

Thesis
On
**ANALYSIS AND VALIDATION OF TRAFFIC NOISE UNDER
DYNAMIC CONDITION NEAR ROUNDABOUT USING MADM
APPROACH**

Submitted in partial fulfilment of the requirements for the award of degree of

**MASTERS OF ENGINEERING
IN
PRODUCTION AND INDUSTRIAL ENGINEERING**

Submitted By

TAVINDER PAL SINGH

Roll No. 801182024

Under the Guidance of

Mr. DALJEET SINGH

Assistant Professor

Mechanical Engineering

Department

Thapar University, Patiala

Dr. V.P.AGRAWAL

Visiting Professor

Mechanical Engineering

Department

Thapar University, Patiala

Dr. S.P.NIGAM

Visiting Professor

Mechanical Engineering

Department

Thapar University, Patiala



**DEPARTMENT OF MECHANICAL ENGINEERING
THAPAR UNIVERSITY,
PATIALA-147004, PUNJAB.**

July, 2013

CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled "ANALYSIS AND VALIDATION OF TRAFFIC NOISE UNDER DYNAMIC CONDITION NEAR ROUNDABOUT USING MADM APPROACH" 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 **Mr. Daljeet Singh, Assistant Professor, Mechanical Engineering Department, , Dr. V.P.Agrawal, Visiting Professor, Mechanical Engineering Department and Dr. S.P. Nigam, Visiting Professor, Mechanical Engineering Department, Thapar university, Patiala.**

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

Dated: 15/12/2013



(Tavinder Pal Singh)

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



(Mr. DALJEET SINGH)

Assistant Professor
Mechanical Engineering
Department

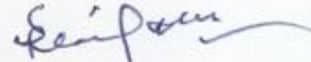
Thapar University, Patiala-147004



(Dr. V.P.AGRAWAL)

Visiting Professor
Mechanical Engineering
Department

Thapar University, Patiala-147004



(Dr. S.P.NIGAM)

Visiting Professor
Mechanical Engineering
Department

Thapar University, Patiala-147004

Countersigned By:



(Dr. AJAY BATISH)

Professor and Head
Mechanical Engineering Department
Thapar University, Patiala-147004



(Dr. S.K. MOHAPATRA)

Senior Professor
Dean of Academic Affairs
Thapar University, Patiala-147004

AKNOWLEDGEMENT

I express my deep sense of gratitude and a very sincere thanks to my guide, **Mr. Daljeet Singh**, Assistant Professor, Mechanical Engineering Department, Thapar University, Patiala, **Dr. V.P Agrawal**, Visiting Professor, Mechanical Engineering Department, Thapar University, Patiala, and **Dr. S.P Nigam**, Visiting Professor, Mechanical Engineering Department, Thapar University, Patiala for their indefatigable guidance and full support which helped me in the accomplishment of this research work. I am highly indebted to him for their painstaking efforts and cooperation all the time during the period of work.

I am highly thankful to **Mr. Tanuj Chopra**, Assistant Professor, Civil Engineering, Thapar University, Patiala for his invaluable suggestions and support.

I do not find enough words with which I can express my feeling of thanks to the head of department and entire faculty of **Mechanical Engineering Department, Thapar University**, for their help, inspiration and moral support, which went a long way in successful completion of my thesis.

I am also thankful to all my friends, who devoted their valuable time and helped me in all possible ways towards successful completion of my thesis work.

Last, but not least, I am highly indebted to my dear parents for their love, support and trust and most important, I thank god to giving me strength to overcome difficulty.

TAVINDER PAL SINGH

ABSTRACT

The problem of roundabout traffic noise measurement has been of concern to Traffic Management for many years. The measurement and prediction process has become more and more difficult due to the availability of large variety of traffic noise prediction models. The models proposed so far consider only physical parameters (Traffic Volume, Traffic Composition, Average Speed etc).

The aim of this work is to propose a methodology by which identification of traffic noise can be made easy. A cause and effect diagram is developed for the attributes identification, those are sufficient to describe the traffic noise. Attribute based coding of traffic noise has been done to convert the information into useful form. Information developed from the quantification of attributes is useful to the designer, traffic management and the user in traffic noise system. The identification and codification of attributes based on alpha numeric code is presented for roundabout traffic noise. The roundabout traffic noise measurement procedure allows rapid convergence from a very large number to controllable shortlist of potentially suitable attributes using “elimination search”. Subsequently, the identification procedure proceeds to evaluate them by a multiple attributes decision making (MADM) method using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach. It helps the user’s to organize the problem to be solved, and carrying out analysis, comparison and ranking of the roundabouts. Three critical roundabouts (Fountain roundabout, Thikri roundabout, and YPS roundabout) have been studied at Patiala city, Punjab, India. Equivalent sound level (L_{eq}) and traffic parameters (traffic volume, percentage of heavy vehicles, average speed, acceleration, and deceleration) have been measured. Noise environment have been compared, worst and best roundabout have been identified. The conclusion arrived from the hypothetical approach MADM has been validated through experimental investigation.

ABBREVIATIONS

Hz	Hertz
Pa	Pascal
SPL	Sound Pressure Level
dB	Decibel
Leq	Equivalent Continuous Sound Level
SEL	Sound Exposure Level
L10	10 percentile exceeded Sound Level
L90	90 percentile exceeded Sound Level
L50	Median value of Sound Level
TNI	Traffic Noise Index
MADM	Multi Attribute Decision Making
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
COS	Coefficient of similarity

TABLE OF CONTENTS

CERTIFICATE.....	i
ACKNOWLEDGEMENTS.....	ii
ABSTRACT.....	iii
ABBREVIATIONS.....	iv
TABLE OF CONTENTS.....	v
LIST OF FIGURES.....	viii
LIST OF TABLES.....	xii
1 INTRODUCTION	1
1.1 Introduction to Acoustics	1
1.1.1 Basics of Acoustics	1
1.1.2 Fundamentals of Acoustic.....	1
1.2 Introduction to Noise	6
1.2.1 Noise	6
1.2.2 A-Weighted SPL.....	8
1.2.3 Sound Sources.....	9
1.2.4 Noise Measurement Techniques and Instrument	9
2 VEHICULAR TRAFFIC NOISE	11
2.1 Introduction to Vehicular Traffic Noise.....	11
2.1.1 Highway Noise Descriptors	11
2.1.2 Vehicle Noise Characteristics	12
2.1.3 Vehicle Noise Sources	12
2.2 Effects of various factors on traffic noise	13
3 LITERATURE REVIEW	15
3.1 General Literature Review about Traffic Noise Models.....	15
3.1.1 Some early traffic noise models as formulated by different persons are discussed below .	15
3.1.2 FHWA highway traffic noise prediction model.....	16
3.1.3 RSL 90 (Richtlinien fuÈ r den LaÈ rmschutz an StraÙen).....	17
3.1.4 Stop and Go Model	17
3.1.5 ASJ1998 (Acoustical Society of Japan).....	18
3.2 Literature Review on Traffic Noise	19
3.3 Literature Review on System Approaches	28
3.4 Gap analysis.....	29
4 EXPERIMENTAL NOISE STUDY	31
4.1 Nature of noise.....	31

4.2	Site Selection	31
4.3	Measurement Procedure	33
4.4	Measurements	36
5	ATTRIBUTE KNOWLEDGE BASED METHODOLOGY	37
5.1	Methodology	37
5.1.1	Identification of Research papers.....	38
5.1.2	Grouping of research papers	39
5.1.3	Coding of research papers.....	39
5.2	Cause and effect analysis for attributes identifications.....	40
5.2.1	Identification of Attributes.....	41
5.2.2	Coding of attributes.....	43
5.3	Procedure to develop an Attribute Information Matrix.....	44
5.4	Advantages of the Attribute Information Matrix	46
5.5	Gap Analysis.....	46
5.5.1	Importance of gap analysis	46
5.6	Attribute Information Matrix	47
6	IDENTIFICATION, EVALUATION AND RANKING OF ROUNDABOUT TRAFFIC NOISE...	49
6.1	Methodology	49
6.2	Traffic Noise Attributes in Dynamic Condition Near Roundabout	50
6.2.1	Identification of roundabout attributes.....	50
6.2.2	Quantification and measurement of the attributes	52
6.3	Cause and Effect Analysis	52
6.4	Usefulness.....	53
6.5	Coding Scheme and Classification	54
6.6	Quantitative Attributes.....	54
6.7	Qualitative Attributes.....	56
6.8	Identification Procedure.....	61
6.8.1	Stage -1 Elimination Search Method	61
6.8.2	Stage-2 Evaluation Using TOPSIS Method.....	61
6.8.3	Stage-3 Ranking and Optimum Identification Procedure	63
6.9	Illustrative example of identification procedure	65
7	RESULTS AND DISCUSSION	74
8	CONCLUSION AND FUTURE SCOPE	76
	REFERENCE.....	78
	APPENDIX A.....	81
	APPENDIX B.....	86

LIST OF FIGURES

Figure 1.1 Sound waves propagate outwards as the source vibrates	2
Figure 1.2 Wavelength of a sound wave.....	3
Figure 1.3 Amplitude of sound waves	3
Figure 1.4 Equal loudness curves	4
Figure 1.5 Single frequency components and multi frequency components [28].....	4
Figure 1.6 Weighting Curves [16]	6
Figure 1.7 Sound level pressure.....	7
Figure 1.8 ‘A’ Weighted Curve [17].....	8
Figure 1.9 Sound level meter with windscreen.....	10
Figure 3.1 Three sound propagation paths in the build-up area.....	19
Figure 3.2 (i) $L_{Aeq,1 h}$ and $L_{A50,1 h}$ evolutions versus 24 h-descriptors and(ii) $L_{Aeq,24 h}$, $L_{A10,24 h}$, $L_{A50,24 h}$ and $L_{A90,24 h}$ versus $L_{Aeq,1 s}$ evolution	23
Figure 3.3 Comparison of predicted and observed noise levels at Moolchand BRTS corridor.....	27
Figure 3.4 Comparison of predicted and observed noise levels at Ambedkar Nagar BRTS corridor	27
Figure 3.5 (i) Comparison of different observed noise level towards Moolchand at BRTS corridor, (ii) Comparison of different observed noise level towards Ambedkar Nagar at BRTS corridor.....	27
Figure 4.1 Google map image of Fountain roundabout at Patiala city	31
Figure 4.2 Google map image of Thikri roundabout at Patiala city.....	32
Figure 4.3 Google map image of YPS roundabout at Patiala city.	32
Figure 4.4 Sound level meter on a tripod with windscreen.....	33
Figure 4.5 Line diagram of three roundabouts a) fountain roundabout b) Thikri roundabout c) YPS roundabout, with shown position where data obtained.....	35
Figure 4.6 Measurement site at YPS roundabout, Patiala City.....	35
Figure 5.1 Cause and effect analysis of research publication papers.....	41
Figure 6.1 Causes and effect analysis diagram of roundabout traffic noise.	53
Figure 6.2 Line Graph between attributes and weighted normalized values for i^{th} roundabout.....	64
Figure 6.3 Line graph of different roundabout.....	71
Figure 6.4 SWOT Analysis for the reducing of traffic noise under dynamic condition near roundabout...72	

LIST OF TABLES

Table 1.1 Comparison of 1-Octave Band And 1/3 Octave Band [30]	5
Table 3.1 Average and maximum noise levels from passenger cars, light lorries, and lorries in street	20
Table 3.2 LAeq estimation (in dB(A)) at the 5 points of experimentation through the three different calculations; in clear : error exceeds 1 dB(A); in dark grey: error exceeds 2 dB(A); in black: error exceeds 3 dB(A).	26
Table 4.1 Setting of SLM.....	36
Table 5.1 Coding Scheme for Research Papers	40
Table 5.2 List of Attributes Identified From Different Research Publications	42
Table 5.3 Coding scheme for attributes	44
Table 5.4 Attribute information matrix ‘m x n’	45
Table 5.5 Attributes information matrix for 12 papers and 10 attributes.....	47
Table 6.1 Lists of Attributes Identified From Different Research Publications	50
Table 6.2 Coding of Average Traffic Volume for Roundabout Traffic Noise.	54
Table 6.3 Coding Of Percentage Of Heavy Vehicle For Roundabout Traffic Noise.....	55
Table 6.4 Coding Of Acceleration and Deceleration of Vehicles for Roundabout Traffic Noise	55
Table 6.5 Coding Of Area Condition For Roundabout Traffic Noise.	56
Table 6.6 Coding Of In-Traffic Flow For Roundabout Traffic Noise.	56
Table 6.7 51-Digit Coding Scheme For Characterization of Roundabout Traffic Noise.	57
Table 6.8 Coding Scheme For Roundabout Traffic Noise.....	58
Table 6.9 Representation of Coding Scheme for Roundabout Traffic Noise.	60
Table 6.10 Alternative Roundabout Traffic Noise.....	65
Table 6.11 Minimum Requirements.	66
Table 6.12 Attributes for the Candidate Roundabout.	66
Table 6.13 Evaluation and Ranking Of Three Alternatives Roundabout.	70
Table 6.14 Ranking of Roundabout Based On the Area Under The Curve In Line Diagram.	71
Table 7.1 Evaluation and ranking of the roundabout traffic noise.....	75
Table A.1. Traffic noise data collected from three roundabouts in Patiala city, Punjab, India.....	81

1 INTRODUCTION

1.1 Introduction to Acoustics

1.1.1 Basics of Acoustics

Acoustics

Acoustics refers to the study of sound, namely, its production, transmission through solid and fluid media [13], whether it is created and received by human beings or by the use of machines and measuring instruments. An acoustic signal can arise from a number of sources, e.g., turbulence of air or any other gas, the passage of a body through a fluid, and the impact of a solid against another solid.

Applications of Acoustics

- Medical ultrasonic
- Underwater acoustics
- Architectural acoustics
- Active or passive noise control
- Environmental noise control and many more....[28]

1.1.2 Fundamentals of Acoustic

Basic Theory of Sound

The vibrations in machines and structures result in oscillatory motion that propagates in air and/or water and that is known as sound. Sound may be described as the passage of pressure fluctuations through an elastic medium as the result of a vibrational impetus imparted to that medium. Sound can be classified into two main categories according to whether that medium is strained beyond its elastic limit, as with shock waves, or not, which is the case with most regularly encountered sounds. The present concern is with pressure variations which do not approach the elastic limits.



Figure 1.1 Sound waves propagate outwards as the source vibrates [31]

It is a phenomenon incarnating the nature of waves, sound may contain only one frequency, as in the case of a pure steady-state sine wave (Figure 1.1), or many frequency components, as in the case of noise generated by construction machinery or a rocket engine. The purest type of sound wave [13] can be represented by a sine function (Figure 1.2) where the abscissa represents elapsed time and the ordinate represents the displacement of the molecules of the propagation medium or the deviation of pressure, density, or the aggregate speed of the disturbed molecules from the quiescent (undisturbed) state of the propagation medium.

The most common illustration example of propagation is that of ripples on a liquid surface which travel away from the source at a particular velocity of propagation. It should be noted that the particles of the medium do not move with the ripples, but only vibrate about their mean position- it is the energy which moves away from the source.

Wave Length

The distance travelled by the pressure wave during one complete period of the oscillation is known as the wavelength, and is obviously related to the velocity of propagation 'c' and the frequency 'f' by the relation [17]. This succession of outwardly moving rarefactions and compressions constitutes a wave motion. At a given point in the space, an alternating increase and decrease in pressure occur, with a corresponding decrease and increase in the density.

$$\lambda = \frac{c}{f}$$

Or

As the sound propagates through the air it creates pressure variations and the distance between succeeding pressure maxima is called the wavelength.

Sound waves radiated from a source, propagate through the surrounding medium at a constant speed. The speed of sound in air is $c = 340 \text{ m/s}$ (At the temperature of 20°C).

Example:

$$f = 20 \text{ Hz}$$

$$\lambda = \frac{340}{20} = 17 \text{ (m)}$$

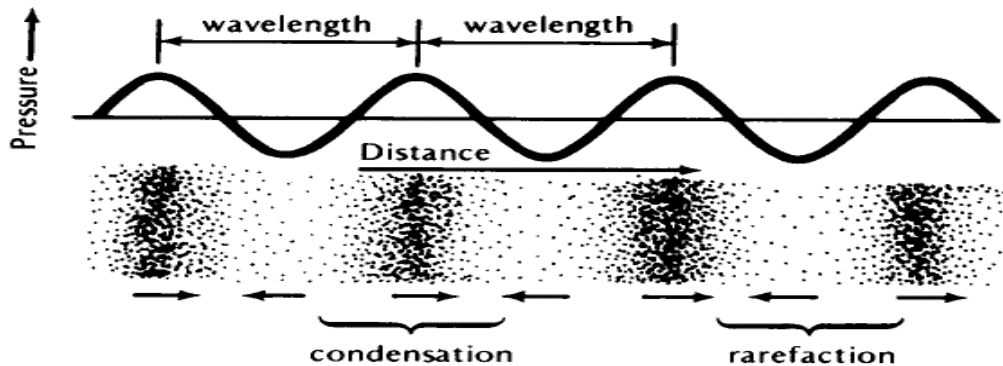


Figure 1.2 Wavelength of a sound wave [29]

Amplitude

Amplitude determines strength of wave [13]. Greater disturbances at the source lead to a greater strength during propagation shown in figure.1.3. The higher the pressure, the louder is the sound. The unit of amplitude is micropascal (μPa).

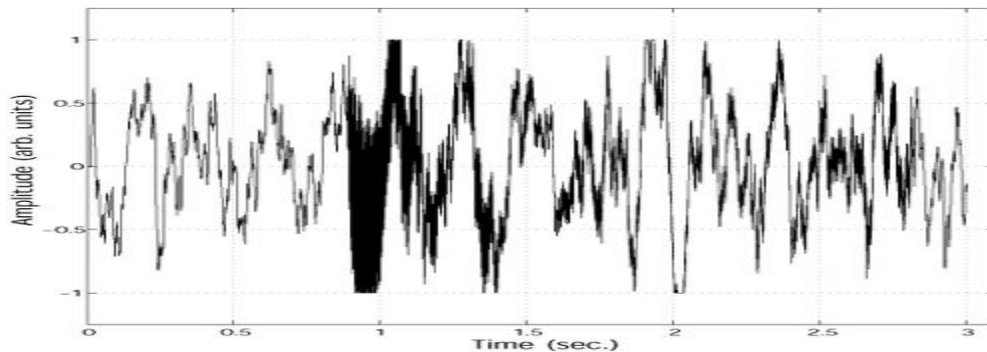


Figure 1.3 Amplitude of sound waves [29]

Frequency

The frequency is the number of pressure variation cycles in the medium per unit time, or simply, the number of cycles per second, and is expressed in Hertz (Hz). The frequency range of sound extends from frequencies much below 1 Hz to several hundred kHz [16]. Noise is usually composed of many frequencies combined together.

The sensitivity of the ear is not constant over the audible range. A set of equal loudness curves have been measured through psycho-acoustic tests, where it has been found that the ear has its highest sensitivity at 4 kHz. Figure.1.4 shows the internationally standardized equal loudness curves. The curve going through e.g. 80 dB at 1000 Hz is denoted the 80 phon curve.

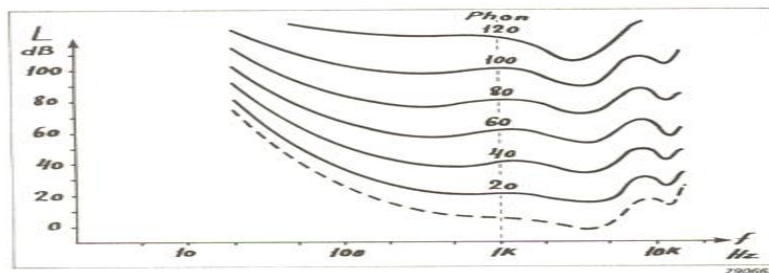


Figure 1.4 Equal loudness curves [16]

Frequency components of sound [16]

- **Single frequency component:** If a sound has components at one frequency only (Figure.1.5), it is said to be a pure tone. Such sounds are not very common in nature, however, and the only common example of a pure tone is the sound of a tuning fork.
- **Multi frequency component:** Sounds have components at several frequencies (Figure.1.5) and the character or timbre of a steady sound is determined by the pressure amplitudes at the different component frequencies.

