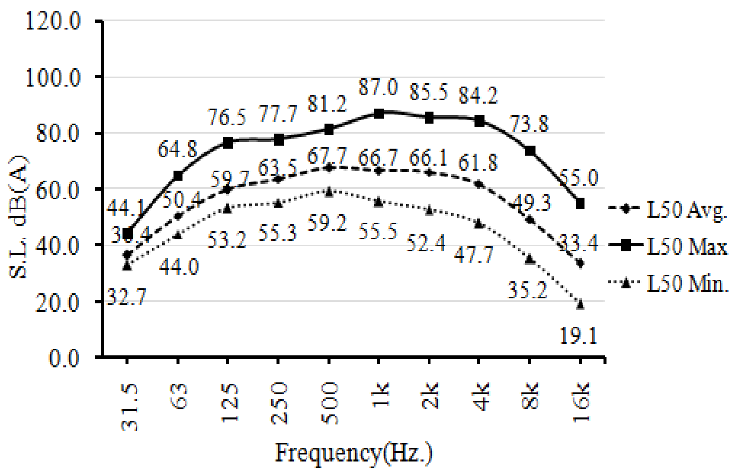
Fig. 5.42 Sound Level vs. Frequency 1/1 octave band (Day 3)



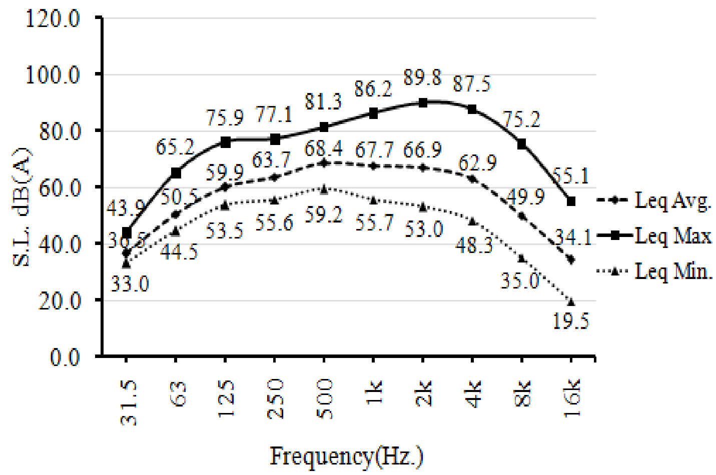
(a)$L_{10(1hour)}$



(b)$L_{90(1hour)}$



(c)$L_{50(1hour)}$



(d)$L_{eq(1hour)}$

Fig. 5.43 Sound Level vs. Frequency 1/1 octave band (Day 4)

From the frequency analysis it was found that the main frequency (Hz.) that has the most contribution to the noise and are dominating in noise spectrum are 500 Hz, 1 Hz, 2 Hz and 4k Hz.. The data for the frequency spectrum graphs can be seen in APPENDIX-G.

Table 5.11 Rank assigned various freq. according to each Sound level descriptor.

Frequency (Hz.)	**L_{eq}**	**Rank**	**L_{10}**	**Rank**
31.5	37.9	9	38	10
63	49.6	8	50.8	8
125	59.2	6	60.4	6
250	61.9	5	63.2	5
500	65.6	3	67.9	3
1k	66.7	2	68.8	2
2k	**67.7**	**1**	**70**	**1**
4k	64.9	4	67.8	4
8k	51.8	7	54.2	7
16k	36.1	10	38.6	9

Frequency. (Hz.)	**L_{50}**	**Rank**	**L_{90}**	**Rank**
31.5	36.9	9	34.9	9
63	49.4	8	47.6	8
125	59.1	6	57.2	6
250	61.7	5	59.9	5
500	65	3	62.6	3
1k	66	2	64.1	2
2k	**66.8**	**1**	**64.3**	**1**
4k	63.6	4	60.2	4
8k	50.9	7	48.4	7
16k	35	10	31.8	10

From the 1/1 Frequency analysis it is found that the frequencies that effect the most the analyzed sound level were found to be 500, 1k, 2k, 4k Hz. These are the one that effect most the areas next to the traffic road areas. Also the same frequencies are known to be annoying frequencies for human hearing. So there should be some preventive steps to lower their dominancy in traffic noise or prevent them from annoying in the surrounding area. From barrier design perspective a material that has absorbing coefficient that of the required frequency absorbing coefficient can be used. Some of the materials that could be suggested in building barriers are shown in Table 5.11.

Table 5.12 Sound absorptive coefficient of constructive materials [47].

	Sound absorption coefficient					
Material	**125 Hz.**	**250 Hz.**	**500 Hz.**	**1k Hz.**	**2k Hz.**	**4k Hz.**
Ballast Stone	0.41	0.53	**0.64**	**0.84**	**0.91**	**0.63**
Brick unglazed, painted carpet, heavy on foam rubber	0.08	0.24	**0.57**	**0.69**	**0.71**	**0.73**
Drapes, Medium velour, 475g/m^2 Draped to half area	0.07	0.31	**0.49**	**0.75**	**0.70**	**0.60**
Fiberglass boards	0.15	0.55	**0.80**	**0.90**	**0.85**	**0.80**

CHAPTER – 6

FINDINGS, CONCLUSIONS AND FUTURE SCOPE

6.1 FINDINGS

From the site measurement findings it is found that on the roundabout L_{eq} noise level varied from 69.3 dB(A) to 81.5 dB(A), L_{10} varied from 72 dB(A) to 83.8 dB(A), L_{50} varied from 66.2 dB(A) to 77.7 dB(A) and L_{90} varied from 59.9 dB(A) to 72.5 dB(A). Traffic composition varied from 288 to 2328 cars/hour, 56 to 600 S.U.V/hour, 4 to 288 H.V/hour, 28 to 728 Three wheeler/hour, 364 to 3032 two wheelers/hour. The acceleration varied from 0.11 to 3.45 m/sec^2 and deceleration varied from 0.12 to 4.43 m/sec^2. The noise at the acceleration lane was found to be 2 dB (A) greater than the deceleration lane.

6.2 DISCUSSION

After collecting all the readings, the next step is to evaluate the readings and based on that give a formulation to the model. It is seen that as there are several parameters which have been taken into consideration, the value of which are ranging from decimal places to thousands of value. Therefore direct comparison with each other is not possible. To perform the analysis, with the help of software aid it is tried to find that what could be the best transformed functions for each of the parameters. Also the transformed functions are then more comparable as they now vary more or less in same range. This could be done with the help of JMP Pro package software, from where the transformed forms of variables are identified. So after the analysis the volume of the vehicles is transformed in to Log_{10} terms, acceleration and deceleration into its squared values and distance is taken as it is. After this the multiple regression analysis is done to formulate the model.

6.3 CONCLUSION

On the basis of noise measurements recorded on the site and the results generated the following conclusions are drawn from the study:

1. From the model developed the L_{eq} noise level varied from 69.9 dB(A) to 81 dB(A), L_{10} varied from 73 dB(A) to 82.4 dB(A) , L_{50} varied from 66.5 dB(A)to 75.5 dB(A)and L_{90} varied from 60.6 dB(A) to 71.9 dB(A). The percentage error was found to be varying between $\pm 3\%$. The values for correlation, Multiple R was found to be 0.84 for L_{eq}, 0.85

for L_{10} and L_{50}, and 0.88 for L_{90} stating that there is good correlation between the actual and the model predicted values, and the factors considered are able to explain the variation well with good prediction capability.

2. Correlation test was carried out to find out that which factor is affecting most the particular sound descriptor and assigned a rank on the basis of the correlation coefficient. The best correlation was found to be varying between 0.5 to 0.8, a negative correlation was found for road width '*l*' stating a negative relation between Noise level and *l*.
3. A t-test was also carried out to check if there was any significant difference between the measured sound level and the predicted sound level. The test stated no significant difference between the two as the 't-statistical' was found to be lying within '$\pm$ t-critical' and the mean values were also found to be much closer for both measured and predicted sound level.
4. Frequency analysis for 1/1 Octave band was done for road traffic noise. The results stated that the frequencies that are most dominant in sound level spectrum are 500, 1k and 2k Hz. The barrier design analysis should consider the material requirement that have more absorption coefficient to abate the peak noise level due to these frequencies.
5. The values of L_{eq} , L_{10} , L_{50} , L_{90} from the experimental readings were found to be high as per Indian standards therefore remedial measures are essential to reduce the harmful effect of noise.

6.4 FUTURE SCOPE

- The present study does not consider the screening effect produced by trees; also the effect of building rows was also not taken into account. The deceleration and acceleration was calculated on an average for all vehicle composition, however the individual vehicle class should be taken into account while measuring.
- Indiscriminate and heavy horn blowing causes high values of L_{max} and consequently affects L_{eq}, L_{10}, L_{50}, L_{90}. Hence thorough study of this aspect could be done and corrections could be incorporated.
- Other factors such as road gradient, temperature conditions, humidity and wind flow could also be included in the prediction and may give better results.
- It is found that a more rigorous approach to matters such as comparison with other techniques could bring a better picture to emerge a good future work.

REFERENCES

[1] Johnson D.R. and Saunders E.G., "The evaluation of noise from freely flowing road traffic". *Journal of Sound and Vibration,* Vol. 7(2), pp. 287-309(1968).

[2] Lewis P.T. and James A., "Noise levels in the vicinity of traffic roundabouts". *Journal of Sound and Vibration*, Vol. 58(2), pp. 293–299(1978).

[3] Lewis P.T. and James A., "On the noise emitted by single vehicles at roundabouts". *Journal of Sound and Vibration*, Vol. 72(1), pp. 51–69(1980).

[4] Stoilova K. and Stoilov T. "Traffic noise and traffic light control". *Transportation Research,* Vol. 3(6), pp. 399-417(1998).

[5] Makarewicz Rufin, Fujimoto Masanori, Kokowski Piotr, "A model of interrupted road traffic noise". *Applied Acoustics*, Vol. 57 pp. 129-137(1999).

[6] To W.M., Chan T.M., "The noise emitted from vehicles at roundabouts". *Acoustical Society of America.* Vol. 107(5), Pt. 1 (2000).

[7] Steele Campbell. "A critical review of some traffic noise prediction models". *Applied Acoustics* Vol. 62, pp. 271-287(1991).

[8]Li Bengang, Tao Shu, Dawson R.W., Cao Jun, Lam Kinche - "A GIS based road traffic noise prediction model". *Applied Acoustics*, Vol.63, pp. 679–691(2002).

[9] Rylander R. and Bjorkman M., "Road traffic noise influenced by road bumps"**.** *Journal of Sound and Vibration,* Vol. 250, pp. 157-159(2002).

[10] Pamanikabuda Pichai, Vivitjinda Prakob, "Noise prediction for highways in Thailand". *Transportation Research* ,Part D7, pp. 441–449 (2002).

[11] S.J. Martin, "Numerical modelling of median road traffic noise barriers"**.** *Journal of Sound and Vibration*, Vol. 251,pp. 671-681(2002).

[12] Calixto Alfredo, FabianoB. Diniz, Paulo H.T. Zannin, "The statistical modeling of road traffic noise in an urban setting". *Cities*, Vol. 20(1), pp. 23–29(2002).

[13] Anyogita S., Prakash Amit, Jain V.K., "A study of noise in CNG driven modes of transport in Delhi". *Applied Acoustics*, Vol. 65, pp. 195–201(2004).

[14] Manoel Joel, Filho Alves, Lenzi Arcanjo, Henrique Paulo, Zannin Trombetta, "Effects of traffic composition on road noise: A case study". *Transportation Research*, Part D9, pp. 75-80(2004).

[15] Nicol F., Wilson M., "The effect of street dimensions and traffic density on the noise level and natural ventilation potential in urban canyons". *Energy and Buildings,* Vol. 36, pp. 423–434(2004).

[16] Tansatcha M., Pamanikabud P., Brown A.L., Affum J.K., "Motorway noise modelling based on perpendicular propagation analysis of traffic noise". *Applied Acoustics*, Vol. 66), pp. 1135–1150(2005).

[17] Sooriyaarachchi R.T. and Sonnadara D.U.J., "Development of a Road Traffic Noise Prediction Model"**.** *Proceedings of the Technical Sessions*, Vol. 22, pp. 17-24(2006).

[18] Chevallier Estelle, Leclercq Ludovic, "A macroscopic theory for unsignalized intersections, *Transportation Research* , Part B 4, pp. 1139–1150(2007).

[19] Cohn F. Louis, Shu Ning, Harris A. Roswell, Kim K. Teak, Li Wensheng, "Comparative evaluation of the ground reflection algorithm in FHWA Traffic Noise Model". *Applied Acoustics*, Vol. 68, pp. 1459–1467(2007).

[20] Makarewicz Rufin and Golebiewski Roman, "Modeling of the roundabout noise impact"*Acoustical Society of America,* PACS number: 43.50, pp. 860–868(2007).

