CHAPTER - 7

RESULTS AND DISCUSSIONS

Noise map made using GIS software is a tool for evaluating accurately the situation in the field of pollution by noises. It is the tool which enables taking the necessary decisions for reducing the risks arising from noise. The use of a GIS software allows getting information on a certain overall geographic area. The area studied is a map that may get to express themselves through various shades of colour intensity noise based on the distance from the road.The average noise levels in residential areas of Nigerian cities exceed allowable limits (KingG et al,2009).

Noise maps illustrate the fact that noise is quite high, and there are areas where the values are in excess of 75 dB. As a result of research carried out, there is a growing awareness of the harmful effect of noise on human health. This leads to a serious approach to the phenomenon of sound pollution produced by surface transport.

Traffic noise prediction models are required as aids in the design of roads and sometimes in the assessment of existing, or of envisaged changes in traffic noise conditions. They are commonly needed to predict sound pressure levels. The developed regression model is applicable only for urban roads.

7.1 Noise Level Observed in the study area

Traffic volume, speed and noise levels are observed for 15 locations where significant noise levels are expected due to heavy traffic volume and speed.The road traffic volume data was collected in all 15 locations from 6.00am to 9.00pm. A gradual increase in traffic volume was observed from 6.00 am to 11.00am and it remains more or less same till 5.00 pm with variation of 15% and it further increases upto 8.00pm then it starts decreasing slowly thereafter.

The spot speeds were also simultaneously measured from 6.00 am to 9.00

pm and it was observed that the speed was higher at 6.00 am and decreased gradually till 11.00 am. Then it remains more or less same upto 5.00 pm and decreases further owing to increase in traffic volume upto 8.00 pm. The speed once again increases from 8.00pm to9.00 pm due to decrease in traffic volume.

The road traffic noise data was collected in all locations from 6.00 am to 9.00pm using sound level meter with an accuracy of 2 dB.

The noise levels were observed from 6.00 am to 9.00 pm at edge of carriageway, 5m, 10m and 15m from edge for ground floor and first floor. The noise levels were found to be more at the edge and decreases gradually with the increase in the distance from the carriageway at all the locations. It was also observed that the noise levels increased from 6.00 am to 11.00 am and remained more or less same upto 5.00 pm and again increases upto 8.00 pm and decreases thereafter. This decrease in noise level is due to decrease in traffic volume. For example, the noise level at ground floor in T.Nagar between 8.00am-9.00am is 82.7dB whereas in first floor it is80.1dB. It shows that noise levels in first floor are lesser than that of ground floor.

7.2 Noise Modelling using Multiple Linear Regression.

A mathematical model using multiple linear regressions was developed. This is presented in tables 5.3 to 5.6 for the four locations of Adyar, Velachery, T.Nagarand Porur respectively. The regression equations for remaining locations are given in Appendix 3.

In the developed models, speed and volume are considered as variables and R^2 values for different distances from the source of noise are determined. The values were found to vary between 0 .76 to 0.98. These values indicate the robustness of the models.

7.3 Noise model for Chennai city

The noise levels were observed in the range of 70-88 dB (A) during peak and non-peak hours. Further the noise levels decrease with increase in distance and height, that is noise level, is lower in first floor of buildings compared to the ground floor. The noise level also decreases when the distance from the carriage way increases. These noise levels are in excess of the prescribed limits. Regression model is built by considering noise as dependant variable and Traffic volume, Speed and receptor distance as independent variables. Separate models were built for the all locations in a stretch in the study area. Finally a combined model for Noise prediction was developed for Chennai city. The R^2 values varied from 0.85 to 0.96 form ground floor and from 0.82 to 0.98 for first floor. An R^2 value of 1 is considered to be the best where as any value above 0.7 is considered to be good (**Nirjar et al 2002**). Though the calculated values are more or less same as observed values, the noise level in Chennai is higher than that of standards specified.

After developing noise model for all 15 locations of the study area, an integrated model was developed for Chennai city using noise data of all locations as given in Tables 7.1 and 7.2.

The model has been developed separately for ground floor and first floor. The R^2 value for edge is less and when the distance increases the R^2 value also increases during morning peak hour whereas it decreases during evening peak hour with increase in distance. The reason is the gradual increase of traffic volume during morning peak hour and sudden increase in traffic volume during evening peak hour.

