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Assessment of Noise Pollution in the City of Chennai

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Abstract

Noise is an unpleasant sound, a by-product of human activities which are detrimental to the quality of human life. Road traffic noise generated by vehicle movements has proven to be the predominant source of noise pollution in the urban environment. Noise pollution increases progressively day after day, year after year due to urbanization, industrialization and motorization in urban areas. The study aims to discuss in detail by evaluating the parameters and indicators which cause noise pollution and also to assess, analyze the noise descriptors and to prepare noise maps in the study area Vadapalani - Arcot Road Signal, Chennai district, Tamilnadu State, India. Noise measurements were measured for 30 minutes for each site location from 04th March to 12th March 2019. Road traffic noise measurements were calculated in days, hours, periods, of two large intersections of state highways, arteries including 40 different locations along the roads. The evaluations were carried out using the digital sound level meter and interpreting as a noise mapping using the QGIS open software platform. The noise map was derived using the measured equivalent energy noise level values. The study summarizes the current noise level which exceeds the limits prescribed by the Central Pollution Control Board. Finally, the paper will conclude solutions and suggestions as a remedy for the noise pollution which must be implemented throughout the development of the city. Several measures have to be practiced and awareness of the public to be promoted to provoke them to join hands to improve Chennai city and make it more sustainable and to provide comfortable living for the urban dwellers, which has to be free from noise pollution.

Keywords: Noise Mapping, Road Traffic Noise, QGIS, Chennai, L_{Aeq}, Noise Descriptors

1. Introduction

The population explosion in recent decades in many cities has resulted in accommodating urban and suburban areas in large numbers, which gradually showed the density increase in the urban areas which plays a vital role in the cause of noise pollution. Noise pollution is termed as unwanted or excessive sound which causes detrimental effects on human health and environmental quality (González, 2014; Griffiths & Langdon, 1968; Ozer et al., 2009; Singh & Davar, 2004). In urban areas, noise pollution is a major environmental concern (Singh & Davar, 2004). Sound waves convey the vibrations of air molecules from the external sound source to the human ear. Sound is called volume in amplitude and pitch in wave frequency. The sound pressure level (SPL) is the volume measured in the logarithmic units called decibels (dB).

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Noise pollution increases progressively day after day, year after year due to urbanization, industrialization and motorisation in urban areas. Nowadays, noise pollution became one of the by-products of human activities, due to large modes of transportation, and an increase in the usage of single usage of vehicle per person which also results in heavy traffic congestion (González, 2014).

An increase in heavy traffic volumes, high-speed vehicles, heavy load trucks and lorries, school and college buses, public intra and intercity transport buses, individually owned motorbikes and cars, autos, share autos, cabs, improper stoppage of vehicles and parking along the roads create annoyable noise in all areas (Ozer et al., 2009). Road vehicle noise play a major vital role in noise generation in the urban environment due to the increase in population and vehicle growth (Aftab, Bashir, & Shafiq, 2007; Alam, 2011; Banerjee et al., 2009; Koushki, Cohn, & Felimban, 1993; Öhrström & Skånberg, 2004).

In addition to traffic noise, noise also arises from construction activities, temple activities, functions, political activities and loudspeakers. This study limits its focus only on assessing the road traffic noise levels with equivalent sound energy level along with the calculation of noise indices and

descriptors in and around the study area Vadapalani major intersection roads in Chennai city.

Noise pollution is not only an environmental hazard, it also leads to health complications in the form of physiological manners and psychological disorders in human health in a large scale has it acts as a continuous process on day-by-day activity to the public (Evans & Hygge, 2007; González, 2014; Griffiths & Langdon, 1968; Hagler & Goiner, 2007). Several studies were prepared by many researchers on noise pollution on various cities worldwide (Jamrah, Al-Omari, & Sharabi, 2006; Ouis, 2001; Sudarshana, 2017; Yusoff & Ishak, 2005). Immediate attention and suggestive support measures to be analyzed to control environmental hazards that severely affect urban dwellers (Öhrström & Skånberg, 2004).

Road traffic is the chief source of noise in the study area. An increase in the high level of noise, influenced more stress on human health and highly impact the quality of life, chronic health ailments such as hypertension, insomnia, cardiovascular diseases, auditory disorders, mental depressions, high blood pressure, diabetic disorders, sexual impotency, respiratory disorders, nervous and neurological damages and have control over the human life scale (Organization, 2011; Tripathi, Pathak, & Upadhyay, 2006).

The study aims to discuss in detail by evaluating the parameters and indicators which causes noise pollution and also to assess, analyze the noise descriptors and to prepare noise map in the study area Vadapalani - Arcot Road Signal, Chennai district, Tamilnadu State, India.

2. Materials and Methods

2.1 Study Area - Vadapalani

Vadapalani is the most popularly known place, located in the heart of Chennai city, Tamilnadu, India. In recent years it is mainly known for its Forum Mall, commercial and entertainment center. One of themost crowded Vadapalani bus terminal points carry buses for various locations from this zone. Many colleges, schools, hospitals in and around Vadapalani also play an important role in crowding this area for developing more floating population during the peak hours.

The main important traditional and spiritual places like Vengeeshawarar and Murugan Temple where this place is named after this temple only also involves in it for gathering the population in this location. Another main privilege goes to the Vadapalani metro station which is noted as the very fastest mode of transportation to acquire people to various destinations for many reasons. The commercial growth along the road and inter connectivity between various modes of transportation exploded in the increase of most crowded area which in turn leads to noise pollution to takes place.

Vadapalani with similar to a commercial hub, it is also well known for its healthcare infrastructure with various more classified hospital services like Sims Hospital, Vasan Eye Care, Vijaya Hospitals, Fortis Hospital, Sooriya Hospital, and also various Scan, and Laboratory service centers.

Population growth has been drastically changed the living style of people in urban areas. The migration rate gradually increases year by year due to occupational, educational needs, etc.,

Due to urbanization and industrialization the transportation has a wide range of expansion, where the growth of vehicles for individual, public also got increased in large manner. Figure1 indicates the vehicular growth in Chennai city for the last decades as per the survey report of Chennai Metropolitan Development Authority (CMDA). Total vehicle population increases by 6.5% per annum due to an increase in the personalized modes of transport. An increase in two-wheeler trips was observed at 29.6% in 2018 when compared with previous studies 2% in 1970, 3% in 1984, 7% in 1995, and 25% in 2008. The above mentioned two figures clearly explains how the population and vehicle growth increased in decades and in further study analysis we will see how these two factors play a major role in the cause of noise pollution as per CMDA, 2008 rating.

The site has been chosen mainly for its mixed zone such as mostly influenced by commercial, residential, and entertainment zone with two main modes of transport facility such as bus transport through Vadapalani bus terminal and metro train mode through Vadapalani metro station. Vadapalani's geographical coordinates are 13° 3' 4" North Latitude and 80° 12' 45" East Longitude in the district of Chennai, Tamilnadu.