[21] Qudais Abo-Saad, Alhiary Arwa, "Statistical models for traffic noise at signalized intersections", *Building and Environment*, Vol. 42, pp. 2939–2948(2007)

[22] Can Arnaud, Leclercq Ludovic, Lelong Joel, "Dynamic estimation of urban traffic noise: Influence of traffic and noise source representations", *Applied Acoustics*, Vol. 69, pp. 858–867(2008)

[23] Banerjee D., Chakraborty S.K., Bhattacharyya S., Gangopadhyay A., "Modeling of road traffic noise in the industrial town of Asansol, India", *Transportation Research*, Part D 13, pp. 539–541(2008)

[24] Rajakumara H. N. and Mahalinge Gowda R. M., "Road Traffic Noise Prediction Model under Interrupted Traffic Flow Condition", *Environ Model Assess* Vol. 14, pp. 251–257(2009).

[25] Chevallier E., Can A., Nadji M., Leclercq L., "Improving noise assessment at intersections by modeling traffic dynamics". *Transportation Research*, Part D 14, pp.100–110(2009).

[26] Guarnaccia Claudio, "Analysis of Traffic Noise in a Road Intersection Configuration"., *WSEAS Transactions on systems*, Vol. 9(8), pp. 121-430(2010)

[27] Parida M., Mishra R. K., Rangnekar S., "Evaluation and analysis of traffic noise along bus rapid transit system corridor**".** *International journal of environment and Science Technology*, Vol.7(4), pp. 737-750(2010).

[28] Law Chi-wing, Lee Chee-kwan, Shiu-wai Lui Aaron , Yeung Maurice Kwok-leung, Lam Kin-che, "Advancement of three-dimensional noise mapping in Hong Kong". *Applied Acoustics*, Vol. 72, pp. 534–543(2011).

[29] Montellaa Alfonso, Ariab Massimo, D'Ambrosiob Antonio, Galantea Francesco,Maurielloa Filomena, Pernettic Mariano, "Simulator evaluation of drivers' speed, deceleration and lateral position at rural intersections in relation to different perceptual cues". *Accident Analysis and Prevention*, Vol. 43, pp. 2072– 2084(2011).

[30] Bueno M., Luong J., Vinuela U., Teran F., Paje S.E., "Pavement temperature influence on close proximity tire/road noise". *Applied Acoustics*, Vol.72, pp. 829–835(2011).

[31] Zhao Jianqiang, Zhang Xiaoning , Chen Ying, "A novel traffic-noise prediction method for non-straight roads". *Applied Acoustics*, Vol.73, pp. 276–280 (2012).

[32] Coensel B. De, Cana A., Degraeuwe B., Vlieger I. De, Botteldooren D, "Effects of traffic signal coordination on noise and air pollutant emissions". *Environmental Modelling & Software*, Vol. 35, pp. 74-83 (2012).

[33] Tripathi V., Mittal A. and Ruwali P., "Efficient Road Traffic Noise Model for Generating Noise Levels in Indian Scenario". *International Journal of Computer Applications* ,Volume 38(4), pp. 281- 286 (2012).

[34] Calvo J.A., Caldas C. Alvarez, Roman J.L. San, Cobo P., "Influence of vehicle driving parameters on the noise caused by passenger cars in urban traffic". *Transportation Research*, Part D 17, pp. 509–513 (2012).

[35] Subramani T., Kavitha M., Sivaraj K.P., "Modelling Of Traffic Noise Pollution" **.** *International Journal of Engineering Research and Applications (IJERA)*, Vol. 2(3), pp.3175-3182 (2012).

[36] Nigam S.P., "Introduction to noise", *Noise control program*, Thapar University, Patiala, (2008).

[37] Nigam S.P., "Vehicular traffic coise and its characterization**"** , *National conference of Mechanical engineering*, Thapar University, Patiala, (2008).

Web References:

[38] http://dragonphysics.pbworks.com/w/page/18192590/Sound%20Properties

[39] http://images.yourdictionary.com/wavelength

[40] http://physics-animations.com/Physics/English/wave_txt.htm#Waves (Viewed on 15 August 2012)

[41] Acoustics and Your Environment, "*The Basis of Sound and Highway Traffic Noise"*, http://www.youtube.com/watch?v=-9Y8n0lBC7Q (Viewed on 22February 2012).

[42] http://www.noisemeters.com/help/faq/octave-bands.asp

[43] http://www.vettaville.nl/vvFletcher%20Munson%20eng.htm

[44]http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/design/design03.cfm

[45] www.sciencedirect.com

Book references:

[46] **Malcolm J. Crocker**. "*Handbook of Noise and Vibration Control"*. John Wiley & Sons,.

[47] **Cyril M. Harris. "***Handbook of Acoustical and noise control*". Third Edition.

[48] **S.C. Gupta and V.K. Kapoor, '***Fundamental of Mathematical Statistics'***.** Sultan Chand & Sons, New Delhi, (2006).

APPENDIX A- Data collected for three roundabouts

S.No.	Traffic Composition					Acc. (m/s²) (*a*)	Dec. (m/s²) (*d*)	Dist. (mtr) (*l*)	Sound Level dB (A)			
	Car (C)	S.U.V. (S)	H.V.	Three Wheeler (T_1)	Two Wheeler (T_2)				L_{eq}	L_{10}	L_{50}	L_{90}
Fountain Chowk Roundabout												
1	2016	416	84	240	1448	1.96	2.94	13.5	73.5	79	73	70.1
2	1672	456	96	128	2176	1.92	2.76	13.5	77.5	78.8	72.8	68.8
3	1480	320	152	216	1776	1.87	2.88	13.5	76.7	76.4	71.8	69.5
4	1480	272	188	184	1440	1.88	2.89	13.5	74.4	78.2	71.9	69.3
5	1456	288	116	240	1472	1.87	3.01	13.5	74.2	76.9	71.7	67.9
6	1152	400	120	240	1336	1.76	2.89	13.5	73.6	75.6	71	68.7
7	696	160	48	568	1296	3.38	4.34	9.8	79.5	79.7	72.3	67.6
8	840	112	44	560	1568	3.13	4.12	9.8	76.9	78	72.1	67.6
9	1096	80	36	536	1240	2.98	3.89	9.8	75.5	78.1	72.2	68
10	832	144	36	576	1456	3.13	3.91	9.8	73	78.6	72.5	68.1
11	528	128	28	536	744	3.15	4.03	9.8	74.1	78.8	73.1	66.1
12	536	216	20	536	720	3.09	3.77	9.8	76.6	79	73.3	68.8
13	528	112	56	528	784	3.32	3.93	9.8	79.6	83.8	76.5	67.8
14	560	144	72	560	816	3.12	4.11	9.8	74.6	78.4	72.3	66
15	920	144	32	208	1920	1.61	3.67	8	76.1	79.3	74.2	69.9
16	1056	208	48	224	2336	1.45	3.56	8	75.7	79.5	74	70.1
17	792	232	64	240	1552	1.56	3.78	8	78.7	81.6	75.3	70.7
18	1056	600	168	392	1408	1.54	3.56	8	78	82.7	76.7	71.9
19	1168	272	176	488	1040	1.34	3.89	8	79.3	83.2	77.7	72.5
20	1056	240	212	432	1344	1.54	4.43	10.7	73.5	79.5	73.6	70
21	1160	248	132	424	1552	1.45	4.12	10.7	78.7	80.6	73.8	69.9
22	1752	384	220	240	1864	1.56	3.34	10.7	79.6	79.6	73.7	69.3
23	920	144	76	208	2128	1.87	3.43	10.6	77.5	79.2	74	69.5
24	760	224	64	224	1792	0.56	2.77	10.6	78.9	81.6	75.3	70.8

S.No.	Traffic Composition					Acc. (m/s^2) (*a*)	Dec. (m/s^2) (*d*)	Dist. (mtr) (*l*)	Sound Level dB (A)			
	Car (C)	S.U.V. (S)	H.V.	Three Wheeler (T_1)	Two Wheeler (T_2)				L_{eq}	L_{10}	L_{50}	L_{90}
25	1040	320	148	240	904	0.67	2.67	10.6	80.5	83	76.7	72.1
26	768	216	160	392	840	0.98	2.78	10.6	80.8	83.2	76.8	72.1
27	1544	384	168	488	1104	1.78	2.99	11.6	76.8	78.2	72.6	69.7
28	1936	272	184	432	1344	1.88	2.89	11.6	76.2	80.2	73.2	69.3
29	2048	400	200	424	1656	1.87	3.01	11.6	76.3	79.5	73.9	70.5
30	1320	360	148	240	1016	1.76	2.89	11.6	77.9	79.7	73.7	69.1
31	592	64	12	192	1024	1.78	2.45	12	73	80.1	73.9	69.6
32	352	112	12	136	776	1.65	3.14	12	75.3	81	73.9	69.7
33	1480	392	72	664	1696	1.56	3.02	10	78	80.2	72.8	68.2
34	1624	376	32	600	1744	1.45	3.01	10	77.9	79.4	72.6	68.2
35	1704	392	48	464	2488	1.33	3.11	10	76.1	78	71.7	68
36	1744	400	124	336	2320	1.45	2.98	9	77.9	78.7	72.1	68.3
37	1952	424	84	512	1760	1.67	2.67	9	78.2	79.5	74.4	72.1
38	1840	336	68	688	1672	1.78	2.78	9	77.2	79.8	74.9	72.3
39	1152	64	16	152	864	1.88	2.89	12	73	78.8	72.9	68.8
Thikkari Chowk Roundabout												
40	1280	168	168	464	1528	1.31	3.11	9	80.5	83.2	73.5	68.9
41	1344	176	208	504	1752	1.67	3.24	9	81.4	82.7	74.3	69.6
42	1048	216	244	472	1592	1.78	3.12	9	80.4	81.7	75.1	69.8
43	904	256	140	488	1592	1.45	3.09	9	79.5	82.3	74.1	69.7
44	1176	304	152	496	1528	1.98	2.89	9.5	78.2	81.4	74.9	70.1
45	1200	272	196	560	1608	1.87	2.67	10.6	78.6	80.7	75.4	71.9
46	1224	456	220	504	1312	1.76	2.76	10.6	78.9	81.3	76.2	71.8
47	1600	272	240	520	1368	1.34	3.33	11.6	78.6	81	74.9	70.3
48	696	152	32	208	1488	1.92	0.275	11.6	73.7	76.9	71.3	66.9
49	1008	200	48	240	1448	1.98	0.345	11.6	74.3	76.9	71.6	67.8

S.No.	Traffic Composition					Acc. (m/s^2) (*a*)	Dec. (m/s^2) (*d*)	Dist. (mtr) (*l*)	Sound Level dB (A)			
	Car (C)	S.U.V. (S)	H.V.	Three Wheeler (T_1)	Two Wheeler (T_2)				L_{eq}	L_{10}	L_{50}	L_{90}
50	960	208	68	200	1640	1.89	0.453	9.5	77.3	78.5	72	67.9
51	1328	152	48	176	1288	1.86	0.345	9.5	75.5	77.7	72.1	67.7
52	768	224	64	208	840	1.87	0.564	9.5	78	77.7	70.6	66.1
53	952	160	56	136	1152	1.98	0.233	9	74.6	77.6	71.2	66.3
54	744	200	36	184	1136	1.78	0.433	9	75.9	78	71.8	67.3
55	920	280	16	208	1296	1.77	0.234	9	77.4	80	73	67.8
56	1040	312	208	488	1840	2.77	3.4	9	79.4	81	75	70.3
57	1176	248	232	416	1456	2.45	3.56	8	81.2	82.7	75.8	71.1
58	976	208	216	432	1480	2.67	3.24	8	79.7	79.9	74.2	70
59	1000	224	172	400	1800	2.77	3.44	8	82.5	83.4	75.9	71
60	1016	304	200	360	1080	2.77	3.45	8	76.3	79.1	72.1	66.4
61	992	520	244	464	1168	2.89	3.43	9	80.5	80.4	72.6	67.6
62	936	240	244	320	1336	2.99	3.22	9	78.4	79.6	73.1	68.2
63	888	224	184	320	1104	2.78	2.98	9	78.5	80.6	73.7	68.8
64	1784	400	112	640	2696	1.92	3.11	9	76.9	79.4	71.9	67
65	2144	400	140	576	3032	1.98	3.24	9.5	79.9	81.7	74	69.6
66	1272	384	152	680	2496	1.88	3.12	9.5	79.5	80.8	72.8	68.3
67	1616	344	168	640	2280	3.44	0.233	9.5	82.9	81.8	74.9	69.8
68	1336	288	164	448	1496	3.12	0.433	9.5	77.6	79.8	73.2	67.6
69	1512	400	156	608	1792	2.45	0.234	9	79.2	80.1	74.3	69.5
70	1392	296	108	376	1224	2.77	0.456	9	79.4	80.9	72.7	67.9
71	1984	384	132	576	2064	3.12	0.456	9	82.5	81.9	73.7	68.9
72	2328	360	124	728	2328	3.23	0.556	9	80.3	80.7	73	69
73	920	184	36	80	1504	3.23	1.78	9	75.9	77	72	67.3
74	1752	168	32	104	1336	3.21	1.55	9	75.8	78.7	73.4	70.7
75	976	208	52	224	1608	3.33	1.33	9	76.3	79.4	73.4	70.9