Table 7.1Noise Model for Ground Floor at Various Distances from theSource for Chennai city

Sl. No	Distances from noise source (m)	Morning peak (9.00am to10:00 am)		Evening peak (5:00 pm to 6:00 pm)	
		Model	R^2 Value	Model	R^2 Value
1	Edge	$y= 56.22+0.0061x_1+0.019x_2$	0.89	$y= 62.67+0.004x_1+0.325x_2$	0.92
2	5	$y=55.30+0.0038x_1+0.00387x_2$	0.93	$y= 57.21+0.0036x_1+0.382x_2$	0.91
3	10	$y=60.97 +0.0029x_1+0.0058x_2$	0.94	$y=68.03+0.0011x_1+0.206x_2$	0.89
4	15	$y=56.35+0.0037x_1+0.017x_2$	0.96	$y= 51.75+0.006x_1+0.204x_2$	0.85

where,

y = Noise levels in dB(A)

x_1 = Volume of traffic in the nearside (veh/hr)

x_2 = Mean speed of traffic in the nearside of observer (kmph)

Table 7.2Noise Model for First Floor at Various Distances from the Source for Chennai city

Sl. No	Distances from noise source (m)	Morning peak (9.00 am to 10:00 am)		Evening peak (5:00 pm to 6:00 pm)	
		Model	R^2 Value	Model	R^2 Value
1	5	$y=60.18+0.0075x_1+0.017x_2$	0.82	$y=30.85+0.000062x_1+0.57x_2$	0.98
2	10	$y=57.22+0.008x_1 +0.0067x_2$	0.85	$y=52.28+0.0017x_1+0.474x_2$	0.96
3	15	$y=53.76+0.010x_1+0.0017x_2$	0.87	$y=33.65+0.0037x_1+0.6005x_2$	0.92

where,

y = Noise levels in dB(A)

x_1 = Volume of traffic in the nearside (veh/hr)

x_2 = Mean speed of traffic in the nearside of observer (kmph)

7.4 Effect of change in speed on noise model

The road traffic noise depends on many variables such as speed, volume, road surface, vehicle condition, life of vehicle, distance from source both horizontal and vertical direction.But speed, volume and distance from source are the major contributing factors for noise.

In order to study the factor which has high correlation with road traffic noise in the developed model, at first only speed was varied for 30kmph,40kmph and 50kmph and volume and distance from source were kept constant. Table 7.3 shows noise levels for speed of 30kmph. The rate of increase in noise level is less in first floor and more in ground floor. Similarly the noise level was more near the source and less as the distance increases.

Table 7.3Predicted noise levels (in dB) when speed is kept 30kmph

	Peak hours		8-9 hr	9-10 hr	17-18 hr	18-19 hr
Adyar	First Floor	15m	64.5	64.39	64.95	65.39
		10m	74.79	74.74	75.02	75.23
		5m	78.95	78.81	79.53	80.1
	Ground Floor	15m	81.9	81.86	82.07	82.24
		10m	97.4	96.82	99.8	102.12
		5m	83.69	83.62	83.97	84.24
		Edge	91.63	91.55	91.95	92.26
Velachery	First Floor	15m	55.75	56.28	56.76	56.93
		10m	67.22	68.3	69.29	69.65
		5m	70.82	70.93	71.04	71.07
	Ground Floor	15m	72.75	78.87	84.48	86.49
		10m	83.06	83.08	83.10	83.11
		5m	87.37	87.41	87.45	87.46
		Edge	94.25	94.27	94.29	94.29
T. Nagar	First Floor	15m	72.56	72.62	72.64	72.68
		10m	75.78	75.86	75.89	75.94
		5m	74.59	74.63	74.65	74.67
	Ground Floor	15m	76.89	76.91	76.92	76.93
		10m	80.82	80.84	80.85	80.87
		5m	79.86	79.88	79.89	79.91
		Edge	78.43	78.85	79.01	79.29
Porur	First Floor	15m	62.98	62.98	63.82	64.02
		10m	80.53	80.53	80.68	80.72
		5m	78.99	78.99	79.01	79.02
	Ground Floor	15m	91.4	91.4	91.45	91.46
		10m	94.25	94.25	94.29	94.3
		5m	93.08	93.08	93.14	93.16
		Edge	93.08	93.08	93.14	93.16

Tables 7.4 and 7.5 show the noise levels for speeds of 40kmph and 50kmph respectively. The rate of increase in noise level is less in first floor and more in ground floor. Similarly the noise level is more near the source and less as the distance increases.