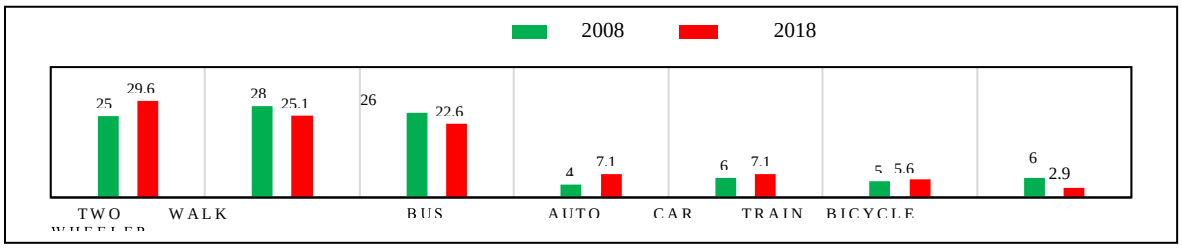


Figure 1. **Modal share in Chennai city** (Source: Comprehensive Mobility Plan of 2019)

The study area delineates around Vadapalani - Arcot Road Signal as a central focal point and a distance stretching from 0.25km towards North, 0.62km towards South, 0.16km towards East, 0.91km towards West, which include the two main roads comprising of two arterial road of State Highways (SH2) - Jawaharlal Nehru Road from North to South State Highway 113 (SH113) - Arcot Road, NSK Salai from East to West (see fig. 3).

The below said two State highways meet together at Vadapalani which is one of the major intersection roads in Chennai city is considered as a study area location.

i. Arterial Road Route 1 ----- 0.87 km (North to South) (A1)
(Jawaharlal Nehru Road / inner ring road (SH2) - Vadapalani Arcot Road – Major
Intersection From Koyambedu to Ashok Nagar
ii. Arterial Road Route 2 ----- 1.07 km (East to West) (A2)
(Arcot Road /NSK Salai (SH113) - Vadapalani Arcot Road- Major Intersection
From Porur to Kodambakkam

These are the major reasons which influenced to consider this location into a study area in assessing and evaluating the noise causing factors along these two roads in both ways.

The main objective of the study area is

a) To assess and monitor the peak traffic noise level using the digital sound meter in various locations in 3 different periods per day.
b) To analyze the road traffic noise in spatial aspects in the study area and compare with allowable permissible noise standards.
c) To prepare a noise map using QGIS to identify the hotspot noise zone.

Assessing the road traffic noise through sampling, analysis, and interpolation methods have been adopted to acquire accurate results. The study area is earmarked with 40 locations along the two arterial roads of State Highways comprised of 15 commercials, 9 residentials, 10 silence zones, (like temples, schools, hospitals,) and 6 signals/ intersection locations points. Road traffic is the chief source of noise in these areas (Banerjee & Chakraborty, 2006; Banerjee et al., 2009).

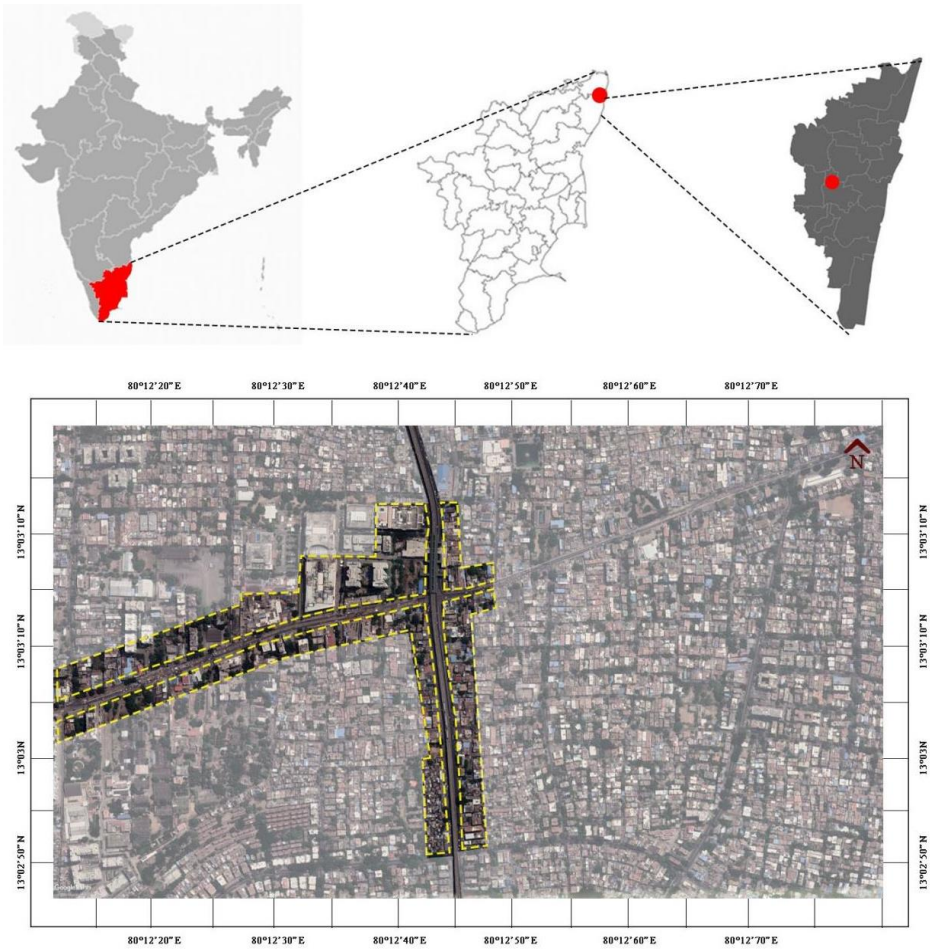


Figure 2. **Vadapalani Delineated Study Area map** (source: google earth)

Figure 3. **Enlarged Study Area map** (source: google earth)

Assessing the road traffic noise through sampling, analysis, and interpolation methods have been adopted to acquire accurate results. The study area is earmarked with 40 locations along the two arterial roads of State Highways comprised of 15 commercials, 9 residentials, 10 silence zones, (like temples, schools, hospitals,) and 6 signals/ intersection locations points. Road traffic is the chief source of noise in these areas (Banerjee & Chakraborty, 2006; Banerjee et al., 2009).

Selection of location has been classified into zones purely based on the functional activity of the buildings only to compare with permissible standard guidelines formulated by CPCB.

Permissible Standard Guidelines - Noise Level

The Central Pollution Control Board (CPCB) of India has laid down the ambient air quality standard for noise in 4 zones wise classification according to its usage in two specified day and night timings with permissible audible limits to the human ear refer Table 1. The Noise control and Regulation Rules 2000 (CPCB, 2001).

Note:

A silence zone is an area comprising not less than 100 meters around hospitals, educational institutions, courts, religious places, or any other area which is declared as such by the competent authority.

dB(A) Leq denotes the time-weighted average of the level of sound in decibels on scale A which is relatable tohuman hearing.

A “decibel” is a unit in which noise is measured.

“A” in **dB(A) Leq,** denotes the frequency weighting in the measurement of noise and corresponds to frequency response characteristics of the human ear.

Leq - it is an energy mean of the noise level over a specified period. The unit of sound intensity measurement is decibel dB.

Table 1: **Ambient Air Quality Standards in respect of Noise in India**

Type of Area	Category of Area / Zone	Limit in dB(A) Leq	
		Day time (6.00a.m to10.00 p.m)	Night Time (10.00p.m to 6.00a.m)
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

(Source: The Noise Pollution (Regulation and Control) Rules, 2000).

2.2 Experimental Procedure

The study is carried by using the instrument with portable Digital sound meter, with A-weighting frequency network as per IEC61672 specifications, the frequency ranges of 31.50Hz to 8k Hz and measuring range between 30 - 130 dB, ½ inch electret condenser microphone,0.5 seconds (0.5s) fast response sensitive sensor and also with multi function acoustics and calibrated before sampling. Each sampling was taken at a height of 1.50 meters high from the ground level and 3 - 7 meters distant from the main noise source object/roadside.

