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Statistical Analysis of Traffic Noise in Delhi During Odd-Even Vehicle Rationing Program

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ABSTRACT
Traffic noise is one of the most common problems in metro cities like Delhi which encounters this problem ever since the rising population and vehicle growth. In the present work, statistical assessment of noise pollution indices against the limits prescribed by Central Pollution Control Board, New Delhi has been done. A continuous one month noise data was taken from CPCB real time noise monitoring network during the month of April'16 which marks the beginning of second phase of odd-even vehicle rationing program in Delhi. For the study, A-weighted hourly average for peak hours of L_{10}, L_{50} and L_{90} during daytime and A-weighted daily average of L_{eq} was taken. The noise levels were undertaken for 30 days intervals from 1st April'16 to 30th April'16. The equivalent noise levels were calculated and relatively observed using various softwares like XLSTAT, SPSS and SIGMAPLOT. Noise Pollution level (NPL) and Traffic Noise Index (TNI) has been calculated from L_{10}, L_{50} and L_{90} percentile noise levels to estimate the noise pollution at survey stations. From the statistical calculation of the noise indices it is observed that there is a slight reduction in equivalent noise levels during odd-even program but still it is above the prescribed noise limits and the city continues to suffer severe noise pollution problems.

KEYWORDS: Odd-Even program, Traffic Noise Index, Noise Pollution Level, Statistical Data analysis, Noise, XLSTAT

I. INTRODUCTION

Noise pollution has been a matter of concern from past few decades in India and has been a common problem in all metro cities especially Delhi [1]. It the capital of India located at 28.38° North and 77.13° E. The city is categorize under metropolitan area city of India and is one of the busiest place worldwide. Thus Delhi also faces the universal problem of severe pollution due to urban and industrial environment [2-5]. The pressure and disorganized expansion of the population is worsening the environment [6]. With a rapid boost in population Delhi faces a transport crisis due to congestion, noise pollution, traffic fatalities and other problems [7-9]. There has been a gigantic growth in the vehicular population infuriating traffic jamming and escalating air and noise pollution in the national capital region [10]. Constant growth in the number of diesel vehicles adds up to the crisis of air and noise pollution [11]. Thus the level of air and noise pollution in Delhi has risen up to very alarming rates which discourage the inhabitants to dwell in the region [12].

In India, Noise figured only incidentally in general legislation of the Govt. of India as a Component in Indian Penal Code, Motor Vehicles Act (1939), and Industries Act (1951) [13-14]. Some of the states also had noise limits incorporated in certain manner in their legislation. In 1986, the Environment (Protection) Act was legislated [15-16]. A review of the status report indicates that noise Surveys were made in India in the sixties by the National Physical Laboratory, New Delhi. The findings of this survey clearly established the existence of high noise levels in Delhi, Bombay and Calcutta. An expert committee on noise Pollution was set up by the Ministry of Environment, Govt. of India, in early 1986 to look into the present status of Noise pollution in India Expert Committee submitted its report in June 1987 [17-18].

Table.1 Upper limits of noise for desirable and prohibitive levels of traffic noise

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

(Source: CPCB noise standards, 2000)

Recently the Delhi government had launched a program termed as odd-even vehicle rationing program scheme that restricted the use of vehicles with reference to their number plates [20-22]. The objective of the rationalization program was to reduce the number of vehicles moving on the roads of Delhi to somewhat lower down the pollution level [23]. The odd and even program in DELHI had been administered as an emergency stroke to seize the elevated emergency peak of the risen pollution level which had been registered 2-3 times more than the standards (Environment Pollution (Prevention and Control) Authority for NCR report, 2016) [24-25]. The mounting motor vehicle population raises uncontrolled noise pollution with a short and long term impact on physiological and psychological well being of humans. Thus a precautionary action has been taken by the government to immediately lower down the rising pollution levels [26]. The odd-even program is intended for instantaneous aid as the number of private cars on roads were almost halved, which add up to pollution level and create congestion and jams amidst the city. The first phase of this program was in January and second one was in April each for 15 days. The course of action depends upon the type and location of zones where the noise level is really high [27]. In recent years noise has become an important field of research along with other form of pollution. This is quite clear from the studies carried out in the past [28]. It is evident from the studies that the vehicles are a major noise source causing problems to the passengers and people in the residential and commercial areas that lie in the vicinity of the traffic [29-30]. Keeping the effects of odd-even program in mind, the present study was carried out with the objective to evaluate the noise indices at the selected observation stations so as to analyze the level of noise pollution during the odd-even program and also to compare the equivalent noise levels before and during the odd-even program against the prescribed CPCB noise standard limits.