Table 7.4 Predicted noise levels (in dB) when speed is kept 40kmph

	Peak hours		8-9 hr	9-10 hr	17-18 hr	18-19 hr
Adyar	First Floor	15m	62.46	62.35	62.91	63.35
		10m	69.51	69.46	69.73	69.95
		5m	72.18	72.04	72.76	73.33
	Ground Floor	15m	74.38	74.34	74.55	74.71
		10m	87.8	87.22	90.2	92.52
		5m	75.39	75.32	75.67	75.94
		Edge	81.83	81.75	82.15	82.46
Velachery	First Floor	15m	50.35	50.88	51.36	51.53
		10m	63.42	64.50	65.49	65.85
		5m	65.83	65.94	66.05	66.08
	Ground Floor	15m	64.86	70.98	76.59	78.6
		10m	64.16	64.18	64.2	64.21
		5m	65.27	65.31	65.35	65.36
		Edge	68.55	68.57	68.59	68.59
T. Nagar	First Floor	15m	58.96	59.02	59.04	59.08
		10m	59.93	60.01	60.04	60.09
		5m	58.19	58.23	58.25	58.27
	Ground Floor	15m	62.69	62.71	62.72	62.73
		10m	65.9	65.92	65.93	65.94
		5m	68.68	68.7	68.71	68.73
		Edge	70.63	71.05	71.21	71.49
Porur	First Floor	15m	62.12	62.12	62.96	63.16
		10m	72	72	72.15	72.18
		5m	72.65	72.65	72.67	72.68
	Ground Floor	15m	80.7	80.7	80.75	80.76
		10m	84.31	84.31	84.35	84.36
		5m	88	88.04	88.14	88.19
		Edge	85.25	85.25	85.31	85.33

Table 7.5Predicted noise levels (in dB) when speed is kept 50kmph

	Peak hours		8-9 hr	9-10 hr	17-18 hr	18-19 hr
Adyar	First Floor	15m	60.42	60.31	60.88	61.31
		10m	64.23	64.17	64.45	64.67
		5m	65.41	65.27	65.99	66.56
	Ground Floor	15m	66.82	66.98	67.19	67.33
		10m	78.2	77.62	80.6	82.92
		5m	67.09	67.02	67.37	67.74
		Edge	72.03	71.95	72.35	72.66
Velachery	First Floor	15m	44.95	45.48	45.96	46.13
		10m	59.62	60.7	61.69	62.05
		5m	60.95	61.02	61.09	61.19
	Ground Floor	15m	56.97	63.09	68.7	70.71
		10m	45.26	45.28	45.3	45.31
		5m	43.17	43.21	43.25	43.26
		Edge	42.85	42.87	42.89	42.89
T. Nagar	First Floor	15m	45.36	45.42	45.44	45.48
		10m	44.08	44.16	44.19	44.24
		5m	41.79	41.83	41.85	41.87
	Ground Floor	15m	48.49	48.51	48.52	48.53
		10m	50.98	51	51.01	51.02
		5m	57.5	57.52	57.53	57.55
		Edge	62.83	63.25	63.41	63.69
Porur	First Floor	15m	61.26	61.26	62.1	62.3
		10m	63.46	63.46	63.61	63.64
		5m	66.31	66.31	66.33	66.34
	Ground Floor	15m	70	70	70.05	70.06
		10m	74.38	74.38	74.42	74.43
		5m	76.4	76.4	76.51	76.54
		Edge	77.42	77.42	77.48	77.5

7.5 Effect of change in volume on noise

Another factor having high correlation with noise is volume of traffic. Hence the volume is changed to 800, 1200 and 1500 vehicles per hour keeping speed constant and the effect on the model is studied.