The whole study duration was divided into 30 minutes time slots for each sampling with three specified timings (Morning: 7.00 - 9.30 a.m.), (Afternoon: 12.00 - 2.30 p.m.), (Evening: 6.00 - 8.30 p.m.), with five sampling locations per day from 04th March to 12th March 2019 (excluding Sunday). All readings are monitored in good climatic conditions with normal wind speed.

2.3 Computation of Noise Descriptors

The noise level calculations were depicted mainly based on equivalent sound energy level. Along with various noise indices and descriptors were also computed using the formulas to evaluate the accurate noise level results.

2.3.1 Assessment of Equivalent Energy Level

The Equivalent noise level (Leq) is measured in different locations in different time intervals where Leq represents the equivalent sound energy level. Noise descriptors like L_{10}, L_{50}, L_{90}, were also assessed for better results. The A-weighted equivalent sound pressure level, L_{Aeq}, Day time average sound pollution level, $L_{D,}$ Night time average sound pollution level, $L_{N,}$ Day and Night time average sound pollution level, $L_{DN,}$ were computed as follows:

$$LAeq = 10 \log_{10} [\frac{1}{N} \sum_{i=1}^{N} (\text{antilog} \frac{LAi}{10} \text{ni})] \quad (1)$$

$$LD = 10 \log_{10} \times \frac{1}{2} [\text{antilog} \frac{L\,Aeq(M)}{10} + \text{antilog} \frac{L\,Aeq(A)}{10}] \quad (2)$$

$$LN = 10 \log_{10} \times \frac{1}{2} [\text{antilog} \frac{L\,Aeq(A)}{10} + \text{antilog} \frac{L\,Aeq(E)}{10}] \quad (3)$$

$$L_{DN} = 10 \log_{10} \times \frac{1}{24} [15 \times \text{antilog} \frac{L\,D}{10} + 15 \times \text{antilog} \frac{LN+10}{10}] \quad (4)$$

Where L_{Ai} - i th A-weighted sound pressure level (dB),

N - total number of readings

L_{Aeq} - A-weighted equivalent sound pressure level

L_{AeqM} - A-weighted equivalent sound pressure level during morning observation

L_{AeqA} - A-weighted equivalent sound pressure level during afternoon observation

L_{AeqE} - A-weighted equivalent sound pressure level during evening observation

The computation of noise level by using the Griffiths and Langdon model the formulas.

2.3.2 Assessment of Percentile Noise Levels

L_{10} : It is the level which exceeds 10% of the total observation time in dB(A).
It summarizes the peak levels of intruding noise.
(i.e., ten percentile time exceeding noise level).

L_{50} : It is the level which exceeds 50% of the total observation time in dB(A).
It summarizes the average noise levels.
(i.e., fifty percentile time exceeding noise level).

L_{90} : It is the level which exceeds 90% of the total observation time in dB(A).
It summarizes the background noise levels.
(i.e., ninety percentile time exceeding noise level).

2.3.3 Assessment of Noise Descriptors

The Traffic Noise Index, TNI, the Noise Pollution Level, L_{NP}, Noise Climate, NC, were computed as follows by using these formulas:

$$TNI = 4 (L_{10} - L_{90}) + L90 - 30 \text{ dB (A)} \quad (5)$$

$$L_{NP} = Leq + a (L_{10} - L_{90}) \text{ where a = 1.0 (constant in the equation)} \quad (6)$$

$$NC = L_{10} - L_{90} \quad (7)$$

Table 2. **Diurnal Peak Hours Noise Index Value of Study Area** (Lmin, Lmax, Lmean & L_{Aeq},)

VADAPALANI			Lmin			Lmax			Lmean			L_{Aeq}		
Sl. No	Route/ Zone	Description	M	A	E	M	A	E	M	A	E	M	A	E
1	A1 - S1	Vadapalani Murugan Temple	69	65	76	74	70	81	72	68	79	72	70	78
2	A1 - R1	Individual House - 01	63	67	71	68	72	76	66	70	74	69	65	72
3	A1 - C1	Commercial Shop - 01	71	72	76	83	78	85	77	75	81	79	78	80
4	A1 - S2	SIMS Hospital	64	60	80	82	81	86	73	71	83	75	75	79
5	A1 - C2	Vadapalani Metro Station	70	72	74	83	78	85	77	75	80	78	78	81
6	A1 - R2	Appasamy Trellis (North)	62	64	66	69	70	74	66	67	70	68	65	70
7	A1 - IN1	Vadapalani - Arcot Road Signal	80	83	89	86	85	93	83	84	91	80	84	86
8	A1 - C3	Commercial Shop - 02	70	71	75	84	79	86	77	75	81	75	75	81
9	A1 - S3	Vengeeswarar Temple	69	73	77	75	72	81	72	73	79	78	77	79
10	A1 - R3	Individual house - 02	68	70	75	80	77	83	74	74	79	74	70	75
11	A1 - IN2	Vadapalani Flyover	75	79	86	84	84	90	80	82	88	78	77	81
12	A1 - C4	Commercial Shop - 03	73	76	79	82	75	86	78	76	83	79	78	79
13	A1 - S4	Shakespeare Matriculation School	66	61	74	72	70	77	69	66	76	75	74	74
14	A1 - IN3	Sivan Koil Street Signal	76	74	78	80	81	85	78	78	82	78	75	82
15	A1 - R4	Individual house - 03	61	67	70	67	71	75	64	69	73	73	69	76
16	A1 - S5	P & G Nursing Home	65	68	80	80	79	84	73	74	82	73	70	77
17	A1 - C5	Madurai Kumar Restaurant	76	77	84	84	78	87	80	78	86	84	78	84
18	A1 - IN4	Lakshman Sruthi Signal	79	84	86	84	83	91	82	84	89	82	82	86
19	A1 - S6	Siddha Hospital	72	74	79	79	82	85	76	78	82	82	82	84
20	A2 - IN5	Palani Andavar Koil Street Signal	70	73	85	86	82	90	78	78	88	80	75	80
21	A2 - C6	R8 - Vadapalani Police Station	75	78	84	85	80	87	80	79	86	83	82	84
22	A2 - S7	Vasan Eye Care	72	74	79	76	74	84	74	74	82	80	76	86
23	A2 - C7	Hotel Aadhitya - 3 Star	63	72	78	75	81	84	69	77	81	75	73	79
24	A2 - R5	Canara Bank Quarters	62	62	68	64	65	75	63	64	72	79	76	78
25	A2 - P1	Chennai Corporation Park - 01	51	51	60	64	58	67	58	55	64	69	66	71
26	A2 - R6	Appasamy Trellis (South)	60	65	67	70	68	75	65	67	71	71	69	78
27	A2 - C8	Forum Vijaya Mall	67	72	80	84	79	86	76	76	83	80	79	81
28	A2 - R7	Arcot Terrace Apartment	65	68	77	80	75	85	73	72	81	76	75	76
29	A2 - C9	Rahat Plaza	65	72	76	74	75	82	70	74	79	72	72	73
30	A2 - C10	Hotel Maurya International - 3Star	62	71	77	73	79	85	68	75	81	72	71	75
31	A2 - S8	Vijaya Hospital	70	69	77	76	73	82	73	71	80	82	73	78
32	A2 - C11	Vadapalani Bus Terminal	69	76	89	78	78	90	74	77	90	79	76	81
33	A2 - R8	Vijayashanthi Towers Apartment	65	72	79	74	75	91	70	74	85	73	71	76
34	A2 - P2	Chennai Corporation Park - 02	62	58	63	63	57	69	63	58	66	65	66	70
35	A2 - R9	Appasamy Orchards Apartment	64	72	83	76	78	89	70	75	86	76	74	78
36	A2 - S9	Karthikeyan Matriculation School	69	70	77	73	70	76	71	70	77	77	76	78
37	A2 - C12	AVM Rajeshwari Theatre	63	65	76	72	67	77	68	66	77	65	64	69
38	A2 - S10	Fortis Hospital	69	63	75	74	72	79	72	68	77	79	75	80
39	A2 - C13	HP Petrol Pump	70	73	85	77	75	88	74	74	87	79	77	80
40	A2 - IN6	Saligramam - Arcot Road Signal	68	79	84	84	83	91	76	81	88	84	78	86

Key: M - Morning, A - Afternoon, E – Evening, A1 - Route 1, A2 - Route 2,
C - Commercial, R - Residential, S - Silence zone, IN - Intersection / Road Signals, All units are in dB(A).