II. MATERIAL AND METHODS

This section discusses the methodology adopted for the research work at selected observation stations in Delhi. A continuous one month noise data was taken during the month of April'16 in which the second phase of odd-even vehicle rationing program from 16th April'16 had commenced. The equivalent noise levels were statistically observed using various multiple statistics software like Microsoft Excel with added plugin XLSTAT (Version 2016.02.28451), SPSS statistics (version 23) and Sigmaplot (version 12.0). The noise levels are divided into two data sets ie, 1st april to 15th april (set 1) and 16th april to 30th april (set 2). For assessment of relative noise levels at the selected stations four parameters ie, A-weighted hourly average of $\boldsymbol{L_{10}}$, $\boldsymbol{L_{50}}$, $\boldsymbol{L_{90}}$ and $\boldsymbol{L_{eq}}$ for the peak hours (8:00am-10:00am and 5:00pm-7:00pm) were considered. Noise Pollution level (NPL) and Traffic Noise Index (TNI) has been calculated from L_{10}, L_{50} and L_{90} percentile noise levels to evaluate the extent of noise pollution at survey stations [31-34]. A graphical representation of NPL and TNI has been done to determine the average slope of noise levels during odd-even vehicle rationing phase [34-38]. Furthermore, with the help of XLSTAT software, time series forecasting of $\boldsymbol{L_{eq}}$ has been done to spot the change in noise pollution level in the forecasted $\boldsymbol{L_{eq}}$ vs. actual $\boldsymbol{L_{eq}}$ values [42-48]. Additionally, the mean values of equivalent noise level were analyzed and relatively compared to standard noise levels provided by CPCB (2001) [38-43].

2.1 Selection of observation stations

For the collection of Traffic noise data 3 stations were selected at different points in Delhi. These stations covered entire zones of Delhi giving an estimate of relative noise pollution level in adjoining areas [44-45]. The observation stations selected were Punjabi Bagh, Anand Vihar and R.K.Puram. The stations have been selected as per the locations undertaken by CPCB in their real time ambient noise monitoring network. The stations are well connected with the other parts of the city through transportations and metro rail network. They form a commercial and residential hub and therefore need to be monitored for noise levels. They also form a triangular zone diving Delhi into 3 halves giving more or less brief idea about the adjoining prevailing noise conditions [46]. Geographical locations of these stations have been mentioned in Table 3.1 which illustrates the latitude and longitude of the place from where the study was carried out.

Table.2 Geographical locations of the selected stations along with the noise zone they fall in.

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

(Source: CPCB real time national ambient noise monitoring network)

2.2 Data collection

The odd-even period marked one month noise level study collecting daily hourly average of the peak hour noise parameters as prescribed further in this section. Since the study aims to determine the noise levels at various locations in Delhi both primary and secondary data were taken into consideration. Primary data was obtained from site survey whereas secondary data was taken from CPCB ambient real time noise monitoring network.

2.3 Parameters and equations used to calculate Noise Indices

These are the empirical equations used for the statistical calculation of noise pollution level. These equations have been widely used by the research workers in their study [47-48]. For measurement and analysis the whole traffic is considered a line source [49]. The problem of variability of noise with time, due to the passage of of different types of vehicle and their physical state is overcome by statistical analysis of noise level defining different parameters like maximum, minimum, and average noise levels [50-51]. Other parameters taken to check the level of noise pollution are TNI (traffic noise index), NPL (noise pollution level) and NC (noise climate) [52].

