21 An Assessment of Traffic Noise Level in Agartala Municipal Corporation Using Geo-spatial Technology in Tripura, India

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Abstract

Vehicular noise greatly affects the population who are exposed to it, particularly the road users or those who are located alongside transport lines. Though noise pollution does not have an immediate health impact, long-term exposure to it might be detrimental for human physical as well as mental health. In Agartala Municipal Corporation, there has been a significant rise in the number of vehicles over a period of last ten years; therefore, the noise created by them also has become an issue of concern. The present study is an attempt to evaluate the level of traffic noise along twelve major roads in Agartala Municipal Corporation. This study would not only throw an insight into the vulnerable areas affected by noise pollution in the city but also address the population most likely to be affected by it. An effort has been made to show the relationship of traffic noise level with traffic volume and road character like the carriageway width, and it could be established that the nature of road and traffic composition has a positive relation with noise level in the city. In order to optimize the level and efficiency of noise effect in the city, geospatial techniques were used to prepare a noise map through IDW interpolation method.

Keywords

Noise pollution · Equivalent noise level · Traffic volume · Geospatial technology

21.1 Introduction

The environmental noise climate is influenced drastically by road traffic noise as a continuous sound is produced by passage of each vehicle which fluctuates hourly in an irregular drift (Halim and Abdullah 2014). Thus, noise pollution due to vehicular traffic has become one of the growing environmental problems of urban centers that needs to be addressed (Bhosale et. al. 2010; Chauhan et al. 2010). With the increase in population numbers, travel demand has also significantly amplified. Thus, in order to meet the increasing need for mobility more and more vehicles, both public and majorly private have started playing on roads. The resultant effect is that motor vehicles in the cities have become the

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main source of urban noise emission (Tiwari et al. 2013), contributing about 55% to the total noise (Sinha and Sridharan 1999). This not only causes irritation to the road users and those occupying space alongside roads but it also slowly and adversely affects human health (Das and Jamatia 2014). It has been found in several researches that the threshold of listening was affected by long-term exposure to noise (Coles et al. 1968; Passchier-Vermeer 1974; Ward 1975; Berger et al. 1978; Stevin 1982; Alberti 1998; Nash 2000). So, noise pollution caused by traffic has appeared as a fundamental issue to urban people and planner (Halim and Abdullah 2014).

The northeastern state of Tripura has been experiencing steady urban growth over the decade. The environmental condition of Agartala Municipal Corporation (AMC), the capital of the state, has been changing abruptly along with the rapid growth of urbanization (Sen et al. 2014). AMC has about 4.95% of area under transport services, and the number of registered vehicles has increased by 58.8% over a period of last five years. Among all the vehicles, the highest growth rate was recorded in auto rickshaws followed by two-wheelers and personalized vehicles. Furthermore, of the total length of road network about one fifth witness peak traffic flows of more than 4000 PCU (Government of Tripura 2006). Consequently, noise levels are quite high in the city.

Under such situation, this work aims to study the status of vehicular noise level along twelve major roads within Agartala Municipal Corporation and to assess the vulnerable zones affected by noise pollution in the city. An attempt has also been made to categorize the population who are most likely exposed to noise pollution along the selected twelve roads. This would help in better understanding the adversity of traffic noise pollution at these areas.

21.2 Methods and Materials

21.2.1 Study Area

Agartala Municipal Corporation is located on the major corridors of movement in the state and is connected to the rest of the country by surface through a single road, i.e., the Assam-Agartala-Sabroom road (NH8/44). The city has a high population growth rate and the density in the city core to that of the peripheral areas is highly variant. The city core area accounts to about 17% of the total area which accommodates about 50% of the population of the city, enhancing the travel demand in the core areas of the city by manifold. Further popularity of personalized vehicles and intermediate para-transit modes in intra-city travel causes stress to the pollution levels in the city. The vehicular noise level of 12 selected roads under Agartala Municipal Corporation was surveyed. The roads were selected on the basis of its carrying capacity and importance. All these roads are the major roads of the Municipal Corporation and support highest traffic volume.