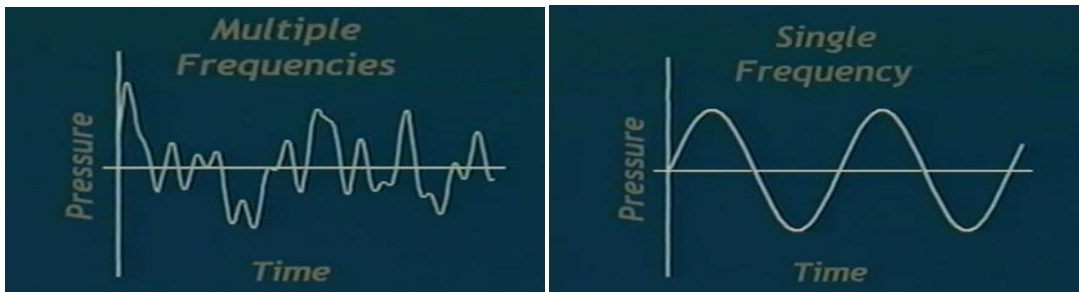


Figure 1.5 Single frequency components and multi frequency components [28]

Because most sound is complex, fluctuating in amplitude and frequency content, the relationships between sound energy level and frequency are required for meaningful analysis. Sound in the *audio* frequency range of approximately 20 Hz–20 kHz can be heard by humans. Although it is possible to analyze a source on a frequency by frequency basis, this is both impractical and time-consuming. For this reason, a scale of *octave bands* and *one-third octave*

bands has been developed [16]. Each band covers a specific range of frequencies and excludes all others as shown in as Table.1.1.

Table 1.1 Comparison of 1-Octave Band And 1/3 Octave Band [30]

1 OCTAVE			1/3 OCTAVE			
<i>Lower cutoff frequency (Hz)</i>	<i>Center frequency (Hz)</i>	<i>Upper cutoff frequency (Hz)</i>	<i>Lower cutoff frequency (Hz)</i>	<i>Center frequency (Hz)</i>	<i>Upper cutoff frequency (Hz)</i>	
11	16	22	14.1	16	17.8	
			17.8		20	22.4
			22.4		25	28.2
22	31.5	44	28.2	31.5	35.5	
			35.5		40	44.7
			44.7		50	56.2
44	63	88	56.2	63	70.8	
			70.8		80	89.1
			89.1		100	112
88	125	177	112	125	141	
			141		160	178
			178		200	224
177	250	355	224	250	282	
			282		315	355
			355		400	447
355	500	710	447	500	562	
			562		630	708
			708		800	891
710	1,000	1,420	891	1,000	1,122	
			1,122		1,250	1,413
			1,413		1,600	1,778
1,420	2,000	2,840	1,778	2,000	2,239	
			2,239		2,500	2,818
			2,818		3,150	3,548
2,840	4,000	5,680	3,548	4,000	4,467	
			4,467		5,000	5,623
			5,623		6,300	7,079
5,680	8,000	11,360	7,079	8,000	8,913	
			8,913		10,000	11,220
			11,220		12,220	14,130
11,360	16,000	22,720	14,130	16,000	17,780	
			17,780		20,000	22,390

Weighting Curves

The non-linear response of the ear has lead to the introduction of weighting filters, making it possible to carry out measurements, which correlate well with the response of the ear [16] (Figure1.6).

The most commonly used of these curves is the A-weighting curve, because it gives the best correlation between the measured values and the annoyance and harmfulness of the sound signal. It follows approximately the 40 phon curve in Figure. 4. The B-weighting and C-weighting curve follow more or less the 70 phon and the 100 phon curves. The D-weighting curve follows a contour of perceived noisiness, and is used for aircraft noise measurement.

Weighting filters can easily be built into portable Sound Level Meters, and the sound level measured is then given in dB (A) in cases where an A-weighting filter has been used.

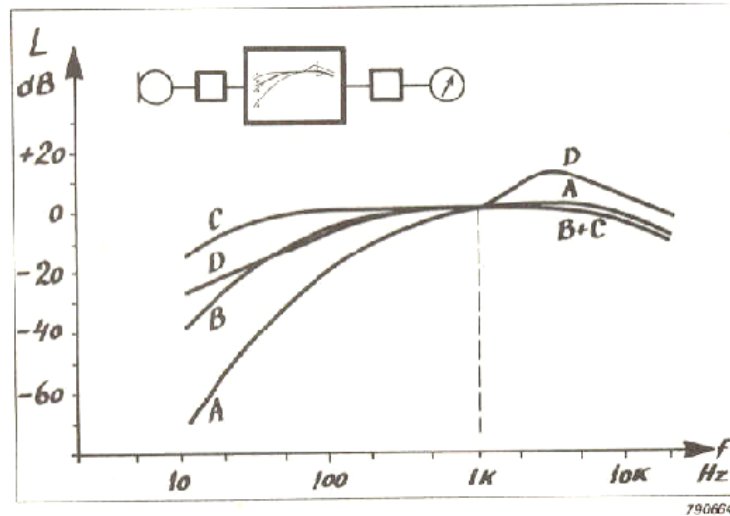


Figure 1.6 Weighting Curves [16]

1.2 Introduction to Noise

1.2.1 Noise

Noise is any unwanted or damaging sound in the atmosphere. Noise changes from nuisance noise to loud industrial noise. It can be continuous or intermittent. Both types can be damaging to the human ear depending on the level of noise and the length of time someone is exposed to it.

The major sources of noise are:

1. Industrial noise (plant and machinery, tools, compressed air & steam processes)
2. Traffic noise (Two wheeler, Auto-mobile, S.U.V, etc.)
3. Community noise (workplaces where low-level annoyance noise occurs for example there are a crowd of people talking, mobile cell ringing, etc.)

Out of above three parameters, the source that affects the most is Traffic noise. In traffic noise, nearly 70% of noise is producing by vehicle noise. Vehicle noise, principally, develop from two parameters i.e. Engine noise and Tire noise. The major concern is to study the vehicular traffic noise and its prediction.

In common sounds the range of sound pressure amplitudes encountered is considerable. Close to a jet aircraft on take-off, for example, pressure amplitude is of the order $1/1000$ (10^{-3}) of the atmospheric pressure. On the other end of the scale, the minimum audible sound is of the order $1/10,000,000,000$ (10^{-10}) atmosphere. Such a wide range of amplitudes gives problems in establishing a convenient scale of measurement which gives adequate resolution throughout the range of sound pressures, emphasizing the high amplitude components whilst still

accommodating low amplitudes. For this purpose the decibel scale is very convenient. The decibel is the logarithm of a ratio of two quantities (in electrical and pressure measurements these quantities are usually expressed in units of power) and therefore has no units. For measurements of sound pressure the decibel is defined as $10 \log_{10} (P/P_0)^2$ where usually P is the sound pressure amplitude of the measured sound while P_0 is a reference pressure. The reference pressure is taken to be the minimum sound pressure at 1000 Hz which is audible to a person with normal hearing. The decibel expression is then referred to as the Sound Pressure Level (SPL) [23].

$$\text{SPL} = 20 \log_{10} \left(\frac{P}{2 \times 10^{-5}} \right) \text{ dB}$$

p = time averaged pressure

p_{ref} = ref. pressure value (2×10^{-5} Newton's per square meter)

$p_{\text{ref}}(\text{air}) = 2 * 10^{-5} \text{ Pa} = 20 \text{ micro Pascal}$

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

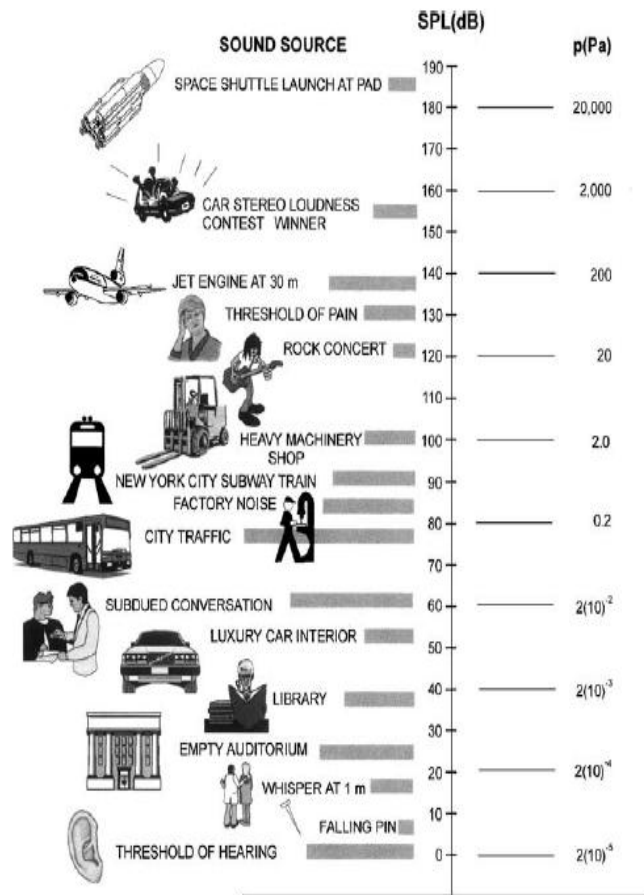


Figure 1.7 Sound level pressure [26]

Algorithm

As in normal addition method [17]

$$80 + 80 = 160$$

But in the addition of S.P.L.,

$$80 \text{ dB} + 80 \text{ dB} \neq 160 \text{ dB}.$$

The following expression is used to do so.

$$L_{\Sigma} = 10 \cdot \log_{10} \left(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + \dots + 10^{\frac{L_n}{10}} \right) \text{ dB}$$

This is done as the decibel scale is logarithmic. Therefore, first need is to convert the each decibel value to linear scale and then added and then converted back to the logarithmic scale.

L1, L2,..... Ln represents different sound pressure levels. Hence,

$$L(\text{total}) = 10 \cdot \text{Log}_{10}(10^{(80/10)} + 10^{(80/10)}) = 83.01 \text{ dB}.$$

1.2.2 A-Weighted SPL

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-Weight” to each different sound pressure level frequency. A weight is a response 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. It emphasizes[17]:

Positive adjustment for 1000 to 6300 Hz range

Negative adjustment for range of 20 to 1000 and 6300 Hz to above

So after applying A weight to the normal decibel value it has A weighted S.P.L.

$$\text{dB} \longrightarrow [\text{A-Weighted}] \longrightarrow \text{dB(A)}$$

This dB(A) is internationally accepted to measure the environmental noise

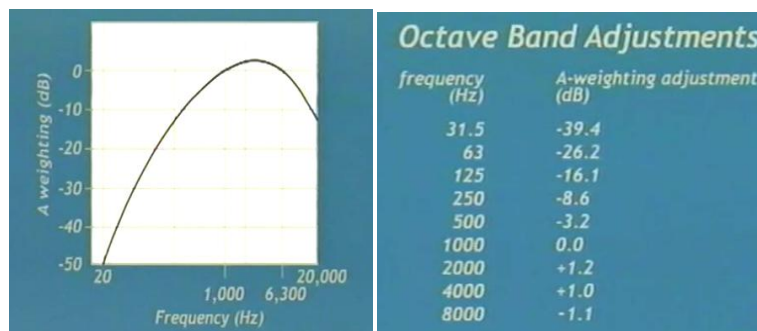


Figure 1.8 ‘A’ Weighted Curve [17]

1.2.3 Sound Sources

An importance is constituted between 3 different types of sound sources: [23]

1. *Point source*
2. *Line source*
3. *Plane source*

1. A sound source can be considered as a point source, if its dimensions are small in relation to the distance to the receiver and it radiates an equal amount of energy in all sides. Typical point sources are aircraft, individual road vehicles and industrial plants. The sound pressure level reduces 6 dB whenever the distance to a point source is doubled.
2. A line source may be continuous propagation, such as from a pipe having a turbulent fluid, or can be composed of a large number of point sources so closely spaced that their emission may be considered as emanating from a notional line connecting them. The sound pressure level reduces 3 dB, whenever the distance from a line source is doubled.
3. A plane source can be described as follows. If a piston source is constrained by hard walls to radiate all its power into an elemental tube to produce a plane wave, the tube will contain a amount of energy numerically equal to the power output of the source. In the ideal state there will be no attenuation along the tube. Plane sources are very rare and just found in duct systems.

1.2.4 Noise Measurement Techniques and Instrument

Noise measuring devices typically use a sensor to receive the noise signals emanating from a source. The sensor, however, not only senses the noise from the source, but also detects all ambient background noise. Thus, measuring the value of the detected noise is incorrect, 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.

The Sound Level Meter

The sound level meter (SLM), a most valuable means of assaying noise environments, amplifies the signal from a sensing microphone and processes the information for visual display or information storage. It is generally portable and battery operated. The quality ratings of sound level meters are specified by the American National Standards Institute (ANSI) and the International Electro-technical Commission (IEC) according to the precision of these

instruments. Measurement precision depends on a number of factors, including meter calibration, method of surveying, and frequency content of the noise being measured.

Elements of sound level meter

1. Microphone:

Microphones serve as transducers by receiving and sensing pressure fluctuations and converting them into electrical signals that are relayed to other electronic components. The quality of a microphone determines the accuracy of a measurement system. A top-caliber measuring (or a sound reproduction) system can be undermined by the use of a microphone that is of a lesser caliber. Different types of microphones are:

- a. Capacitor (Condenser) Microphone
- b. Pre-polarized Microphone
- c. Piezoelectric Microphone

2. Amplifier: It amplifies the signal from microphone sufficiently to permit measurement of low SPL. It amplifies sound over a broad frequency range. It maintains the amplification constant.

3. Rectifier: It rectifies the signal from analog signal to digital signal.

4. Smoothing circuit: Weighted level

5. Meter



Figure 1.9 Sound level meter with windscreen

Out Door Measurement Use of Windscreen

Wind can have significant impact on outdoor acoustical measurement.

1. Wind effects can be minimized to protect microphone.
2. Wind generated Noise can be reduced significantly by fitting a wind screen.

VEHICULAR TRAFFIC NOISE

2.1 Introduction to Vehicular Traffic Noise

Currently all the developing countries like India are facing threat due to vehicular noise pollution. Migration of people towards urban areas from rural, population growth expansion of cities, infrastructure development, and urbanization are important factors resulting in motorization and consequent increase in levels of various urban pollution. This increase in population coupled with the increase in number of motor vehicles is showing alarming levels of traffic congestion, noise pollution, and air pollution and road accidents. Noise emitted from traffic contributes about 55% of total noise pollution in India [23]. Thus the fundamental component is the noise produced by the individual vehicles, which depend on the vehicle class and its mode of operation. The overall noise is also dependant on the characteristics of the vehicle flow and the relative proportions of the vehicle types included in the flow. The knowledge of these factors is thus necessary to define the characteristics of highway noise and to subsequently predict the associated noise level in the surrounding area. The amount of knowledge required depends on the degree of accuracy desired in the predictions, which in turn is a performance of the method selected to characterize the temporal variation of the noise. Thus the evolution of highway noise model will depend on the noise descriptor selected.

2.1.1 Highway Noise Descriptors

The following descriptors are in common use: [16]

1. Percentile Exceeded Sound Level, L_X

This defines the sound level that has been exceeded “X” percent of time in a measurement period. The percentile exceeded sound levels most commonly used are L_{10} and L_{50} .

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

Equivalent continuous (A-weighted) sound level is defined as the steady sound level that contains the same amount of acoustic energy as the fluctuating level over the prescribed period of time. Common prescribed periods are one hour (L_{1h}), 24 hours (L_{24h}), day time hours (7 A.M. to 10 P.M.) (L_d), and the night time hour (10 P.M. to 7 A.M.) (L_n),

$$L_{eq} = 10 \log_{10} \frac{1}{T} \int_0^T \left[\frac{p}{p_{ref}} \right]^2 dt \quad \text{where,}$$

T = Total measurement time

P = A-weighted instantaneous acoustic pressure

P_{ref} = reference acoustic pressure = 20 (μPa)

3. Day Night Average Sound level, L_{dn}

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

4. Traffic Noise Index (TNI)

The traffic noise index is used to describe community noise. The traffic noise index is defined by

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

Where, L₁₀ = 10 percentile exceeded sound level

L₉₀ = 90 percentile exceeded sound level

All these are in dB and measured during 24 hours period.

2.1.2 Vehicle Noise Characteristics

Highway traffic consists of a large collection of vehicles of different types, makes and models [16]. The relative proportion (mix) of which depends on the type of highway and the time of day, among other factors. In the assessment of highway noise by calculation it is convenient to assume that there are two main categories of vehicles. These are:

(i) *Automobiles*

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

(ii) *Heavy trucks/buses*

Heavy trucks are defined as transport vehicle with Gross Vehicle Weight Ratings (GVWR) of more than 4536 kg (includes buses and heavy trucks).

2.1.3 Vehicle Noise Sources

The noise produced by a vehicle is dependent on the mode of operation of the vehicle. Truck noise can be considered to be produced by two major sources [16]. These are:

i. *Power plant and transmission noise source*

Power plant and transmission noise source includes engine, exhaust, intake, cooling system and drive train noise

ii. *Running gear noise sources*

Running gear noise source includes the tyre-road interaction, differential and propulsion shaft noise etc.

Noise increases in power plant with increase in engine speed but noise in running increases as vehicle speed increase. Truck tends to operate at a nominally constant engine speed, so that engine and exhaust noise do not change appreciably with vehicle speed. Therefore, at higher vehicle speeds tyre-pavement is dominant, while at lower highway speeds the engine-exhaust noise interactions become the dominant source of noise.

2.2 Effects of various factors on traffic noise

A traffic noise is more complex due to the facts that highways are not straight, flat or free from natural terrain variation. The factors like density, vehicle speed, width of median, traffic mix and number of lanes are not constant. Therefore, for traffic noise each of these parameters is taken into account. Traffic noise depends on the following factor [16]:

1. Traffic Parameters

Traffic volume

Average Speed

Percentage of Heavy Vehicles

Deceleration

Acceleration

2. Roadways characteristics

Pavement width

Flow characteristics

Gradient

Surface finish

Ground cover

3. Observer characteristics

Observer distance

Element size

Shielding

Observer relative height

Process Time

4. Environmental characteristics

Ambient Temperature

Humidity

Wind Velocity

3 LITERATURE REVIEW

In modern times, noise is recognized as a serious health problem. Annoyance caused by noise has been known since antiquity but it is only during recent times that the importance of environmental factors is taken into consideration in transport planning decisions. In fact, out of all the environmental pollution factors that are affected by the use of transportation means, noise is perhaps the most commonly cited. More than 70% of total noise in our environment is due to vehicular noise [5]. Noise pollution caused by automobiles has become a big social, problem and will become more serious and wide spread. To create a healthy and set up noise free environment, a noise prediction models are required so that the noise level along a busy highway can be predicted and investigated in advance during planning and design process [6]. These models are commonly needed to predict sound pressure levels, specified in terms of L_{eq} , L_{10} , etc., set by the descriptors and government authorities. Steele [1] reviewed all the traffic noise models (include the CRTN model of UK, the FHWA model of US, the RLS90 model of Germany, and the ASJ model of Japan.) meet the requirement of traffic management and some traffic noise models to permit for other road vehicles as well as automobiles and heavy vehicles. Papers are reviewed on the MADM approaches to see the usefulness, implementation criteria and procedure of implementation. All the above mentioned and important work are discussed as follows:

3.1 General Literature Review about Traffic Noise Models

3.1.1 Some early traffic noise models as formulated by different persons are discussed below

- Probably the earliest road traffic noise model was that given in the **1952 Handbook of Acoustic Noise Control** [1]. It was offered for speeds of 35 ± 45 mph and distances greater than 20 feet. The 50 percentile was there given as:

$$L_{50} = 68 + 8.5 \log (V) - 20 \log (D)$$

where,

V = traffic volume in vehicles per hour,

D = distance from the traffic lane, in feet.

- In 1965, **Nickson and Lamure [1]** separately advanced models of the form:

$$L_{50} = C + 10 \log (V/D)$$

where,

C is a constant for individual noise levels and L_{50} is in dB (A)

- Vehicle speed was introduced as a relevant factor by **Johnson et al.[1]**1968, who proposed:

$$L_{50} = 3.5 + 10 \log (V.S^3/D)$$

where,

S=mean vehicle speed in mph, and L_{50} is in dB (A).

This was stated to apply to 20% heavy vehicles, but their data were said to agree within 1 dB for heavy vehicles from 0 to 40%. Corrections were included for excess ground attenuation and for gradients.