Equivalent continuous Sound level (L_{eq}): Continuous steady noise level which would have the same total A-weighted acoustic energy as the real fluctuating Noise measured over the same period of time.

$$L_{eq} = 10 \log (1/T\int (P_{(t)}/P_{(0)})^2 dt \quad (1)$$

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

$$\text{TNI} = 4(L_{10} - L_{90}) + L_{90} - 30 \text{ dB} \quad (2)$$

Noise Pollution Level (NPL): Noise pollution level is sometimes used to describe community noise which employs the equivalent continuous (A-weighted) sound level and the magnitude of the time fluctuations in levels.

$$\text{NPL} = L_{50} + L_{10} + L_{90} + ((L_{10} - L_{90})^2/60 \quad (3)$$

Where, L_{10}= It is the noise level exceeded for 10% of the time of the measurement duration.

L_{50} = It is the noise level exceeded for 50% of the measurement duration

L_{90}= It is taken to be the ambient or background noise level as used

$P_{(t)}$= Instantaneous sound pressure.

$P_{(0)}$= Reference sound pressure.

XLSTAT and SPSS were used for analytical study of time series forecasting where the noise data was forecasted for a certain period of time depending on its past trend. Equation of the trend line has been modeled through XLSTAT based upon various dependent and independent variables [53].

To check the relative change in data, cumulative frequency analysis and RMSE (root mean square error) test has been done. Furthermore, regression tests (R^2) and chi-square test has been done to check the goodness of fit of the observed noise sample from the calculated noise sample [54]. In our present study, mathematical modeling has been done using empirical equations to estimate the noise levels. As discussed that environmental noise modeling is associated with certain set of restrictions and conditions, the noise level thus estimated is a fixed representation of particular interest [55-57]. Since the approach to environment noise modeling varies in every condition depending upon the complexity of the scenario [58-59]. However, certain logistic and systematic approach is followed irrespective of the type and conditions available like the noise sources details and the technical study of the physical environment [60].

III. RESULTS AND DISCUSSION

The noise parameters, as taken from CPCB real time noise monitoring network, were tabulated and the mean values of A-weighted L_{10}, L_{50}, L_{90} and L_{eq} hourly noise levels for the peak hours were taken for study. The data includes 1st to 15th April (15 days before odd-even program) and 16th to 30th April (15 days during odd-even program). Subsequently L_{10}, L_{50}, L_{90} were used to calculate NPL and TNI noise indices using the formula given in section 3.4. The results have been displayed in the table 4.1 and the graphs have been displayed in figure 4.2.

The behavior of the noise levels during odd-even program has been justified by calculating TNI and NPL, calculating the percentage difference in the mean L_{eq} and then observing the difference in forecasted L_{eq} vs. actual L_{eq}. Results at all three steps show that the noise level has reduced to a certain extent but on the other hand it is still above the prescribed CPCB standard limits.

Table.3 Percentile Noise Levels at R.K.Puram during April'16 (Source CPCB Real Time Ambient Noise Monitoring Network).

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

Table.4 Percentile Noise Levels at Anand Vihar during April'16 (Source CPCB Real Time Ambient Noise Monitoring Network).

	Leq dB(A)	NPL dB(A)	TNI dB(A)		Leq dB(A)	NPL dB(A)	TNI dB(A)
DAY 1	67.07	61.11	65.2	DAY 16	67.46	73.11	60.6
DAY 2	66.71	70.99	61.3	DAY 17	67.24	72.31	61.6

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

Table.5 Percentile Noise Levels at Punjabi Bagh during April'16 (Source CPCB Real Time Ambient Noise Monitoring Network).

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

The noise parameters given in table.3-5 are plotted and relatively compared to verify the deviation from the mean values. Figure.1 shows the plot of TNI and NPL that also displays the gradient of its trend line. It can be deduced from the graph that overall the noise indices have reduced. The equation of the trend line is given in Table.6 which shows the variation of variable 'y' with respect to 'x' where 'y' and 'x' is noise index and time relatively.