The above noise index is calculated as Lmin - Minimum noise level, Lmax - Maximum noise level, Leq - Equivalent noise level,

Table 3. **Diurnal Peak Hours Noise Index Value of Study Area** (L_{10}, L_{50}, L_{90},)

VADAPALANI			L10			L50			L90		
Sl. No	Route/ Zone	Description	M	A	E	M	A	E	M	A	E
1	A1 - S1	Vadapalani Murugan Temple	75	71	79	63	59	67	60	58	65
2	A1 - R1	Individual House - 01	70	67	70	58	56	63	52	49	52
3	A1 - C1	Commercial Shop - 01	75	75	78	69	68	70	61	59	66
4	A1 - S2	SIMS Hospital	74	71	77	68	67	72	62	58	69
5	A1 - C2	Vadapalani Metro Station	78	76	80	70	69	71	65	64	69
6	A1 - R2	Appasamy Trellis (North)	70	68	72	60	58	65	58	56	63
7	A1 - IN1	Vadapalani - Arcot Road Signal	83	82	87	79	74	81	72	70	77
8	A1 - C3	Commercial Shop - 02	75	74	76	65	67	72	61	59	63
9	A1 - S3	Vengeeswarar Temple	75	72	78	70	69	71	61	58	67
10	A1 - R3	Individual house - 02	72	69	75	70	67	70	63	62	64
11	A1 - IN2	Vadapalani Flyover	82	78	83	65	65	71	68	62	68
12	A1 - C4	Commercial Shop - 03	79	75	80	69	68	70	64	60	65
13	A1 - S4	Shakespeare Matriculation School	71	69	76	69	66	69	58	56	66
14	A1 - IN3	Sivan Koil Street Signal	73	69	80	63	64	68	56	52	66
15	A1 - R4	Individual house - 03	69	69	72	66	60	69	60	57	60
16	A1 - S5	P &G Nursing Home	70	69	74	66	60	69	62	57	64
17	A1 - C5	Madurai Kumar Restaurant	82	79	82	73	70	79	68	64	70
18	A1 - IN4	Lakshman Sruthi Signal	81	80	85	76	74	78	65	64	72
19	A1 - S6	Siddha Hospital	80	77	83	75	71	79	64	60	69
20	A2 - IN5	Palani Andavar Koil Street Signal	76	70	79	69	65	67	60	56	64
21	A2 - C6	R8 - Vadapalani Police Station	81	80	82	75	74	76	66	65	70
22	A2 - S7	Vasan Eye Care	77	73	81	64	62	69	60	59	70
23	A2 - C7	Hotel Aadhitya - 3 Star	72	69	72	65	64	69	61	59	63
24	A2 - R5	Canara Bank Quarters	75	72	78	71	69	70	60	58	65
25	A2 - P1	Chennai Corporation Park - 01	70	69	71	61	59	63	53	53	56
26	A2 - R6	Appasamy Trellis (South)	70	68	75	64	61	70	58	56	63
27	A2 - C8	Forum Vijaya Mall	75	74	76	70	69	71	61	59	66
28	A2 - R7	Arcot Terrace Apartment	74	69	76	69	68	70	62	58	69
29	A2 - C9	Rahat Plaza	73	70	73	63	62	64	55	53	57
30	A2 - C10	Hotel Maurya International - 3Star	72	71	73	64	63	68	59	57	61
31	A2 - S8	Vijaya Hospital	76	76	82	61	59	66	62	60	67
32	A2 - C11	Vadapalani Bus Terminal	76	74	78	66	65	70	60	60	63
33	A2 - R8	Vijayashanthi Towers Apartment	70	68	75	66	64	71	60	58	65
34	A2 - P2	Chennai Corporation Park - 02	65	64	69	61	59	63	55	50	57
35	A2 - R9	Appasamy Orchards Apartment	70	67	73	64	63	65	51	52	56
36	A2 - S9	Karthikeyan Matriculation School	76	70	79	70	69	71	63	59	70
37	A2 - C12	AVM Rajeshwari Theatre	66	65	70	59	55	60	53	49	54
38	A2 - S10	Fortis Hospital	74	71	77	69	66	69	64	57	65
39	A2 - C13	HP Petrol Pump	75	73	77	65	64	69	60	56	61
40	A2 - IN6	Saligramam - Arcot Road Signal	75	72	78	70	67	70	62	56	66

Key: M - Morning, A - Afternoon, E - Evening
All units are in dB(A).

Table 4. **Diurnal Peak Hours Noise Index Value of Study Area** (TNI, L_{NP}, NC,)

VADAPALANI			TNI			LNP			NC		
Sl. No	**Route/ Zone**	**Description**	**M**	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**
1	A1 - S1	Vadapalani Murugan Temple	90	80	91	87	83	92	15	13	14
2	A1 - R1	Individual House - 01	94	91	94	87	83	90	18	18	18
3	A1 - C1	Commercial Shop - 01	87	93	84	93	94	92	14	16	12
4	A1 - S2	SIMS Hospital	80	80	71	87	88	87	12	13	8
5	A1 - C2	Vadapalani Metro Station	87	82	83	91	90	92	13	12	11
6	A1 - R2	Appasamy Trellis (North)	76	74	69	80	77	79	12	12	9
7	A1 - IN1	Vadapalani - Arcot Road Signal	86	88	87	91	96	96	11	12	10
8	A1 - C3	Commercial Shop - 02	87	89	85	89	90	94	14	15	13
9	A1 - S3	Vengeeswarar Temple	87	84	81	92	91	90	14	14	11
10	A1 - R3	Individual house - 02	69	60	78	83	77	86	9	7	11
11	A1 - IN2	Vadapalani Flyover	94	96	98	92	93	96	14	16	15
12	A1 - C4	Commercial Shop - 03	94	90	95	94	93	94	15	15	15
13	A1 - S4	Shakespeare Matriculation School	80	78	76	88	87	84	13	13	10
14	A1 - IN3	Sivan Koil Street Signal	94	90	92	95	92	96	17	17	14
15	A1 - R4	Individual house - 03	66	75	78	82	81	88	9	12	12
16	A1 - S5	P &G Nursing Home	64	75	74	81	82	87	8	12	10
17	A1 - C5	Madurai Kumar Restaurant	94	94	88	98	93	96	14	15	12
18	A1 - IN4	Lakshman Sruthi Signal	99	98	94	98	98	99	16	16	13
19	A1 - S6	Siddha Hospital	98	98	95	98	99	98	16	17	14
20	A2 - IN5	Palani Andavar Koil Street Signal	94	82	94	96	89	95	16	14	15
21	A2 - C6	R8 - Vadapalani Police Station	96	95	88	98	97	96	15	15	12
22	A2 - S7	Vasan Eye Care	98	85	84	97	90	97	17	14	11
23	A2 - C7	Hotel Aadhitya - 3 Star	75	69	69	86	83	88	11	10	9
24	A2 - R5	Canara Bank Quarters	90	84	87	94	90	91	15	14	13
25	A2 - P1	Chennai Corporation Park - 01	91	87	86	86	82	86	17	16	15
26	A2 - R6	Appasamy Trellis (South)	76	74	81	83	81	90	12	12	12
27	A2 - C8	Forum Vijaya Mall	87	89	76	94	94	91	14	15	10
28	A2 - R7	Arcot Terrace Apartment	80	72	67	88	86	83	12	11	7
29	A2 - C9	Rahat Plaza	97	91	91	90	89	89	18	17	16
30	A2 - C10	Hotel Maurya International - 3Star	81	83	79	85	85	87	13	14	12
31	A2 - S8	Vijaya Hospital	88	94	97	96	89	93	14	16	15
32	A2 - C11	Vadapalani Bus Terminal	94	86	93	95	90	96	16	14	15
33	A2 - R8	Vijayashanthi Towers Apartment	70	68	75	83	81	86	10	10	10
34	A2 - P2	Chennai Corporation Park - 02	65	76	75	75	80	82	10	14	12
35	A2 - R9	Appasamy Orchards Apartment	97	82	94	95	89	95	19	15	17
36	A2 - S9	Karthikeyan Matriculation School	85	73	76	90	87	87	13	11	9
37	A2 - C12	AVM Rajeshwari Theatre	75	83	88	78	80	85	13	16	16
38	A2 - S10	Fortis Hospital	74	83	83	89	89	92	10	14	12
39	A2 - C13	HP Petrol Pump	90	94	95	94	94	96	15	17	16
40	A2 - IN6	Saligramam - Arcot Road Signal	84	90	84	97	94	98	13	16	12