- In the 1969 year, **Galloway et al.** introduced a further variable, T, the percentage of heavy trucks. Their equation was:

$$L_{50} = 20 + 10 \log (V.S^2/D) + .4(T)$$

where,

L_{50} is in dB (A)

3.1.2 FHWA highway traffic noise prediction model

FHWA was developed in the United States of America Department of Transportation Federal Highway administration by **Barry and Reagan [1]**. The model assumes point sources travelling at constant speed. The authors compared predicted A-weighted sound pressure levels with data collected in a program known as the Four State Noise Inventory.

L_{eq} is calculated for each class of vehicle and for each hour (on the hour) according to:

$$L_{eq} = \overline{L_0} + 0.115 \cdot \sigma^2 + 10 \log \left[\frac{N \cdot \pi \cdot D_0}{T \cdot S} \right] + 10 \log \left[\frac{D_0}{D} \right]^{1+\alpha} + 10 \log \left(\frac{\psi \alpha (\varphi_1 + \varphi_2)}{\pi} \right) + \Delta_s$$

L_{eq} is the equivalent continuous sound pressure level. For the i^{th} class it is expressed as $L_{eq}(h)_i$.

L_0 is the class SPL at the reference distance. The bar indicates the mean.

σ is the standard deviation for the class.

N_i is the number of vehicles of the i^{th} class passing during the relevant hour.

D_0 is the reference distance (usually 15 m).

D is the perpendicular distance from the centre line of the traffic lane to the receiver.

α is a site parameter, $0 < \alpha < 1$.

S_i is the mean speed of the i^{th} class.

T is the duration, usually 1 h.

ϕ_1 and ϕ_2 are the angles from the perpendicular of the limits of the observer's view of a section of the roadway.

Δ_s is the excess attenuation due to barriers, buildings, wood, etc.

In comparing some Florida traffic with the national noise emission levels, the mean errors were found to be -0.05 -0.95 and -1.3 dB (A) at, respectively 15, 30, and 60 m. The corresponding standard deviations were 1.64 1.82 and 2.39 dB. However, comparison between different noise emission levels in Florida only gave mean errors of +0.58 -23 and -0.57 dB (A) with slightly smaller standard deviations.

3.1.3 RSL 90 (Richtlinien für den Lärm-schutz an Straßen)

RLS-90 1990: (Guidelines for Noise protection on Streets) This model [1] was developed for Germany. It incorporates traffic flow design data where the actual flow is not known. It is different from others considered here for including a program for parking lots.

The assessed sound pressure level for a street is

$$L_r = L_m + K, \quad \text{where,}$$

L_m is the mean A-weighted level,

K is the addition for the increased effect of traffic light controlled intersections and other intersections.

The mean A-weighted level is given by

$$L_m = 10 \log\{10^{0.1.L_{m,n}} + 10^{0.1.L_m}\}$$

Where, n and f represent the near and farther lanes, respectively.

3.1.4 Stop and Go Model

This model was developed for the central part of Bangkok by the Urban Transport Department in 1997 [18]. In this model, two analytical approaches are used for interrupted traffic flow noise.

Single-model Analysis

This approach was applied first to build a single stop-and go traffic flow model. The model developed in this study is given as follows:

$$L_{eq} = 71.05 + 0.10S_n + 0.95 \log V_n + 0.04S_f + 0.015 \log V_f - 0.111D_g$$

Where,

S_n and S_f are the mean speed of traffic on near side and far side of the observer in kilometers per hour,

V_n and V_f are the volume of traffic for near side and far side of traffic in vehicles per hour,

D_g is the geometric mean of the road-side section, in meters, and D_n and D_f are the distance from the observer to the central line of the near and far-side roadway in meters.

Separate-lane Model Analysis

This approach acknowledges the difference in traffic in traffic noise characteristics between the acceleration lane and deceleration lane of both sides of the urban road.

Acceleration Lane Interrupted Traffic Noise Model

$$L_{eq} = 56.91 + 0.09S_n(a) + 5.22 \log V_n(a) + 0.04S_f(a) + 0.02 \log V_f(a) - 0,006D_g(a)$$

Deceleration Lane Interrupted Traffic Noise Model

$$L_{eq} = 71.12 + 0.07S_n(b) + 0.42 \log V_n(b) + 0.08S_f(b) + 0.44 \log V_f(b) - 0,061D_g(b)$$

3.1.5 ASJ1998 (Acoustical Society of Japan)

ASJ1998 (Acoustical Society of Japan's) [9] developed a model for Japan. It predicted equivalent continuous A-weighted sound pressure level according to energy-based calculation. In this model, the first step was to calculate the time history of A-weighted sound level at the receptor point caused by an isolated vehicle passage on the road (lane) under consideration. This gives a “unit pattern” (for each vehicle type and for each lane of a particular road under consideration) at a receptor point. By squaring and integrating the unit pattern, total sound pressure exposure over the time interval during which the source passes the lane under consideration is obtained. The quantity expressed in dB (A) of the total sound pressure exposure is sound exposure level (LAE). Considering the traffic volume, equivalent continuous sound pressure (A weighted) level (L_{Aeq}) for a particular lane is obtained.

$$L_{Aeq} \text{ (without buildings)} = 10 \log_{10} \left(10^{(LAE/10)} * \frac{N}{t} \right)$$

Where

N is traffic volume (vehicles/ second) and

t is time interval in seconds.

Finally L_{Aeq} is calculated by combining these results on energy base. In this case ASJ Model-1998 provides a method for estimating sectional energy-averaged equivalent continuous A-weighted sound pressure level (L_{Aeq}) which is calculated by the next equation:

$$L_{Aeq} \text{ (average)} = L_{Aeq, T} + \Delta L_{build}$$

Where,

ΔL_{Build} is the sectional energy-averaged excess attenuation by the buildings.

$$\Delta L_{Build} = \log_{10}\{(C1 + C2 + C3)/C\}$$

Where,

C is the sound-energy contributing from the line source without buildings;

C_1 is the contribution from Path 1 which propagates through both FRB and RGB;

C_2 is the contribution from Path 2 which propagates over FRB and through RGB;

C_3 is the contribution from Path 3 which propagates over both FRB and RGB;

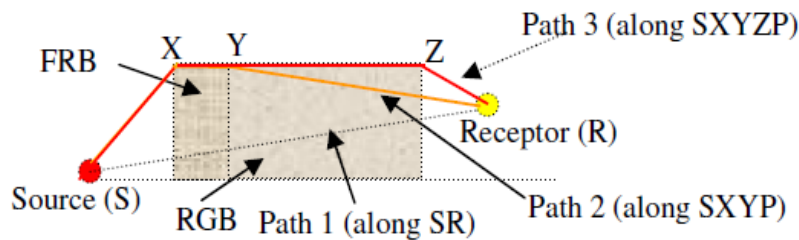


Figure 3.1 Three sound propagation paths in the build-up area.

DRONE (Dynamic area wide Road traffic Noise simulator) has been developed by the integration of traffic simulator with traffic noise prediction model (ASJ Model-1998). Noise contribution from vehicles using the metropolitan expressway also needs to be incorporated. ASJ noise calculation steps also need to be optimized based on calculation time and accuracy of noise prediction.

3.2 Literature Review on Traffic Noise

Uris and Cervera [2] presented road traffic noise in three different cities and community response. Road traffic was obtained by the equivalent continuous sound pressure level. To obtain the community response a questionnaire had been designed. Consequences from measurements and questionnaire had been compared and it had been found out that, heavy goods traffic is the origin of disturbance and indisposition.

Rylander and Bjorkman [3] studied road traffic noise influenced by road bumps. Two streets with a maximum speed of 50 km/h were selected for the study. Measurements were made in a section without any obstacles and in a section with short bump. The maximum noise level from each passing vehicle type was manually recorded and the vehicles were classified as passenger cars, light Lorries and Lorries. In that particular street, no buses were present.

Table 3.1 Average and maximum noise levels from passenger cars, light lorries, and lorries in street

Type of vehicle	No bump	Bump
Passenger car		
Number measured	33	67
Average dB(A)	73	74
Max dB (A)	77	90
Light Lorries		
Number measured	7	32
Average dB(A)	74	73
Max dB(A)	78	81
Lorries		
Number measured	10	19
Average dB(A)	82	82
Max dB(A)	86	87

The value was 1-13 dB (A) higher when road bumps were present with the highest increase caused by passenger cars in Table 3.1. It was suggested that the noise consequences must be taken into consideration when bumps are present for road traffic speed control purposes.

Li et al. [4] developed an integrated GIS traffic noise prediction model based on data obtained from Beijing highways and produced results comparable in accuracy with those of the US FHWA model already in use in China. An integrated noise-GIS system was developed to provide general functions for noise modeling and an additional tool for noise abatement design, where a new interaction mode in “WHAT IF Question/Explanation” format was used. The new system has improved both the accuracy and efficiency of traffic noise assessment and noise design in the Chinese context.

Pandya [7] assessed traffic noise and its impact on the community. A study of the subjective reaction of the people towards noise has indicated that, in an urban centre, the major contribution towards noise comes from traffic activities. Noise levels were measured continuously at the major traffic junctions in the city area as well as on the state and national highways during peak hours. The traffic volume was also determined by counting the heavy, medium and light vehicles at these junctions. Measurement of L_{eq} was of prime importance, for which a Modular Integrating Precision Sound Level Meter was used. The average L_{eq} for day and night times were calculated as per standard procedure and compared. In order to assess the Traffic Noise Index (TNI) at the junctions, a statistical module was attached to the sound level meter and L_{10} , L_{50} , L_{90} were recorded.

The noise equivalent level L_{eq} varied between 75 to 81 dB (A) at these location. It is observed that for dense traffic, L_{10} is about 3 dB above L_{eq} and L_{50} is about 1-2 dB lower. The TNI was in the range of 68-96. The high noise climate also had an impact on the neighboring residential areas in Table 3.2. Several different approaches were considered for the regulatory control of the community noise resulting from road traffic activities.

Gaja et al. [8] determined the appropriate measuring time in order to obtain a 24-h noise level suitable to represent the annual equivalent level for 5 years of continuous noise measurements carried out at one of the most important hotspot in Valencia (Spain). A kind of results from these strategies concluded is as follow:

- a random day,
- 7 consecutive days,
- 14 consecutive days,
- 28 consecutive days,
- 7 random days,
- 28 random days,
- 2 random non-consecutive weeks within a year,
- 3 random non-consecutive weeks within a year,
- 4 random non-consecutive weeks within a year

They found number of conclusions in terms of the most suitable urban traffic noise measurement techniques and finally, concluded that a random day strategy for sampling was found to give a more accurate representation than a consecutive day's strategy.

Tang and Tong [10] developed the formulas for the prediction of the $L_{A 10}, L_{A 50}, L_{A 90}$ and $L_{A eq}$ by regression analysis and simple physical consideration of the traffic noise production mechanisms and performance of the existing noise prediction models in the predicting traffic noise from inclined roads was evaluated in Hong Kong. Results suggested tyre noise has the major contribution to the overall noise environment when the source was an inclined trunk road. Also, the road gradient was found to have a higher contribution to the traffic noise than assumed in the existing models, nevertheless this become unimportant when the background noise level $L_{A 90}$ was concerned.

Coensel et al. [11] introduced a tool for dynamic traffic noise prediction, based on micro simulation of the traffic in an urban neighborhood coupled with a state-of-the-art beam trace propagation model. The unique feature of this approach was that it allows to estimate the effect of traffic flow management on noise in a much wider area than previous models. The model was compared with measurements of $L_{A eq, 1s}$ over 15 min and in general good agreement was found for all the statistical properties of this fluctuating noise level. Further improvement could include the introduction of corrections on the emission of accelerating and decelerating vehicles, the introduction of correct motorcycle and tram emission spectra, and the implementation of diffuse reflections in the propagation model.

Gündoğdu et al. [12] investigated effect of traffic composition on the noise pollution in a small city Erzurum, located in eastern Turkey. Manual noise measurements and vehicle counts were performed at the four heaviest traffic points in the city for periods of 12 hr. using the information on vehicle composition and the maximum legal noise emissions of each type of vehicles, two prediction models based on genetic algorithms had been developed that could be used as tools for in-city traffic flow redesign. The models had been validated against some of the noise data. Measured traffic noise levels had been compared with predictions using the new models and some existing ones and relatively good agreement had been obtained between them.

Can et al. [14] laid emphasis on dynamic estimation of urban traffic noise. Different traffic and noise source representations for L_{Aeq} and statistical levels estimation were tested. Four scenarios representative of the urban traffic conditions were tested assuming the same noise emission law for each vehicle. MCL model and mCF model were found to be based on the same macroscopic behavior rule and only differed on traffic representation. MCF model and mCF model were both car-following models differing on behavior rule, which were respectively macroscopic and microscopic.

Macroscopic behavior rule (MCL model and MCF model), traffic representation did not affect L_{Aeq} estimation but statistical description estimation was affected. Microscopic traffic representation was found to be more relevant. MCF model and mCF model had difference under 1 dB (A) for both L_{10} and L_{90} estimation. The difference was ever under 0.2 dB (A) for L_{eq} estimation for scenarios with traffic signal in Table 3.3. It seemed that details pointed up by mCF model were smoothed by the aggregation of the acoustic descriptors calculation. Secondly, those details were not necessarily relevant. So an accurate macroscopic behavior rule was found sufficient to assess averaged and statistical noise levels.

Can et al. [15] captured urban traffic noise dynamic through relevant description. Analysis conducted in this article was based on acoustical measurements taken at five points which depict different typical urban traffic situation. First the sensitivity of existing descriptors to noise dynamics was investigated. Secondly, the mean noise pattern that repeats at the traffic signal frequency was reconstituted for the point in front of the traffic signal. The main characteristic of this pattern was the clear distinction between the green and the red phase.

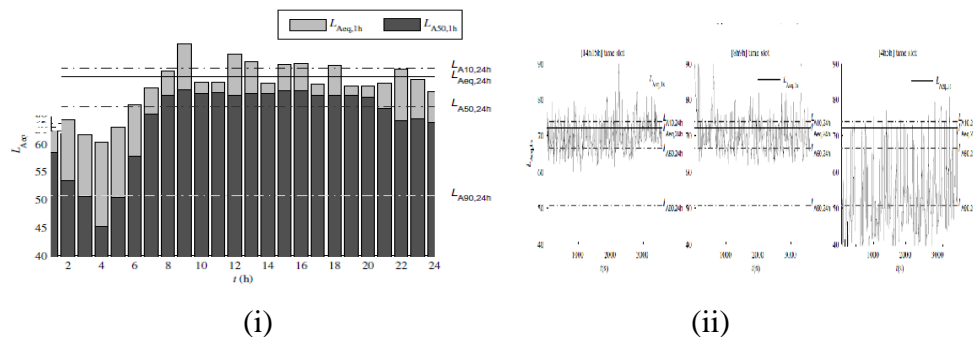


Figure 3.2 (i) $L_{Aeq,1h}$ and $L_{A50,1h}$ evolutions versus 24 h-descriptors and(ii) $L_{Aeq,24h}$, $L_{A10,24h}$, $L_{A50,24h}$ and $L_{A90,24h}$ versus $L_{Aeq,1s}$ evolution

Limits of L_{Aeq} and statistical descriptors to highlight noise variations are shown. When calculated over long-period scale (about 24 h), those descriptors could not capture long-term (from one hour to another hour) or short-term (within 1 h) noise variations. And Noise variations around this mean noise pattern were then studied. Descriptors were proposed to catch noise variations at the traffic signal scale, by highlighting average maximum and minimum levels reached in each cycle, and the percentage of cycles when maximum or minimum noise levels reached a given value over the period of calculation.

Rajakumara and Gowda [18] developed a regression noise prediction model for acceleration and deceleration lanes at Bangalore city. Interrupted conditions were caused by changing signals resulting in deceleration and acceleration noises as vehicles approach and depart from each other. Traffic noise data were collected simultaneously with that of traffic composition, traffic flow, and vehicles spot speed by using the Micro-15 noise dosimeter and Lutron SL-4001 sound level meter.

The basic concept used in this study for model development was as follows

$$L_{eq} = a_{a0} + a_{a1}Q_E + a_2S_E + a_3R + a_4L$$

Where,

L_{eq} = equivalent traffic in noise dB(A)

a_0, a_1, a_2, a_3, a_4 = Coefficients of be determined by the multiple regression analysis of data

Q_E = equivalent traffic flow in vehicles per hour,

S_E = equivalent traffic speed in km per hour,

R = position of the sound level meter = $\sqrt{x^2 + y^2}$

L = the queue of waiting vehicles on the deceleration lane in meter.

Acceleration lane model

The final form of the acceleration lane model obtained from analysis was described mathematically in the equation

$$L_{Eq}(1h) = 59.21 + 0.043S_E + 5.71 \log Q_E - 0.197R$$

Deceleration Lane Model

The final form of the Deceleration lane model obtained from analysis was described mathematically in the equation

$$L_{Eq}(1h) = 65.12 + 0.061S_E + 2.14 \log Q_E + 0.923 \log L - 0.041R$$

In this study, a prediction accuracy of the model developed was observed. A comparative statistical test was applied to the result of two models by using ‘t-test’ technique to see how well these models. In urban areas, most of the traffic flow is interrupted by traffic signals, which cause acceleration and deceleration traffic noise during its movement. Therefore, the study reveals that the noise prediction models developed in this study can be used for studying the environmental impact of road traffic noise.

Chevalier et al. [19] proposed dynamic noise model filling the shortage of accurate noise estimation procedures at roundabouts. The noise emissions due to stochastic vehicle interaction at roundabout entries is been fully captured by combining a microscopic traffic flow model with noise emission laws and propagation calculation. The traffic outputs were fed into relevant noise emission laws depending on the vehicle type and the prevailing road pavement type. Analytical noise prediction models disregarded those impacts as that are basis of average flow demand patterns and pre-defined kinematic profiles. The only way to capture all traffic dynamics impacts on noise levels found was to combine a traffic simulation tool with noise emission laws and a sound propagation model. Yet, such existing dynamic noise prediction packages failed in representing vehicle interactions when the roundabout was congested and were difficult to calibrate due to their numerous parameters.

A new traffic simulation tool, specifically developed for roundabouts, was therefore proposed. It has few easy-to-calibrate parameters and can be readily combined with noise emission and propagation laws. The obtained noise package was able to produce relevant dynamic noise contour maps which can support noise emission assessment of local traffic management policies. Results were validated against empirical data collected on a French suburban roundabout on two different peak periods.

Can et al. [20] accounted for how traffic dynamic improves noise assessment by analyzing three traffic representations that are:

- (i) A coarse static calculation based on mean speeds and flow rates
- (ii) A refined static calculation based on mean kinematics patterns
- (iii) A whole dynamic noise estimation model that considers vehicle propagation on the network

The three methodologies were applied on real traffic situations and compared to on-field noise levels. Traffic and acoustic measurements were taken at 5 points that depict usual traffic situations: close to a traffic signal, between two consecutive traffic signals, and close to a bus station.

Table 3.2 LAeq estimation (in dB(A)) at the 5 points of experimentation through the three different calculations; in clear : error exceeds 1 dB(A); in dark grey: error exceeds 2 dB(A); in black: error exceeds 3 dB(A).

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean error
Measurement	73.8	73.5	70.3	71.2	71.2	
Coarse static representation	75.1	76.5	74.4	74.3	74.4	3.1
Refined static representation	74.5	76.0	73.2	73.5	73.1	2.2
Dynamic representation	75.3	71.9	70.6	70.3	70.7	1.1

Finally, the dynamic model guaranteed a precise estimation of L_{Aeq} (error falls below 2 dB (A) for all the points), since the characteristics of the traffic flow in urban area (queue formation and discharge at each traffic signal, platoons of vehicles behind buses, etc.) were represented. Estimation seemed particularly precise in front of the traffic signal: error falling below 1 dB (A) for P₃, P₄ and P₅, what can be linked to a precise localization of accelerating zones.

Chevallier et al. [21] compared the noise levels obtain by these three methodologies at signalized intersections and roundabouts. Static noise models only considered free-flow constant-speed traffic with uniformly distributed vehicles. Analytic noise models assume that all vehicles were isolated from one another but account for their mean kinematic profile over the network. Micro-simulation noise models relaxed the hypothesis of no interaction between vehicles and fully capture traffic flow dynamic effects such as queue evolution. It revealed that micro-simulation noise models outperform the other approaches. In this paper, a roundabout was found to induce a 2.5 dB (A) noise reduction compared to a signalized intersection in under saturated conditions but the acoustic contributions of both kinds of junctions balance in oversaturated conditions.