In order to study the factor which has high correlation with road traffic noise in the developed model, the volume alone wasvaried for 800vehicles/hour, 1200 vehicles/hour and 1500 vehicles/hour.Tables 7.6 to 7.8 show noise levels for volumes of 800vehicles/hour, 1200 vehicles/hour and 1500 vehicles/hour. The rate of increase in noise level was found to be less in first floor and more in ground floor. Similarly the noise level is more near the source and less as the distance increases.

Table 7.6Predicted noise levels (in dB) when volume is 800 vehicles/hour

	Peak hours		8-9 hr	9-10 hr	17-18 hr	18-19 hr
Adyar	First Floor	15m	64	62.98	61.86	61.6
		10m	75.58	72.93	70.03	69.34
		5m	79.3	75.92	72.19	71.31
	Ground Floor	15m	83.34	79.58	75.44	74.47
		10m	94.49	89.69	84.41	83.16
		5m	85.07	80.92	76.36	75.28
		Edge	93.28	88.38	82.99	81.72
Velachery	First Floor	15m	52.37	52.96	53.07	51.23
		10m	64.43	64.84	64.92	63.63
		5m	67.91	68.46	68.56	66.86
	Ground Floor	15m	64.68	65.55	65.71	63.03
		10m	72.27	74.35	74.73	68.3
		5m	74.75	77.18	77.62	70.11
		Edge	79.59	82.42	82.93	74.19
T. Nagar	First Floor	15m	64.76	66.25	66.53	61.9
		10m	66.69	68.43	68.75	63.36
		5m	65.21	67.02	67.34	61.77
	Ground Floor	15m	68.78	70.34	70.63	65.8
		10m	72.3	73.94	74.24	69.17
		5m	73.46	74.69	74.92	71.12
		Edge	73.62	74.48	74.64	71.99
Porur	First Floor	15m	61.41	61.63	61.73	61.84
		10m	70.86	73.08	74.11	75.13
		5m	71.87	73.52	74.28	75.04
	Ground Floor	15m	79.39	82.17	83.45	84.74
		10m	83.09	85.68	86.87	88.06
		5m	86.53	89.55	90.94	92.33
		Edge	84.26	86.3	87.24	88.17

Table 7.7Predicted noise levels (in dB) when volume is 1200 vehicles/hour

	Peak hours		8-9 hr	9-10 hr	17-18 hr	18-19 hr
Adyar	First Floor	15m	65.18	64.16	63.04	62.78
		10m	76.16	73.52	70.61	69.93
		5m	80.83	77.44	73.72	72.84
	Ground Floor	15m	83.78	80.02	75.88	74.91
		10m	100.75	95.95	90.67	89.43
		5m	85.8	81.65	77.09	76.01
		Edge	94.12	89.22	83.83	82.56
Velachery	First Floor	15m	53.54	54.13	54.24	52.4
		10m	66.83	67.24	67.32	66.03
		5m	68.16	68.71	68.81	67.11
	Ground Floor	15m	78.28	79.15	79.31	76.63
		10m	72.32	74.4	74.78	68.35
		5m	74.84	77.27	77.71	70.2
		Edge	79.63	82.46	82.97	74.24
T. Nagar	First Floor	15m	64.88	66.37	66.65	62.02
		10m	66.85	68.59	68.91	6352
		5m	65.29	67.1	67.42	61.85
	Ground Floor	15m	68.82	70.38	70.67	65.84
		10m	72.34	73.99	74.28	69.21
		5m	73.52	74.75	74.97	71.17
		Edge	74.5	75.36	75.52	72.87
Porur	First Floor	15m	62.97	63.19	63.29	63.4
		10m	71.14	73.36	74.38	75.41
		5m	71.91	73.56	74.32	75.08
	Ground Floor	15m	79.47	92.25	83.54	84.82
		10m	83.17	85.75	86.94	88.13
		5m	86.73	89.75	91.14	92.53
		Edge	84.38	86.42	87.36	88.3