Key: M - Morning, A - Afternoon, E - Evening

TNI - Traffic noise index, L_{NP} – Noise Pollution Level, NC- Noise Climate

All units are in dB(A).

Table 5. **Diurnal Peak Hours Noise Index Value of Study Area** (L_D, L_N, L_{DN},)

VADAPALANI			LDay	LNight	LDayNight
Sl. No	**Route/ Zone**	**Description**	**L_D**	**L_N**	**L_{DN}**
1	A1 - S1	Vadapalani Murugan Temple	71	74	112
2	A1 - R1	Individual House - 01	67	69	105
3	A1 - C1	Commercial Shop - 01	79	79	123
4	A1 - S2	SIMS Hospital	75	77	118
5	A1 - C2	Vadapalani Metro Station	78	80	122
6	A1 - R2	Appasamy Trellis (North)	67	68	104
7	A1 - IN1	Vadapalani - Arcot Road Signal	88	88	137
8	A1 - C3	Commercial Shop - 02	75	78	118
9	A1 - S3	Vengeeswarar Temple	78	78	122
10	A1 - R3	Individual house - 02	72	73	113
11	A1 - IN2	Vadapalani Flyover	78	79	122
12	A1 - C4	Commercial Shop - 03	79	79	123
13	A1 - S4	Shakespeare Matriculation School	75	74	117
14	A1 - IN3	Sivan Koil Street Signal	77	79	120
15	A1 - R4	Individual house - 03	71	73	111
16	A1 - S5	P &G Nursing Home	72	74	112
17	A1 - C5	Madurai Kumar Restaurant	81	83	127
18	A1 - IN4	Lakshman Sruthi Signal	86	87	134
19	A1 - S6	Siddha Hospital	83	87	130
20	A2 - IN5	Palani Andavar Koil Street Signal	73	78	114
21	A2 - C6	R8 - Vadapalani Police Station	79	83	123
22	A2 - S7	Vasan Eye Care	74	81	116
23	A2 - C7	Hotel Aadhitya - 3 Star	68	76	107
24	A2 - R5	Canara Bank Quarters	69	77	109
25	A2 - P1	Chennai Corporation Park - 01	59	69	92
26	A2 - R6	Appasamy Trellis (South)	65	74	102
27	A2 - C8	Forum Vijaya Mall	73	80	115
28	A2 - R7	Arcot Terrace Apartment	70	76	110
29	A2 - C9	Rahat Plaza	69	73	108
30	A2 - C10	Hotel Maurya International - 3 Star	67	73	105
31	A2 - S8	Vijaya Hospital	72	76	112
32	A2 - C11	Vadapalani Bus Terminal	73	79	114
33	A2 - R8	Vijayashanthi Towers Apartment	68	74	107
34	A2 - P2	Chennai Corporation Park - 02	64	68	101
35	A2 - R9	Appasamy Orchards Apartment	69	76	109
36	A2 - S9	Karthikeyan Matriculation School	73	77	114
37	A2 - C12	AVM Rajeshwari Theatre	64	67	100
38	A2 - S10	Fortis Hospital	72	78	113
39	A2 - C13	HP Petrol Pump	74	79	116
40	A2 - IN6	Saligramam - Arcot Road Signal	73	82	115

L_D – Day equivalent noise level. L_N – Night equivalent noise level. Ldn – Day-Night equivalent noise level.
All units are in dB(A).

3. Results and Discussion

3.1 Statistical Assessment

Sampling locations were categorized into three zones purely depending upon their functional usage to evaluate and to compare with the noise limit permitted by CPCB guidelines. The study area analysis was done according to the spatial-temporal variation of road traffic noise located in 40 locations comprising of two major State highways (arterial roads) in Vadapalani.

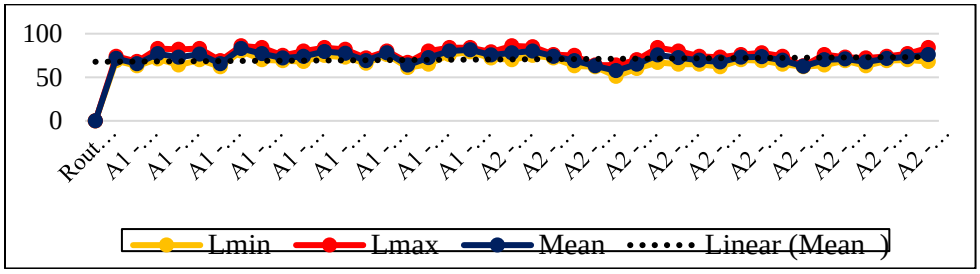
Figure 1 shows the increase and model share of vehicle growth in Chennai city for two consecutive decades. Figure 2 & 3 show the Google image map of the identification of selected location points of the study area. Figure 4 - 7 summarizes the comparatives of noise level, descriptors for 3 peak hours measured in various periods. Figure 8 - 10 summarizes the GIS-based noise mapping for each three peak hour timings based on the survey for 40 locations, such as morning, afternoon and evening separately. Table 1 clearly indicates the permissible noise limit as per CPCB Standards for 4 different zones. Table 2 - 5 predicts the various traffic noise parameters based on the survey of the selected locations of the study area according to 3 zones, such as commercial, residential, silence zone. Conclusively, Table 6 assesses and evaluates the cluster analysis of all the 40 locations in the study area.