21.2.2 Data Collection Process

The data for the study has been collected through an extensive field survey. Traffic Noise was recorded on two time periods, i.e., peak hour (9:30–10:30 a.m.) and lean hour (2:00–3:00 p.m.) for duration of five minutes at an interval of fifteen minutes for a period of one hour at road junctions with the help of handheld noise meter.

Assessment of traffic volume and composition was also measured to ascertain their influence on traffic noise level. For this purpose, traffic count was carried out at junctions of each road for one hour at an interval of fifteen minutes both for peak and lean hour. Carriageway width for each of the roads was measured at major and minor junctions with the help of 100-m measuring tape, and the average of the values was considered as width of the road.

In order to assess the variation of traffic noise at different land use zones, namely industrial zone, commercial zone, residential zone, and silent zones in the city, the maximum, minimum, and equivalent noise level of two locations under each of these zones at four different time periods, i.e., 9:30–11 a.m., 2–2:30 p.m., 5–6:30 p.m., and 7:30–9 p.m. from the month of January to March, 2019, was monitored. The land use components along the roads were assessed through field survey using 100-m measuring tape at 20-m interval. The affected population has been estimated with the help of land use survey considering a buffer of 100 m along the roads. Target group discussion with a structured schedule following random sampling technique was undertaken for 10 persons under different sections along each road.

21.2.3 Data Analysis

The Equivalent Noise Level for each of the roads was calculated to find out the status of traffic noise pollution in the city using the following formula which had been developed based on Sen et al. (2014)

$$L_{eq} = 10 \log \sum_{i=1}^{n} (10) * L_i/10 * t_i \qquad (21.1)$$

where L_{eq} = Equivalent Noise Level, n = Total number of sound samples, L_i = The noise level of any ith sample, and t_i = Time duration of ith sample.

Noise pollution indices were calculated using Gaussian percentile to obtain the noise pollution level. Different percentile values like L_{10}, L_{50}, and L_{90} were computed from the sampled data, and the parameters were used for the evaluation of Noise climate (NC) and Noise pollution Level (LPL) (Tripathi et al. 2006).

Noise climate (NC) is the range over which the sound levels are fluctuating in an interval of time and was assessed using the following formula

$$NC = (L_{10} - L_{90}) \qquad (21.2)$$

where NC is Noise Climate, L_{10} is the level of sound exceeding for 10% of the total time of measurement or Peak noise level, L_{50} is the level of sound exceeding for 50% of total time of measurement or mean sound level, and L_{90} is the level of sound exceeding for 90% of total time of measurement or background or residual noise level (Hunashal and Patil 2012).

As L_{eq} is an insufficient descriptor of the annoyance caused by fluctuating noise, therefore Noise pollution level expressed in dB was calculated by using the following formula.

$$NPL = L_{eq} + NC \qquad (21.3)$$

NPL is the noise pollution level, L_{eq} is Equivalent noise level, and NC is the noise climate.

Another noise descriptor used to measure traffic noise pollution is Traffic noise index (TNI). TNI can be measured by using the following equation.

$$TNI = 4(L_{10} - L_{90}) + L_{90} - 30 \text{ dB (A)} \qquad (21.4)$$

Traffic noise index (TNI) is another parameter, which indicates the degree of variation in a traffic flow. This is also expressed in dB (A) and can be computed by the following formula (Pradhan et al. 2012).

21.2.4 Noise Mapping Using Geospatial Techniques

In order to estimate the overall noise pollution scenario of Agartala Municipal Corporation, noise contours are computed in GIS by spatial interpolation method. The noise data obtained from the twelve selected roads were mapped by interpolating noise levels computed on a raster of points (de Kluijver and Stoter 2003; Esmeray and Eren 2021). Among the various spatial interpolation techniques, Inverse Distance Weighted (IDW) interpolations were used for the study which estimates the noise level L_p at each point p, as an average of the noise levels collected at the M fixed samples (Can et al. 2014) and the map was prepared in QGIS software.