Mishra et al. [22] laid emphasis on the newly introduced bus rapid transit system (BRTS) corridor at New Delhi. The paper included interpretation of primary data to predict the noise levels along the BRTS corridor. It focused on comparative study of modeled and measured noise levels. It also discussed about the impact of this corridor on land use and socio-economic aspects of lives of residents and road users living along this corridor. It recommended mitigating measures like design of noise barrier for stretches where the noise level exceeds the standards set by the Central Pollution Control Board. It observed data different value of noise level has been calculated for effect of the noise on human health, the hourly variation of L_{10} , L_{50} , L_{90} and L_{eq} noise levels.

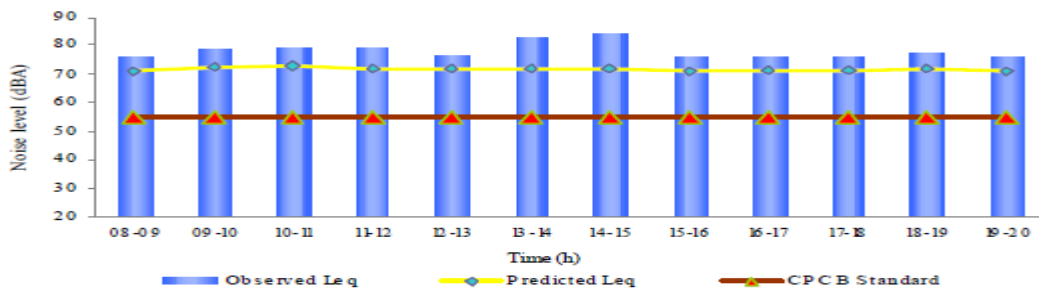


Figure 3.3 Comparison of predicted and observed noise levels at Moolchand BRTS corridor

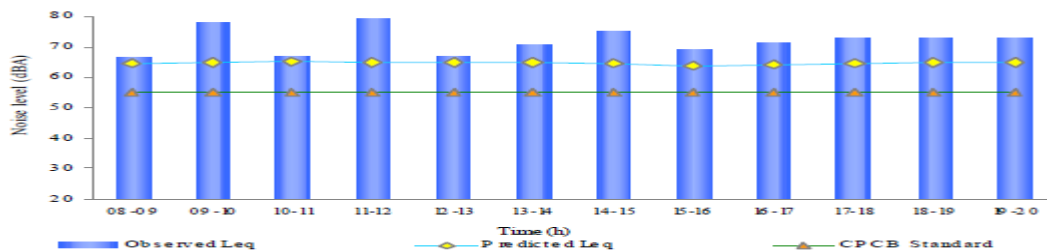


Figure 3.4 Comparison of predicted and observed noise levels at Ambedkar Nagar BRTS corridor

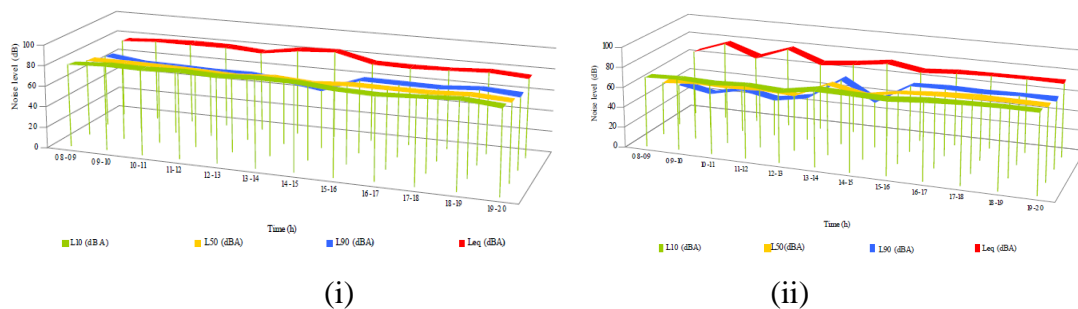


Figure 3.5 (i) Comparison of different observed noise level towards Moolchand at BRTS corridor, (ii) Comparison of different observed noise level towards Ambedkar Nagar at BRTS corridor

On the basis of data analysis, Figure 3.3 shows the comparison of predicted and observed noise levels at both sides of Moolchand bus rapid transit corridor. It indicated the highest predicted and observed value of noise level during 10:00 to 11:00 pm and 2:00 pm to 3:00 pm, respectively, whereas lowest predicted and observed noise value was found during single hour i.e. 4:00 pm to 5:00 pm and Similarly, Figure 3.4. depicted the highest modeled and monitored value of noise level during 10:00 pm to 11:00pm. While the lowest modeled and monitored value was found during 4:00 pm to 5:00 pm and 11:00 to 12:00 pm, respectively. Maximum value of L_{10} , L_{50} , L_{90} and L_{eq} is found during 13-14, 18-19, 18-19 and 14-15 h, respectively at Moolchand BRTS corridor (Figure 3.5 (i)). On the other hand, during 18-19 h, the highest value of L_{10} , L_{50} and L_{90} is obtained but maximum L_{eq} is found during 11-12 h at other location (Ambedkar Nagar) of BRTS corridor (Figure.3.5 (ii)).

3.3 Literature Review on System Approaches

Bhangale et al. [24] studied the selection of robot with large number of parameters with MADM approach. Robots were characterized in terms of its attributes. With the help of this approach different robots were specified more precisely in terms of attributes. Further these attributes were used for the selection and evaluation of the robots for different applications using MADM approach.

Babu et al. [25] Multi attribute decision making approach was used for the selection of materials for the wind turbine blades. Selection of material depends on many parameters low cost, high stiffness, low density and long fatigue life. Attributes were collected relating to the wind turbine blade material. A finite number of attributes were shortlisted for the selection of blade material. Technique for order preference by similarity to ideal solution (TOPSIS) was used for the selection of blade material. This gives the solution nearer to the ideal best one and farthest from the negative ideal solution. Different methods for MADM approach were Weighted Sum, Lexicographic, AHP, SMART, TOPSIS, ELECTRE, PROMETHEE, Goal Programming etc. different methods give different results. There was a need of great knowledge of decision makers about the alternatives and their preference weights.

Kumar and Agrawal [26] used multi attribute decision making approach for the selection of materials for the electroplating system. Selection of material was dependent of many parameters, Hardness (HV), Thickness (μm), Aesthetic, Adhesion and Cost. Attributes were collected relating to the electroplating material. A finite number of attributes were shortlisted for the selection of electroplating material. Technique for order preference by similarity to ideal solution (TOPSIS) was used for the selection of electroplating. This gave the solution nearer to the ideal best one and farthest from the negative ideal solution. The different methods for MADM approach are Weighted Sum, Lexicographic, AHP, SMART, TOPSIS, ELECTRE, PROMETHEE, Goal Programming etc., provided different methods give different results.

Kiran et al. [27]: presented a methodology useful in optimal selection of a mechatronic system based on the Multi Attribute Decision Matrix (MADM) approach. A coding scheme which is a collection of 88 attributes which characterize a mechatronic system and is useful in differentiating mechatronic system alternatives is proposed. An illustrative example of selecting a hard disk drive (HDD), a mechatronic system, for the up-gradation of consumer's office desktops is given to explain the methodology. Authors also identified 3- stage selection procedure, which includes elimination search, TOPSIS based evaluation and ranking, other graphical methods (linear graph and spider diagram), works on the information of the pertinent attributes. This procedure ranks the mechatronic system alternatives based on the Euclidian distance of alternatives from hypothetically best and hypothetically worst mechatronic systems.

3.4 Gap in Literature

Literature review is the way to get the information from the data available in the form of research papers on the particular research field. Knowledge is extracted from the information to reach the concluding point or gap on which further research has to be carried out. Literature review requires to represents the history of the particular research field, what is being done in that field, what is going in that field, what are the basic parameters (attributes) of the field etc.

After carrying out extensive literature survey, it is seen that different countries have different model (like reviewed six traffic noise emission models i.e. FHWA highway traffic noise prediction model, FHWA traffic model version 1.0, CORTN model, RLS 90, MITHRA and StL-86 model [1]) for the traffic noise to meet the requirements of government regulations and many designers. All the models discussed here have acoustic energy descriptors usually explicit as L_{eq}

or in two cases as a pseudo- L_{10} . The L_{eq} models admit of easy corrections for interrupted flow, multiple streams and multiple roads. Estimated the urban traffic noise through relevant description [15] and analyzed traffic representation for traffic dynamic improves noise assessment [20]. A holistic approach was adopted to study the impact of noise on the community and at the work place of an industry [7]. It was developed an interrupted model for Indian condition [18].

In this study a new methodology is proposed to collect the complete information about the research field in terms of its attributes and make a permanent database of knowledge about that field. This information is collected from the research papers available on that field. This type of information is very useful for new researcher, designer, etc. This methodology is applied on traffic noise and show the type of information developed from the matrix.

The use of systems approach MADM for the evaluation, ranking and identification of the roundabout traffic noise has not been attempted before.

Some **gaps** are **identified** on the basis of which aim for further study has been decided. Some are:

It is been identified that no work has been done in the traffic noise with the application of MADM (Multi attributes decision making) approaches. With a help of MADM-TOPSIS method, an evaluation, ranking and identification of a free flow, interrupted flow, roundabout, fly over, impact on the community, etc could be possible.

4 EXPERIMENTAL NOISE STUDY

4.1 Nature of noise

At present noise become one of a major source of pollution. The survey was conducted to know about the major source that contributes towards noise and it was observed that traffic noise become highly contributing factor in noise. The main sources of traffic noise are heavy commercial vehicles, light motor vehicles, two-wheeler (geared and non-geared type), etc. The noise nuisance was aggravated by the indiscriminate horn blowing, a characteristic of Indian driving pattern and accompanied by rapid accelerations and overtaking by the vehicles.

4.2 Site Selection

To achieve this objective, first step was site selection. So, surveys of different areas and nature of noise problem, there are five roundabouts in Patiala city out of which three roundabouts have large traffic volume were selected for accumulate data with dynamic traffic condition. These three roundabouts are i) Thikri roundabout ii) Fountain roundabout iii) Y.P.S roundabout, Patiala city, Punjab, India. These sites are mainly use for commercial purpose. A google map image of three roundabouts as shown in figure.(4.1-4.3).



Figure 4.1 Google map image of Fountain roundabout at Patiala city



Figure 4.2 Google map image of Thikri roundabout at Patiala city.

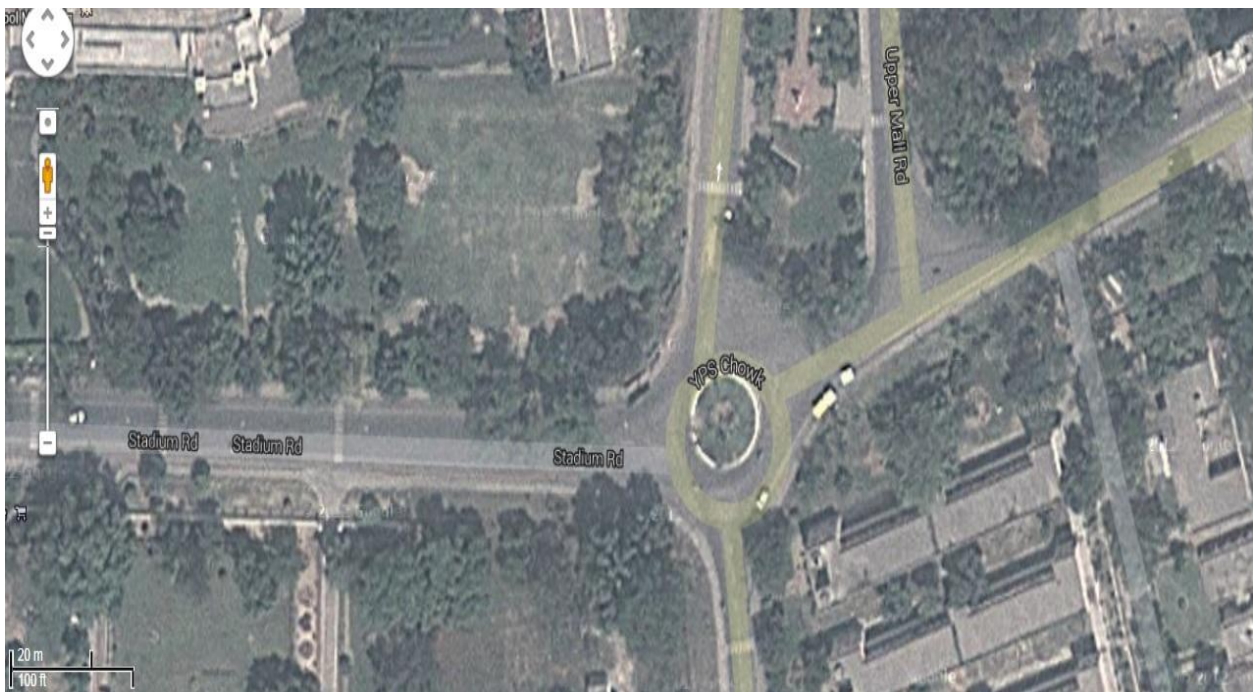


Figure 4.3 Google map image of YPS roundabout at Patiala city.

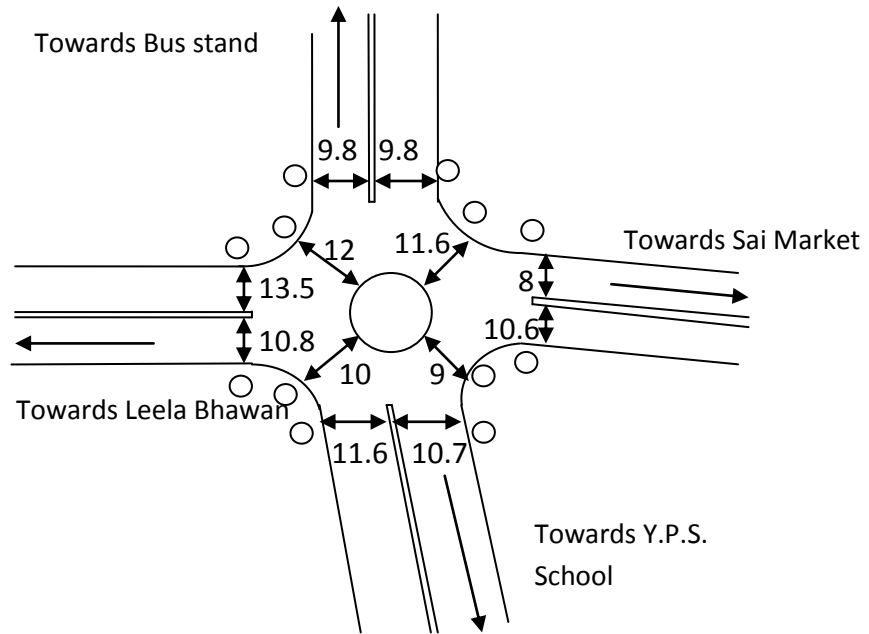
4.3 Measurement Procedure

For traffic noise measurements at a suitable site, systematic noise monitoring was done during April 2013 - May 2013 using Sound Level Meters (Cesva SC-310) as shown in figure 4.4.

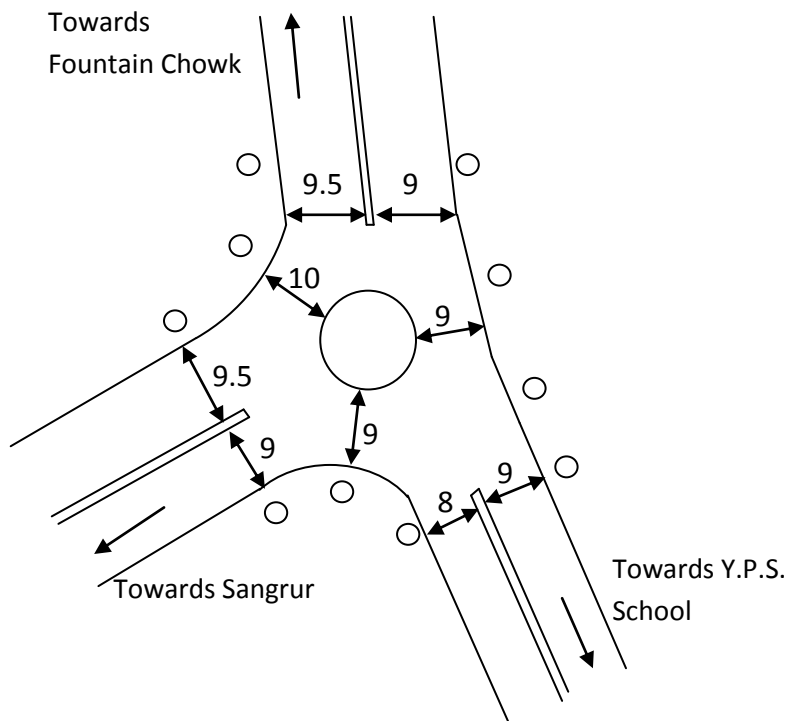


Figure 4.4 Sound level meter on a tripod with windscreen

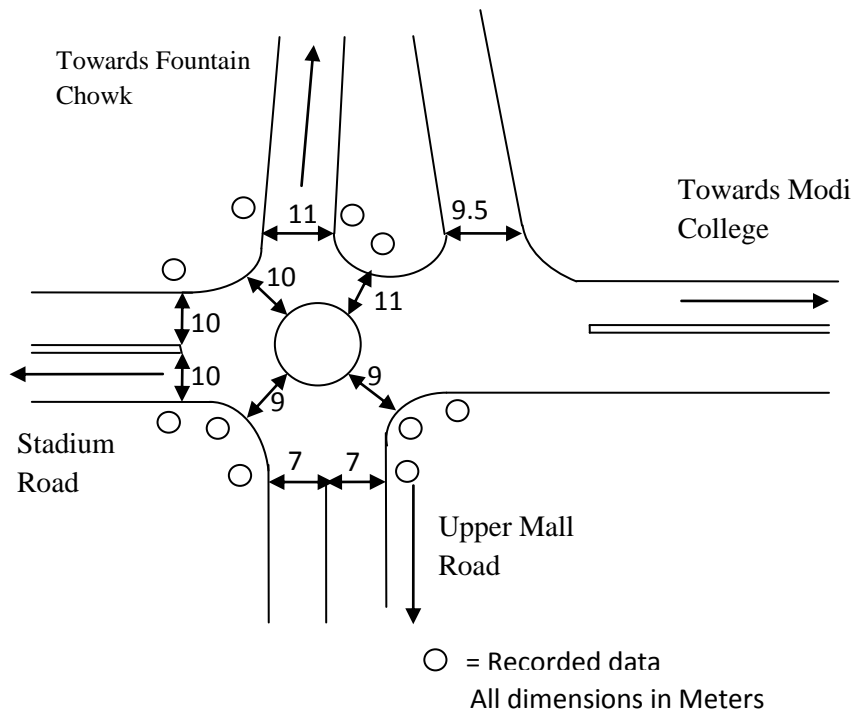
The Sound Level Meter was suitably calibrated. The microphone mounted on a tripod at a suitable predetermined spot at a height of about 1.2 meter from the ground. Wind screen was used to avoid the disturbance of wind during recordings on the microphone. During site study several parameters like flow rate for each class of vehicles (Cars, Heavy vehicles, S.U.V., two-wheeler and three-wheeler), Average speed, acceleration, and deceleration were considered. Data was recorded for a total of 15 days for three roundabouts with each roundabout data collection at 15 minutes for each hour for a week from 10.00 A.M to 1 P.M and 2 P.M to 5 P.M. Equivalent Sound level L_{eq} was recorded. The vehicle acceleration and deceleration were recorded to analyses the affect of acceleration and deceleration throughout a roundabout. A distance of 60 meters front wise the measuring point was determined for measuring initial speed/ final speed and time interval was measured by stopwatch. The average speeds of vehicles were recorded by radar gun. Traffic volume for each of the vehicle class was recorded by using 5 counter meters. The data was obtained from different positions at roundabouts in shown in figure 4.5.



a) Fountain roundabout



b) Thikri roundabout



c) YPS roundabout

Figure 4.5 Line diagram of three roundabouts a) fountain roundabout b) Thikri roundabout c) YPS roundabout, with shown position where Recorded data.



Figure 4.6 Measurement site at YPS roundabout, Patiala City

4.4 Measurements

The data was measured at the three roundabouts as per the described procedures.

The measured parameters were traffic volume, average speed of vehicles, and percentage of heavy vehicles, acceleration and deceleration is shown in Table 1 of the *Appendix A*. The Equivalent Sound level L_{eq} was recorded to get validated the analytical model is shown in Table 1 of the *Appendix A*. The acceleration and deceleration was measured by using equation of motion ($s = ut + \frac{1}{2}at^2$). The temperature and humidity were also monitored throughout.