3.2 Comparative Assessment

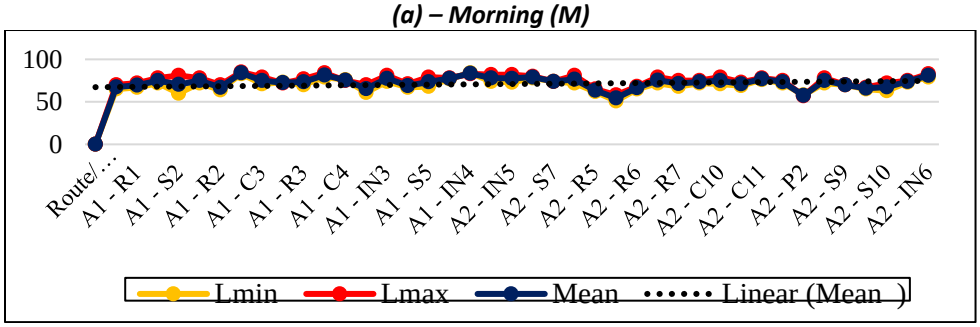
The observed mean noise level values at 40 study area locations in the morning time range between 58 to 83 dB(A), afternoon time ranges between 55 to 84 dB(A), evening time ranges between 64 to 91 dB(A). In the above three values the lower value is found to be in the park area and the higher values are at intersections of the road signals.

Similarly, values of LAeq ranges between (65 to 84), (64 to 84), & (69 to 86), L10, (65 to 83), (64 to 82), & (69 to 87), L50 (58 to 79), (55 to 74), & (60 to 81), & L90 (51 to 72), (49 to 70), & (54 to 77), dB(A) in the morning, afternoon & evening respectively.

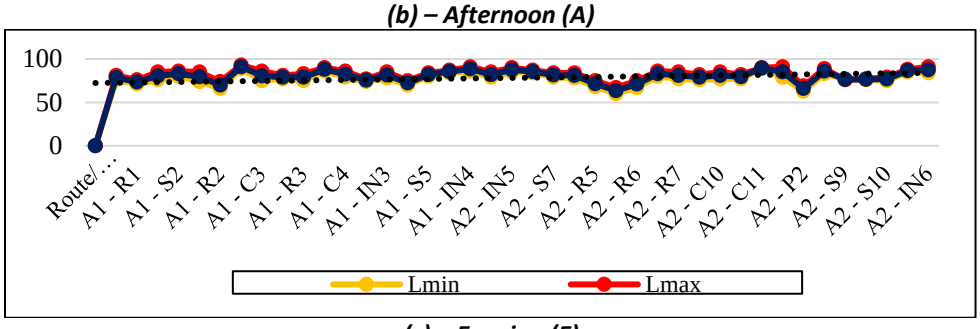
The values of the traffic noise index (TNI) ranges between 64 to 99 dB(A), in the morning, 68 to 98 dB(A), in the afternoon & 67 to 98 dB(A), in the evening.



(a) – Morning (M)



(b) – Afternoon (A)



(c) – Evening (E)

Figure 4. **Comparative of Lmin, Lmax, and Lmean during M, A & E hours**

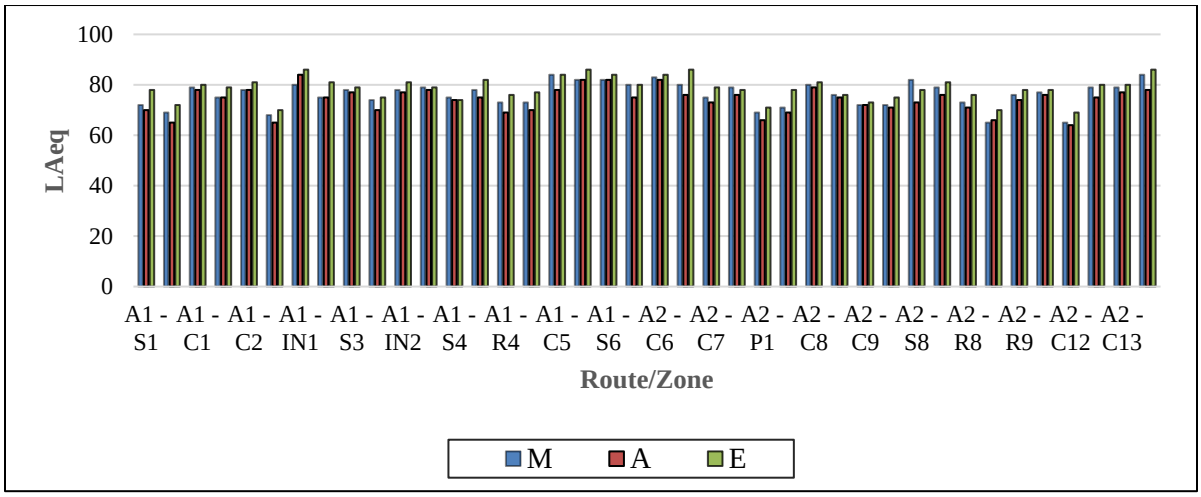
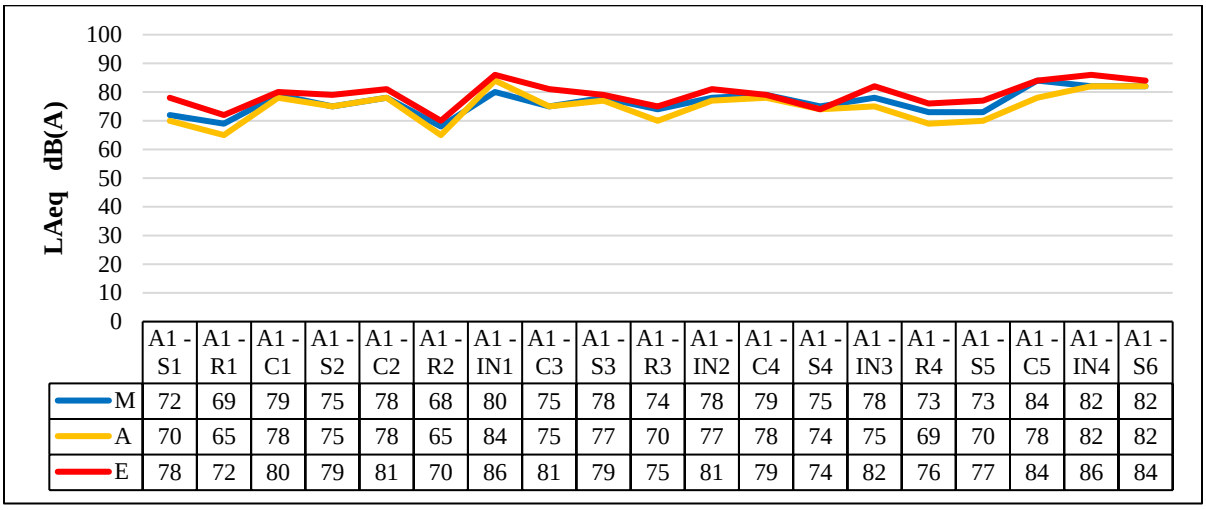
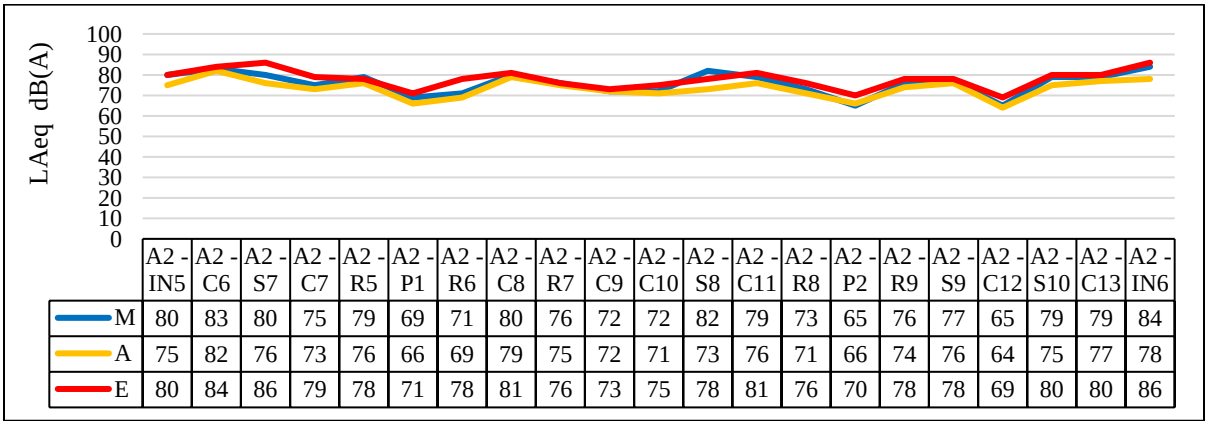