21.3 Results and Discussion

21.3.1 Noise Level in Different Roads of AMC

The issues of noise pollution across the world's cities have been organized in many research (Singh and Daver 2004; Li et al. 2002; Morillas et al. 2002; Zannin et al. 2002; Alberola et al.

2005; Lebiedowska 2005; Pucher et al. 2005; Tansatcha et al. 2005) and have identified the sources of city noise (Dursun et al. 2006; Ausejo et al. 2010; Al-Qdah 2014). Noise of vehicle's engine and traffic horns are the main source of noise pollution related to transportation and other responsible factors of traffic noise are traffic speed, composition, volume, and management system (Cohen and McVoy 1982; Banerjee et al. 2008; Al-Mutairi et al. 2009; Swain et al. 2012). Noise level has been measured at 12 selected roads (Table 21.1) within Agartala Municipal Corporation, and attempt has been made to establish its relationship with volume of traffic and the type of vehicles that occupy the roads.

21.3.1.1 Noise Descriptors Used in Assessment of Traffic Noise Level

The statistical equivalent sound pressure level was measured at different time intervals during peak hour and lean hour traffic conditions. Table 21.2 depicts the equivalent noise level (L_{eq}) and statistical sound level descriptors such as L_{10}, L_{50}, and L_{90}. L_{eq} is the constant sound level while the statistical equivalent sound pressure level was measured at different time intervals of 10%, 50%, and 90% to calculate the traffic indices.

21.3.1.2 Noise Climate

The greater the difference between L10 and L90, the traffic noise index (TNI) will increase even more and subsequently, noise level to the recipient environment results in more annoyance (Nassiri et al. 2016). During peak hour, it has been observed that Agartala-Sabroom road, Akhaura road, and Dhaleswar A.A road record NC value more than 10 dB. Even during lean hours, NC value exceeds 8 dB for all the selected roads except GB-ITI road, Airport road, and Jail-Ashram road. So, it could be stated that the noise climate of the selected roads depicts relatively high fluctuation of noise level during peak hour and also in lean hour which create significant amount noise pollution.

21.3.1.3 Noise Pollution Level

Noise pollution level (NPL) values at different road stretches are displayed in Table 21.3. Noise pollution results reveal that during peak hours maximum NPL of 87.10 dB was observed in Dhaleswar A.A road followed by Agartala-Sabroom road (82.26 dB), Akhaura road (82.07 dB), and Motorstand road (80.43 dB). The prime causes are traffic congestion, horning from vehicles and noise from shops and markets located along these roads. During lean hours, average noise level in the previously mention road remains

Table 21.1 Selected roads within AMC

S. No.	Road name	Extension	
		From	To
1	VIP road	North gate	Secretariat
2	GB-ITI road	GB Bazar	Up to Jail-Ashram Road
3	Airport road	Bhati Abhoynagar	Narsinghgarh
4	Bamutia road	Music college	Bamutia Market
5	Jail-Ashram road	m/s Sarada Iron B.K Road	Satadal Sangha, Dhaleswar
6	Dhaleswar A.A road	Motorstand Shani Temple	Chandrapur Bazar
7	Barjala road	Durga Chowmohani bridge	Panchabati Kali Bari
8	TG road	Ramnagar Rd no.4	Up to Ramnagar Rd no.9
9	HGB road	Battala Bazar	Kaman Chowmohani
10	Akhaura road	Old RMS Chowmohani	Akhaura check post
11	Motorstand road	Motorstand Shani Temple	Kaman Chowmohani
12	Agartala-Sabroom road	Battala Bazar	Amtali (within AMC)