The following settings were kept on the Sound Level Meter for the above measurements:

Table 4.1 Setting of SLM

Time weighting	“Slow”
Pre-set time	“15 minute”
Frequency weighting	“A”
Displayed parameter	L_{eq}

5 ATTRIBUTE KNOWLEDGE BASED METHODOLOGY

The available literature reviews on traffic noise have many limitations. The area of traffic noise and their uses are spread at very fast rate day by day. So it is very difficult to derive the appropriate knowledge in the area of traffic noise. A lot of work has been done in the field of traffic noise and lot of research is going on continuously to improve the various models of traffic noise. In this chapter, attribute knowledge base methodology for literature for literature review based on different pertinent attributes of traffic noise is proposed. The attribute based methodology is not only beneficial for academic research point of view, but also for descriptors producing various traffic noise models. The attribute based methodology highlights the attributes of the papers in particular areas in which various researchers have given their contribution. According to the work done on different attributes, the academic value of the different papers and their coding can be done by using proposed methodology. With the same procedure an 'm x n' matrix is prepared having 'm' no of attributes and 'n' number of papers. This methodology gives a quick review about the various papers in particular area of research. Methodology can be applied in smaller and bigger areas in the field of traffic noise. Here, demonstration is made on Traffic noise.

5.1 Methodology

This methodology full of knowledge base is very useful. The methodology applied in this is called Matrix methodology. In this methodology, an 'm x n' attribute information matrix is prepared. Various steps are involved in preparing this Matrix. From this Matrix, it is very easy to find out the academic value of any paper based on different attributes discussed in it. This may be applied in smaller and bigger areas of traffic noise. Here, demonstration will be made by taking literature review of smaller traffic noise. It can also to be extended in other directions of traffic noise based upon the author recommendation.

Step- by Step procedure for Attribute based Literature review

Step-1 In this step, researchers/designers/traffic management decide their area, aims and objectives of literature review and gap analysis.

Step-2 In this step, cause and effect analysis is prepared to identify all the groups/subgroups of attributes to be studied.

Step-3 In this step, a list of identified attributes is prepared from different research publications selected for literature review.

Step-4 In this step, characterization of papers can be done with respect to ‘m’ number of attributes as

$$P_j = [A_{1j}, A_{2j}, A_{3j}, \dots \dots \dots A_{ij}, A_{mj}], \text{ where, } i=1, 2, 3, m$$

Step-5 In this step, ‘m x n’ knowledge base Matrix (or ‘m x n’ information Matrix) is defined, where rows represents attributes and columns represent research papers.

Step-6 In this step, every attribute is coded in the interval scale of 0-5 based on depth of study has been done in a particular paper. (i.e. code 5 represents the attribute very high studied, code 4 represents highly studied, code 3 represents average studied, code 2 represents less studied, code 1 represents very less studied and code 0 for absent (i.e. that particular attribute is totally absent in papers).

Step-7 In this step, a comprehensive knowledge base Matrix for all the ‘n’ papers collected from all sources related to area under consideration is prepared. It is preferable to develop user friendly software for permanent storage and retrieval and for upgrading purpose.

Step-8 In this step, summation of weights of all the attributes in the i^{th} row (represents the interest and depth of study of different attributes) is calculated. Similarly, summation of weights of all the papers in the j^{th} column (represents the academic importance of different papers with respect to particular attributes) is calculated.

5.1.1 Identification of Research papers

The first step in developing the attribute information matrix is to identify the various research papers and research publications related to different traffic noise. The research papers are characterized during different periods of time. The research papers and publications are

identified through various internet links and through colleges and research institutes related to different traffic noise etc.

5.1.2 Grouping of research papers

In this, identified research papers/publications are grouped according to their year of publication. The grouping of different papers can be done in four different ways. Firstly, grouping of research papers and publications according to different periods of time, like from (1995-2000), (2001-2005), (2006-2010) and (2010-2015) and onwards.

Secondly, grouping of research papers and publications is done according to subject /area wise. Thirdly, grouping of research papers and publications is done according to different categories as review papers, article papers, conferences and patents. Fourthly, grouping of research papers and publications is done according to their scientific index/impact factor etc. The grouping of papers is necessary to understand what has been done and what has not been done during that period of time. what are the different procedures, tools, techniques, methods that many researchers opt, different issues on which more discussion and work carried out till today are easily identified.

5.1.3 Coding of research papers

In this, coding of different research papers is identified. The coding of the research papers can be done in the interval scale of 0-5 as shown in Table 5.1. Coding could be done on the basis of highly studied, average studied, very less studied and absent, attributes with respect to the corresponding papers.

While coding, several factors are kept in mind, like, depth of analysis on particular attribute, scientific index/impact factor of journal, Level of publishing journal etc.

Table 5.1 Coding Schemes for Research Papers

Categories	Codes
Attribute which is absent.	0
Attribute which is very less studied with respect to its corresponding paper.	1
Attribute which is less studied with respect to its corresponding paper.	2
Attribute which is average studied with respect to its corresponding paper.	3
Attribute which is highly studied with respect to its corresponding paper.	4
Attribute which is very high studied with respect to its corresponding paper.	5

5.2 Cause and effect analysis for attributes identifications

Cause and effect analysis is applied for recognizance of different attributes and their influence to decide the academic value of different attributes. In this work, several causes and their effect are found out which are important to produce a less traffic noise in the vicinity in terms of academic value of papers.

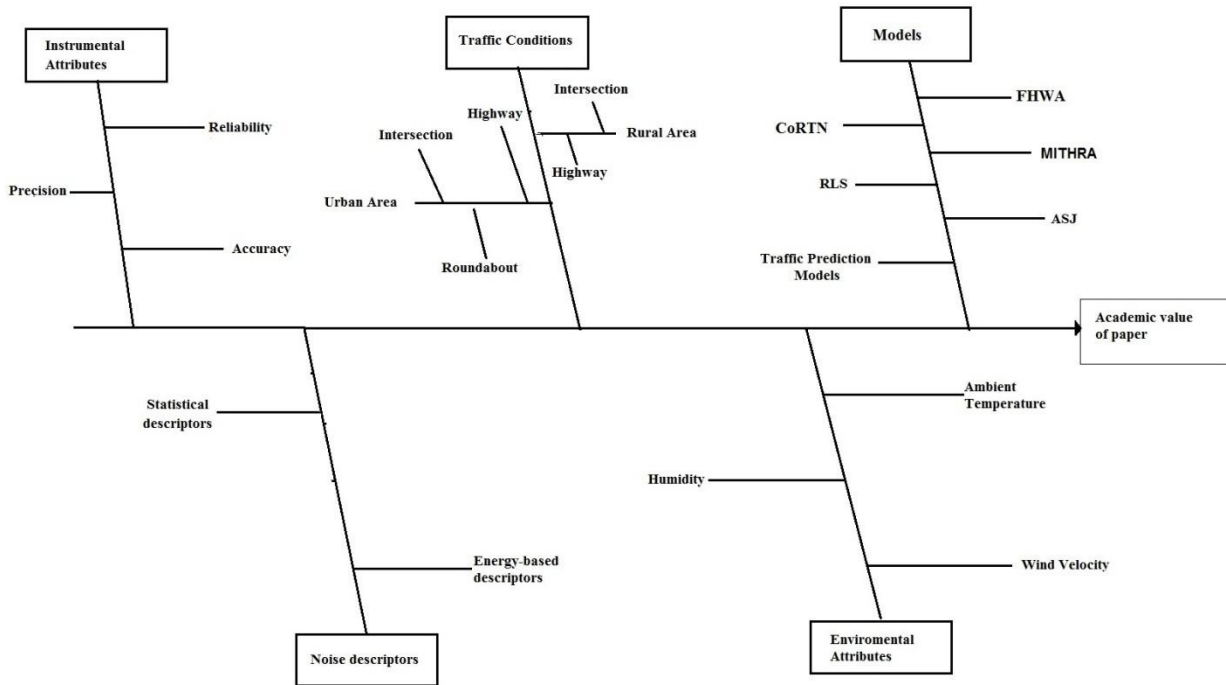


Figure 5.1 Cause and effect analysis of research publication papers.

Cause and effect analysis is one of the tools which is used to obtain good quality product from past many years. Using cause and effect diagram, all the groups and subgroups of attributes are identified as shown in figure 5.1.

5.2.1 Identification of Attributes

The second step in developing the attribute information matrix is to identify all the relevant attributes from different research publications. The attributes identified are those having significant effect on the various characteristics of traffic noise.

Table 5.2 shows the various attributes which is identified from different research papers have significant effect on traffic noise properties. Here, 51 attributes are identified from 22 papers which are related to different properties.

Table 5.2 List of Attributes Identified from Different Research Publications

Design Attributes	
1. Geometric Dimensions	2. Number of lanes in roadway
3. Traffic Area Conditions	4. In –city traffic flow
Physical/Observer Attributes	
5. Traffic volume	6. Road Gradient
7. Average Speed	8. Percentage of Heavy Vehicles
9. Distance	10. Deceleration
11. Acceleration	12. Engine Noise
13. Process Time	14. Tire Noise
	15. Aerodynamic Noise
Environmental Attributes	
16. Ambient Temperature	17. Humidity
	18. Wind Velocity
Performance Attributes	
19. Microscopic Traffic Tool	20. Mean Kinematic Pattern
21. Vehicle propagation	22. Noise Emission Law
23. Traffic Modeling	24. Traffic Noise Screening
25. Equivalent Sound Pressure Level	26. Statistical Description
27. Energy based Description	28. Traffic Noise Index
29. Dynamic Area wide Road Traffic Noise Simulation	30. Calibration
31. GIS Based Integration Tool	32. Regression Analysis
33. Multi Regression Analysis	34. Validation

Instrumental Attributes	
35. Repeatability	36. Accuracy
37. Precision	38. Reliability
General Attributes	
39. Noise Pollution	40. Sleep Disturbance
41. Hearing Impairment	42. Blood Pressure
43. Working Disturbance	44. Annoyance
	45. Irritation
Control Attributes	
46. Traffic lights	47. Noise Barriers
48. Foliage	49. Ground cover
50. Road pavement	51. Rows of Building

From all these attributes any researcher may easily predict on which papers and on which attribute, more concentration is given by different researchers and in what depth work has been done on particular attribute.

5.2.2 Coding of attributes

Ranking or coding of identified attributes is done on the basis, highly studied, less studied and attributes which is very useful in the interval scale from 0-5 by team of experts of respective area identified for research as shown in Table 5.3.

Table 5.3 Coding scheme for attributes

Categories	Codes
Very highly studied attributes	5
Highly studied attributes	4
Average studied attributes	3
Less studied attributes	2
Very less studied attributes	1
Absent	0

Which defines 0 for absent, 1 for very less studied, 2 for less studied, 3 for average studied, 4 for highly studied and 5 for very high studied and on basis of this one can easily found out on which attribute more study has been done and to how much depth.

5.3 Procedure to develop an Attribute Information Matrix

1. In the attribute information Matrix, all the rows represent the number of attributes which are related to the traffic noise and have significant effect on the various physical and performance properties.

The attributes/ research issues/property are represented by ' A_i ', where 'i' varies from 1 to 'm' and 'm' represents the m^{th} attribute and the column represents the number of papers. The papers are represented by ' P_j ', where 'j' varies from 1 to 'n'. Where 'n' represents the nth paper. Then there is formation of 'm x n' Matrix.

2. First column of the Matrix represents the first paper.
3. First row represents the first attribute find out from the research publications.
4. In this attribute information Matrix ' A_{ij} ' represents the inheritance/ presence/depth of analysis modeling etc, of the i^{th} attribute in the j^{th} paper on the interval scale of 0-5.
5. $\sum A_i$ denotes the sum total of all the values of attributes along each row with respect to the corresponding papers.
6. $\sum P_n$ denotes the sum total of all the values of different papers along column wise with respect to the corresponding attributes.
7. Lastly, $\sum total$ represents the total sum corresponding to both attributes and papers.

From, $\sum A_i$ and $\sum P_n$ the academic value of each paper is decided. Attribute Information Matrix.
Table 5.4.

Table 5.4 Attribute Information Matrix ‘m x n’

PAPER ATTRIBUTE	P_1	P_2	---	--	--	P_j	---	---	P_n	SUM
A_1										$\sum_1^n a_{1j}$
A_2										$\sum_1^n a_{2j}$

A_i						a_{ij}				$\sum_1^n a_{ij}$

A_m										$\sum_1^n a_{mj}$
SUM	$\sum_1^m a_{i1}$	$\sum_1^m a_{i2}$				$\sum_1^m a_{ij}$			$\sum_1^m a_{in}$	Total

Columns represent the paper on the desired area of research and the rows represent the attributes finding from these papers. The summation of the attributes and papers can be calculated as follows:-

For Attributes:- $\sum A_m = \sum A_1 + \sum A_2 + \sum A_3 + \dots + \sum A_m + \dots$ (1)

Where, $\sum A_m$ represents sum of ‘m’ attributes

For Papers:- $\sum P_i = \sum P_1 + \sum P_2 + \sum P_3 + \dots + \sum P_n + \dots$ (2)

Where, $\sum P_n$ represents sum of 'n' papers.

The value of ' $\sum A_{ij}$ ' of i^{th} attribute with respect to j^{th} paper can be given as:-

$$\sum A_{ij} = \sum A_i + \sum P_j$$

5.4 Advantages of the Attribute Information Matrix

The attribute information matrix above formed has a large number of advantages. Attributes information matrix is used as a full source of deriving information and knowledge from different research publications/paper for researcher/designer/traffic management etc for their basic and commercial research purposes. The proposed methodology is also useful with respect to time, cost, efforts, knowledge, storage and retrieval and also for the up gradation etc.

5.5 Gap Analysis

The next step in introduced methodology is to do a gap analysis to find out gaps from the former work. With the help of Attribute Information Matrix, it is very simple to find out the gap from the literature available over the periods of time. By this way, it is simple to fix up in which direction anyone could put his contribution towards one's goal.

5.5.1 Importance of gap analysis

- I. **Researcher:** - This identification can help the researcher for the database storage and retrieval. This will produce the computerized database, which can be used in different format for different location by different people in the world. It will also help the researcher to identify the best possible traffic noise condition for the particular location whenever it is required. From the Attribute Information Matrix, it is simple for a researcher to find the gap between the work, i.e. what has been done or what has not been done. Using this methodology, software could be uploaded in the library of colleges which is to be updated as per the new requirement of researchers. Even, M.E students could also used this software for their thesis work in selecting the most appropriate area of research according to their interest.
- II. **Designer:** - This identification of the attributes can help to generate various alternative designs for city, roads, roundabouts, flyover to reduce the effect of traffic noise. The designer can identify the critical attributes, which directly influences the performance. The designer

can change these censorial attributes and monitor them to control particular parameters so that the required performance can be obtained from the roundabout.

- III. **Management:** - The quantification and invigilation of the attribute magnitudes can help the traffic management to control the traffic in an appropriate manner by diverging the traffic with which less effect of traffic noise pollution. Moreover, management can find out the alternatives by observing the attributes magnitude. Management can use the database to produce optimum roundabout conditions for the minimum traffic noise.

- IV. **Short term and long term strategic point:-**Attribute Information matrix is very important for any organisation to make their good strategy. By Attribute Information Matrix, they can easily know about the various trends of research changes from previous years to today scenario. Accordingly by keeping these points in mind a good strategy plan can be made in accordance with their field of work.

5.6 Attribute Information Matrix

Following table show the Attribute Information Matrix, i.e. how this matrix is used. In this Matrix, 10 attributes are selected with respected to the corresponding 12 papers.

Table 5.5 Attributes information matrix for 12 papers and 10 attributes

Number of papers		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	Sum
Reference of papers		17	11	19	16	13	6	5	10	7	14	12	4	
S/No	Attributes													$\sum A_i$
	$A_i, i=1, \dots, m$													
A_1	Traffic Volume	1	3	2	3	2	4	0	2	4	3	3	2	29
A_2	Road Gradient	0	3	0	0	0	0	0	0	4	0	0	0	07
A_3	Speed	3	4	3	2	4	0	2	0	4	3	1	1	27
A_4	Deceleration	0	0	2	0	2	3	1	0	0	3	1	0	12
A_5	Acceleration	2	0	5	2	2	0	3	0	0	2	1	1	18
A_6	Distance	0	0	0	1	0	0	0	0	0	4	2	0	07
A_7	Process time	0	0	0	0	1	0	0	5	0	0	0	0	06
A_8	Percentage of heavy vehicles	1	4	1	2	3	0	0	2	3	0	3	2	21
A_9	Tyre Noise	0	4	0	0	0	0	0	0	2	0	5	0	11
A_{10}	Aerodynamic Noise	0	3	0	0	0	0	0	0	3	0	3	0	09
$\sum P_i$		07	21	13	10	14	07	06	09	20	15	19	07	147 158

After selecting, papers and attributes coding of different attributes with respect to their corresponding papers can be done by using Table 5.5 and procedure to develop a Attribute Information Matrix is followed, where $\sum A_i$ and $\sum P_n$ for all the attributes with respect to their corresponding paper is calculated.

6 IDENTIFICATION, EVALUATION AND RANKING OF ROUNDABOUT TRAFFIC NOISE

This chapter deals with implementing a novel method to help the decision-maker for identification of a roundabout that will meet all the requirements of the acoustics engineers. In this a reliable and exhaustive data of roundabout is to be generated and maintained based on their different pertinent attributes. It is useful for better understanding, comparison and analysis and for comparison; ranking, validation and optimum identification of roundabout on the basis of noise around it. The multiple attribute decision making problems is solved by Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS). The technique converts database into knowledge base by considering normalization, relative weights, positive benchmarked and negative benchmarked solutions and normalized weighted database into single numerical suitability index for each roundabout solution. It helps the traffic management to save time by providing a tool for identification the roundabout most suited for low noise. The identification procedure allows rapid convergence from large number of roundabout to a manageable shortlist of potentially suitable roundabout using elimination search based on the few critical identification attributes. Subsequently, the identification procedure proceeds to rank and validate the alternatives in the shortlist by employing different attributes based specification and graphical methods. The ranks of the dynamic roundabout are calculated with respect to the best possible roundabout, say -ve benchmark roundabout, for particular location. The coding scheme and the identification procedures, mathematical and graphical, with example are also illustrated.

6.1 Methodology

MADM techniques are product identification techniques. Multiple attributes are processed in MADM techniques for ranking finite number of alternatives to arrive at a single choice for the best product. This method uses Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) MADM technique to identify a best possible roundabout traffic noise. The weighted

normalized attributes for the +ve and -ve benchmark roundabout are considered as attributes for arriving at best possible roundabout traffic noise to deploy in the location.

Step-by-step procedure for optimum identification of roundabout

Step-1:- Decide about the aims and objective for which noise free roundabout is to be used for vicinity.

Step-2:- Identify the entire possible alternative roundabout available in a particular area.

Step-3:- Develop an n-digit coding scheme for characterization/specification for storage and retrieval in the computer.

Step-4:- Carry out elimination search to reduce the large list of alternatives dynamic roundabout as 1st stage of 3 stage identification procedure.

Step-5:- Select TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) as attributes based evaluation procedure for this small list of alternatives.

Step-6:- After evaluation, rank the roundabout in order of preference for noise and validate with observed values by sound level meter.

6.2 Traffic Noise Attributes in Dynamic Condition near Roundabout

Proper identification of attributes under dynamic condition near roundabout is critically important when comparing various roundabouts.

6.2.1 Identification of roundabout attributes

The attributes on which Traffic noise under dynamic condition near roundabout depends are found out based on its broad area as general parameters, physical/observer parameters, and performance, environmental, instrumental, control based etc as shown in Table 6.1.