Figure 5. **Comparative of LAeq with permissible noise standards during M, A & E hours**



	A1 - S1	A1 - R1	A1 - C1	A1 - S2	A1 - C2	A1 - R2	A1 - IN1	A1 - C3	A1 - S3	A1 - R3	A1 - IN2	A1 - C4	A1 - S4	A1 - IN3	A1 - R4	A1 - S5	A1 - C5	A1 - IN4	A1 - S6
M	72	69	79	75	78	68	80	75	78	74	78	79	75	78	73	73	84	82	82
A	70	65	78	75	78	65	84	75	77	70	77	78	74	75	69	70	78	82	82
E	78	72	80	79	81	70	86	81	79	75	81	79	74	82	76	77	84	86	84

Figure 6. **Comparative of Route 1 L_{Aeq} during M, A & E hours**



	A2 - IN5	A2 - C6	A2 - S7	A2 - C7	A2 - R5	A2 - P1	A2 - R6	A2 - C8	A2 - R7	A2 - C9	A2 - C10	A2 - S8	A2 - C11	A2 - R8	A2 - P2	A2 - R9	A2 - S9	A2 - C12	A2 - S10	A2 - C13	A2 - IN6
M	80	83	80	75	79	69	71	80	76	72	72	82	79	73	65	76	77	65	79	79	84
A	75	82	76	73	76	66	69	79	75	72	71	73	76	71	66	74	76	64	75	77	78
E	80	84	86	79	78	71	78	81	76	73	75	78	81	76	70	78	78	69	80	80	86

Figure 7. **Comparative of Route 2 L_{Aeq} during M, A & E hours**

The values of the Noise Pollution Level (L_{NP}) ranges between 75 to 98 dB(A), in the morning, 77 to 99 dB(A), in the afternoon & 79 to 99 dB(A), in the evening and also Noise Climate (NC) values ranges between 08 to 19 dB(A), in the morning, 07 to 18 dB(A), in the afternoon & 08 to 18 dB(A), in the evening respectively.

3.3 Noise Mapping

Noise mapping is more about graphical presentation of the measured noise level in spatial distribution of the study area using goggle co-ordinates to locate the position and drafted as a map using open software QGIS.

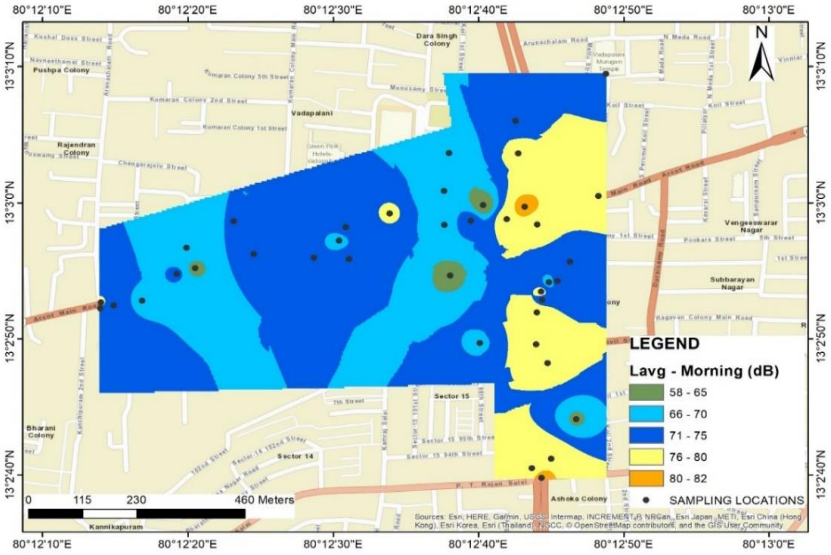


Figure 8. **Vadapalani noise mapping during the morning period**

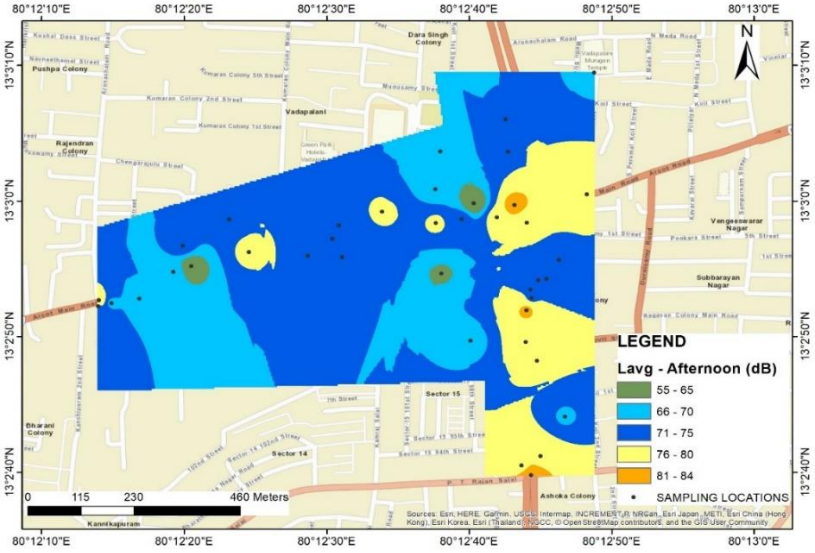


Figure 9. **Vadapalani noise mapping during the afternoon period**

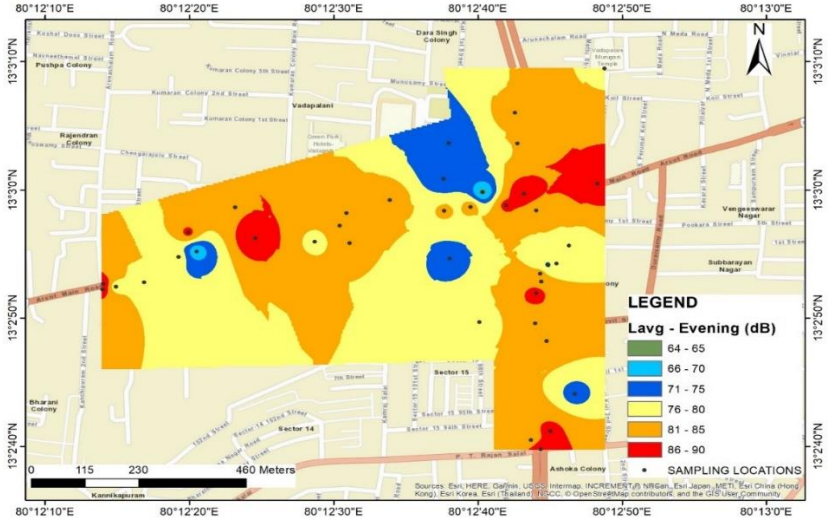


Figure 10. **Vadapalani noise mapping during the evening period**

This map can clearly explain how the noise level is high or low in the location, hot spot zone identifying, and also how the noise level spatially distributed from the selection leg point of the noise readings. This is the easiest and convenient mode of assessing and evaluating the noise levels in nowadays. The noise map identifies the noise levels are higher along the 2 arterial roads and variation occurs relatively by the traffic flow pattern and time duration of the day.