Table 21.2 Noise level (dB) variation at selected roads of AMC

Road name	Time							
	Peak hour traffic flow				Lean hour traffic flow			
	L_{eq}	L_{10}	L_{50}	L_{90}	L_{eq}	L_{10}	L_{50}	L_{90}
VIP road	68.35	71.20	65.61	61.51	60.70	63.25	58.27	54.63
GB-ITI road	60.00	62.52	57.6	54.00	50.76	52.91	48.73	45.68
Airport road	60.10	62.62	57.69	54.09	55.90	58.26	53.66	50.31
Jail-Ashram road	65.78	68.53	63.15	59.20	53.90	56.17	51.74	48.51
Bamutia road	63.58	66.24	61.04	57.22	59.70	62.21	57.31	53.73
Barjala road	68.20	71.05	65.47	61.38	51.78	53.97	49.70	46.60
T.G road	68.78	71.65	66.02	61.90	61.90	64.49	59.42	55.71
Dhaleswar A.A road	76.30	79.47	73.24	68.67	68.90	71.77	66.14	62.01
Motorstand road	70.45	73.38	67.63	63.40	64.89	67.60	62.29	58.40
Akhaura road	71.89	74.88	69.01	64.70	67.45	70.26	64.75	60.70
H.G.B road	69.90	72.81	67.10	62.91	61.78	64.37	59.31	55.60
Agartala-Sabroom road	72.40	75.42	69.50	65.16	64.96	67.67	62.36	58.46

Table 21.3 Variation of noise descriptors (NC, L_{np}, TNI) at selected roads of AMC

Road name	Time					
	Peak hour traffic flow			Lean hour traffic flow		
	NC (dB)	NPL (dB)	TNI (dB)	NC (dB)	NPL (dB)	TNI (dB)
VIP road	9.69	78.04	70.27	8.62	69.32	59.11
GB-ITI road	8.52	68.52	58.08	7.23	57.99	44.60
Airport road	8.53	68.63	58.21	7.95	63.85	52.11
Jail-Ashram road	9.33	75.11	66.52	7.66	61.56	49.15
Bamutia road	9.02	72.60	63.30	8.48	68.18	57.65
Barjala road	9.67	77.87	70.06	7.37	59.15	46.06
T.G road	9.75	78.53	70.90	8.78	70.68	60.83
Dhaleswar A.A road	10.8	87.10	81.87	9.76	78.66	71.05
Motorstand road	9.98	80.43	73.32	9.20	74.09	65.20
Akhaura road	10.18	82.07	75.42	9.56	77.01	68.99
H.G.B road	9.90	79.80	72.51	8.77	70.55	60.68
Agartala-Sabroom road	10.26	82.26	76.20	9.21	74.17	65.30

high (more than 60 dB). GB-ITI road and Barjala road are the only two roads among the twelve selected roads where noise pollution level is less than 50 dB during lean hours.

21.3.1.4 Traffic Noise Index

The maximum TNI value was observed in the peak hours due to maximum number of traffic accompanied by traffic congestion and other background sound originating from surrounding areas as the selected areas are the arterial roads connecting busy intersections of the city. During peak hour traffic, maximum TNI value has been observed in Dhaleswar A.A. road (81.87 dB), Agartala-Sabroom road (76.20 dB), and Akhaura road (75.42 dB). Whereas minimum TNI value has been observed in GB-ITI road (58.08 dB), Airport Road (58.21 dB), and Bamutia road (63.30 dB) primarily due to less traffic congestion and comparatively fewer number of vehicles compared to other selected roads (Table 21.3). During lean hour traffic scenario, it has been observed that GB-ITI road (44.60 dB), Barjala road (46.06 dB), and Jail-Ashram road (49.15 dB) have less TNI value due to fewer vehicle number. Whereas in the case of Dhaleswar road, Akhaura road, Agartala-Sabroom road, and Motorstand road, TNI values are relatively high even in lean hours.