Table 6.1 Lists of Attributes Identified From Different Research Publications

Design Attributes	
1. Geometric Dimensions	2. Number of lanes in roadway
3. Traffic Area Conditions	4. In –city traffic flow
Physical Attributes	

-
- | | |
|-------------------|---------------------------------|
| 5. Traffic volume | 6. Road Gradient |
| 7. Average Speed | 8. Percentage of Heavy Vehicles |
| 9. Distance | 10. Deceleration |
| 11. Acceleration | 12. Engine Noise |
| 13. Process Time | 14. Tire Noise |
| | 15. Aerodynamic Noise |
-

Environmental Attributes

- | | |
|-------------------------|-------------------|
| 16. Ambient Temperature | 17. Humidity |
| | 18. Wind Velocity |
-

Performance Attributes

- | | |
|---|-----------------------------|
| 19. Microscopic Traffic Tool | 20. Mean Kinematic Pattern |
| 21. Vehicle propagation | 22. Noise Emission Law |
| 23. Traffic Modeling | 24. Traffic Noise Screening |
| 25. Equivalent Sound Pressure Level | 26. Statistical Description |
| 27. Energy based Description | 28. Traffic Noise Index |
| 29. Dynamic Area wide Road Traffic Noise Simulation | 30. Calibration |
| 31. GIS Based Integration Tool | 32. Regression Analysis |
| 33. Multi Regression Analysis | 34. Validation |
-

Instrumental Attributes

- | | |
|-------------------|-----------------|
| 35. Repeatability | 36. Accuracy |
| 37. Precision | 38. Reliability |
-

General Attributes

- | | |
|---------------------|-----------------------|
| 39. Noise Pollution | 40. Sleep Disturbance |
|---------------------|-----------------------|
-

41. Hearing Impairment	42. Blood Pressure
43. Working Disturbance	44. Annoyance
	45. Irritation

Control Attributes

46. Traffic lights	47. Noise Barriers
48. Foliage	49. Ground cover
50. Road pavement	51. Rows of Building

From all these attributes any researcher may easily predict on which papers and on which attribute, more concentration is given by different researchers and in what depth work has been done on particular attribute.

6.2.2 Quantification and measurement of the attributes

The traffic noise is expressed in a elaborate method by the attributes which are quantitative in nature e.g. traffic average speed 30 km/h , acceleration 6 m/s² etc. these attributes are articulated in the form of numerical value like 0,1,2,3,.....n. But, there are some attributes which only gives knowledge or information about the traffic noise e.g. Noise barriers, Road pavement, etc..., are known as information attributes. These attributes do not assign any numerical value and are only depict by alphabets A, B, C, D.....etc. Normally the quantification of many of the attributes is not provided by the traffic management. But if the traffic management identifies and provides these attributes by itself then it will be useful to the researcher, designer, etc.

A cause and effect analysis diagram is drawn to identify all the different attributes and other parameters of traffic noise which require attention of researchers in the subject area under consideration.

6.3 Cause and Effect Analysis

Cause and effect analysis diagram is a technique which is very useful in identification and displaying all the possible cause of a particular problem as shown in figure 6.1. In the diagram the relationship between the optimized traffic noise for roundabouts and all factors that are

affecting and are responsible for the optimization of the traffic noise for roundabouts are represented graphically.

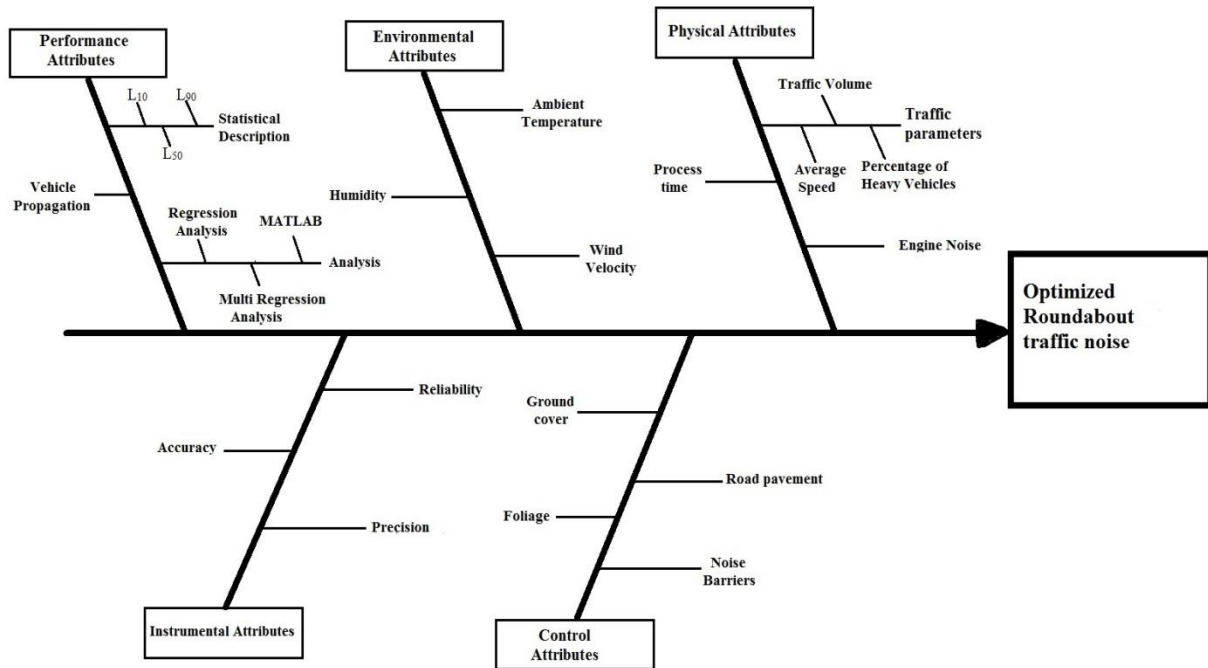


Figure 6.1 Causes and effect analysis diagram of roundabout traffic noise.

The biggest advantage of this diagram is that it is easy to read and understand the relationships between different parameters. The cause and effect diagram of optimized roundabouts of traffic noise represents the various factors affecting the optimized roundabouts. The main causes here are explained under different categories such as performance, Environmental, Instrumental Attributes, etc... which are further sub-divided into different causes affecting the optimized roundabouts. The causes and effect analysis diagram plays a very important role in the identification of attributes as it constitutes nearly all the factors affecting the roundabout traffic noise

6.4 Usefulness

- i. The identification of the attributes is very useful for a well-established dynamic condition near roundabout. With the use of the entire information data available, a lot of information and from which very precious knowledge is gained, this is beneficial for the one who is planning to start/control dynamic conditions near roundabouts in this area.

- ii. It is also helpful for an existing roundabout which is already established; in this case the sensitivity analysis can also be performed on a single or multiple numbers of attributes. This is considered very important as working and concentrating on one or two attributes rather than working on all of them.

6.5 Coding Scheme and Classification

After the identification of the attributes the next step is to assign codes to the attributes which is either a numerical value or an alphabet. This is done under the coding scheme which is very important as it gives all the detailed information about the attributes. The attributes are qualitative and quantitative in nature. The qualitative attributes are non-affirmatory and are of subjective or fuzzy type whereas the quantitative attributes are deterministic in nature. In this paper the quantitative attributes are given codes on an interval scale of 0-4, where 0 indicates that no information is available about the attribute and 4 indicates the best information and alternative present in the attribute.

6.6 Quantitative Attributes

Table 6.2 Coding of Average Traffic Volume for Roundabout Traffic Noise.

Average Traffic volume (units)	Code
Nil	0
0-100	1
100-200	2
200-500	3
Above 500	4

Coding of average traffic volume of roundabouts of traffic noise is shown in **Table 6.2**. These codes are used to specify an average traffic noise of the roundabout in the respective shell number 5, since it is allotted to it, as shown in **Table 6.7**. Here the roundabout under consideration has the average traffic volume 472 vehicles, which is given a code 3 as shown in **Table 6.8**.

Table 6.3 Coding Of Percentage Of Heavy Vehicle For Roundabout Traffic Noise.

Percentage of heavy vehicles (%)	Code
Nil	0
0-1 (%)	1
1-2 (%)	2
2-5 (%)	3
5(%) and above	4

Coding of percentage of heavy vehicles of roundabout traffic noise is shown in **Table 6.3**. These codes are used to specify the percentage of heavy vehicle of roundabout traffic noise in the respective shell number 8, since it is allotted to it, as shown in **Table 6.7**. Here the roundabout traffic noise under consideration has the percentage of heavy vehicle of 7.6%, which is given a code 4 as shown in **Table 6.8**.

Table 6.4 Coding Of Acceleration and Deceleration of Vehicles for Roundabout Traffic Noise

Acceleration/Deceleration (m/s²)	Code
Nil	0
0-1 (m/s ²)	1
1-2 (m/s ²)	2
2-5 (m/s ²)	3
5 above	4

Coding of acceleration/ deceleration of vehicles for roundabout traffic noise is shown **Table 6.4**. These codes are used to specify the acceleration/ deceleration of vehicles for roundabout traffic noise in the respective manner 11, since it is allotted to it, **Table 6.7**. Here the roundabout traffic noise under consideration has the average acceleration/ deceleration of vehicles of 2.45 m/s² which is given a code 3 as shown in **Table 6.8**.

6.7 Qualitative Attributes

Table 6.5 Coding Of Area Condition For Roundabout Traffic Noise.

Area Condition	Code
Not available	N
Urban Area	U
Sub Urban Area	SU
Rural Area	R

Coding of Area condition for roundabout traffic noise is shown in **Table 6.5**. These codes are used to specify the area condition for roundabout traffic in the respective shell number 3, since it is allotted to it, as shown in the **Table 6.7**. Here the roundabout traffic noise under consideration is urban in nature, which is given a code U as shown in **Table 6.8**.

Table 6.6 Coding Of In-Traffic Flow For Roundabout Traffic Noise.

In-Traffic flow	Code
Not available	N
Free flow	F
Interrupted flow	I

Coding of In-traffic flow for roundabout traffic noise is shown in **Table 6.6**. These codes are used to specify the In-traffic flow for roundabout traffic I the respective shell number 4, since it is allotted to it, as shown the **Table 6.7**. Here the roundabout traffic noise consideration is interrupted flow around roundabout, which is given a code I as shown in **Table 6.8**.

The above mentioned attributes tabulated in the form of 51-digit coding scheme for characterization of roundabout traffic noise.

Table 6.7 51-Digit Coding Scheme for Characterization of Roundabout Traffic Noise.

Design	1	2	3	4	
Physical	5	6	7	8	9
	10	11	12	13	14
	15				
Environmental	16	17	18		
Performance	19	20	21	22	23
	24	25	26	27	28
	29	30	31	32	33
	34				
Instrumental	35	36	37	38	
General	39	40	41	42	43
	44	45			
Control	46	47	48	49	50
	51				

Coding scheme of roundabout traffic noise “Thikri roundabout at Pataila city” traffic noise is shown in Table 6.8.

Table 6.8 Coding Scheme For Thikri Roundabout.

S/No	Attributes	Information	Code
1	Geometric Dimensions	-	0
2	Number of lanes	2 lane	2L
3	Traffic Area Condition	Urban Area	U
4	In- City flow	Interrupted flow	I
5	Traffic Volume	472 vehicles	3
6	Road Gradient	-	0
7	Average speed	28.75	4
8	Percentage of heavy vehicles	7.8%	4
9	Distance	-	0
10	Deceleration	1.95	2
11	Acceleration	2.45	3
12	Engine noise	-	0
13	Process Time	8 hr/day	4
14	Tyre Noise	-	0
15	Aerodynamic Noise	-	0
16	Ambient Temperature	30-40°	3
17	Humidity	15-33%	4
18	Wind Velocity	-	0
19	Microscopic Traffic Tool	-	0
20	Mean kinematic Pattern	-	0
21	Vehicle propagation	-	0
22	Noise Emission Law	-	0
23	Traffic Modelling	-	0
24	Traffic Noise Screening	-	0
25	Equivalent Sound Pressure Level	L_{eq}	EL
26	Statistical Description	L₁₀, L₉₀	SD
27	Energy based Description	L_{1,Aeq}	ED
28	Traffic Noise Index	-	0

29	Dynamic Area wide Road Traffic Noise Simulation	-	0
30	Calibration	-	0
31	GIS Based Integration Tool	-	0
32	Regression Analysis	-	0
33	Multi Regression Analysis	-	0
34	Validation	-	0
35	Repeatability	-	0
36	Precision	-	0
37	Repeatability	-	0
38	Precision	-	0
39	Noise Pollution	Disrupt the activity	NP
40	Sleep Disturbance	-	0
41	Hearing Impairment	-	0
42	Blood Pressure	-	0
43	Working Disturbance	-	0
44	Annoyance	-	0
45	Irritation	-	0
46	Traffic Light	-	0
47	Noise Barriers	Sound Wall, Sound Beam, Sound Barrier	NB
48	Foliage	-	0
49	Ground cover	-	0
50	Road pavement	-	0
51	Rows of Building	-	0

Here, coding scheme for all the 51 attributes are shown for roundabout traffic noise under consideration. All these attributes for "Thikri roundabout at Patiala city" traffic noise is collected from 7 days survey data of roundabout. Table 6.8 clearly indicates that the information supplied by this table is meager to the designer, traffic management, etc... it required to be more

elaborate. Here that most of the cells are having ‘0’ as code in them. The ‘0’ represents that the information relating to the particular cell is not available due to lack of experiment equipments, so all the information can not provided to the designer, traffic management etc. if all information is provided to designer, traffic management etc. it makes the data exhaustive.

Table 6.9 Representation of Coding Scheme for Roundabout Traffic Noise.

Design	0	2L	U	I	
Physical	3	0	4	4	0
	2	3	0	4	0
	0				
Environmental	3	4	0		
Performance	0	0	0	0	0
	0	EL	SD	ED	0
	0	0	0	0	0
	0				
Instrumental	0	0	0	0	
General	0	0	0	0	0
	0	0			
Control	0	NB	0	0	0
	0				

Moreover, the data has storage, retrieval and the identification procedure more precise and accurate. Representation of coding scheme for roundabout traffic noise “Thikri roundabout at Patiala city” can be done for all 51 attributes as shown in Table 6.9.

The alphabets used in the coding scheme for roundabout traffic noise has unique information in itself, like, here condition of Area where the traffic flow is urban represented by letter ‘U’. Similarly, it is interrupted flow represented by ‘I’. Rest of numerical codes are given on the basis of their relative importance highest cod i.e. ‘4’ to highly important attribute and lesser code like ‘3’ and ‘2’and ‘1’to very less important attributes and ‘0’ for totally absent attribute. This coding

scheme is also used for the visual comparison between two roundabouts up to certain extent. It allows faster comparison in various formats.

6.8 Identification Procedure

The identification of the best possible roundabout which is least effected from traffic noise can be done. The main emphasis is to identify a roundabout which is less in noise and effective for use in different location. So after consideration and evaluation of all the attributes of the different a particular area.

The identification procedure consists of three stages which are as follows:

- i. Elimination search
- ii. Evaluation using TOPSIS procedure
- iii. Ranking and Optimum Identification Procedure

6.8.1 Stage -1 Elimination Search Method

After the identification of 51 attributes, the attributes which are not important in the identification of roundabout traffic noise are eliminated and the attributes which have direct effect on the identification procedure are separated out. These attributes are called as pertinent attributes. According to their applicability some values are assigned to these attributes by obtaining information from the user and group of experts. These values are called as the threshold values. Hence the main focus is on the pertinent attributes by scanning the database of roundabout traffic noise.

6.8.2 Stage-2 Evaluation Using TOPSIS Method

A mini-database is formed which comprises of all the satisfying solutions. Now best solution has to be obtained out of all. These solutions are ranked in order of merit in the identification procedure.

Decision Matrix

All the information available from the database about these satisfying solutions is represented in the matrix form. This matrix is called as decision matrix '**D**'.

Each row of the matrix is allocated to the different roundabouts and each column to one attribute.

Therefore an element d_{ij} where,

d_{ij} = value of j^{th} attribute for i^{th} roundabouts. The order of the decision matrix is $m \times n$, where

m= number of shortlisted roundabouts.

n= number of pertinent attributes.

Normalized Specifications

The second step is construction of the normalized specification matrix, N, from the decision matrix, D. Normalization is used to bring the data within particular range or scale, and moreover it provides the dimensionless magnitudes. The phenomenon is used to calculate the normalized specification matrix. The normalized specification matrix has the magnitudes of all the attributes of the roundabout traffic noise on the common scale of 0 to 1. It is a sort of value, which indicates the standing of that particular attribute magnitude when compared to the whole range of the magnitudes for all candidate roundabout traffic noise.

An element n_{ij} of the normalized matrix N be calculated as:-

$$n_{ij} = \frac{d_{ij}}{\sqrt{\sum_{i=1}^m d_{ij}^2}} \tag{1}$$

Where, d_{ij} is an element of the decision matrix, D.

Relative Importance Matrix

The next step is to obtain information from the user or the group of experts by help of questionnaire on the relative importance of one attribute with respect to another. The information is sought in terms of a ratio. Information on all such pair-wise comparisons is stored in a matrix called as relative importance matrix, ‘A’, which is n x n matrix. Here a_{ij} contain the relative importance of i^{th} attribute over the j^{th} attribute i.e (w_i/w_j) where w_i, w_j are the weight vectors. The symmetric terms of the matrix are reciprocals of each other while the diagonal is unity. The information stored in a matrix is on pair-wise basis.

Now by using Eigen vector method the maximum Eigen value λ is obtained by the use of the equation shown below:

$$(A - \lambda I)W = 0 \tag{2}$$

$$\text{Where } W = \{w_1, w_2, w_3, \dots, w_n\}^T, \text{ where } \sum_{i=1}^n w_i = 1 \tag{3}$$

Weighted Normalized Specification Matrix

The weights obtained from the relative importance matrix have to be applied to the normalized specifications since all attributes have different importance while identification of the roundabout traffic noise for particular location. The matrix, which combines the relative weights and normalized specification of the candidates, is weighted normalized matrix, ‘V’. It gives the true comparable values of the attributes. This is obtained as follows:

$$V = \begin{bmatrix} w_1 n_{1,1} & w_2 n_{1,2} & \dots & w_n n_{1,n} \\ w_1 n_{2,1} & \ddots & \dots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ w_1 n_{m,1} & w_2 n_{m,2} & \dots & w_n n_{m,n} \end{bmatrix} = \begin{bmatrix} v_{1,1} & v_{1,2} & \dots & v_{1,n} \\ v_{2,1} & \ddots & \dots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ v_{m,1} & v_{m,2} & \dots & v_{m,n} \end{bmatrix} \quad (4)$$

6.8.3 Stage-3 Ranking and Optimum Identification Procedure

After, the elimination search the finite numbers of attributes which are sufficient to evaluate the roundabouts are shortlisted. On the basis of these attributes a number of roundabout candidates are developed and after that the ranking of the roundabout traffic noise is done mathematically by TOPSIS method or graphically (Line graph methods).

TOPSIS method

The weighted normalized matrix V is used to obtain the +ve and -ve benchmark roundabout, where the both benchmark roundabout are hypothetical roundabout, which are supposed to have best and worst possible attribute magnitudes. The TOPSIS method is based on the concept that the chosen option (optimum) has the shortest distance from the -ve benchmark roundabout (best possible roundabout) and be farthest from the +ve benchmark roundabout (worst possible roundabout). The measure ensures that the top ranked roundabout is closest to -ve benchmark roundabout and farthest from +ve benchmark roundabout. Here, calculations are made on separation measures from +ve and -ve benchmark roundabout, respectively, as S_i^* and S_i^-

The separation from the +ve benchmark roundabout is given by

$$S_i^* = \left[\sum_{j=1}^n (v_{ij} - v_j^*)^2 \right]^{\frac{1}{2}} \quad (i = 1, 2, \dots, m) \quad (5)$$

And separation from the -ve benchmark roundabout is given by

$$S_i^- = \left[\sum_{j=1}^n (v_{ij} - v_j^-)^2 \right]^{\frac{1}{2}} \quad (i = 1, 2, \dots, m) \quad (6)$$

Then the relative closeness to the -ve benchmark roundabout, C^* , which is a measure of the suitability of the roundabout for the chosen location on the basis of attributes considered, is calculated. A roundabout with the smallest C^* is preferable

$$C^* = S_i^- / (S_i^* + S_i^-) \quad (7)$$

Graphical method

After using the TOPSIS procedure for the ranking and identification of the roundabout traffic noise the graphical techniques i.e. Line graph are used for the ranking and thus final identification of the roundabout.

Line Graph

A graph is drawn for the weighted normalized matrix between the weighted normalized values and the attributes ($A_1, A_2, \dots, A_{n-1}, A_n$) as shown in Figure 6.2. These matrices represented graphically using line graph by plotting the magnitude of the attributes on the vertical axis and the attributes on the horizontal axis. The area under the curve in the line diagram for each roundabout is calculated to compare the traffic noise. A traffic noise with the least value of area is ranked highest and traffic noise with the highest value of area under the curve is ranked last. The area under the curve for the line diagram is calculated by the following formulae:

$$\text{Area under the curve } AV_i^L = \frac{[v_{i,1} + 2(v_{i,2} + \dots + v_{i,j} + \dots + v_{i,n-1}) + v_{i,n}]}{2} \quad (8)$$

Where $v_{i,j}$ = The weighted normalized value of j^{th} attribute in i^{th} roundabouts.