Table 7.8 Predicted noise levels (in dB) when volume is 1500 vehicles/hour

	Peak hours		8-9 hr	9-10 hr	17-18 hr	18-19 hr
Adyar	First Floor	15m	66.07	65.05	63.39	63.67
		10m	76.6	73.96	71.05	70.36
		5m	81.97	78.59	74.87	73.99
	Ground Floor	15m	84.11	80.35	76.21	75.24
		10m	105.45	100.65	95.37	94.12
		5m	86.35	82.2	77.63	76.55
		Edge	94.75	89.85	84.46	83.19
Velachery	First Floor	15m	54.41	55.01	55.11	53.28
		10m	68.63	69.04	69.12	67.83
		5m	68.35	68.9	69	67.3
	Ground Floor	15m	88.48	89.35	89.51	86.83
		10m	72.36	74.44	74.81	68.39
		5m	74.9	77.34	77.78	70.26
		Edge	79.67	82.49	83.01	74.27
T. Nagar	First Floor	15m	64.97	66.46	66.74	62.11
		10m	66.97	68.71	69.03	63.64
		5m	65.35	67.16	67.48	61.91
	Ground Floor	15m	68.85	70.42	70.7	65.87
		10m	72.38	74.02	74.32	69.24
		5m	73.56	74.79	75.01	71.21
		Edge	75.16	76.02	76.18	73.53
Porur	First Floor	15m	64.14	64.36	64.46	64.57
		10m	71.35	73.57	74.59	75.62
		5m	71.95	73.59	74.36	75.12
	Ground Floor	15m	79.53	82.31	83.6	84.88
		10m	83.22	85.8	86.91	88.19
		5m	86.88	89.9	91.29	92.68
		Edge	84.47	86.51	87.45	88.39

7.6GIS based noise model

Noise maps are generated using Arc GIS version 10.3 during morning (8-9 am , 9-10 am) peak hours and evening (5-6 PM , 6-7 PM) peak hours for the selected 4 locations and presented in figures 5.1 to 5.12 . The maps for the remaining locations are given in Appendix 4. Further combined location maps during morning and evening peak hours are shown in figures 5.11 to 5.16 for ground floor and figures 5.17 to 5.20 for first floor.

The ground floor noise map of Adyar intersection, shows that the areas of 0.55sq.km,0.133sq.km, 0. 69sq.km and 0.105sq.km were affected by noise levels of 60dB, 50-60dB, 50-45dB and 45-40dB respectively during 5.00 pm to 6.00 pm.

From first floor noise map of Adyar intersection, it was observed that the areas of 0.41sq.km , 0.11sq.km 0.82sq.km and 0.59sq.km were affected by noise levels of 60dB, 50-60dB, 50-45dB and 45-40dB respectively during 5.00 pm to 6.00 pm .The areas affected by these noise level ranges are shown in tables 7.9 to 7.12

From table 7.9, it is observed that the area affected by noise is 0.62 sq.kmat Adyar and it is 0.67 sq.km at T.Nagar. This shows that Adyar and T.Nagar have high levels of noise pollution compared to other locations. Further the noise affected areas are less in the morning compare to evening peak hour. This is due to the heavy volume of traffic during evening peak hours due to closing time of offices and educational institutions. Further in Adyar, the area of 0.62ksq.km is not suitable for living since the noise level is greater than60 dB which is higher than ambient noise level.

Table 7.9 Ground Floor Area (sq.km) from 8-9 hours

Location	>60 dB	50-60 dB	50-45 dB	45-40 dB
Adyar	0.62	0.13	0.09	0.06
Porur	0.46	0.96	0.04	0.04
T Nagar	0.67	0.18	0.07	0.10
Velacherry	0.22	0.78	0.04	0.05

Table 7.10 Ground Floor Area (sq.km) from 17-18 hours

Location	>60 dB	50-60 dB	50-45 dB	45-40 dB
T Nagar	0.70	0.18	0.07	0.08
Adyar	0.55	0.13	0.06	0.10
Porur	0.49	0.11	0.02	0.05
Velacherry	0.23	0.09	0.03	0.08

Table 7.11 First Floor Area (sq.km) from 8-9 hours

Location	>60 dB	50-60 dB	50-45 dB	45-40 dB
T Nagar	0.53	0.20	0.09	0.09
Adyar	0.47	0.09	0.07	0.07
Porur	0.35	0.10	0.046	0.05
Velacherry	0.11	0.1104	0.03	0.04

Table 7.12 First Floor Area (sq.km) from 17-18 hour

Location	>60 dB	50-60 dB	50-45 dB	45-40 dB
T Nagar	0.59	0.17	0.10	0.08
Adyar	0.41	0.11	0.08	0.05
Porur	0.36	0.10	0.04	0.07
Velacherry	0.12	0.10	0.03	0.05

7.7 3D GIS model

3D GIS maps are given in figures 6.3 to 6.6 for the areas of Adyar, T.nagar,Velachery and Porur respectively.