21.3.2 Noise Level and Traffic Volume

Traffic volume refers to the number of vehicles that pass by a road at a given time period. There exists a strong relationship between traffic volume and noise level (Ma et al. 2006; Swain et al. 2012). It has been found that the level of discontentment has increased in urban residential area with the increase in traffic congestion (Tapia Granados 1998). As traffic volume increases, noise level also increases. Traffic volume not only includes noise from vehicles but also from road signaling system, which creates waiting period for moving vehicles. It has been observed that during peak hour the noise level of all the roads is high owing to high traffic volume as compared to the lean hour. In peak hour, the number of vehicles is quite high in Agartala-Sabroom road, Motor stand road, Akhaura road, H.G.B road, Barjala road, and VIP road, and consequently, the noise level of these roads is also higher which establishes that in the case of these roads noise level and traffic volume are directly correlated. However, in the case of GB-ITI road and Dhaleswar A.A. road, the noise level and the traffic volume show negative corelation. In the case of GB-ITI road, traffic volume is significantly less but noise level during peak hour though lesser compared to other roads yet is considerably high as compared to traffic volume. Similarly in the case of Dhaleswar A.A. road which has traffic volume lesser than the ones mentioned above yet it has recorded maximum noise level not only in peak hour but also in lean hour (Fig. 21.1).

In both the roads therefore, the noise could be attributed to something else other than mere traffic volume. The presence of traffic terminal point located in the vicinity of Dhaleswar A.A. road where the noise level has been recorded can be considered to have an impact on the level of noise. It is because during waiting period at traffic signals many vehicles do not switch off the engine and further immediately after the signal turns green drivers tend to start honking to allow them space. While in the case of GB-ITI road the presence of commercial sector is responsible for the high noise level. In the case of lean hour as well, the noise level of Akhaura road, Agartala-Sabroom road, Motorstand road, T.G. road, and HGB road was high and the traffic volume was also high comparatively, but in the case of other roads traffic noise level is much more even when the traffic volume is low. This may be attributed to the other activities that carry on along the road, specifically commercial services which contribute to the noise during lean traffic hours.

21.3.2.1 Relation Between Noise Level and Traffic Volume

Traffic volume is one of the most important factors of traffic noise pollution in urban areas (Crocker 2007; Sulaiman et al. 2018), and Agartala is no exception. The scatter diagram shows the relation between traffic volume and traffic noise, the prior being the independent variable and later the dependent variable. In Fig. 21.2 (a and b), the relationship is clearly established that more the traffic volume more is the noise level. However, in the case of AMC it can be seen that peak hour R^2 value is 0.742, which means both the elements are moderately positively correlated. But in the case of lean hour, the R^2 value is 0.917 that is means; the traffic volume and noise level are strongly positively correlated with one another more than that in the peak hour. It may be interpreted that during peak hour other noises may also have a significant influence on the total noise level.