S.No.	Traffic Composition					Acc. (m/s^2) (*a*)	Dec. (m/s^2) (*d*)	Dist. (mtr) (*l*)	Sound Level dB (A)			
	Car (C)	S.U.V. (S)	H.V.	Three Wheeler (T_1)	Two Wheeler (T_2)				L_{eq}	L_{10}	L_{50}	L_{90}
76	1120	296	240	352	1336	3.23	1.77	9	82.6	81.4	74.3	69.9
77	1152	256	160	288	1616	3.1	1.56	9	81.2	82.8	76	71.4
78	960	216	288	400	1480	3.09	1.66	9	83.4	82.5	74.9	69.8
79	904	256	68	192	1024	2.67	1.45	9	79.6	82.4	73.6	69.2
80	824	208	64	200	1200	2.99	1.88	9	80.3	80.9	74.6	71.1
Y.P.S. Chowk Roundabout												
81	528	168	4	76	776	1.23	3.91	10	71.8	74.6	68.3	63.4
82	488	144	16	44	796	1.43	3.92	10	71.6	74.4	67.8	63.3
83	416	96	8	32	748	1.45	3.1	10	70.9	73.3	66.4	61.6
84	640	88	16	64	920	1.34	3.7	10	71.6	73.6	67.9	62.8
85	476	108	12	28	720	1.56	3.99	10	74.9	73.8	68.2	63.3
86	472	120	12	36	576	1.45	3.56	10	73.2	75.1	69	63.7
87	440	124	12	36	588	1.56	3.77	10	71.6	74.1	67.7	62.5
88	436	136	16	48	516	1.55	3.33	10	72.3	73.4	67.6	62.6
89	624	124	72	44	728	3.45	2.64	7	77.9	77.9	70.1	63.6
90	508	132	48	80	628	2.56	2.1	7	73.8	76.4	68.8	63
91	436	108	44	84	876	3.1	2.57	7	76.4	76.6	69.5	63.4
92	420	140	52	120	936	3.4	2.78	7	78.7	78.8	70.1	63.7
93	476	112	68	84	892	2.7	2.1	7	74.7	76.9	69.5	64.1
94	476	136	36	100	888	2.9	2.47	7	77	76.2	68.5	62.2
95	448	80	60	84	748	2.87	2.2	7	73.8	76.8	68.7	62.4
96	528	96	44	120	712	3.08	2.33	7	75.2	77.6	70.6	64.6
97	396	88	44	56	644	1.33	0.12	11	72.9	75.4	69.4	64.7
98	440	108	32	36	576	1.78	0.11	11	75.1	74.8	68.3	62.5
99	452	84	40	68	548	1.45	0.12	11	72.6	75.7	69.3	63.4
100	388	88	40	88	632	1.55	0.11	11	73	76.3	69.4	63

S.No.	Traffic Composition					Acc. (m/s^2) (*a*)	Dec. (m/s^2) (*d*)	Dist. (mtr) (*l*)	Sound Level dB (A)			
	Car (C)	S.U.V. (S)	H.V.	Three Wheeler (T_1)	Two Wheeler (T_2)				L_{eq}	L_{10}	L_{50}	L_{90}
101	320	100	24	60	492	1.11	0.13	11	71.5	74.8	68.2	61.1
102	468	148	32	56	476	1.08	0.14	11	71.6	74.3	68.3	62.8
103	388	72	8	56	364	0.99	0.43	11	70.5	73.4	66.8	60.7
104	288	60	8	44	372	0.99	0.11	11	69.5	73	66.5	59.9
105	496	132	24	96	696	0.11	2.77	9.8	73.5	75.2	68.8	63.1
106	404	92	28	60	728	0.14	2.67	9.8	73	74.9	68.3	62.1
107	356	72	24	72	480	0.33	2.77	9.8	74.3	74.6	67.4	61.5
108	376	88	16	84	592	0.13	2.61	9.8	73.8	74.5	67.8	61.5
109	372	112	32	72	588	0.11	2.98	9.8	74.9	75.7	68.1	62.2
110	316	116	32	76	460	0.19	3.11	9.8	75.9	74.2	67.6	61.4
111	308	92	24	52	536	0.21	2.13	9.8	72.1	73.8	66.2	60.1
112	420	92	20	68	460	0.14	2.34	9.8	72.8	74.8	68.1	61.8
113	548	116	40	72	796	1.72	1.69	10.5	73.6	74.7	68.8	63.7
114	776	132	64	64	844	1.78	1.56	10.5	74.5	76.4	69.6	64.7
115	772	116	16	64	1096	1.76	1.58	10.5	74.9	75.7	68.9	64
116	916	124	44	100	1112	1.98	1.59	10.5	74.8	76	68.3	63.3
117	556	72	24	48	756	1.67	1.45	10.5	73.4	73.8	66.7	61.3
118	340	108	24	52	700	1.56	1.34	10.5	73.6	74.4	67.4	61.9
119	584	156	20	52	916	1.55	1.33	10.5	73.8	75	67.7	62.6
120	484	104	40	116	764	3.45	1.69	9	74.1	77.4	69.5	64.3
121	544	80	40	108	864	2.56	1.76	9	75	77.1	70.1	65.1
122	396	140	32	156	924	3.1	1.58	9	73.9	75.4	68.9	64.7
123	552	140	64	152	1048	3.4	1.59	9	74.8	75.5	68.2	63.8
124	648	188	80	100	844	1.23	2.64	9	74.8	76.3	70.5	66.7
125	676	136	92	104	828	1.43	2.1	9	73.5	76.1	69.9	65.8
126	552	132	44	136	644	1.45	2.57	9	72.1	74.8	67.9	64.1

S.No.	Traffic Composition					Acc. (m/s^2) (*a*)	Dec. (m/s^2) (*d*)	Dist. (mtr) (*l*)	Sound Level dB (A)			
	Car (C)	S.U.V. (S)	H.V.	Three Wheeler (T_1)	Two Wheeler (T_2)				L_{eq}	L_{10}	L_{50}	L_{90}
127	592	92	84	128	852	1.34	2.78	9	73	75.5	69.2	64.8
128	296	76	60	84	528	1.67	3.91	10	71.6	73.3	67.4	63
129	368	68	56	88	708	1.56	3.92	10	72.4	73.8	67.2	62.2
130	588	88	44	104	800	1.55	3.1	10	70.4	72.7	66.7	62.4
131	548	124	36	64	708	1.1	3.7	11	69.3	72	66.3	62
132	372	56	52	56	428	1.33	3.99	11	71.2	74.1	68.5	61.8
133	376	112	44	96	452	1.78	2.88	11	70.8	74.3	68.1	62
134	352	108	32	48	468	1.45	2.44	11	70	72.5	66.4	60.8
135	480	96	32	72	540	1.55	2.55	11	72	75	68.2	62.8

APPENDIX-B -Multiple Regression Output For L_{eq}

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{eq} dB(A)	L_{eq} Pred. dB(A)	% error
Fountain Chowk Roundabout											
1	3.30	2.62	1.92	2.38	3.16	3.84	8.64	13.5	73.5	75.7	-2.9
2	3.22	2.66	1.98	2.11	3.34	3.69	7.62	13.5	77.5	76.2	1.8
3	3.17	2.51	2.18	2.33	3.25	3.50	8.29	13.5	76.7	76.4	0.4
4	3.17	2.43	2.27	2.26	3.16	3.53	8.35	13.5	74.4	75.9	-2.0
5	3.16	2.46	2.06	2.38	3.17	3.50	9.06	13.5	74.2	75.7	-2.0
6	3.06	2.60	2.08	2.38	3.13	3.10	8.35	13.5	73.6	76.2	-3.4
7	2.84	2.20	1.68	2.75	3.11	11.42	18.84	9.8	79.5	77.2	2.9
8	2.92	2.05	1.64	2.75	3.20	9.80	16.97	9.8	76.9	76.7	0.2
9	3.04	1.90	1.56	2.73	3.09	8.88	15.13	9.8	75.5	75.5	0.0
10	2.92	2.16	1.56	2.76	3.16	9.80	15.29	9.8	73	76.8	-5.2
11	2.72	2.11	1.45	2.73	2.87	9.92	16.24	9.8	74.1	75.7	-2.1
12	2.73	2.33	1.30	2.73	2.86	9.55	14.21	9.8	76.6	75.9	0.9
13	2.72	2.05	1.75	2.72	2.89	11.02	15.44	9.8	79.6	78.9	0.9
14	2.75	2.16	1.86	2.75	2.91	9.73	16.89	9.8	74.6	76.9	-2.9
15	2.96	2.16	1.51	2.32	3.28	2.59	13.47	8	76.1	76.3	-0.3
16	3.02	2.32	1.68	2.35	3.37	2.10	12.67	8	75.7	77.4	-2.2
17	2.90	2.37	1.81	2.38	3.19	2.43	14.29	8	78.7	77.5	1.6
18	3.02	2.78	2.23	2.59	3.15	2.37	12.67	8	78	79.8	-2.3
19	3.07	2.43	2.25	2.69	3.02	1.80	15.13	8	79.3	78.4	1.2
20	3.02	2.38	2.33	2.64	3.13	2.37	19.62	10.7	73.5	77.4	-5.3
21	3.06	2.39	2.12	2.63	3.19	2.10	16.97	10.7	78.7	77.2	2.0
22	3.24	2.58	2.34	2.38	3.27	2.43	11.16	10.7	79.6	78.0	2.0
23	2.96	2.16	1.88	2.32	3.33	3.50	11.76	10.6	77.5	76.4	1.5
24	2.88	2.35	1.81	2.35	3.25	0.31	7.67	10.6	78.9	76.5	3.1
25	3.02	2.51	2.17	2.38	2.96	0.45	7.13	10.6	80.5	79.5	1.3
26	2.89	2.33	2.20	2.59	2.92	0.96	7.73	10.6	80.8	78.9	2.4
27	3.19	2.58	2.23	2.69	3.04	3.17	8.94	11.6	76.8	77.4	-0.8
28	3.29	2.43	2.26	2.64	3.13	3.53	8.35	11.6	76.2	77.2	-1.3

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{eq} dB(A)	L_{eq} Pred. dB(A)	% Error
29	3.31	2.60	2.30	2.63	3.22	3.50	9.06	11.6	76.3	78.0	-2.2
30	3.12	2.56	2.17	2.38	3.01	3.10	8.35	11.6	77.9	76.6	1.6
31	2.77	1.81	1.08	2.28	3.01	3.17	6.00	12	73	72.2	1.2
32	2.55	2.05	1.08	2.13	2.89	2.72	9.86	12	75.3	74.8	0.7
33	3.17	2.59	1.86	2.82	3.23	2.43	9.12	10	78	78.1	-0.2
34	3.21	2.58	1.51	2.78	3.24	2.10	9.06	10	77.9	77.1	1.0
35	3.23	2.59	1.68	2.67	3.40	1.77	9.67	10	76.1	77.8	-2.2
36	3.24	2.60	2.09	2.53	3.37	2.10	8.88	9	77.9	78.9	-1.3
37	3.29	2.63	1.92	2.71	3.25	2.79	7.13	9	78.2	78.6	-0.5
38	3.26	2.53	1.83	2.84	3.22	3.17	7.73	9	77.2	78.3	-1.4
39	3.06	1.81	1.20	2.18	2.94	3.53	8.35	12	73	71.5	2.1
Thikkari Chowk Roundabout											
40	3.11	2.23	2.23	2.67	3.18	1.72	9.67	9	80.5	77.9	3.3
41	3.13	2.25	2.32	2.70	3.24	2.79	10.50	9	81.4	78.5	3.6
42	3.02	2.33	2.39	2.67	3.20	3.17	9.73	9	80.4	79.0	1.8
43	2.96	2.41	2.15	2.69	3.20	2.10	9.55	9	79.5	78.7	1.1
44	3.07	2.48	2.18	2.70	3.18	3.92	8.35	9.5	78.2	78.8	-0.7
45	3.08	2.43	2.29	2.75	3.21	3.50	7.13	9.5	78.6	79.1	-0.6
46	3.09	2.66	2.34	2.70	3.12	3.10	7.62	9.5	78.9	79.4	-0.6
47	3.20	2.43	2.38	2.72	3.14	1.80	11.09	9.5	78.6	78.4	0.2
48	2.84	2.18	1.51	2.32	3.17	3.69	0.08	9	73.7	76.4	-3.6
49	3.00	2.30	1.68	2.38	3.16	3.92	0.12	9	74.3	77.0	-3.5
50	2.98	2.32	1.83	2.30	3.21	3.57	0.21	9	77.3	77.5	-0.2
51	3.12	2.18	1.68	2.25	3.11	3.46	0.12	9	75.5	76.0	-0.7
52	2.89	2.35	1.81	2.32	2.92	3.50	0.32	8	78	77.1	1.1
53	2.98	2.20	1.75	2.13	3.06	3.92	0.05	8	74.6	76.6	-2.6
54	2.87	2.30	1.56	2.26	3.06	3.17	0.19	8	75.9	76.7	-1.1
55	2.96	2.45	1.20	2.32	3.11	3.13	0.05	8	77.4	76.5	1.2
56	3.02	2.49	2.32	2.69	3.26	7.67	11.56	9	79.4	80.0	-0.7
57	3.07	2.39	2.37	2.62	3.16	6.00	12.67	9	81.2	79.0	2.8