The 3D Model, shows that in the locations near respective intersections and along main arterial roads connecting the intersection, the noise levels are very high as shown by red colour in these regions.

The noise pollution level in the study area of Chennai city has been plotted in a map using ArcGIS software.Verification of developed noise model for Teheran showed that the difference between mean and measured values was -0.48dB (Mohseni P.H. et al,1998).

7.8 Model Validation

To validate the model, two equations are taken one at 15m for ground floor and other one at 15 m in first floor equation at Adyar. It is seen that the differences of observed and calculated noise level is between 0.1 dB to 2.45 dB. The difference between observed and estimated noise level for Delhi lies in the range of 1dB - 11 dB (Nirjar, 2003). The error varies from -9.88% to 0.73%. Hence the model developed for busy corridor in Chennai can be applied for any stretch of the road in Chennai and also used for other similar cities in India. Hence the model developed for noise in busy corridor for Chennaicity is withinacceptable limits.The comparisons of observed and calculated values are given in the Table 7.13.

Table 7.13 Comparison of Observed and Calculated Noise Levels(in dB)

Sl. No.	$y=113.27+0.0133x_1-0.609x_2$ (Ground Floor) T.Nagar			$y=123.60+0.002x_1-0.491x_2$ (First Floor) T.Nagar		
	Observed	Calculated	% of Error	Observed	Calculated	% of Error
1	70.08	70.57	-0.71	66.40	69.69	-4.95
2	69.08	68.57	0.73	63.90	70.21	-9.88
3	69.58	69.29	0.41	67.65	71.74	-6.05
4	69.88	69.91	-0.06	67.35	73.43	-9.03
5	70.68	70.63	0.07	68.65	68.58	0.10
6	70.98	71.12	-0.20	68.30	69.42	-1.64
7	72.28	71.77	0.69	68.18	67.90	0.40
8	71.28	71.76	-0.68	66.20	66.77	-0.86
9	79.10	78.44	0.84	73.80	74.19	-0.53
10	78.10	77.99	0.14	71.80	74.33	-3.53
11	78.60	79.15	-0.70	74.05	74.33	-0.38
12	78.90	78.99	-0.11	74.45	74.26	0.26
13	81.3	81.0	-0.06	80.7	80.1	0.6
14	84.8	83.1	0.39	82.4	81.5	0.9

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7.9 Summary

The results obtained in this study show that the city is suffering from severe noise pollution due to the vehicular traffic. This is mainly attributed towards congested traffic area, unplanned road network, reduced one way traffic, construction of silence zone in the main area of the city, unplanned urban sprawl etc. In most of the areas the noise level is exorbitant with more than 85 dB average prevailing across the city during the peak hour. Many schools and hospitals situated in the heart of the city are also affected severely by the noise pollution. Some areas surrounding bus stops show a noise level of 90 dB which is twice as high as the prescribed level by regulatory bodies. Areas surrounding the silence zones are also exposed to heavy noise pollution during this period which will create health related issues to the people dwelling in this area.

In this research, traffic-induced noise levels in the city of Chennai were measured during peak and low traffic times and prediction models are developed using mathematical modelling techniques and GIS. The predicted values obtained from these models are compared and validated. The results showed that the measured noise levels and predicted values using the equations obtained by the multiple regression analysis and GIS maps are very comparable as they are within the allowable limits (i.e. less than plus or minus 2 %).

The work shows capability of the model in predicting the combined traffic noise with a varying traffic volume, speed and distance. Present study reveals that using road transportation noise prediction model developed so far traffic noise level can be reduced and so health problems of people living close proximity to busy road highways.

The road traffic noise on the main roads and minute streets can be estimated by using this prediction model. By introducing the road map data and the traffic data to the prediction model, it is possible to make the citywide noise map.