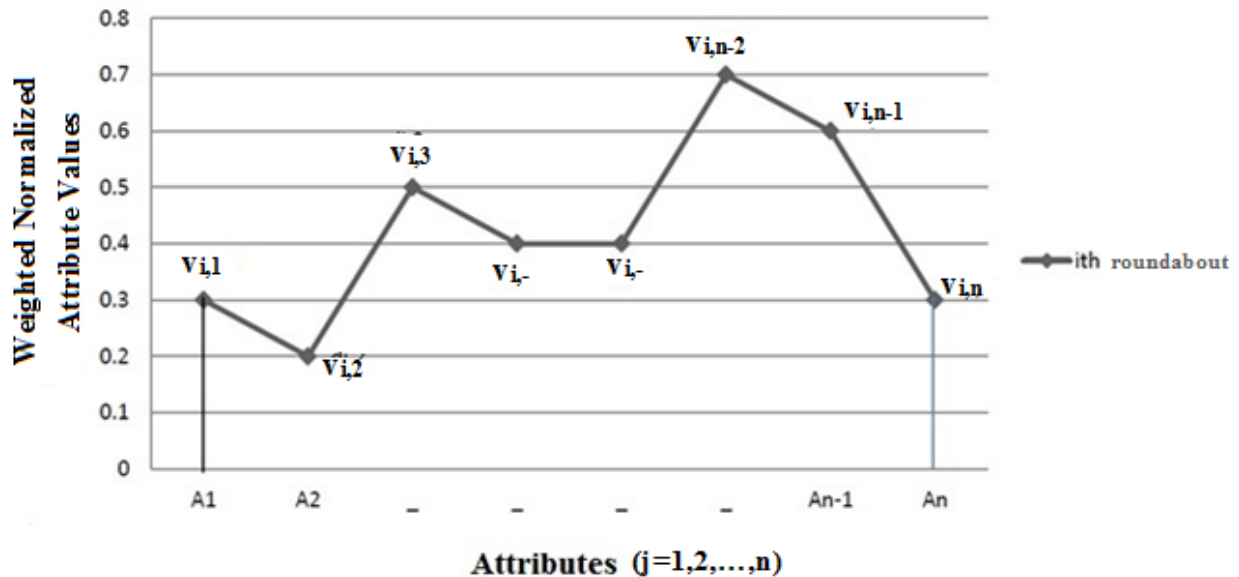


Figure 6. 2 Line Graph between attributes and weighted normalized values for i^{th} roundabout.

Similarly, area under the graph of weighted normalized specification of the i^{th} roundabout, i.e. AV_i^L using their respective elements. $v_{i,n-2}$

Ranking and Identification of the Roundabout Traffic Noise

Now specification matrix is there along with weighted specification matrices ready for all the candidate roundabouts along with the -ve benchmark roundabout. There is a need to measure and to compare the candidates with benchmark roundabout so that be ranked and identified.

Coefficient of Similarity (COS)

The evaluation and ranking of the roundabout is done by using the novel graphical method their similarity to -ve benchmark roundabout. Let the Coefficient of similarity (COS) be the ratio of area under the curve or enclosed by the polygon for the candidate to that of the benchmark roundabout. The value of COS be any -ve fraction ($0 \leq \text{COS} \leq 1$) and a measure of the closeness of candidate roundabout with the benchmark roundabout. The candidates with COS magnitude closer to unity are preferable, since it indicates the closeness to the -ve benchmark roundabout.

Coefficient of similarity (COS) based on decision matrix

Coefficient of similarity (COS) based on weighted normalized matrix

$$COS_i^B = AV_i / AV_B \quad (9)$$

AV_i for i^{th} roundabout and different methods, i.e., line graph, etc.

6.9 Illustrative example of identification procedure

Thus the COS calculations for all the n number of candidate roundabout and for graphical methods, viz., line graph methods using the weighted normalized specifications.

In above mentioned methodology and theory of the MADM-TOPSIS approach will be easily understood with the help of an illustrative example, three alternative roundabouts out of five under traffic noise which are available and are used for different location are selected. The names of the roundabouts at Patiala city are shown in the Table 6.10

Table 6.10 Alternative Roundabout Traffic Noise.

Sr.no	Name of roundabouts
1	Fountain Roundabout
2	Thikri Roundabout
3	YPS Roundabout

Suppose identify a roundabout for a Patiala traffic conditions. It is to be noted that here only roundabout which is a part of traffic is taken into account and is illustrated just to explain the methodology. The minimum requirement is as follows in Table 6.11.

Table 6.11 Minimum Requirements.

1. Traffic volume	More than 100
2. Percentage of heavy vehicles	At least 1.5%
3. Average speed	At least 10.1km/hrs
4. Acceleration	More than 1.00 m/s ²
5. Deceleration	More than 1.00 m/s ²

After analyzing the Patiala city three heavy volume traffic roundabouts as far as are identified and compared and ranked with the use of the MADM-TOPSIS methodology. According to their use for different application areas the best suited roundabout is identified. The values of the quantitative attributes of different roundabouts are shown in the Table 6.12.mentioned below i.e.

Table 6.12 Attributes for the Candidate Roundabout.

Sr. No.	Roundabouts	Traffic volume (units)	Percentage of Heavy Vehicles (%)	Average Traffic Speed (km/h)	Acceleration (m/s ²)	Deceleration (m/s ²)
1.	Fountain roundabout	443	5.6	18.1	1.94	3.37
2.	Thikri roundabout	472	7.6	28.75	2.45	1.95
3.	YPS roundabout	360	2.2	26.26	2	2

Now the procedure for the identification of the roundabout is as follows:

Step-1: Formation of the decision matrix ‘D’, in which the rows of the matrix are roundabouts and the columns are their attribute values.

$$D = \begin{bmatrix} 443 & 5.6 & 18.1 & 1.94 & 3.37 \\ 472 & 7.6 & 28.75 & 2.45 & 1.95 \\ 360 & 2.2 & 26.26 & 2 & 2 \end{bmatrix} \quad (10)$$

Step 2: Construction of relative important matrix from decision matrix. A group of experts was filled the questionnaire shown in *Appendix B* and the importance of one attribute over the other were determined. The following data are recorded (in ration form):

Relative importance of traffic volume over percentage of H.V	= 8/8.3	
=>d[1,2]		=0.963
Relative importance of traffic volume over average speed	=8/7	
=>d[1,3]		=1.143
Relative importance of traffic volume over acceleration	= 8/6.3	
=>d[1,4]		=1.269
Relative importance of traffic volume over deceleration	=8/5.1	
=>d[1,5]		=1.569
Relative importance of percentage of H.V over average speed	=8.3/7	
=>d[2,3]		=1.985
Relative importance of percentage of H.V over acceleration	=8.3/6.3	
=>d[2,4]		=1.318
Relative importance of percentage of H.V over deceleration	= 8.3/5.1	
=>d[2,5]		=1.627
Relative importance of average speed over acceleration	=7/6.3	
=>d[3,4]		=1.111
Relative importance of average speed over deceleration	=7/5.1	
=>d[3,5]		=1.372
Relative importance of acceleration over deceleration	=6.3/5.1	
=>d[4,5]		=1.235

Since $d[i,j] = 1/d[i,j]$ and all $d[i,i] = 1$, the relative importance matrix which is formed from the decision matrix is shown here.

$$A = \begin{bmatrix} 1 & 8/8.3 & 8/7 & 8/6.3 & 8/5.1 \\ 8.3/8 & 1 & 8.3/7 & 8.3/6.3 & 8.3/5.1 \\ 7/8 & 7/8.3 & 1 & 7/6.3 & 7/5.1 \\ 6.3/8 & 6.3/8.3 & 6.3/7 & 1 & 6.3/5.1 \\ 5.1/8 & 5.1/8.3 & 5.1/7 & 5.1/6.3 & 1 \end{bmatrix} \quad (11)$$

Step 3: Now the maximum Eigen value of the relative importance matrix R is to be found out.

Therefore $(A - \lambda_{\max}I)$ is equal to

$$(A - \lambda_{\max}I) = \begin{bmatrix} 1 - \lambda & 0.963 & 1.143 & 1.269 & 1.569 \\ 1.037 & 1 - \lambda & 1.985 & 1.318 & 1.627 \\ 0.875 & 0.843 & 1 - \lambda & 1.111 & 1.372 \\ 0.787 & 0.759 & 0.900 & 1 - \lambda & 1.235 \\ 0.650 & 0.626 & 0.7429 & 0.8254 & 1 - \lambda \end{bmatrix} \quad (12)$$

Also, $(A - \lambda_{\max}I) = 0$, On solving the above matrix have $\lambda_{\max} = 5.015 \approx 5$

Therefore, Now

$$(A - \lambda_{\max}I) = \begin{bmatrix} -4 & 0.963 & 1.143 & 1.269 & 1.569 \\ 1.037 & -4 & 1.985 & 1.318 & 1.627 \\ 0.875 & 0.843 & -4 & 1.111 & 1.372 \\ 0.787 & 0.759 & 0.900 & -4 & 1.235 \\ 0.650 & 0.626 & 0.7429 & 0.8254 & -4 \end{bmatrix} \quad (13)$$

Step 4: In this step the weights for each attributes using the Eigen vector associated with the maximum eigen value are calculated. This can be represented by the equation,

$$(A - \lambda_{\max}I)w = 0$$

$$\begin{bmatrix} -4 & 0.963 & 1.143 & 1.269 & 1.569 \\ 1.037 & -4 & 1.985 & 1.318 & 1.627 \\ 0.875 & 0.843 & -4 & 1.111 & 1.372 \\ 0.787 & 0.759 & 0.900 & -4 & 1.235 \\ 0.650 & 0.626 & 0.7429 & 0.8254 & -4 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{bmatrix} = 0 \quad (14)$$

Also we know that,

$$w_1 + w_2 + w_3 + w_4 + w_5 = 1 \quad (15)$$

On solving this above matrix have,

$$w_1 = 0.2305, w_2 = 0.2392, w_3 = 0.2017, w_4 = 0.1816, w_5 = 0.1470$$

Step 5: In this step the normalized specification matrix is calculated which helps to provide the dimensionless elements of the matrix. It is denoted by ‘N’.

$$n_{ij} = \frac{d_{ij}}{\sqrt{\sum_{i=1}^m d_{ij}^2}} \quad (16)$$

Therefore, normalized specification matrix N is equal to

$$N = \begin{bmatrix} 0.598 & 0.577 & 0.422 & 0.523 & 0.769 \\ 0.637 & 0.784 & 0.669 & 0.660 & 0.445 \\ 0.486 & 0.226 & 0.612 & 0.539 & 0.457 \end{bmatrix} \quad (17)$$

Step 6: In this step the weighted specification matrix is calculated. It is denoted by ‘V’.

$$V = \begin{bmatrix} 0.1378 & 0.1380 & 0.085 & 0.0949 & 0.1130 \\ 0.1468 & 0.1875 & 0.1331 & 0.1198 & 0.0684 \\ 0.1120 & 0.054 & 0.1234 & 0.0978 & 0.06717 \end{bmatrix} \quad (18)$$

The weighted normalized matrix involves both the attribute values and their relative importance to each other. So this matrix provides a very good basis for the comparison of the attributes with each other and with the benchmark roundabout.

TOPSIS method for ranking:

The weight normalized attributes for the positive and negative benchmark roundabouts are obtained which are as follow:

$$V^* = (0.1468, 0.1875, 0.1331, 0.1198, 0.113)$$

$$V^- = (0.112, 0.054, 0.085, 0.0949, 0.0671)$$

Now from the formulas mentioned in the explanatory part of the TOPSIS method and relative closeness to the ideal solution can be calculated and the values for the same are as follow:

The separation from the +ve benchmark roundabout is given by

$$S_i^* = \left[\sum_{j=1}^n (v_{ij} - v_j^*)^2 \right]^{\frac{1}{2}} \quad (i = 1, 2, \dots, m) \quad (19)$$

And separation from the –ve benchmark roundabout is given by

$$S_i^- = \left[\sum_{j=1}^n (v_{ij} - v_1^-)^2 \right]^{\frac{1}{2}} \quad (i = 1, 2, \dots, m) \quad (20)$$

$$\text{Relative Closeness} \quad (21)$$

$$C^* = S_i^- / (S_i^* + S_i^-)$$

$$S_1^* = 0.073 \quad S_1^- = 0.099 \quad C_1^* = 0.5755$$

$$S_2^* = 0.0476 \quad S_2^- = 0.148 \quad C_2^* = 0.7566$$

$$S_3^* = 0.1473 \quad S_3^- = 0.0385 \quad C_3^* = 0.2072$$

As the C^* value of the third roundabout traffic noise is the lowest therefore it is the best roundabout in Patiala city. Also the C^* value of the second roundabout traffic noise is the highest, so it is the worst roundabout available amongst the entire three roundabouts.

Table 6.13 Evaluation and Ranking Of Three Alternatives Roundabout.

Sr.No.	Name of the roundabout	TOPSIS C^*	Rank
1.	Fountain roundabout	0.5755	2 nd
2.	Thikri Roundabout	0.7566	3 rd
3.	YPS roundabout	0.2072	1 st

As shown in the above Table 6.13 YPS roundabout is the lowest ranked traffic noise amongst all the three existing roundabouts on the basis of TOPSIS procedure and is hence the best option for the traffic management.

Graphical technique:

After using the TOPSIS procedure for the ranking and identification of the roundabout under traffic noise with graphical technique i.e. line graph is used for the ranking and thus final identification of the roundabout.

Line Graph

A graph is drawn for the weighted normalized matrix between the weighted normalized values and the attributes for different roundabouts under traffic noise as shown in figure 6.3. The area under the curve in the line diagram for each roundabout is calculated to compare the traffic noise. The roundabout with the least value of area is ranked highest and the roundabout with the

highest value of area under the curve is ranked last. The area under the curve for the line diagram is calculated by the following formulae:

$$\text{Area under the curve } AV_i^L = \frac{[d_{i,1} + 2(d_{i,2} + \dots + d_{i,j} \dots + d_{i,n-1}) + d_{i,n}]}{2} \quad (22)$$

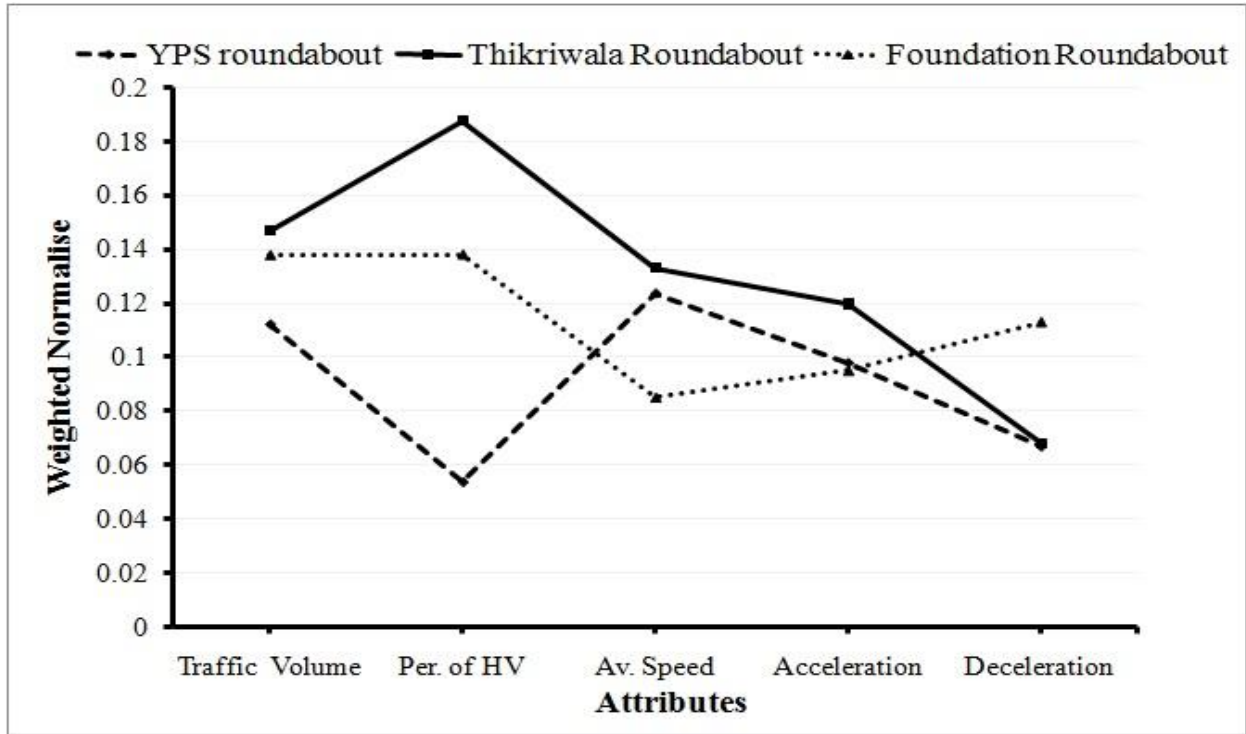


Figure 6. 3 Line graph of different roundabout.

Where $d_{i,j}$ = The weighted normalized value of j^{th} attribute in i^{th} roundabout.

Table 6.14 Ranking of Roundabout Based On the Area under The Curve In Line Diagram.

Sr.No.	Name of the roundabout	Area Under the Curve	Rank
1.	Fountain roundabout	0.685 2	2 nd
2.	Thikri Roundabout	0.847 6	3 rd
3.	YPS roundabout	0.563 8	1 st

As shown in above Table 6.14. The YPS roundabout is the lowest ranked roundabout amongst all the three alternative roundabouts and is hence the best option for the Traffic management

SWOT Analysis

The SWOT analysis is done for the reducing the traffic noise under dynamic condition near roundabout in urban area. As all know that there is a lot of traffic in our country and less use of traffic noise techniques and an opportunity for designer, traffic management etc. here the strength of the traffic noise, its weakness, the various opportunities for control the traffic noise in urban area, and the threats from surroundings are presented below. There is a lot of scope for controlling the traffic condition for noise. In the SWOT analysis it is observed that there is lot of scope of reducing the traffic noise by controlling the traffic near roundabout. If the traffic condition of the roundabout is very less which can be used for design of other roundabout. Designer also would know that what attributes are useful or not useful for design the other roundabout.

Considering SWOT analysis and by the use of TOPSIS procedure and line graph representation the best and the worst roundabout traffic noise possible are identified so as to make it easier for traffic management or designer to choose the design which is closest to the best possible design. The identification of the attributes is done in an exhaustive way which includes all the components of the roundabout. It is done by applying the coding scheme to all the attributes so that even the smallest of the information and parameters affecting the roundabout are presented. This is very useful as it allows even the traffic controller to control the traffic flow according to best possible roundabout. The SWOT analysis of the traffic noise under dynamic condition near roundabout is shown in figure 6.4.

Strength

1. Action plans aiming to reduce the speed of the vehicles near roundabout.
2. Campaigns promotion the reduction of the traffic density(in particular of heavy vehicles)
3. Noise maps
4. Traffic management very often ban heavy vehicles in certain roundabout in day time

Weaknesses

1. No analysis is available for traffic noise.
2. In difference towards noise by Govt.
3. Land availability.

Opportunities

1. Construction of new ring roads, by-pass road, fly over's, etc.
2. Improving the road connection.
3. Construction of noise barriers.

Threats

1. Redesign the roundabouts due to increases the volume of traffic.
2. Relocation of existing area near roundabout is risky.
3. Proximity of pedestrian.

Figure 6.4 SWOT Analysis for the reducing of traffic noise under dynamic condition near roundabout.

7 RESULTS AND DISCUSSION

In this study identification and evaluation of roundabout traffic noise under dynamic conditions is performed using MADM approach. Initially attribute knowledgebase methodology is implemented for data collection and selection of attributes. Then MADM methodology is applied for identity of roundabout traffic noise using experimental data. MADM approach is mainly hypothetical approach which is validated by experimental investigation. Important observations obtained by attribute knowledgebase methodology are:

- Through interactions with the software of information base Matrix, anyone can simply any numbers of papers of his choice of particular attributes from Matrix.
- Information base Matrix plainly highlights, which attribute has not been studied and which has been studied or in what depth it is studied.
- It is necessary to update the information base Matrix time to time as per the requirements of the different designers/ researchers..... etc. So that changes in the trends of the research are easily monitored. The owner of this Matrix software, having a great responsibility to update this Matrix software periodically to make this as a good source of information based knowledge as a library.