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{eq} dB(A)	L_{eq} Pred. dB(A)	% Error
58	2.99	2.32	2.33	2.64	3.17	7.13	10.50	9	79.7	79.1	0.8
59	3.00	2.35	2.24	2.60	3.26	7.67	11.83	9	82.5	81.2	1.6
60	3.01	2.48	2.30	2.56	3.03	7.67	11.90	9.5	76.3	78.6	-3.0
61	3.00	2.72	2.39	2.67	3.07	8.35	11.76	9.5	80.5	79.9	0.7
62	2.97	2.38	2.39	2.51	3.13	8.94	10.37	9.5	78.4	79.0	-0.8
63	2.95	2.35	2.26	2.51	3.04	7.73	8.88	9.5	78.5	78.3	0.2
64	3.25	2.60	2.05	2.81	3.43	3.69	9.67	9	76.9	79.7	-3.5
65	3.33	2.60	2.15	2.76	3.48	3.92	10.50	9	79.9	79.9	0.0
66	3.10	2.58	2.18	2.83	3.40	3.53	9.73	9	79.5	80.1	-0.8
67	3.21	2.54	2.23	2.81	3.36	11.83	0.05	9	82.9	81.0	2.3
68	3.13	2.46	2.21	2.65	3.17	9.73	0.19	9	77.6	79.8	-2.7
69	3.18	2.60	2.19	2.78	3.25	6.00	0.05	9	79.2	80.2	-1.2
70	3.14	2.47	2.03	2.58	3.09	7.67	0.21	9	79.4	78.7	0.9
71	3.30	2.58	2.12	2.76	3.31	9.73	0.21	9	82.5	80.3	2.7
72	3.37	2.56	2.09	2.86	3.37	10.43	0.31	9	80.3	80.5	-0.2
73	2.96	2.26	1.56	1.90	3.18	10.43	3.17	10	75.9	76.0	-0.1
74	3.24	2.23	1.51	2.02	3.13	10.30	2.40	10	75.8	75.3	0.6
75	2.99	2.32	1.72	2.35	3.21	11.09	1.77	10	76.3	77.5	-1.6
76	3.05	2.47	2.38	2.55	3.13	10.43	3.13	9	82.6	79.9	3.4
77	3.06	2.41	2.20	2.46	3.21	9.61	2.43	9	81.2	79.3	2.4
78	2.98	2.33	2.46	2.60	3.17	9.55	2.76	9	83.4	82.2	1.5
79	2.96	2.41	1.83	2.28	3.01	7.13	2.10	9	79.6	77.3	2.9
80	2.92	2.32	1.81	2.30	3.08	8.94	3.53	9	80.3	77.5	3.6
Y.P.S. Chowk Roundabout											
81	2.72	2.23	0.60	1.88	2.89	1.51	15.29	10	71.8	71.5	0.5
82	2.69	2.16	1.20	1.64	2.90	2.04	15.37	10	71.6	72.4	-1.1
83	2.62	1.98	0.90	1.51	2.87	2.10	9.61	10	70.9	71.2	-0.4
84	2.81	1.94	1.20	1.81	2.96	1.80	13.69	10	71.6	72.2	-0.8
85	2.68	2.03	1.08	1.45	2.86	2.43	15.92	10	74.9	72.6	3.2
86	2.67	2.08	1.08	1.56	2.76	2.10	12.67	10	73.2	71.4	2.6

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{eq} dB(A)	L_{eq} Pred. dB(A)	% Error
87	2.67	2.09	1.08	1.56	2.77	2.43	14.21	10	71.6	71.5	0.2
88	2.64	2.13	1.20	1.68	2.71	2.40	11.09	10	72.3	72.1	0.3
89	2.80	2.09	1.86	1.64	2.86	11.90	6.97	7	77.9	76.2	2.2
90	2.71	2.12	1.68	1.90	2.80	6.55	4.41	7	73.8	75.8	-2.7
91	2.64	2.03	1.64	1.92	2.94	9.61	6.60	7	76.4	76.4	0.0
92	2.62	2.15	1.72	2.08	2.97	11.56	7.73	7	78.7	77.4	1.6
93	2.68	2.05	1.83	1.92	2.95	7.29	4.41	7	74.7	76.7	-2.6
94	2.68	2.13	1.56	2.00	2.95	8.41	6.10	7	77	76.4	0.7
95	2.65	1.90	1.78	1.92	2.87	8.24	4.84	7	73.8	76.0	-2.9
96	2.72	1.98	1.64	2.08	2.85	9.49	5.43	7	75.2	76.1	-1.2
97	2.60	1.94	1.64	1.75	2.81	1.77	0.01	11	72.9	73.0	-0.2
98	2.64	2.03	1.51	1.56	2.76	3.17	0.01	11	75.1	72.5	3.6
99	2.66	1.92	1.60	1.83	2.74	2.10	0.01	11	72.6	72.7	-0.2
100	2.59	1.94	1.60	1.94	2.80	2.40	0.01	11	73	73.4	-0.5
101	2.51	2.00	1.38	1.78	2.69	1.23	0.02	11	71.5	72.3	-1.1
102	2.67	2.17	1.51	1.75	2.68	1.17	0.02	11	71.6	72.7	-1.5
103	2.59	1.86	0.90	1.75	2.56	0.98	0.18	11	70.5	70.1	0.6
104	2.46	1.78	0.90	1.64	2.57	0.98	0.01	11	69.5	69.9	-0.6
105	2.70	2.12	1.38	1.98	2.84	0.01	7.67	9.8	73.5	73.3	0.2
106	2.61	1.96	1.45	1.78	2.86	0.02	7.13	9.8	73	72.9	0.1
107	2.55	1.86	1.38	1.86	2.68	0.11	7.67	9.8	74.3	72.0	3.1
108	2.58	1.94	1.20	1.92	2.77	0.02	6.81	9.8	73.8	72.3	2.1
109	2.57	2.05	1.51	1.86	2.77	0.01	8.88	9.8	74.9	73.1	2.5
110	2.50	2.06	1.51	1.88	2.66	0.04	9.67	9.8	75.9	74.6	1.7
111	2.49	1.96	1.38	1.72	2.73	0.04	4.54	9.8	72.1	72.5	-0.5
112	2.62	1.96	1.30	1.83	2.66	0.02	5.48	9.8	72.8	72.0	1.1
113	2.74	2.06	1.60	1.86	2.90	2.96	2.86	10.5	73.6	73.8	-0.3
114	2.89	2.12	1.81	1.81	2.93	3.17	2.43	10.5	74.5	74.3	0.3
115	2.89	2.06	1.20	1.81	3.04	3.10	2.50	10.5	74.9	73.0	2.6

S.No.	$Log_{10}(C)$	$Log_{10}(S)$	$Log_{10}(H.V.)$	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{eq} dB(A)	L_{eq} Pred. dB(A)	% Error
116	2.96	2.09	1.64	2.00	3.05	3.92	2.53	10.5	74.8	74.5	0.4
117	2.75	1.86	1.38	1.68	2.88	2.79	2.10	10.5	73.4	72.3	1.6
118	2.53	2.03	1.38	1.72	2.85	2.43	1.80	10.5	73.6	73.0	0.8
119	2.77	2.19	1.30	1.72	2.96	2.40	1.77	10.5	73.8	73.3	0.6
120	2.68	2.02	1.60	2.06	2.88	11.90	2.86	9	74.1	75.7	-2.1
121	2.74	1.90	1.60	2.03	2.94	6.55	3.10	9	75	74.9	0.2
122	2.60	2.15	1.51	2.19	2.97	9.61	2.50	9	73.9	76.3	-3.1
123	2.74	2.15	1.81	2.18	3.02	11.56	2.53	9	74.8	77.2	-3.1
124	2.81	2.27	1.90	2.00	2.93	1.51	6.97	9	74.8	75.7	-1.2
125	2.83	2.13	1.96	2.02	2.92	2.04	4.41	9	73.5	75.6	-2.8
126	2.74	2.12	1.64	2.13	2.81	2.10	6.60	9	72.1	74.7	-3.5
127	2.77	1.96	1.92	2.11	2.93	1.80	7.73	9	73	75.2	-2.9
128	2.47	1.88	1.78	1.92	2.72	2.79	15.29	10	71.6	73.3	-2.4
129	2.57	1.83	1.75	1.94	2.85	2.43	15.37	10	72.4	73.4	-1.4
130	2.77	1.94	1.64	2.02	2.90	2.40	9.61	10	70.4	72.4	-2.8
131	2.74	2.09	1.56	1.81	2.85	1.21	13.69	11	69.3	71.2	-2.7
132	2.57	1.75	1.72	1.75	2.63	1.77	15.92	11	71.2	71.4	-0.3
133	2.58	2.05	1.64	1.98	2.66	3.17	8.29	11	70.8	73.1	-3.1
134	2.55	2.03	1.51	1.68	2.67	2.10	5.95	11	70	72.2	-3.1
135	2.68	1.98	1.51	1.86	2.73	2.40	6.50	11	72	72.4	-0.6

APPENDIX-C- Multiple Regression output for L_{10}

S.No.	$Log_{10}(C)$	$Log_{10}(S)$	$Log_{10}(H.V.)$	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{10} dB(A)	L_{10} Pred. dB(A)	% Error
Fountain Chowk Roundabout											
1	3.30	2.62	1.92	2.38	3.16	3.84	8.64	13.5	79	78.3	0.9
2	3.22	2.66	1.98	2.11	3.34	3.69	7.62	13.5	78.8	77.5	1.7
3	3.17	2.51	2.18	2.33	3.25	3.50	8.29	13.5	76.4	78.5	-2.6
4	3.17	2.43	2.27	2.26	3.16	3.53	8.35	13.5	78.2	78.1	0.1
5	3.16	2.46	2.06	2.38	3.17	3.50	9.06	13.5	76.9	78.3	-1.8
6	3.06	2.60	2.08	2.38	3.13	3.10	8.35	13.5	75.6	78.4	-3.5
7	2.84	2.20	1.68	2.75	3.11	11.42	18.84	9.8	79.7	80.1	-0.5
8	2.92	2.05	1.64	2.75	3.20	9.80	16.97	9.8	78	80.1	-2.6
9	3.04	1.90	1.56	2.73	3.09	8.88	15.13	9.8	78.1	79.7	-2.0
10	2.92	2.16	1.56	2.76	3.16	9.80	15.29	9.8	78.6	80.1	-1.9
11	2.72	2.11	1.45	2.73	2.87	9.92	16.24	9.8	78.8	79.3	-0.6
12	2.73	2.33	1.30	2.73	2.86	9.55	14.21	9.8	79	79.3	-0.3
13	2.72	2.05	1.75	2.72	2.89	11.02	15.44	9.8	83.8	82.3	1.8
14	2.75	2.16	1.86	2.75	2.91	9.73	16.89	9.8	78.4	80.0	-1.9
15	2.96	2.16	1.51	2.32	3.28	2.59	13.47	8	79.3	78.5	1.0
16	3.02	2.32	1.68	2.35	3.37	2.10	12.67	8	79.5	79.1	0.5
17	2.90	2.37	1.81	2.38	3.19	2.43	14.29	8	81.6	79.1	3.1
18	3.02	2.78	2.23	2.59	3.15	2.37	12.67	8	82.7	80.8	2.3
19	3.07	2.43	2.25	2.69	3.02	1.80	15.13	8	83.2	80.8	3.0
20	3.02	2.38	2.33	2.64	3.13	2.37	19.62	10.7	79.5	80.1	-0.7
21	3.06	2.39	2.12	2.63	3.19	2.10	16.97	10.7	80.6	79.9	0.8
22	3.24	2.58	2.34	2.38	3.27	2.43	11.16	10.7	79.6	79.5	0.1
23	2.96	2.16	1.88	2.32	3.33	3.50	11.76	10.6	79.2	78.5	0.9
24	2.88	2.35	1.81	2.35	3.25	0.31	7.67	10.6	81.6	78.5	3.9
25	3.02	2.51	2.17	2.38	2.96	0.45	7.13	10.6	83	82.0	1.2
26	2.89	2.33	2.20	2.59	2.92	0.96	7.73	10.6	83.2	82.4	1.0
27	3.19	2.58	2.23	2.69	3.04	3.17	8.94	11.6	78.2	80.2	-2.5
28	3.29	2.43	2.26	2.64	3.13	3.53	8.35	11.6	80.2	80.1	0.1