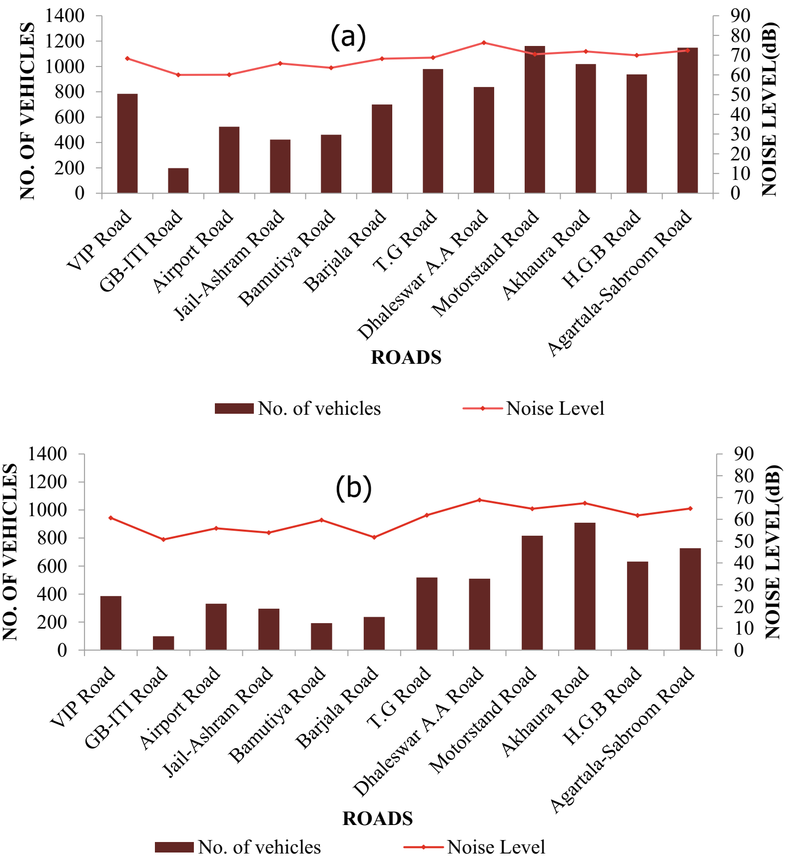

Fig. 21.1 **a** Noise level (dB) and traffic volume on different roads (peak hour); **b** Noise level (dB) and traffic volume on different roads (lean hour)

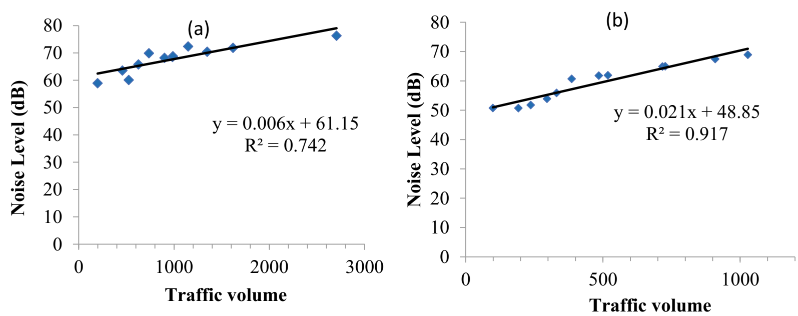

Fig. 21.2 **a** Relation between traffic noise and traffic volume (peak hour); **b** Relation between traffic noise and traffic volume (lean hour)

21.3.2.2 Noise Level and Category of Vehicles

Not only does the traffic volume have an impact on the noise level but also the category of vehicles does affect the level of noise in an area (Alves Filho et al. 2004). This part of the work has been devoted to establishing a comparison between the noise level and the type of vehicle dominating the area. It has been observed in Tables 21.4 and 21.5 that in the case of roads where L_{eq} is very high like that of Dhaleswar A. A. road, that even though total vehicular number plying along this road is low, the number of auto rickshaws and magic cars is significantly high. Contrarily in the case of GB-ITI road and Jail-Ashram road where the numbers of auto

Table 21.4 Peak hour vehicle strength and noise level

Roads	Equivalent noise level (dB)	Bus	Car	Toto	Magic	Auto	Two-wheeler	Jeep	Rickshaw	Truck	Pickup van	Cycle	Total
VIP road	68.35	10	179	2	5	218	293	31	10	0	18	18	784
GB-ITI road	60.00	1	28	1	0	17	125	0	1	0	6	19	198
Airport road	60.10	15	91	5	0	163	219	2	4	0	15	11	525
Jail-Ashram road	65.78	4	32	0	17	147	159	17	16	4	27	0	423
Bamutia road	63.58	14	91	0	2	126	147	13	27	0	22	19	461
Barjala road	68.20	06	21	5	20	252	43	4	64	4	110	171	700
T.G road	68.78	03	143	149	2	220	245	2	19	2	146	48	979
Dhaleswar A.A road	76.30	11	25	53	39	229	275	6	137	3	2	58	838
Motorstand road	70.45	7	144	160	3	245	375	6	138	3	38	42	1161
Akhaura road	71.89	8	68	147	42	135	284	14	77	27	182	35	1019
H.G.B road	69.90	11	72	184	3	267	334	7	54	0	2	3	937
Agartala-Sabroom road	72.40	16	124	201	12	243	374	13	102	5	47	11	1148