Main procedural steps and results obtained using MADM approach is mentioned below step by step:

1. Formation of the decision matrix 'D' which is represented by equation 11.
2. Construction of relative important matrix from decision matrix is represented by equation 12.
3. Eigen value of the relative importance matrix R is calculated.
4. Weights for each attributes using the Eigen vector associated with the maximum Eigen value are calculated in equation 14.
5. Normalized specification matrix is calculated in equation 18, which helps to provide the dimensionless elements of the matrix. It is denoted by 'N'.

6. The weighted specification matrix is calculated in equation 19. It is denoted by 'V'.
7. TOPSIS method is used to ranking for identification of roundabout.
8. Graphical method is used to ranking for identification of roundabout.
9. SWOT analysis for the reducing of traffic noise under dynamic condition near roundabout is done as shown figure 6.4.

Then, the validation of MADM approach is done by experimental investigation shown in Table 7.1

Table 7.1 Evaluation and ranking of the roundabout traffic noise

Sr. No.	Name of the roundabout	TOPSIS Closeness	Rank	Area Under the Curve	Rank	Equivalent Sound Pressure Level dB (A)	Rank
1.	Foundation roundabout	0.575 5	2 nd	0.685 2	2 nd	78.2	2 nd
2.	Thikri Roundabout	0.756 6	3 rd	0.847 6	3 rd	80.4	3 rd
3.	YPS roundabout	0.207 2	1 st	0.563 8	1 st	75	1 st

Now depending on the comparison of the results obtained based on the three techniques namely TOPSIS relative closeness, graphical technique and experimental analysis, it is summarized that the results obtained by all three techniques provide similar results.

MADM is important to conceptual planning of city and different roundabouts design has evaluated and identified the roundabout.

8 CONCLUSION AND FUTURE SCOPE

A novel approach of literature review of traffic noise is proposed which is very useful for the researchers, designers, and traffic managements. In this information matrix is formed from the information available in the different publication data.

- The amount of research work done on each individual attribute also clearly calculated from the information matrix, with the help of which the gap analysis is carried out efficiently and effectively.
- From the information matrix paper related to the particular attributes are found out and get the information about those particular attributes.
- With this attribute based literature review the knowledge related to performance, design, environmental is easily obtained from the information matrix.
- This information matrix is a permanent source of knowledge and need to be updated so that anyone takes more benefit from this database.

Multi attribute based identification procedure is developed for the roundabout traffic noise. There are number of attributes which are collected those are effect the identification of the roundabout traffic noise.

- Instead of conventional way here considered the MADM approach to identification of roundabout for traffic management, designer, etc.
- Experiment has been designed to validate the result of analytical model.
- On the basis of these attributes user classify the traffic condition more precisely for the identification.
- Information develops from the quantification of attributes is useful to the traffic management. In quantification of attributes traffic management get the idea about the relative values of attribute an alternative which helps in the control the traffic by divergence.

- Information develops from the quantification of attributes is useful to the designer. Similar to the traffic management, designer also gets the values of different design alternative values which help in the design improvement.
- Information develops from the quantification of attributes is useful to the user in the identification of roundabout. As the values of different attributes are given, user selects the system as per his requirement.

Future Scope

- A permanent database can be developed in the form of information matrix. Software can be developed to make it available on the internet. This database is flexible with the addition of any new literature paper
- This identification approach can be applied on the fly over's noise problem, for the identification of suitable fly over for a given location.

REFERENCE

- [1] **Steele, C., (2001)**, “A critical review of some traffic noise prediction models”, *Applied Acoustic*, 62,271-287.
- [2] **Uris, A., and Cervera, F., (2001)**, “Community response to road traffic noise in the littoral region near Valencia (Spain)”, *International Journal of Environmental Health Research*, 11, 349-355.
- [3] **Rylander, R., and Bjorkman, M., (2002)**, “Road traffic noise influenced by road bumps”, *Journal of sound and vibration*, 250, 157-159.
- [4] **Li, B., Tao, S., Dawson, D.W., Cao, J., and Lam, K., (2002)**, “A GIS based road traffic noise prediction model”, *Applied Acoustics*, 63, 679-691.
- [5] **Calixto, A., Diniz, F.B. and Zannin P.H.T., (2003)**, “The statistical modeling of road traffic noise in an urban setting”, *Cities*, 20 (1), 23-29.
- [6] **Brown, A.L. and Macdonald, G.T., (2003)**, “From environmental impact assessment to environmental design and planning, *Australian Journal of Environmental Management*”, 2, 65-77.
- [7] **Pandya, G.h., (2003)**, “Assessment of the traffic noise and its impact on the community”, *International Journal of Environmental studies*,60(6),595-602.
- [8] **Gaja, E., Gimenez, A., Sancho, S., and Reig, A., (2003)**, “Sampling techniques for the estimation of the annual equivalent noise level under urban traffic conditions”, *Applied Acoustics*, 64, 43-53.
- [9] **Bhaskar, A., Chung, E., Kuwahara, M., and Oshino, Y., (2004)**, “Integration of road traffic noise model (ASJ) and traffic simulation (AVENUE) for built-up area”, *Tenth International Conference on Urban Transport and the Environment in the 21st Century, URBAN TRANSPORT X*, 16, 783-794.
- [10] **Tang, S.K., and Tong, K.K., (2004)**, “Estimating traffic noise for inclined roads with freely flowing traffic”, *Applied Acoustics*, 65,171-181.
- [11] **Coensel, B.D., Muer, T.D., Yperman, I., and Botteldooren, D., (2005)** “The Influence of traffic flow dynamics on urban soundscapes”, *Applied Acoustics*, 66, 175-194.
- [12] **Gündoğdu, O., Gökdağ, M., and Yüksel, F., (2005)**, “A traffic noise prediction method based on vehicle composition using genetic algorithms”, *Applied Acoustics*, 66, 799-809.

- [13] Raichel, D.R., (2006), “The science and application of acoustics”, Springer, 2, 13-14.
- [14] Can, A., Leclercq, L., and Lelong, J., (2008), “Dynamic estimation of urban traffic noise: Influence of traffic and noise source representations”, Applied Acoustics, 69, 858-867.
- [15] Can, A., Leclercq, L., Lelong, J., and Defrance, J., (2008), “Capturing urban traffic noise dynamic through relevant description”, Applied Acoustics, 69, 1270-1280.
- [16] Nigam, S.P., (2008), “Introduction to noise”, Noise control program, Thapar University, Patiala.
- [17] Nigam, S.P., (2008), “Vehicular traffic noise and its characterization”, National Conference of Mechanical Engineering at Thapar University, Patiala.
- [18] Rajakumara, H.N., and Mahalinge Gowda, R.M., (2009), “Road traffic noise prediction model under interrupted traffic flow condition”, Environ Model Assess, 14, 251-257.
- [19] Chevallier, E., Leclercq, L., Lelong, J., and Chatagnon, R., (2009), “Dynamic noise modeling at roundabouts”, Applied Acoustics, 70, 761-770.
- [20] Can, A., Leclercq, L., Lelong, J., and Defrance, J., (2009) “Accounting for traffic dynamics improve noise assessment: Experimental evidence”, Applied Acoustic, 70, 821-829.
- [21] Chevallier, E., Can, A., Nadji, M., and Leclercq, L., (2009), “Improving noise assessment at intersections by modeling traffic dynamics”, Transportation Research Part D, 14, 100-110.
- [22] Mishra, R. K., Parida, M., and Rangnekar, S., (2010), “Evaluation and analysis of traffic noise along bus rapid transit system corridor”, Int. J. Environ. Sci. Tech., 7 (4), 737-750.
- [23] The Hindu, (1997). Survey on environment-97. A report published by The Hindu (National News Paper), New Delhi, India.

MADM REFERENCES:

- [24] Bhangale, P., Agrawal, V., and Saha, S., (2004), “Attribute based specification, comparison and selection of a robot”, Mechanism and Machine Theory, 39, 1345-1366.
- [25] Babu, K.S., Raju, N.V., Reddy, M.S., and Rao, D.N., (2006), “The material selection for typical wind turbine blades Using a MADM approach & analysis of blades”, MCDM, 19-23.

- [26]Kumar, A., and Agrawal, V.P., (2009), “Attribute based specification, comparison and selection electroplating system using MADM approach”, Expert Systems with Applications,36, 10815-10827.
- [27] Kiran, C.P., Clement, V., and Agrawal, V.P., (2011), “Coding, evaluation and optimal selection of a mechatronic system”, Expert Systems with Applications, 38, 9704-9712.

WEB REFERENCES:

- [28]Acoustics and Your Environment: The Basis of Sound and Highway Traffic Noise, <http://www.youtube.com/watch?v=-9Y8n0IBC7Q> (Viewed on 13 Nov2012)
- [29] City University of Hong Kong, <http://personal.cityu.edu.hk/~bsapplec/sound.htm> (Viewed on 21 Nov 2012)
- [30]Harmonic science, http://library.thinkquest.org/06aug/02101/physics_soundwaves.htm (Viewed on 22 Nov 2012)
- [31] Paphysicalscience, <http://paphysicalscience.wikispaces.com/Waves> (Viewed on 30 Nov 2012)

APPENDIX-A

Table 1. Traffic noise data recorded from three roundabouts in Patiala city, Punjab, India.

	Car	SUV	H.V.	Acc.	Deacc.	Three wheelers	Two wheelers	L _{eq}	Speed	TIME
Day 1 (9/4)	89	20	12	3.43	4.41	72	165	81.1	13.9	9 to 9.15
Fountain roundabout	107	14	11	3.18	4.18	71	200	78.4	17.2	10 to 10.15
	140	10	9	3.02	3.95	68	158	77.0	14.0	11 to 11.15
	106	18	9	3.18	3.97	73	186	74.5	17.6	2 to 2.15
	67	16	7	3.20	4.09	68	95	75.6	18.7	3 to 3.15
	68	28	5	3.14	3.83	68	92	78.1	14.3	4 to 4.15
Day 2 (10/4)	67	14	14	3.37	3.99	67	100	81.2	22.4	9 to 9.15
	71	18	18	3.17	4.17	71	104	76.1	24.5	10 to 10.15
	257	53	21	1.99	2.98	31	185	75.0	25.1	11 to 11.15
	213	58	24	1.95	2.80	16	277	79.1	23.4	12 to 12.15
	189	41	39	1.90	2.92	28	226	78.2	24.55	2 to 2.15
	189	35	48	1.91	2.93	23	184	75.9	23.55	3 to 3.15
	186	37	30	1.90	3.06	31	188	75.7	27.45	4 to 4.15
	147	51	31	1.79	2.93	31	170	75.1	26.44	5 to 5.15
Day 3 (11/4)	117	18	19	1.90	3.48	27	271	79.1	20.6	9 to 9.15
	97	29	16	0.57	2.81	29	228	80.5	20.44	10 to 10.15
	133	41	38	0.68	2.71	31	115	82.1	19.55	11 to 11.15
	98	28	41	0.99	2.82	50	107	82.4	18.9	12 to 12.15
	197	49	43	1.81	3.03	62	141	78.3	17.9	2 to 2.15
	247	35	47	1.91	2.93	55	171	77.7	18.8	3 to 3.15
	261	51	51	1.90	3.06	54	211	77.8	19.7	4 to 4.15

	168	46	38	1.79	2.93	31	130	79.5	20.3	5 to 5.15
Day 4 (12/4)	117	18	8	1.63	3.73	27	245	77.6	13.96	9 to 9.15
	135	27	12	1.47	3.61	29	298	77.2	14.6	10 to 10.15
	101	30	16	1.58	3.84	31	198	80.3	15.44	11 to 11.15
	135	77	43	1.56	3.61	50	180	79.6	14.66	12 to 12.15
	149	35	45	1.36	3.95	62	133	80.9	16.5	2 to 2.15
	135	31	54	1.56	4.50	55	171	75.0	14.33	3 to 3.15
	148	32	34	1.47	4.18	54	198	80.3	15.66	4 to 4.15
	223	49	56	1.58	3.39	31	238	81.2	15.67	5 to 5.15
Day 5 (15/4)	75	8	3	1.81	2.49	24	131	74.5	16.4	9 to 9.15
	45	14	3	1.67	3.19	17	99	76.8	19.5	10 to 10.15
	189	50	18	1.58	3.07	85	216	79.6	17.5	11 to 11.15
	207	48	8	1.47	3.06	77	222	79.5	12.55	12 to 12.15
	217	50	12	1.35	3.16	59	317	77.6	12	2 to 2.15
	222	51	32	1.47	3.02	43	296	79.5	13.4	3 to 3.15
	249	54	21	1.70	2.71	65	224	79.8	14.5	4 to 4.15
	235	43	17	1.81	2.82	88	213	78.7	16.5	5 to 5.15
Avg.	153	35	25	1.94	3.37	49	186	78.2	18.1	Avg
Day 6 (16/4)	147	8	4	1.91	2.93	19	110	74.5	24.20	9 to 9.15
Thikaari	89	19	8	1.95	0.28	27	190	75.2	24.40	10 to 10.15
	129	26	12	2.01	0.35	31	185	75.8	26.60	11 to 11.15
	122	27	17	1.92	0.46	26	209	78.8	26.20	12 to 12.15
	169	19	12	1.89	0.35	22	164	77.0	27.30	2 to 2.15
	98	29	16	1.90	0.57	27	107	79.6	26.40	3 to 3.15
	121	20	14	2.01	0.24	17	147	76.1	25.50	4 to 4.15
	95	26	9	1.81	0.44	23	145	77.4	27.60	5 to 5.15
Day 7 (18/4)	163	21	43	1.33	3.16	59	195	82.1	29.40	9 to 9.15

	171	22	53	1.70	3.29	64	223	83.0	30.10	10 to 10.15
	134	28	62	1.81	3.17	60	203	82.0	29.80	11 to 11.15
	115	33	36	1.47	3.14	62	203	81.1	27.60	12 to 12.15
	150	39	39	2.01	2.93	63	195	79.8	28.40	2 to 2.15
	153	35	50	1.90	2.71	71	205	80.2	29.10	3 to 3.15
	156	58	56	1.79	2.80	64	167	80.5	29.20	4 to 4.15
	204	35	61	1.36	3.38	66	174	80.2	28.90	5 to 5.15
Day 8 (19/4)	227	51	29	1.95	3.16	82	344	78.4	24.30	9 to 9.15
	273	51	36	2.01	3.29	73	387	81.5	29.20	10 to 10.15
	162	49	39	1.91	3.17	87	318	81.1	28.90	11 to 11.15
	206	44	43	3.49	0.24	82	291	84.6	32.40	12 to 12.15
	170	37	42	3.17	0.44	57	191	79.2	27.90	2 to 2.15
	193	51	40	2.49	0.24	78	228	80.8	27.60	3 to 3.15
	177	38	28	2.81	0.46	48	156	81.0	30.10	4 to 4.15
	253	49	34	3.17	0.46	73	263	84.2	33.40	5 to 5.15
Day 9 (22/4)	133	40	53	2.81	3.45	62	235	81.0	30.20	9 to 9.15
	150	32	59	2.49	3.61	53	186	82.8	30.10	10 to 10.15
	124	27	55	2.71	3.29	55	189	81.3	32.10	11 to 11.15
	128	29	44	2.81	3.49	51	230	84.2	33.10	12 to 12.15
	130	39	51	2.81	3.50	46	138	77.8	31.20	2 to 2.15
	126	66	62	2.93	3.48	59	149	82.1	26.40	3 to 3.15
	119	31	62	3.03	3.27	41	170	80.0	31.20	4 to 4.15
	113	29	47	2.82	3.02	41	141	80.1	29.80	5 to 5.15
Day 10 (23/4)	117	23	9	3.28	1.81	10	192	77.4	29.70	9 to 9.15
	223	21	8	3.26	1.57	13	170	77.3	25.40	10 to 10.15
	124	27	13	3.38	1.35	29	205	77.8	25.30	11 to 11.15
	143	38	61	3.28	1.80	45	170	84.3	25.60	12 to 12.15
	147	33	41	3.15	1.58	37	206	82.8	33.40	2 to 2.15

	122	28	73	3.14	1.68	51	189	85.1	28.90	3 to 3.15
	115	33	17	2.71	1.47	24	131	81.2	33.20	4 to 4.15
	105	27	16	3.03	1.91	26	153	81.9	29.60	5 to 5.15
Avg.	153	34	36	2.45	1.95	49	198	80.4	28.75	Avg.
Day 11 (24/4)	159	32	18	3.50	2.68	11	186	79.5	25.81	9 to 9.15
YPS	130	34	12	2.60	2.13	20	160	75.3	24.60	10 to 10.15
	111	28	11	3.15	2.61	21	223	77.9	25.60	11 to 11.15
	107	36	13	3.45	2.82	31	239	80.3	28.90	12 to 12.15
	121	29	17	2.74	2.13	21	227	76.2	26.50	2 to 2.15
	121	35	9	2.94	2.51	26	226	78.5	28.70	3 to 3.15
	114	20	15	2.91	2.23	21	191	75.3	25.40	4 to 4.15
	135	24	11	3.13	2.36	31	182	76.7	26.20	5 to 5.15
Day 12 (25/4)	135	43	1	1.25	3.97	19	198	73.2	22.30	9 to 9.15
	124	37	4	1.45	3.98	11	203	73.0	23.30	10 to 10.15
	106	24	2	1.47	3.15	8	191	72.3	22.10	11 to 11.15
	163	22	4	1.36	3.76	16	235	73.0	23.30	12 to 12.15
	121	28	3	1.58	4.05	7	184	76.4	25.60	2 to 2.15
	120	31	3	1.47	3.61	9	147	74.7	24.30	3 to 3.15
	112	32	3	1.58	3.83	9	150	73.0	23.60	4 to 4.15
	111	35	4	1.57	3.38	12	132	73.7	24.60	5 to 5.15
Day 13 (26 /4)	126	34	6	0.11	2.81	24	177	75.0	20.90	9 to 9.15
	103	23	7	0.14	2.71	15	186	74.5	24.60	10 to 10.15
	91	18	6	0.33	2.81	18	122	75.8	24.40	11 to 11.15
	96	22	4	0.13	2.65	21	151	75.3	24.50	12 to 12.15
	95	29	8	0.11	3.02	18	150	76.4	24.30	2 to 2.15
	81	30	8	0.19	3.16	19	117	77.4	27.60	3 to 3.15
	79	23	6	0.21	2.16	13	137	73.5	23.70	4 to 4.15

	107	23	5	0.14	2.38	17	117	74.3	24.60	5 to 5.15
Day 14 (30/4)	101	22	11	1.35	0.12	14	164	74.4	32.44	9 to 9.15
	112	28	8	1.81	0.11	9	147	76.6	33.10	10 to 10.15
	115	21	10	1.47	0.12	17	140	74.1	31.80	11 to 11.15
	99	22	10	1.57	0.11	22	161	74.5	31.20	12 to 12.15
	82	26	6	1.13	0.13	15	125	72.9	29.70	2 to 2.15
	119	38	8	1.10	0.15	14	121	73.0	22.20	3 to 3.15
	99	18	2	1.00	0.44	14	93	71.9	19.70	4 to 4.15
	73	15	2	1.00	0.11	11	95	70.9	20.10	5 to 5.15
Day 15 (1/5)	123	27	10	3.50	1.72	30	195	75.6	26.40	9 to 9.15
	139	20	10	2.60	1.79	28	220	76.5	27.40	10 to 10.15
	101	36	8	3.15	1.60	40	236	75.4	26.40	11 to 11.15
	141	36	16	3.45	1.61	39	267	76.3	27.50	12 to 12.15
	165	48	20	1.25	2.68	26	215	76.3	28.70	2 to 2.15
	140	30	10	1.75	1.72	18	203	75.1	26.50	3 to 3.15
	198	34	16	1.81	1.58	16	215	76.0	28.70	4 to 4.15
Avg	149	40	5	2	2	13	234	75.3	26.26	Avg

Questionnaire

Ques : To What extent ,do you feel speed of the vehicles effect the noise pollution?

Ans : Low High

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

Ques: To what extent, do you feel population of vehicles effect the noise pollution?

Ans: Low High

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

Ques: To what extent, do you feel percentage of heavy vehicles effect the noise pollution?

Ans: Low High

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

Ques: To what extent, do you feel acceleration of vehicles effect the noise pollution?

Ans: Low High

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

Ques: To what extent, do you feel deceleration of vehicles effect the noise pollution?

Ans: Low High

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---