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{10} dB(A)	L_{10} Pred. dB(A)	% Error
29	3.31	2.60	2.30	2.63	3.22	3.50	9.06	11.6	79.5	80.3	-1.0
30	3.12	2.56	2.17	2.38	3.01	3.10	8.35	11.6	79.7	78.7	1.2
31	2.77	1.81	1.08	2.28	3.01	3.17	6.00	12	80.1	78.9	1.5
32	2.55	2.05	1.08	2.13	2.89	2.72	9.86	12	81	79.0	2.5
33	3.17	2.59	1.86	2.82	3.23	2.43	9.12	10	80.2	80.9	-0.9
34	3.21	2.58	1.51	2.78	3.24	2.10	9.06	10	79.4	80.3	-1.1
35	3.23	2.59	1.68	2.67	3.40	1.77	9.67	10	78	80.3	-2.9
36	3.24	2.60	2.09	2.53	3.37	2.10	8.88	9	78.7	80.4	-2.1
37	3.29	2.63	1.92	2.71	3.25	2.79	7.13	9	79.5	80.9	-1.7
38	3.26	2.53	1.83	2.84	3.22	3.17	7.73	9	79.8	81.2	-1.8
39	3.06	1.81	1.20	2.18	2.94	3.53	8.35	12	78.8	76.0	3.7
Thikkari Chowk Roundabout											
40	3.11	2.23	2.23	2.67	3.18	1.72	9.67	9	83.2	80.6	3.2
41	3.13	2.25	2.32	2.70	3.24	2.79	10.50	9	82.7	81.0	2.1
42	3.02	2.33	2.39	2.67	3.20	3.17	9.73	9	81.7	81.0	0.9
43	2.96	2.41	2.15	2.69	3.20	2.10	9.55	9	82.3	80.7	1.9
44	3.07	2.48	2.18	2.70	3.18	3.92	8.35	9.5	81.4	80.8	0.7
45	3.08	2.43	2.29	2.75	3.21	3.50	7.13	9.5	80.7	81.2	-0.6
46	3.09	2.66	2.34	2.70	3.12	3.10	7.62	9.5	81.3	81.1	0.3
47	3.20	2.43	2.38	2.72	3.14	1.80	11.09	9.5	81	81.0	0.1
48	2.84	2.18	1.51	2.32	3.17	3.69	0.08	9	76.9	78.4	-1.9
49	3.00	2.30	1.68	2.38	3.16	3.92	0.12	9	76.9	79.0	-2.6
50	2.98	2.32	1.83	2.30	3.21	3.57	0.21	9	78.5	78.9	-0.5
51	3.12	2.18	1.68	2.25	3.11	3.46	0.12	9	77.7	78.2	-0.7
52	2.89	2.35	1.81	2.32	2.92	3.50	0.32	8	77.7	78.7	-1.3
53	2.98	2.20	1.75	2.13	3.06	3.92	0.05	8	77.6	78.0	-0.5
54	2.87	2.30	1.56	2.26	3.06	3.17	0.19	8	78	78.4	-0.5
55	2.96	2.45	1.20	2.32	3.11	3.13	0.05	8	80	78.3	2.1
56	3.02	2.49	2.32	2.69	3.26	7.67	11.56	9	81	81.3	-0.3
57	3.07	2.39	2.37	2.62	3.16	6.00	12.67	9	82.7	80.8	2.4

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{10} dB(A)	L_{10} Pred. dB(A)	% Error
58	2.99	2.32	2.33	2.64	3.17	7.13	10.50	9	79.9	80.8	-1.1
59	3.00	2.35	2.24	2.60	3.26	7.67	11.83	9	83.4	80.7	3.4
60	3.01	2.48	2.30	2.56	3.03	7.67	11.90	9.5	79.1	80.2	-1.4
61	3.00	2.72	2.39	2.67	3.07	8.35	11.76	9.5	80.4	81.0	-0.8
62	2.97	2.38	2.39	2.51	3.13	8.94	10.37	9.5	79.6	80.2	-0.8
63	2.95	2.35	2.26	2.51	3.04	7.73	8.88	9.5	80.6	79.9	0.8
64	3.25	2.60	2.05	2.81	3.43	3.69	9.67	9	79.4	81.7	-2.8
65	3.33	2.60	2.15	2.76	3.48	3.92	10.50	9	81.7	81.7	0.0
66	3.10	2.58	2.18	2.83	3.40	3.53	9.73	9	80.8	81.9	-1.3
67	3.21	2.54	2.23	2.81	3.36	11.83	0.05	9	81.8	82.2	-0.5
68	3.13	2.46	2.21	2.65	3.17	9.73	0.19	9	79.8	81.1	-1.6
69	3.18	2.60	2.19	2.78	3.25	6.00	0.05	9	80.1	81.7	-2.0
70	3.14	2.47	2.03	2.58	3.09	7.67	0.21	9	80.9	80.4	0.7
71	3.30	2.58	2.12	2.76	3.31	9.73	0.21	9	81.9	81.8	0.2
72	3.37	2.56	2.09	2.86	3.37	10.43	0.31	9	80.7	82.3	-1.9
73	2.96	2.26	1.56	1.90	3.18	10.43	3.17	10	77	76.7	0.4
74	3.24	2.23	1.51	2.02	3.13	10.30	2.40	10	78.7	77.1	2.1
75	2.99	2.32	1.72	2.35	3.21	11.09	1.77	10	79.4	78.9	0.6
76	3.05	2.47	2.38	2.55	3.13	10.43	3.13	9	81.4	80.8	0.8
77	3.06	2.41	2.20	2.46	3.21	9.61	2.43	9	82.8	80.2	3.2
78	2.98	2.33	2.46	2.60	3.17	9.55	2.76	9	82.5	81.0	1.8
79	2.96	2.41	1.83	2.28	3.01	7.13	2.10	9	82.4	81.1	1.6
80	2.92	2.32	1.81	2.30	3.08	8.94	3.53	9	80.9	78.8	2.7
Y.P.S. Chowk Roundabout											
81	2.72	2.23	0.60	1.88	2.89	1.51	15.29	10	74.6	74.4	0.2
82	2.69	2.16	1.20	1.64	2.90	2.04	15.37	10	74.4	74.2	0.3
83	2.62	1.98	0.90	1.51	2.87	2.10	9.61	10	73.3	73.1	0.2
84	2.81	1.94	1.20	1.81	2.96	1.80	13.69	10	73.6	74.8	-1.7
85	2.68	2.03	1.08	1.45	2.86	2.43	15.92	10	73.8	73.0	1.0
86	2.67	2.08	1.08	1.56	2.76	2.10	12.67	10	75.1	73.4	2.3

S.No.	$Log_{10}(C)$	$Log_{10}(S)$	$Log_{10}(H.V.)$	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{10} dB(A)	L_{10} Pred. dB(A)	% Error
87	2.64	2.09	1.08	1.56	2.77	2.43	14.21	10	74.1	73.4	0.9
88	2.64	2.13	1.20	1.68	2.71	2.40	11.09	10	73.4	74.1	-0.9
89	2.80	2.09	1.86	1.64	2.86	11.90	6.97	7	77.9	76.1	2.4
90	2.71	2.12	1.68	1.90	2.80	6.55	4.41	7	76.4	76.7	-0.4
91	2.64	2.03	1.64	1.92	2.94	9.61	6.60	7	76.6	77.0	-0.5
92	2.62	2.15	1.72	2.08	2.97	11.56	7.73	7	78.8	77.9	1.2
93	2.68	2.05	1.83	1.92	2.95	7.29	4.41	7	76.9	77.2	-0.4
94	2.68	2.13	1.56	2.00	2.95	8.41	6.10	7	76.2	77.2	-1.4
95	2.65	1.90	1.78	1.92	2.87	8.24	4.84	7	76.8	76.9	-0.2
96	2.72	1.98	1.64	2.08	2.85	9.49	5.43	7	77.6	77.5	0.1
97	2.60	1.94	1.64	1.75	2.81	1.77	0.01	11	75.4	74.9	0.7
98	2.64	2.03	1.51	1.56	2.76	3.17	0.01	11	74.8	73.9	1.2
99	2.66	1.92	1.60	1.83	2.74	2.10	0.01	11	75.7	75.1	0.8
100	2.59	1.94	1.60	1.94	2.80	2.40	0.01	11	76.3	75.7	0.9
101	2.51	2.00	1.38	1.78	2.69	1.23	0.02	11	74.8	74.5	0.4
102	2.67	2.17	1.51	1.75	2.68	1.17	0.02	11	74.3	74.6	-0.5
103	2.59	1.86	0.90	1.75	2.56	0.98	0.18	11	73.4	73.5	-0.1
104	2.46	1.78	0.90	1.64	2.57	0.98	0.01	11	73	73.0	0.0
105	2.70	2.12	1.38	1.98	2.84	0.01	7.67	9.8	75.2	75.8	-0.8
106	2.61	1.96	1.45	1.78	2.86	0.02	7.13	9.8	74.9	75.0	-0.1
107	2.55	1.86	1.38	1.86	2.68	0.11	7.67	9.8	74.6	74.8	-0.3
108	2.58	1.94	1.20	1.92	2.77	0.02	6.81	9.8	74.5	75.1	-0.8
109	2.57	2.05	1.51	1.86	2.77	0.01	8.88	9.8	75.7	75.2	0.6
110	2.50	2.06	1.51	1.88	2.66	0.04	9.67	9.8	74.2	75.2	-1.3
111	2.49	1.96	1.38	1.72	2.73	0.04	4.54	9.8	73.8	74.4	-0.8
112	2.62	1.96	1.30	1.83	2.66	0.02	5.48	9.8	74.8	74.7	0.1
113	2.74	2.06	1.60	1.86	2.90	2.96	2.86	10.5	74.7	75.6	-1.2
114	2.89	2.12	1.81	1.81	2.93	3.17	2.43	10.5	76.4	75.8	0.8

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{10} dB(A)	L_{10} Pred. dB(A)	% Error
115	2.89	2.06	1.20	1.81	3.04	3.10	2.50	10.5	75.7	75.2	0.7
116	2.96	2.09	1.64	2.00	3.05	3.92	2.53	10.5	76	76.6	-0.8
117	2.75	1.86	1.38	1.68	2.88	2.79	2.10	10.5	73.8	74.4	-0.9
118	2.53	2.03	1.38	1.72	2.85	2.43	1.80	10.5	74.4	74.6	-0.3
119	2.77	2.19	1.30	1.72	2.96	2.40	1.77	10.5	75	74.8	0.2
120	2.68	2.02	1.60	2.06	2.88	11.90	2.86	9	77.4	77.1	0.4
121	2.74	1.90	1.60	2.03	2.94	6.55	3.10	9	77.1	76.8	0.4
122	2.60	2.15	1.51	2.19	2.97	9.61	2.50	9	75.4	77.6	-2.9
123	2.74	2.15	1.81	2.18	3.02	11.56	2.53	9	75.5	78.1	-3.4
124	2.81	2.27	1.90	2.00	2.93	1.51	6.97	9	76.3	77.0	-0.9
125	2.83	2.13	1.96	2.02	2.92	2.04	4.41	9	76.1	77.1	-1.3
126	2.74	2.12	1.64	2.13	2.81	2.10	6.60	9	74.8	77.0	-2.9
127	2.77	1.96	1.92	2.11	2.93	1.80	7.73	9	75.5	77.3	-2.3
128	2.47	1.88	1.78	1.92	2.72	2.79	15.29	10	73.3	75.6	-3.0
129	2.57	1.83	1.75	1.94	2.85	2.43	15.37	10	73.8	75.8	-2.7
130	2.77	1.94	1.64	2.02	2.90	2.40	9.61	10	72.7	74.0	-1.8
131	2.74	2.09	1.56	1.81	2.85	1.21	13.69	11	72	73.4	-1.9
132	2.57	1.75	1.72	1.75	2.63	1.77	15.92	11	74.1	74.3	-0.3
133	2.58	2.05	1.64	1.98	2.66	3.17	8.29	11	74.3	75.6	-1.7
134	2.55	2.03	1.51	1.68	2.67	2.10	5.95	11	72.5	74.2	-2.2
135	2.68	1.98	1.51	1.86	2.73	2.40	6.50	11	75	75.0	0.0

APPENDIX-D -Multiple Regression output for L_{50}

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{50} dB(A)	L_{50} Pred. dB(A)	% Error
Fountain Chowk Roundabout											
1	3.30	2.62	1.92	2.38	3.16	3.10	2.50	13.5	73	72.9	0.1
2	3.22	2.66	1.98	2.11	3.34	3.92	2.53	13.5	72.8	72.0	1.1
3	3.17	2.51	2.18	2.33	3.25	2.79	2.10	13.5	71.8	72.8	-1.4
4	3.17	2.43	2.27	2.26	3.16	2.43	1.80	13.5	71.9	72.4	-0.7
5	3.16	2.46	2.06	2.38	3.17	2.40	1.77	13.5	71.7	72.7	-1.4
6	3.06	2.60	2.08	2.38	3.13	11.90	2.86	13.5	71	72.7	-2.3
7	2.84	2.20	1.68	2.75	3.11	6.55	3.10	9.8	72.3	73.7	-1.9
8	2.92	2.05	1.64	2.75	3.20	9.61	2.50	9.8	72.1	73.7	-2.1
9	3.04	1.90	1.56	2.73	3.09	11.56	2.53	9.8	72.2	73.3	-1.5
10	2.92	2.16	1.56	2.76	3.16	1.51	6.97	9.8	72.5	73.6	-1.6
11	2.72	2.11	1.45	2.73	2.87	2.04	4.41	9.8	73.1	72.7	0.5
12	2.73	2.33	1.30	2.73	2.86	2.10	6.60	9.8	73.3	72.8	0.7
13	2.72	2.05	1.75	2.72	2.89	1.80	7.73	9.8	76.5	75.4	1.5
14	2.75	2.16	1.86	2.75	2.91	2.79	15.29	9.8	72.3	73.3	-1.4
15	2.96	2.16	1.51	2.32	3.28	2.43	15.37	8	74.2	72.0	3.0
16	3.02	2.32	1.68	2.35	3.37	2.40	9.61	8	74	72.6	1.9
17	2.90	2.37	1.81	2.38	3.19	1.21	13.69	8	75.3	74.3	1.3
18	3.02	2.78	2.23	2.59	3.15	1.77	15.92	8	76.7	74.1	3.5
19	3.07	2.43	2.25	2.69	3.02	3.17	8.29	8	77.7	75.9	2.4
20	3.02	2.38	2.33	2.64	3.13	2.10	5.95	10.7	73.6	74.0	-0.5
21	3.06	2.39	2.12	2.63	3.19	2.40	6.50	10.7	73.8	73.9	-0.1
22	3.24	2.58	2.34	2.38	3.27	3.10	2.50	10.7	73.7	73.5	0.3
23	2.96	2.16	1.88	2.32	3.33	3.92	2.53	10.6	74	72.3	2.4
24	2.88	2.35	1.81	2.35	3.25	2.79	2.10	10.6	75.3	74.7	0.8
25	3.02	2.51	2.17	2.38	2.96	2.43	1.80	10.6	76.7	75.3	1.9
26	2.89	2.33	2.20	2.59	2.92	2.40	1.77	10.6	76.8	75.7	1.5
27	3.19	2.58	2.23	2.69	3.04	11.90	2.86	11.6	72.6	74.2	-2.1
28	3.29	2.43	2.26	2.64	3.13	6.55	3.10	11.6	73.2	74.1	-1.2