Table.6 Equations of the linear trend line along with standard deviation

Site	**Noise Indices**	**Equation of line**
R.K.Puram	TNI	$y = -0.276x + 56.05$
	NPL	$y = -0.077x + 65.14$
Anand Vihar	TNI	$y = -0.056x + 63.15$
	NPL	$y = -0.002x + 72.35$
Punjabi Bagh	TNI	$y = -0.159x + 62.47$
	NPL	$y = -0.045x + 65.33$

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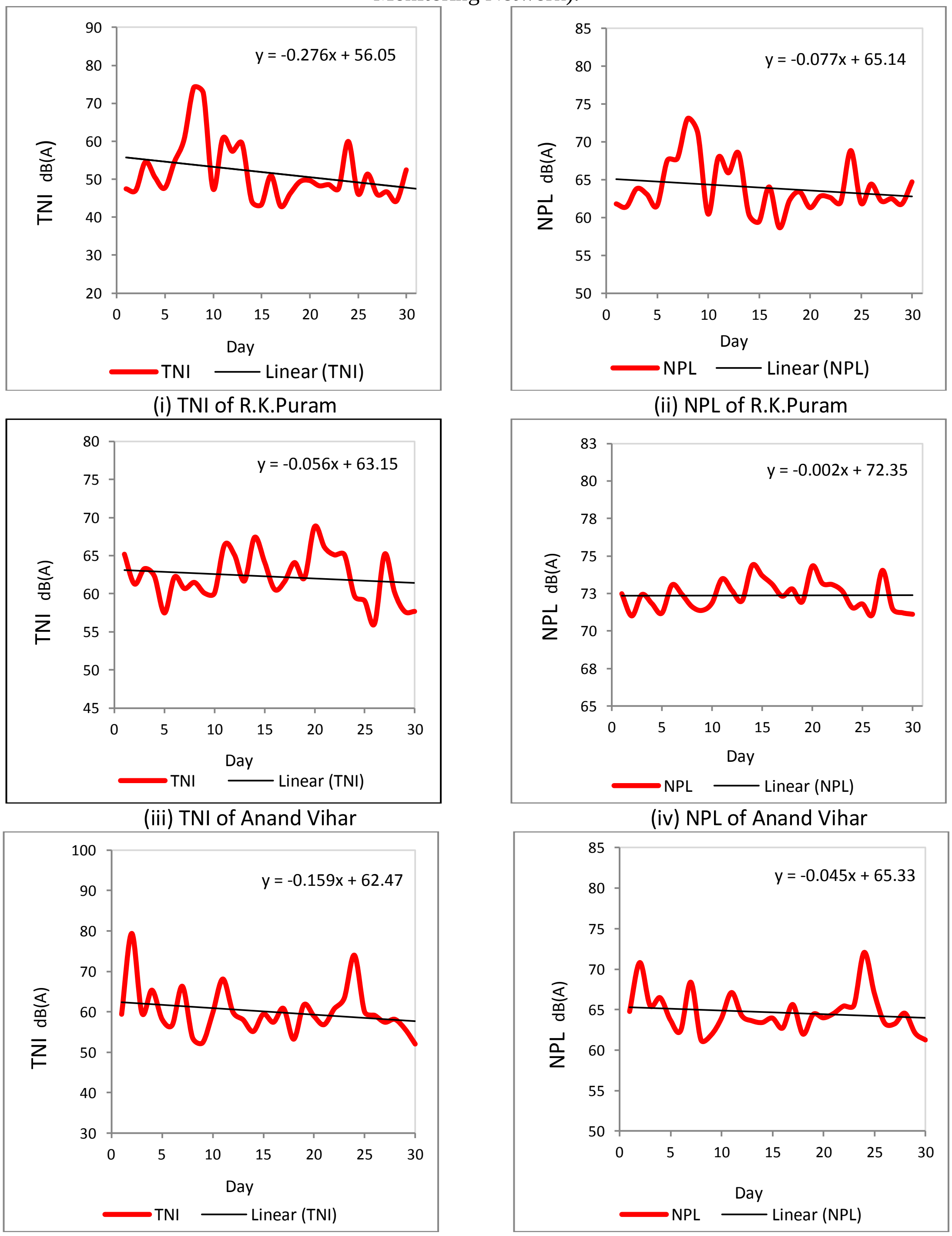
The slope of the linear trend line y= mx+c is negative (-ve) for all parameters denoting a fall in ambient noise levels during the month of April'16. Additionally the correlation coefficient (r_{xy}) for the graph is also negative (-ve) which indicates that the NPL and TNI indices have lowered with the advancement of time.