The average mean of the noise level in Route 1 (SH2) varies from 68 to 88 dB(A) and arterial road Route 2 (SH113) vary from 72 to 83 dB(A) respectively average by morning, afternoon and evening peak hours per day.

In 15 commercial locations the average noise level varies from 66 to 83 dB(A) during 3 peak hours duration, 6 intersection/signals vary from 78 to 88 dB(A), residential locations vary from 68 to 78 dB(A), and silence zone areas varies from 73 to 86 dB(A). Buildings that are spatially having distant from the

main road are noticed to have less noise level when analyzed with buildings closer to the roads. Along the main road, many hospital buildings are located very closely nearer to the road where the noise level is higher. This study clearly understood spatial planning with closer distance from main road approach also one of the factors to noise pollution. Noise levels are higher than the permissible standard limits on the selected study area during all three peak hours taken for the survey. Park areas are in lower noise levels when compared to other selected locations of the study area due to landscape features that acted as a barrier.

The survey of the study area results identifies that A Weighted Equivalent noise level (LAeq), noise descriptors like L_{10}, L_{50} & L_{90} varies by the location and time duration of the day mainly due to the traffic volume variation, heavy horned vehicles, a speaker mounted vehicle, unruffled vehicles at road intersections/signal junctions. This occurs mainly due to the decrease in the width of the road by encroachment along the major roads become a narrow passage, over parking of vehicles, vehicle stoppages, traffic congestions. The major criteria analyzed were no green belts found along the road, setbacks are not followed, sound-absorbing materials are not applied on the exteriors, no provision forsound barriers.

3.4 Cluster Analysis

The study concludes with the above assesses and analysis in a clear form with cluster analysis method to categorize into the tabular form to identify the noise risk zone comparatively with standard guidelines to be more specific to find solutions. Table 5 clearly summarize the intensity of noise level based on L_{Aeq} noise level in 40 different locations in the three respective peak hours such as morning, afternoon and evening durations.

Table 6. **Classification of Noise Risk Zone with Cluster Analysis**

Intensityof noise dB(A)	zone	Morning	Afternoon	Evening
Below 65	Normal	A2- P2, A2-C12,	A1- R1, A1- R2, A2- C12,	NIL
66 - 70	Tolerable	A1- R1, A1- R2, A2- P1,	A1- S1, A1-R3, A1- R4, A1- S5, A2- P1, A2- R6, A2- P2,	A1- R2, A2- P2, A2- C12,
71 - 75	Low risk	A1- S1, A1- S2, A1- C3, A1- R3, A1- S4, A1- R4, A1- S5, A2-C7, A2- R6, A2- C9, A2- R8,	A1- S2, A1- C3, A1- S4, A1- IN3, A2- IN5, A2-C7, A2- R7, A2- C9, A2- C10, A2- S8, A2- R8, A2- R9, A2- S10,	A1- R1, A1-R3, A1- S4, A2- P1, A2- C9, A2- C10,
76 - 80	Moderate risk	A1- C1, A1- C2, A1- IN1, A1- S3, A1- IN2, A1- C4, A1- IN3, A2- IN5, A2- S7, A2- R5, A2- C8, A2- R7, A2- C11, A2- R9, A2- S9, A2- S10, A2- C13,	A1- C1, A1- C2, A1- S3, A1- IN2, A1- C4, A1- C5, A2- S7, A2- R5, A2- C8, A2- C11, A2- S9, A2- C13, A2- IN6,	A1- S1, A1- C1, A1- S2, A1- S3, A1- C4, A1- R4, A1- S5, A2- IN5, A2-C7, A2- R5, A2- R6, A2- R7, A2- S8, A2- R8, A2- R9, A2- S9, A2- S10, A2- C13,
81 - 85	High risk	A1- C5, A1- IN4, A1- S6, A2- C6, A2- S8, A2- IN6,	A1- IN1, A1- IN4, A1- S6, A2- C6,	A1- C2, A1- C3, A1- IN2, A1- IN3,
Above 86	Extremely high risk	NIL	NIL	A1- IN1, A1- IN4, A2- S7, A2- IN6, A1- C5, A1- S6, A2- C6, A2- C8, A2- C11,

The buildings which are found to be far away from the major road in the mean of setbacks seem to be having a lesser noise level when compared with the buildings abating the setbacks. The noise levels in the two identified parks are lesser when compared to other locations. The noise levels are normally unacceptable in all the locations of the study area permitted by CPCB standard guidelines and even major hospital buildings are located abating the road without proper setbacks and green belts.

4. Conclusion

This study accurately portrays and evaluates the noise level that is present at and close to the Vadapalani Signal and Arcot Road crossings. The Central Pollution Control Board established guideline limit for road traffic noise has been exceeded. Long-term harmful health consequences on city people could emerge from an increase in noise levels. Less noise is present in the open regions both during the day and at night. The use of public, commercial, and private transportation vehicles, roadside construction work activities, and intolerable honking horns indicate higher noise levels in conflict with high rise residential buildings, residential homes, malls, theatres, shopping complexes, commercial areas, hospitals, schools, colleges, and temples, etc. Based on the results of the study, immediate action should be taken to reduce or control the noise emitted by all types of vehicles by using physical or technical monitoring equipment. This includes activating immediate measures, inspecting the source of the noise level in higher frequencies, and taking the necessary mitigation measures. The noise level can be reduced by offering or placing a noise barrier between the source and receiver. For some particular tree species, the creation of an open area or green landscape belt can reduce noise levels. Adding sound-absorbing material to the facade treatment of the building is a more precise method of controlling noise levels.

One of the greatest remedies may be to enforce tight laws relating to noise level monitoring and routinely inspect instruments in various areas to be used to reduce noise pollution. The city will benefit from the integration of several modes of transportation in order to lessen traffic and noise pollution, as well as to activate controls for monitoring pollution threats on a regular basis.

4.1 Suggestive Measures

a) Subsidizing the transit cost for students, employees, regular to and fro end-users will promote the usage of public transport instead of private mode which in turn decreases the trip levels, individual vehicle movement.
b) Flexible work time schedules reduce the congestion, noise level, efficient utilization of Public transport.
c) The green belt or green vertical wall barriers with sound control could attenuate the Sound levels.
d) Along with all these preventive measures, communities should come in front and take the pledge not to create noise from their vehicles honing, regular checking of vehicles functionality.
e) Usage of sound-absorbing materials for all kinds of buildings both for interiors and exteriors should give thorough knowledge to the users.
f) Proper laws to be enacted by the building regulation authority and regular monitoring of these activities can play a major role in controlling and preventing noise pollution in our areas and as a whole to the regional level.

Indeterminately, hostile accomplishment and enactment of new laws, new policy implementation and proper guidelines to be adopted strictly on protecting and maintaining the environment in identifying the problems related to noise pollution and take challenge over to create a sustainable urban development in Chennai city.

Abbreviations

CPCB	Central Pollution Control Board
LAeq	Equivalent noise level
TNI	Traffic Noise Index
L_{np}	Noise Pollution Level
NC	Noise Climate

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