S.No.	$Log_{10}(C)$	$Log_{10}(S)$	$Log_{10}(H.V.)$	$Log_{10}(T)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{50} dB(A)	L_{50} Pred. dB(A)	% Error
29	3.31	2.60	2.30	2.63	3.22	3.50	9.06	11.6	73.9	74.4	-0.7
30	3.12	2.56	2.17	2.38	3.01	3.10	8.35	11.6	73.7	72.7	1.4
31	2.77	1.81	1.08	2.28	3.01	3.17	6.00	12	73.9	72.2	2.4
32	2.55	2.05	1.08	2.13	2.89	2.72	9.86	12	73.9	72.5	1.9
33	3.17	2.59	1.86	2.82	3.23	2.43	9.12	10	72.8	74.7	-2.6
34	3.21	2.58	1.51	2.78	3.24	2.10	9.06	10	72.6	74.3	-2.3
35	3.23	2.59	1.68	2.67	3.40	1.77	9.67	10	71.7	74.2	-3.4
36	3.24	2.60	2.09	2.53	3.37	2.10	8.88	9	72.1	74.1	-2.6
37	3.29	2.63	1.92	2.71	3.25	2.79	7.13	9	74.4	74.5	-0.2
38	3.26	2.53	1.83	2.84	3.22	3.17	7.73	9	74.9	74.8	0.1
39	3.06	1.81	1.20	2.18	2.94	3.53	8.35	12	72.9	70.3	3.7
Thikkari Chowk Roundabout											
40	3.11	2.23	2.23	2.67	3.18	1.72	9.67	9	73.5	74.0	-0.7
41	3.13	2.25	2.32	2.70	3.24	2.79	10.50	9	74.3	74.4	-0.1
42	3.02	2.33	2.39	2.67	3.20	3.17	9.73	9	75.1	74.2	1.2
43	2.96	2.41	2.15	2.69	3.20	2.10	9.55	9	74.1	74.0	0.1
44	3.07	2.48	2.18	2.70	3.18	3.92	8.35	9.5	74.9	74.2	0.9
45	3.08	2.43	2.29	2.75	3.21	3.50	7.13	9.5	75.4	74.5	1.2
46	3.09	2.66	2.34	2.70	3.12	3.10	7.62	9.5	76.2	74.5	2.3
47	3.20	2.43	2.38	2.72	3.14	1.80	11.09	9.5	74.9	74.5	0.5
48	2.84	2.18	1.51	2.32	3.17	3.69	0.08	9	71.3	71.5	-0.3
49	3.00	2.30	1.68	2.38	3.16	3.92	0.12	9	71.6	72.2	-0.8
50	2.98	2.32	1.83	2.30	3.21	3.57	0.21	9	72	72.1	-0.1
51	3.12	2.18	1.68	2.25	3.11	3.46	0.12	9	72.1	71.6	0.7
52	2.89	2.35	1.81	2.32	2.92	3.50	0.32	8	70.6	71.6	-1.5
53	2.98	2.20	1.75	2.13	3.06	3.92	0.05	8	71.2	71.0	0.2
54	2.87	2.30	1.56	2.26	3.06	3.17	0.19	8	71.8	71.3	0.6
55	2.96	2.45	1.20	2.32	3.11	3.13	0.05	8	73	71.6	2.0
56	3.02	2.49	2.32	2.69	3.26	7.67	11.56	9	75	74.5	0.7
57	3.07	2.39	2.37	2.62	3.16	6.00	12.67	9	75.8	74.1	2.3

S.No.	$Log_{10}(C)$	$Log_{10}(S)$	$Log_{10}(H.V.)$	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{50} dB(A)	L_{50} Pred. dB(A)	% Error
58	2.99	2.32	2.33	2.64	3.17	7.13	10.50	9	74.2	74.0	0.3
59	3.00	2.35	2.24	2.60	3.26	7.67	11.83	9	75.9	73.9	2.7
60	3.01	2.48	2.30	2.56	3.03	7.67	11.90	9.5	72.1	73.6	-2.0
61	3.00	2.72	2.39	2.67	3.07	8.35	11.76	9.5	72.6	74.3	-2.3
62	2.97	2.38	2.39	2.51	3.13	8.94	10.37	9.5	73.1	73.4	-0.5
63	2.95	2.35	2.26	2.51	3.04	7.73	8.88	9.5	73.7	73.1	0.8
64	3.25	2.60	2.05	2.81	3.43	3.69	9.67	9	71.9	75.3	-4.5
65	3.33	2.60	2.15	2.76	3.48	3.92	10.50	9	74	75.4	-1.8
66	3.10	2.58	2.18	2.83	3.40	3.53	9.73	9	72.8	75.3	-3.3
67	3.21	2.54	2.23	2.81	3.36	11.83	0.05	9	74.9	75.2	-0.3
68	3.13	2.46	2.21	2.65	3.17	9.73	0.19	9	73.2	74.1	-1.2
69	3.18	2.60	2.19	2.78	3.25	6.00	0.05	9	74.3	74.8	-0.7
70	3.14	2.47	2.03	2.58	3.09	7.67	0.21	9	72.7	73.5	-1.1
71	3.30	2.58	2.12	2.76	3.31	9.73	0.21	9	73.7	74.9	-1.7
72	3.37	2.56	2.09	2.86	3.37	10.43	0.31	9	73	75.5	-3.3
73	2.96	2.26	1.56	1.90	3.18	10.43	3.17	10	72	70.2	2.6
74	3.24	2.23	1.51	2.02	3.13	10.30	2.40	10	73.4	70.8	3.7
75	2.99	2.32	1.72	2.35	3.21	11.09	1.77	10	73.4	72.2	1.7
76	3.05	2.47	2.38	2.55	3.13	10.43	3.13	9	74.3	73.7	0.8
77	3.06	2.41	2.20	2.46	3.21	9.61	2.43	9	76	73.3	3.7
78	2.98	2.33	2.46	2.60	3.17	9.55	2.76	9	74.9	73.9	1.4
79	2.96	2.41	1.83	2.28	3.01	7.13	2.10	9	73.6	71.8	2.5
80	2.92	2.32	1.81	2.30	3.08	8.94	3.53	9	74.6	71.9	3.8
Y.P.S. Chowk Roundabout											
81	2.72	2.23	0.60	1.88	2.89	1.51	15.29	10	68.3	68.6	-0.5
82	2.69	2.16	1.20	1.64	2.90	2.04	15.37	10	67.8	68.1	-0.5
83	2.62	1.98	0.90	1.51	2.87	2.10	9.61	10	66.4	66.9	-0.8
84	2.81	1.94	1.20	1.81	2.96	1.80	13.69	10	67.9	68.8	-1.3
85	2.68	2.03	1.08	1.45	2.86	2.43	15.92	10	68.2	67.0	1.7
86	2.67	2.08	1.08	1.56	2.76	2.10	12.67	10	69	67.3	2.5

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{50} dB(A)	L_{50} Pred. dB(A)	% Error
87	2.64	2.09	1.08	1.56	2.77	2.43	14.21	10	67.7	67.3	0.5
88	2.64	2.13	1.20	1.68	2.71	2.40	11.09	10	67.6	67.8	-0.4
89	2.80	2.09	1.86	1.64	2.86	11.9	6.97	7	70.1	68.8	1.9
90	2.71	2.12	1.68	1.90	2.80	6.55	4.41	7	68.8	69.4	-0.9
91	2.64	2.03	1.64	1.92	2.94	9.61	6.60	7	69.5	69.6	-0.2
92	2.62	2.15	1.72	2.08	2.97	11.5	7.73	7	70.1	70.4	-0.5
93	2.68	2.05	1.83	1.92	2.95	7.29	4.41	7	69.5	69.8	-0.4
94	2.68	2.13	1.56	2.00	2.95	8.41	6.10	7	68.5	70.0	-2.1
95	2.65	1.90	1.78	1.92	2.87	8.24	4.84	7	68.7	69.5	-1.1
96	2.72	1.98	1.64	2.08	2.85	9.49	5.43	7	70.6	70.1	0.7
97	2.60	1.94	1.64	1.75	2.81	1.77	0.01	11	69.4	68.2	1.7
98	2.64	2.03	1.51	1.56	2.76	3.17	0.01	11	68.3	67.4	1.4
99	2.66	1.92	1.60	1.83	2.74	2.10	0.01	11	69.3	68.5	1.2
100	2.59	1.94	1.60	1.94	2.80	2.40	0.01	11	69.4	68.9	0.7
101	2.51	2.00	1.38	1.78	2.69	1.23	0.02	11	68.2	67.9	0.5
102	2.67	2.17	1.51	1.75	2.68	1.17	0.02	11	68.3	68.2	0.2
103	2.59	1.86	0.90	1.75	2.56	0.98	0.18	11	66.8	67.1	-0.5
104	2.46	1.78	0.90	1.64	2.57	0.98	0.01	11	66.5	66.5	0.0
105	2.70	2.12	1.38	1.98	2.84	0.01	7.67	9.8	68.8	69.4	-0.8
106	2.61	1.96	1.45	1.78	2.86	0.02	7.13	9.8	68.3	68.4	-0.2
107	2.55	1.86	1.38	1.86	2.68	0.11	7.67	9.8	67.4	68.3	-1.3
108	2.58	1.94	1.20	1.92	2.77	0.02	6.81	9.8	67.8	68.6	-1.2
109	2.57	2.05	1.51	1.86	2.77	0.01	8.88	9.8	68.1	68.7	-0.9
110	2.50	2.06	1.51	1.88	2.66	0.04	9.67	9.8	67.6	68.6	-1.4
111	2.49	1.96	1.38	1.72	2.73	0.04	4.54	9.8	66.2	67.7	-2.3
112	2.62	1.96	1.30	1.83	2.66	0.02	5.48	9.8	68.1	68.2	-0.2
113	2.74	2.06	1.60	1.86	2.90	2.96	2.86	10.5	68.8	69.1	-0.4
114	2.89	2.12	1.81	1.81	2.93	3.17	2.43	10.5	69.6	69.3	0.4

S.No.	$Log_{10}(C)$	$Log_{10}(S)$	$Log_{10}(H.V.)$	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{50} dB(A)	L_{50} Pred. dB(A)	% Error
115	2.89	2.06	1.20	1.81	3.04	3.10	2.50	10.5	68.9	68.9	0.0
116	2.96	2.09	1.64	2.00	3.05	3.92	2.53	10.5	68.3	70.2	-2.7
117	2.75	1.86	1.38	1.68	2.88	2.79	2.10	10.5	66.7	68.0	-1.9
118	2.53	2.03	1.38	1.72	2.85	2.43	1.80	10.5	67.4	68.0	-0.8
119	2.77	2.19	1.30	1.72	2.96	2.40	1.77	10.5	67.7	68.5	-1.1
120	2.68	2.02	1.60	2.06	2.88	11.9	2.86	9	69.5	70.0	-0.7
121	2.74	1.90	1.60	2.03	2.94	6.55	3.10	9	70.1	69.8	0.4
122	2.60	2.15	1.51	2.19	2.97	9.61	2.50	9	68.9	70.5	-2.3
123	2.74	2.15	1.81	2.18	3.02	11.5	2.53	9	68.2	71.0	-3.9
124	2.81	2.27	1.90	2.00	2.93	1.51	6.97	9	70.5	70.3	0.2
125	2.83	2.13	1.96	2.02	2.92	2.04	4.41	9	69.9	70.3	-0.6
126	2.74	2.12	1.64	2.13	2.81	2.10	6.60	9	67.9	70.3	-3.4
127	2.77	1.96	1.92	2.11	2.93	1.80	7.73	9	69.2	70.5	-1.8
128	2.47	1.88	1.78	1.92	2.72	2.79	15.29	10	67.4	69.0	-2.3
129	2.57	1.83	1.75	1.94	2.85	2.43	15.37	10	67.2	69.3	-3.0
130	2.77	1.94	1.64	2.02	2.90	2.40	9.61	10	66.7	67.3	-0.9
131	2.74	2.09	1.56	1.81	2.85	1.21	13.69	11	66.3	67.4	-1.6
132	2.57	1.75	1.72	1.75	2.63	1.77	15.92	11	68.5	68.1	0.7
133	2.58	2.05	1.64	1.98	2.66	3.17	8.29	11	68.1	69.1	-1.5
134	2.55	2.03	1.51	1.68	2.67	2.10	5.95	11	66.4	67.7	-2.0
135	2.68	1.98	1.51	1.86	2.73	2.40	6.50	11	68.2	68.6	-0.7