Figure.1 Percentile Noise Levels at Punjabi Bagh during April'16 (Source CPCB Real Time Ambient Noise Monitoring Network).



(i) TNI of R.K.Puram
(ii) NPL of R.K.Puram
(iii) TNI of Anand Vihar
(iv) NPL of Anand Vihar
(v) TNI of Punjabi Bagh
(vi) NPL of Punjabi Bagh

Table.6 Descriptive results of the statistical analysis of equivalent noise level (L_{eq})

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

The result of the statistical analysis performed on the mean L_{eq} values has been shown in Table.6. Observations clearly suggest that the mean L_{eq} for all the 3 stations has always been above the prescribed limits (CPCB noise rules 2000). The mean value of L_{eq} for R.K.Puram has reduced from 61.28 dB(A) to 60.47 dB(A) but it still above the prescribed limit of 50 dB(A) for the silence zone. For Anand Vihar the mean value of L_{eq} has reduced from 68.43 dB(A) to 67.53 dB(A) but it is still above the prescribed limit of 65 dB(A). And for Punjabi Bagh the mean value of L_{eq} has reduced from 59.38 dB(A) to 58.73 dB(A) which is also above the prescribed limit of 55 dB(A). The relative mean L_{eq} values have been shown in figure.2.

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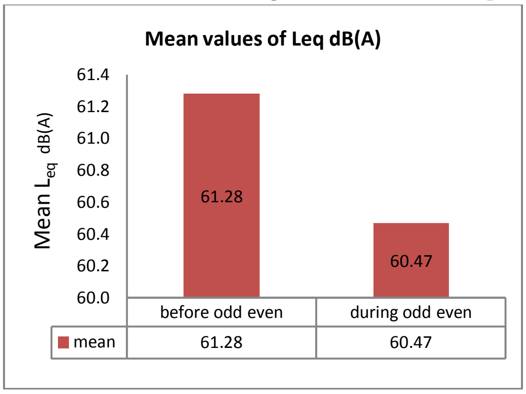
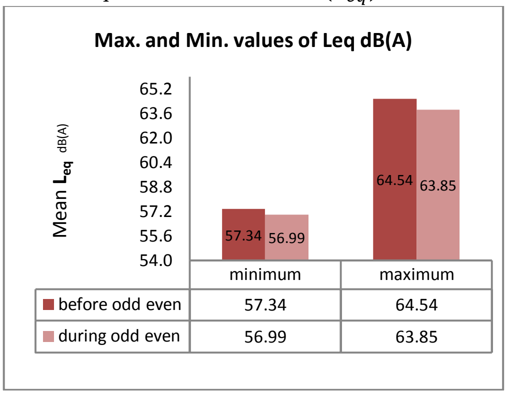
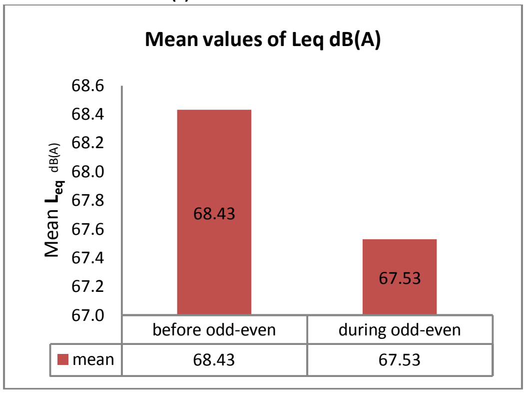
Figure.2 Relative comparison of mean equivalent noise level (L_{eq})



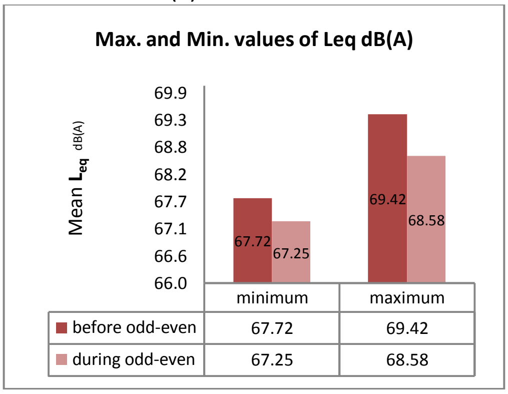
(i) R.K.Puram



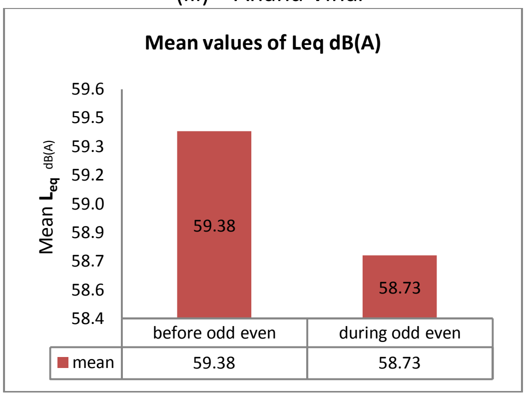
(ii) R.K.Puram



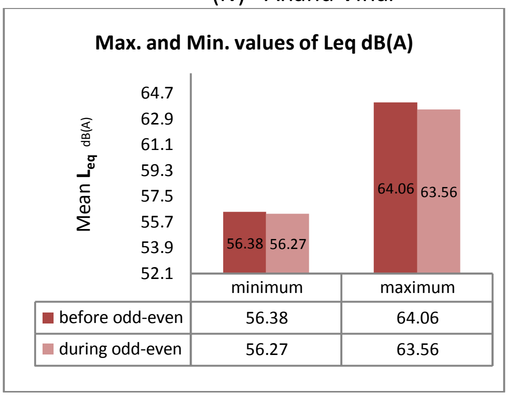
(iii) Anand Vihar



(iv) Anand Vihar



(v) Punjabi Bagh



(vi) Punjabi Bagh

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

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

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

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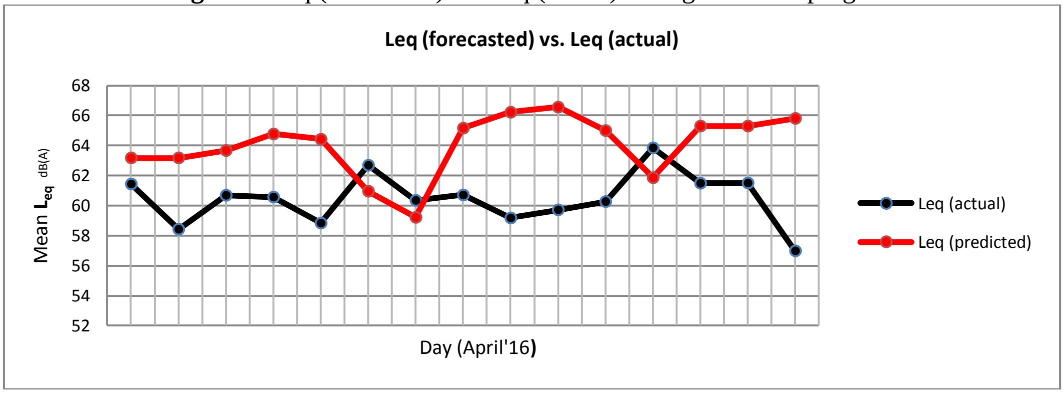
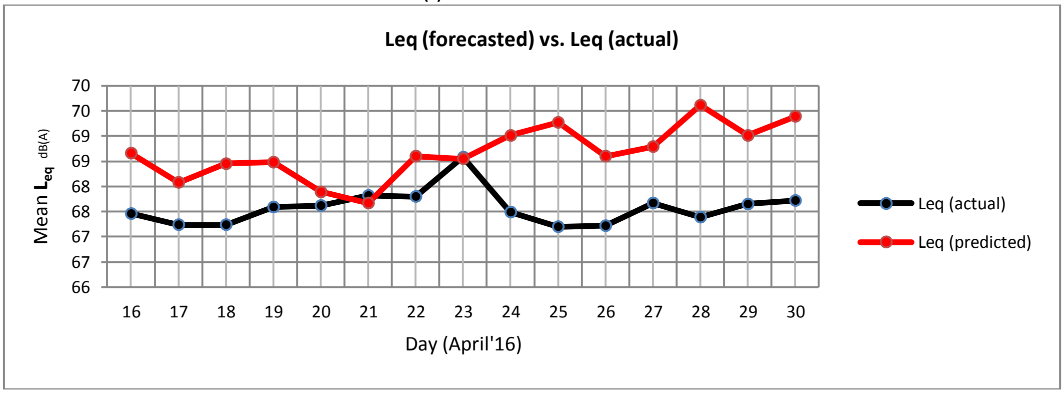
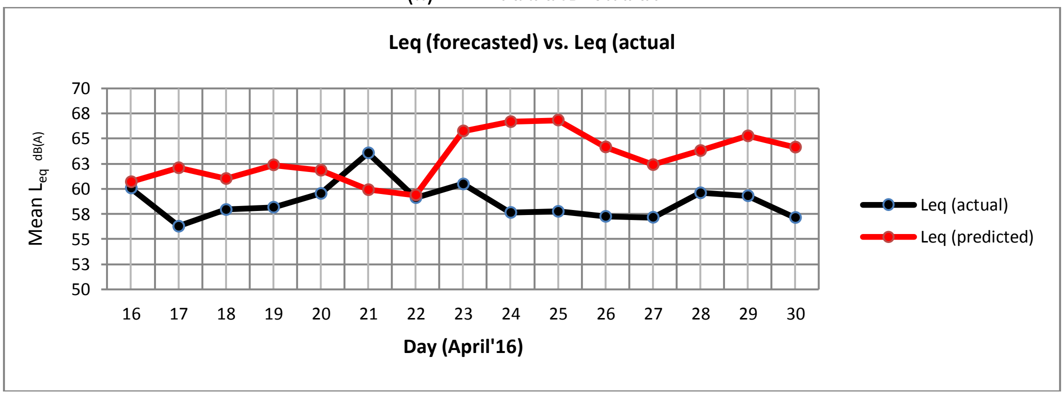
Figure.3 Leq (forecasted) vs. Leq (actual) during odd-even program



(i) R.K.PURAM



(ii) ANAND VIHAR



(iii) PUNJABI BAGH

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

IV. CONCLUSION

On the basis of profound analysis the study concludes to confer significant results in areas of noise level determination and forecasting from the combined efforts of previous researches and present study. Determination of noise level and forecasting initiates to establish subsequent results. The present work using the collected data on noise generating parameters was applied to evaluate the vehicular traffic noise, and to suggest suitable model based on Indian conditions. It is clear from observation that all selected stations were exposed to higher noise level as compared to Indian standard noise levels prescribed by Central Pollution Control Board (CPCB), New Delhi, India. To minimize the level of noise pollution several measures can be taken such as proper maintenance of motor vehicles, roads, plantation of trees, traffic movements should be controlled effectively by traffic police and to alert the public about the alarming noise pollution. To trounce these tribulations many efforts have been made in the past. Development in noise control strategy has vividly grown at a rapid rate creating sophisticated techniques and modern methods. Basically, diminution in noise is the only way to control it. Noise control technique in contemporary time refers to optimization of noise level keeping efficient and outfitted considerations in mind. However, even as such domination and management measures are complex to uphold, the benefits made from these trial actions will only diminish over time. Long-term actions with strong monetary impetus to ensure beneficial results are crucial for superior quality of environment.

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