APPENDIX-E - Multiple Regression output for L_{90}

S. No.	$Log_{10}(C)$	$Log_{10}(S)$	$Log_{10}(H.V.)$	$Log_{10}(T)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{90} dB(A)	L_{90} Pred. dB(A)	% Error
Fountain Chowk Roundabout											
1	3.30	2.62	1.92	2.38	3.16	3.84	8.64	13.5	70.1	69.9	0.3
2	3.22	2.66	1.98	2.11	3.34	3.69	7.62	13.5	68.8	69.3	-0.8
3	3.17	2.51	2.18	2.33	3.25	3.50	8.29	13.5	69.5	69.6	-0.2
4	3.17	2.43	2.27	2.26	3.16	3.53	8.35	13.5	69.3	69.1	0.4
5	3.16	2.46	2.06	2.38	3.17	3.50	9.06	13.5	67.9	69.4	-2.2
6	3.06	2.60	2.08	2.38	3.13	3.10	8.35	13.5	68.7	69.1	-0.6
7	2.84	2.20	1.68	2.75	3.11	11.4	18.84	9.8	67.6	68.6	-1.5
8	2.92	2.05	1.64	2.75	3.20	9.80	16.97	9.8	67.6	68.9	-1.9
9	3.04	1.90	1.56	2.73	3.09	8.88	15.13	9.8	68	68.6	-0.8
10	2.92	2.16	1.56	2.76	3.16	9.80	15.29	9.8	68.1	68.8	-1.1
11	2.72	2.11	1.45	2.73	2.87	9.92	16.24	9.8	66.1	67.0	-1.4
12	2.73	2.33	1.30	2.73	2.86	9.55	14.21	9.8	68.8	67.1	2.4
13	2.72	2.05	1.75	2.72	2.89	11.0	15.44	9.8	67.8	67.2	0.9
14	2.75	2.16	1.86	2.75	2.91	9.73	16.89	9.8	66	67.7	-2.5
15	2.96	2.16	1.51	2.32	3.28	2.59	13.47	8	69.9	67.6	3.3
16	3.02	2.32	1.68	2.35	3.37	2.10	12.67	8	70.1	68.5	2.3
17	2.90	2.37	1.81	2.38	3.19	2.43	14.29	8	70.7	69.9	1.1
18	3.02	2.78	2.23	2.59	3.15	2.37	12.67	8	71.9	69.5	3.4
19	3.07	2.43	2.25	2.69	3.02	1.80	15.13	8	72.5	71.4	1.5
20	3.02	2.38	2.33	2.64	3.13	2.37	19.62	10.7	70	69.6	0.5
21	3.06	2.39	2.12	2.63	3.19	2.10	16.97	10.7	69.9	69.8	0.2
22	3.24	2.58	2.34	2.38	3.27	2.43	11.16	10.7	69.3	70.0	-1.0
23	2.96	2.16	1.88	2.32	3.33	3.50	11.76	10.6	69.5	68.3	1.7
24	2.88	2.35	1.81	2.35	3.25	0.31	7.67	10.6	70.8	69.0	2.5
25	3.02	2.51	2.17	2.38	2.96	0.45	7.13	10.6	72.1	71.7	0.6
26	2.89	2.33	2.20	2.59	2.92	0.96	7.73	10.6	72.1	71.2	1.2
27	3.19	2.58	2.23	2.69	3.04	3.17	8.94	11.6	69.7	70.1	-0.6

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	l	L_{90} dB(A)	L_{90} Pred. dB(A)	% Error
28	3.29	2.43	2.26	2.64	3.13	3.53	8.35	11.6	69.3	70.3	-1.5
29	3.31	2.60	2.30	2.63	3.22	3.50	9.06	11.6	70.5	70.9	-0.6
30	3.12	2.56	2.17	2.38	3.01	3.10	8.35	11.6	69.1	68.6	0.7
31	2.77	1.81	1.08	2.28	3.01	3.17	6.00	12	69.6	68.7	1.3
32	2.55	2.05	1.08	2.13	2.89	2.72	9.86	12	69.7	68.1	2.3
33	3.17	2.59	1.86	2.82	3.23	2.43	9.12	10	68.2	70.7	-3.7
34	3.21	2.58	1.51	2.78	3.24	2.10	9.06	10	68.2	70.5	-3.3
35	3.23	2.59	1.68	2.67	3.40	1.77	9.67	10	68	67.8	0.3
36	3.24	2.60	2.09	2.53	3.37	2.10	8.88	9	68.3	70.4	-3.1
37	3.29	2.63	1.92	2.71	3.25	2.79	7.13	9	72.1	70.7	2.0
38	3.26	2.53	1.83	2.84	3.22	3.17	7.73	9	72.3	70.8	2.1
39	3.06	1.81	1.20	2.18	2.94	3.53	8.35	12	68.8	67.0	2.6
Fountain Chowk Roundabout											
40	3.11	2.23	2.23	2.67	3.18	1.72	9.67	9	68.9	69.5	-0.9
41	3.13	2.25	2.32	2.70	3.24	2.79	10.50	9	69.6	70.0	-0.6
42	3.02	2.33	2.39	2.67	3.20	3.17	9.73	9	69.8	69.6	0.3
43	2.96	2.41	2.15	2.69	3.20	2.10	9.55	9	69.7	69.4	0.5
44	3.07	2.48	2.18	2.70	3.18	3.92	8.35	9.5	70.1	69.8	0.4
45	3.08	2.43	2.29	2.75	3.21	3.50	7.13	9.5	71.9	70.1	2.5
46	3.09	2.66	2.34	2.70	3.12	3.10	7.62	9.5	71.8	70.0	2.5
47	3.20	2.43	2.38	2.72	3.14	1.80	11.09	9.5	70.3	70.3	0.0
48	2.84	2.18	1.51	2.32	3.17	3.69	0.08	9	66.9	66.7	0.2
49	3.00	2.30	1.68	2.38	3.16	3.92	0.12	9	67.8	67.7	0.2
50	2.98	2.32	1.83	2.30	3.21	3.57	0.21	9	67.9	67.6	0.4
51	3.12	2.18	1.68	2.25	3.11	3.46	0.12	9	67.7	67.3	0.7
52	2.89	2.35	1.81	2.32	2.92	3.50	0.32	8	66.1	66.3	-0.3
53	2.98	2.20	1.75	2.13	3.06	3.92	0.05	8	66.3	66.2	0.2
54	2.87	2.30	1.56	2.26	3.06	3.17	0.19	8	67.3	66.3	1.5
55	2.96	2.45	1.20	2.32	3.11	3.13	0.05	8	67.8	66.9	1.3
56	3.02	2.49	2.32	2.69	3.26	7.67	11.56	9	70.3	70.0	0.5

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{90} dB(A)	L_{90} Pred. dB(A)	% Error
57	3.07	2.39	2.37	2.62	3.16	6.00	12.67	9	71.1	69.5	2.3
58	2.99	2.32	2.33	2.64	3.17	7.13	10.50	9	70	69.2	1.2
59	3.00	2.35	2.24	2.60	3.26	7.67	11.83	9	71	69.4	2.3
60	3.01	2.48	2.30	2.56	3.03	7.67	11.90	9.5	66.4	68.7	-3.5
61	3.00	2.72	2.39	2.67	3.07	8.35	11.76	9.5	67.6	69.5	-2.9
62	2.97	2.38	2.39	2.51	3.13	8.94	10.37	9.5	68.2	68.7	-0.7
63	2.95	2.35	2.26	2.51	3.04	7.73	8.88	9.5	68.8	68.2	0.9
64	3.25	2.60	2.05	2.81	3.43	3.69	9.67	9	67	71.6	-6.9
65	3.33	2.60	2.15	2.76	3.48	3.92	10.50	9	69.6	71.9	-3.4
66	3.10	2.58	2.18	2.83	3.40	3.53	9.73	9	68.3	69.0	-1.0
67	3.21	2.54	2.23	2.81	3.36	11.83	0.05	9	69.8	71.0	-1.7
68	3.13	2.46	2.21	2.65	3.17	9.73	0.19	9	67.6	69.5	-2.8
69	3.18	2.60	2.19	2.78	3.25	6.00	0.05	9	69.5	70.6	-1.6
70	3.14	2.47	2.03	2.58	3.09	7.67	0.21	9	67.9	68.9	-1.5
71	3.30	2.58	2.12	2.76	3.31	9.73	0.21	9	68.9	71.0	-3.0
72	3.37	2.56	2.09	2.86	3.37	10.43	0.31	9	69	69.5	-0.7
73	2.96	2.26	1.56	1.90	3.18	10.43	3.17	10	67.3	66.0	2.0
74	3.24	2.23	1.51	2.02	3.13	10.30	2.40	10	70.7	69.8	1.3
75	2.99	2.32	1.72	2.35	3.21	11.09	1.77	10	70.9	69.7	1.7
76	3.05	2.47	2.38	2.55	3.13	10.43	3.13	9	69.9	68.9	1.4
77	3.06	2.41	2.20	2.46	3.21	9.61	2.43	9	71.4	68.8	3.7
78	2.98	2.33	2.46	2.60	3.17	9.55	2.76	9	69.8	69.0	1.2
79	2.96	2.41	1.83	2.28	3.01	7.13	2.10	9	69.2	66.9	3.3
80	2.92	2.32	1.81	2.30	3.08	8.94	3.53	9	71.1	70.8	0.4
Y.P.S. Chowk Roundabout											
81	2.72	2.23	0.60	1.88	2.89	1.51	15.29	10	63.4	63.8	-0.6
82	2.69	2.16	1.20	1.64	2.90	2.04	15.37	10	63.3	63.2	0.1
83	2.62	1.98	0.90	1.51	2.87	2.10	9.61	10	61.6	61.9	-0.5
84	2.81	1.94	1.20	1.81	2.96	1.80	13.69	10	62.8	64.1	-2.0
85	2.68	2.03	1.08	1.45	2.86	2.43	15.92	10	63.3	62.1	1.8

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	$Log_{10}(T_1)$	$Log_{10}(T_2)$	a^2	d^2	*l*	L_{90} dB(A)	L_{90} Pred. dB(A)	% Error
86	2.67	2.08	1.08	1.56	2.76	2.10	12.67	10	63.7	62.2	2.4
87	2.64	2.09	1.08	1.56	2.77	2.43	14.21	10	62.5	62.2	0.6
88	2.64	2.13	1.20	1.68	2.71	2.40	11.09	10	62.6	62.4	0.2
89	2.80	2.09	1.86	1.64	2.86	11.90	6.97	7	63.6	63.1	0.7
90	2.71	2.12	1.68	1.90	2.80	6.55	4.41	7	63	63.5	-0.7
91	2.64	2.03	1.64	1.92	2.94	9.61	6.60	7	63.4	63.7	-0.5
92	2.62	2.15	1.72	2.08	2.97	11.56	7.73	7	63.7	64.5	-1.2
93	2.68	2.05	1.83	1.92	2.95	7.29	4.41	7	64.1	64.0	0.2
94	2.68	2.13	1.56	2.00	2.95	8.41	6.10	7	62.2	64.2	-3.2
95	2.65	1.90	1.78	1.92	2.87	8.24	4.84	7	62.4	63.4	-1.7
96	2.72	1.98	1.64	2.08	2.85	9.49	5.43	7	64.6	64.1	0.7
97	2.60	1.94	1.64	1.75	2.81	1.77	0.01	11	64.7	62.9	2.8
98	2.64	2.03	1.51	1.56	2.76	3.17	0.01	11	62.5	62.2	0.5
99	2.66	1.92	1.60	1.83	2.74	2.10	0.01	11	63.4	63.0	0.6
100	2.59	1.94	1.60	1.94	2.80	2.40	0.01	11	63	63.5	-0.7
101	2.51	2.00	1.38	1.78	2.69	1.23	0.02	11	61.1	62.2	-1.8
102	2.67	2.17	1.51	1.75	2.68	1.17	0.02	11	62.8	62.8	0.0
103	2.59	1.86	0.90	1.75	2.56	0.98	0.18	11	60.7	61.4	-1.2
104	2.46	1.78	0.90	1.64	2.57	0.98	0.01	11	59.9	60.6	-1.1
105	2.70	2.12	1.38	1.98	2.84	0.01	7.67	9.8	63.1	64.1	-1.6
106	2.61	1.96	1.45	1.78	2.86	0.02	7.13	9.8	62.1	63.1	-1.6
107	2.55	1.86	1.38	1.86	2.68	0.11	7.67	9.8	61.5	62.4	-1.5
108	2.58	1.94	1.20	1.92	2.77	0.02	6.81	9.8	61.5	63.0	-2.4
109	2.57	2.05	1.51	1.86	2.77	0.01	8.88	9.8	62.2	63.1	-1.4
110	2.50	2.06	1.51	1.88	2.66	0.04	9.67	9.8	61.4	62.6	-2.0
111	2.49	1.96	1.38	1.72	2.73	0.04	4.54	9.8	60.1	61.9	-3.1
112	2.62	1.96	1.30	1.83	2.66	0.02	5.48	9.8	61.8	62.5	-1.1
113	2.74	2.06	1.60	1.86	2.90	2.96	2.86	10.5	63.7	64.1	-0.6
114	2.89	2.12	1.81	1.81	2.93	3.17	2.43	10.5	64.7	64.6	0.1

S.No.	Log_{10}(C)	Log_{10}(S)	Log_{10}(H.V.)	Log_{10}(T_1)	Log_{10}(T_2)	a^2	d^2	*l*	L_{90} dB(A)	L_{90} Pred. dB(A)	% Error
115	2.89	2.06	1.20	1.81	3.04	3.10	2.50	10.5	64	64.6	-0.9
116	2.96	2.09	1.64	2.00	3.05	3.92	2.53	10.5	63.3	64.7	-2.2
117	2.75	1.86	1.38	1.68	2.88	2.79	2.10	10.5	61.3	63.0	-2.8
118	2.53	2.03	1.38	1.72	2.85	2.43	1.80	10.5	61.9	62.6	-1.1
119	2.77	2.19	1.30	1.72	2.96	2.40	1.77	10.5	62.6	63.8	-1.9
120	2.68	2.02	1.60	2.06	2.88	11.90	2.86	9	64.3	64.3	0.1
121	2.74	1.90	1.60	2.03	2.94	6.55	3.10	9	65.1	64.4	1.1
122	2.60	2.15	1.51	2.19	2.97	9.61	2.50	9	64.7	64.8	-0.2
123	2.74	2.15	1.81	2.18	3.02	11.56	2.53	9	63.8	65.6	-2.8
124	2.81	2.27	1.90	2.00	2.93	1.51	6.97	9	66.7	65.2	2.2
125	2.83	2.13	1.96	2.02	2.92	2.04	4.41	9	65.8	65.1	1.0
126	2.74	2.12	1.64	2.13	2.81	2.10	6.60	9	64.1	64.7	-1.0
127	2.77	1.96	1.92	2.11	2.93	1.80	7.73	9	64.8	65.2	-0.6
128	2.47	1.88	1.78	1.92	2.72	2.79	15.29	10	63	63.0	0.0
129	2.57	1.83	1.75	1.94	2.85	2.43	15.37	10	62.2	63.7	-2.4
130	2.77	1.94	1.64	2.02	2.90	2.40	9.61	10	62.4	64.7	-3.7
131	2.74	2.09	1.56	1.81	2.85	1.21	13.69	11	62	64.0	-3.3
132	2.57	1.75	1.72	1.75	2.63	1.77	15.92	11	61.8	62.3	-0.8
133	2.58	2.05	1.64	1.98	2.66	3.17	8.29	11	62	63.4	-2.2
134	2.55	2.03	1.51	1.68	2.67	2.10	5.95	11	60.8	62.1	-2.2
135	2.68	1.98	1.51	1.86	2.73	2.40	6.50	11	62.8	63.3	-0.8

APPENDIX- F

DATA SAMPLES FOR T-TEST FOR EACH DESCRIPTOR

Measured L_{eq} dB(A)	Predicted L_{eq} dB(A)
80.5	77.9
81.4	78.5
80.4	79.0
79.5	78.7
78.2	78.8
78.6	79.1
78.9	79.4
78.6	78.4
73.7	76.4
74.3	77.0
77.3	77.5
75.5	76.0
78	77.1
74.6	76.6
75.9	76.7
77.4	76.5
79.4	80.0
81.2	79.0
79.7	79.1
82.5	79.2
76.3	78.6
80.5	79.9
78.4	79.0
78.5	78.3
76.9	79.7

Measured L_{10} dB(A)	Predicted L_{10} dB(A)
83.2	80.6
82.7	81.3
81.7	81.0
82.3	80.7
81.4	80.8
80.7	81.2
81.3	81.1
81	81.0
76.9	78.4
76.9	79.0
78.5	78.9
77.7	78.2
77.7	78.7
77.6	78.0
78	78.4
80	78.3
81	81.3
82.7	80.8
79.9	80.8
83.4	80.7
79.1	80.1
80.4	81.0
79.6	80.2
80.6	79.9
79.4	81.7

Measured L_{50} dB(A)	Predicted L_{50} dB(A)
73.5	74.1
74.3	74.5
75.1	74.3
74.1	74.2
74.9	74.3
75.4	74.6
76.2	74.5
74.9	74.6
71.3	71.8
71.6	72.3
72	72.2
72.1	71.7
70.6	71.7
71.2	71.3
71.8	71.5
73	71.9
75	74.5
75.8	74.1
74.2	73.9
75.9	73.9
72.1	73.5
72.6	74.2
73.1	73.3
73.7	73.1
71.9	75.3

Measured L_{90} dB(A)	Predicted L_{90} dB(A)
68.9	69.5
69.6	70.0
69.8	69.6
69.7	69.4
70.1	69.8
71.9	70.1
71.8	70.0
70.3	70.3
66.9	66.7
67.8	67.7
67.9	67.6
67.7	67.3
66.1	66.3
66.3	66.2
67.3	66.3
67.8	66.9
70.3	70.0
71.1	69.5
70	69.2
71	69.4
66.4	68.7
67.6	69.5
68.2	68.7
68.8	68.2
67	71.6

APPENDIX-G

DATA FOR DIFFERENT SOUND DESCRIPTOR S.L. FOR 1/1 OCTAVE BAND

			Frequency (Hz.)									
			31.5	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**16k**
Day 1	L10 (dB)	Avg.	38.1	50.8	60.4	63.2	67.9	68.8	70.0	67.8	54.2	38.6
		Max.	44.1	60.3	72.1	75.5	85.5	96.0	93.2	96.4	78.7	63.5
		Min.	34.7	45.6	54.8	55.8	57.8	57.5	57.0	52.2	40.5	21.6
	L90 (dB)	Avg.	34.9	47.6	57.2	59.9	62.6	64.1	64.3	60.2	48.4	31.8
		Max.	41.0	55.4	67.0	69.4	76.0	76.5	80.9	79.1	67.4	51.3
		Min.	29.8	40.7	50.1	53.1	55.9	54.0	54.5	49.7	36.6	19.5
	L50 (dB)	Avg.	36.9	49.4	59.1	61.7	65.0	66.0	66.8	63.6	50.9	35.0
		Max.	42.9	58.3	71.0	73.3	81.7	85.5	86.5	92.3	76.2	58.6
		Min.	33.2	45.0	52.4	54.9	56.9	56.0	56.5	51.2	38.1	20.4
	Leq (dB)	Avg.	37.0	49.6	59.2	61.9	65.6	66.7	67.7	64.9	51.8	36.1
		Max.	42.9	57.9	70.6	72.5	81.0	87.3	85.8	91.6	74.9	58.9
		Min.	33.7	44.8	53.2	55.2	57.0	57.3	56.5	51.1	39.7	20.5
Day 2	L10 (dB)	Avg.	36.9	50.7	59.6	62.4	66.7	64.5	64.0	61.7	48.2	33.1
		Max.	44.9	57.7	70.6	73.3	94.1	96.5	94.7	94.3	77.2	59.4
		Min.	33.0	45.6	52.8	54.9	54.9	54.0	50.9	45.1	29.3	14.2
	L90 (dB)	Avg.	33.8	47.4	56.3	58.9	61.2	59.2	57.8	53.4	41.0	25.7
		Max.	42.7	55.4	66.6	67.6	82.2	78.5	77.9	81.7	60.6	49.7
		Min.	28.6	42.4	49.3	52.2	52.6	51.0	48.9	42.1	26.9	13.8
	L50 (dB)	Avg.	35.6	49.3	58.2	60.8	63.8	61.4	60.6	57.2	44.4	29.3
		Max.	44.4	56.7	68.6	70.7	90.8	89.0	83.5	91.3	67.4	57.8
		Min.	31.5	44.3	52.4	54.4	54.5	52.5	49.9	44.1	28.8	13.8
	Leq (dB)	Avg.	35.7	49.5	58.3	61.0	64.4	62.2	61.5	58.7	45.4	30.4
		Max.	44.1	56.6	68.6	69.7	91.1	91.3	86.9	90.6	69.4	56.7
		Min.	32.1	44.6	51.8	54.4	54.5	53.0	50.0	44.0	28.8	14.2
Day 3	L10 (dB)	Avg.	37.5	51.6	60.6	63.6	67.4	67.6	66.7	63.3	51.0	35.3
		Max.	42.4	62.2	75.3	77.3	84.6	90.5	89.1	89.3	76.7	56.2
		Min.	33.7	45.6	54.8	56.6	57.8	54.5	54.0	48.7	31.3	17.5
	L90 (dB)	Avg.	34.3	48.1	57.1	60.3	62.7	62.8	61.5	56.7	45.5	29.4
		Max.	40.3	58.3	72.1	73.3	74.5	76.0	76.9	77.1	65.0	47.2
		Min.	28.9	42.4	51.2	54.0	55.4	52.0	50.9	45.1	29.8	16.7
	L50 (dB)	Avg.	36.2	50.2	59.1	62.1	64.9	64.9	63.8	59.6	48.1	32.4
		Max.	41.2	61.3	74.5	75.5	76.9	82.5	80.4	85.2	68.4	52.1
		Min.	32.7	44.0	53.6	55.3	57.3	53.5	52.9	46.2	30.8	16.7
	Leq (dB)	Avg.	36.3	50.3	59.3	62.3	65.4	65.5	64.5	60.7	48.8	33.1
		Max.	41.4	60.9	74.4	75.0	76.9	85.1	80.3	84.6	69.8	52.7
		Min.	32.9	44.9	53.7	55.7	57.4	53.8	53.4	47.3	31.0	17.1

			Frequency (Hz.)									
			31.5	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**16k**
Day 4	L10 (dB)	Avg.	37.6	51.8	61.1	65.2	71.1	70.5	69.6	65.8	52.2	36.4
		Max.	44.6	66.1	77.3	79.5	87.9	92.5	97.2	94.3	82.6	62.3
		Min.	33.7	45.6	54.0	57.1	60.2	57.5	54.5	50.2	35.7	20.4
	L90 (dB)	Avg.	34.5	48.3	57.8	61.5	64.6	64.0	63.2	58.4	46.7	30.4
		Max.	42.9	63.9	74.9	72.9	78.8	80.0	80.9	80.7	68.9	50.1
		Min.	30.1	42.0	51.2	54.0	56.9	54.0	51.4	45.1	32.7	17.5
	L50 (dB)	Avg.	36.4	50.4	59.7	63.5	67.7	66.7	66.1	61.8	49.3	33.4
		Max.	44.1	64.8	76.5	77.7	81.2	87.0	85.5	84.2	73.8	55.0
		Min.	32.7	44.0	53.2	55.3	59.2	55.5	52.4	47.7	35.2	19.1
	Leq (dB)	Avg.	36.5	50.5	59.9	63.7	68.4	67.7	66.9	62.9	49.9	34.1
		Max.	43.9	65.2	75.9	77.1	81.3	86.2	89.8	87.5	75.2	55.1
		Min.	33.0	44.5	53.5	55.6	59.2	55.7	53.0	48.3	35.0	19.5

APPENDIX-H

CALCULTION FOR TRAFFIC VOLUME

Date………………..

Site…………………………….………..

Vehicle type	Tally Chart			
	Time…….			
Cars				
S.U.V.				
Heavy Vehicles(Bus, Truck, Tractor)				
Three wheelers				
Two wheelers(Motorcycle,Scooter)				

APPENDIX-I

Site:…………………………………………………….

Measurement period: 1hour.

Sound level meter Microphone:

Distance from center of the road (meter)…………………………..

Height of microphone from ground level (meter)……………………………..

Temperature:………^{0}C

S.No.	Time & Date	Sound Pressure Level dB(A)			
	Time…….	L_{eq}	L_{10}	L_{50}	L_{90}
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

APPENDIX-J

OBSERVATION/CALCULATION FOR ACCELERATION/DECELERATION AND MEASURING DISTANCE

Distance Travelled (meter)……..

$$a \ or \ d = \frac{2(s - (1000u.t/3600)}{t^2} \quad m/sec^2$$

S.No.	**Time (sec.)**		**Speed (km/hr)**				*a* (m/sec^2)	*d* (m/sec^2)	Distance '*l*' (mtr.)
	$T_{approach}$	$T_{leaving}$	$u_{approach}$	$v_{approach}$	$u_{leaving}$	$v_{leaving}$			
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									