Table 21.5 Lean hour vehicle strength and noise level

Roads	Equivalent noise level (dB)	Bus	Car	Toto	Magic	Auto	Two-wheeler	Jeep	Rickshaw	Truck	Pickup van	Cycle	Total
VIP road	60.70	6	79	10	2	116	155	2	1	0	5	10	386
GB-ITI road	50.76	5	17	2	0	27	40	2	1	2	0	3	99
Airport road	55.9	07	50	0	07	81	180	5	0	0	1	0	331
Jail-Ashram road	53.90	39	4	0	12	97	97	0	39	6	2	0	296
Bamutia road	59.70	2	12	30	22	53	19	13	28	0	9	4	192
Barjala road	51.78	5	16	14	0	43	125	1	10	1	7	15	237
T.G road	61.90	2	41	78	0	109	205	10	49	5	9	10	518
Dhaleswar A.A road	68.90	7	45	97	0	10	207	2	36	3	10	0	510
Motorstand road	64.89	16	45	135	132	135	201	11	66	11	51	14	817
Akhaura road	67.45	14	101	150	30	204	243	40	99	4	17	7	909
H.G.B road	61.78	5	24	160	41	76	163	26	110	6	10	11	632
Agartala-Sabroom road	64.96	0	22	20	3	144	283	3	210	2	25	15	727

rickshaws are less, L_{eq} is also low. Again in the case of Akhaura road and Agartala-Sabroom road total vehicular number being high, mention may be made of truck, magic cars, auto rickshaws, buses, and private cars. L_{eq} is also quite high.

21.3.2.3 Traffic Noise and Carriageway Width

A carriageway consists of a width of road on which a vehicle is not restricted by any physical barriers or separation to move laterally. A carriageway generally consists of a number of traffic lanes together with any associated shoulder, but may be a sole lane in width, for example, a highway off ramp.

Carriageway width reflects the number of vehicles on road at a time. It is considered that more the vehicles running along a road at a time more will be the noise level. Figure 21.3 shows that relationship between noise level and carriageway width depicts a R^2 value is 0.424, which means the relationship between the carriageway width and noise level is positively correlated, but their degree of correlation is not very strong in the case of AMC.

21.3.3 Noise Mapping

Geospatial technologies could provide great potential to optimize the quality of noise effect studies because traffic noise and its environmental effect have numerous spatial components. Spatial noise contour maps are useful to urban planning agencies, traffic engineers, cities, and governmental agencies and can be used as indicators to identify factors that influence traffic noise levels (Obaidat 2011). A noise map has been prepared using Inverse Distance Weighted (IDW) interpolation method to depict the overall character of noise pollution within AMC incorporating the previously collected field data on noise level at traffic intersections (Fig. 21.4). It reflected a distance decay effect where noise level has shown to decrease from CBD toward the peripheral areas of the city. The map reflects that the highest noise level was along Agartala-Sabroom road, TG road, Akhaura road, and HGB road, medium noise level has been recorded in and along Barjala road, Bamutia road, etc. This complies with the research findings that along these roads not only is the vehicular population high but also the concentration of commercial activities is greater. The lowest level of noise was observed in the outer parts of the city, which may be attributed to the less movement of vehicles, human crowd, and less busy commercial areas in the periphery of the city.

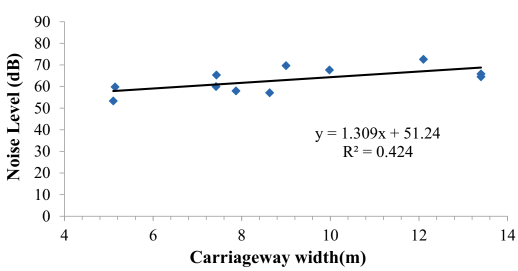

Fig. 21.3 Carriageway width of the study area

21.3.4 Traffic Noise at Terminals

The relationship between mobility in transport sector and noise level is well established. In this section, attempt has been made to assess the noise level at terminals of the three modes of transport available in the city, i.e., Road transport, Rail transport, and Air transport. Not only does the movement of vehicles along roads or rail lines creates noise pollution, but the terminals of surface transport as well as aviation sector create quite considerable noise pollution. With this perspective, the noise level at three selected terminal stations and their approach roads have been recorded (Table 21.6). Noise level has been measured for 20-m distance from these terminal points at an interval of 5 m both for morning and evening peak hours.

21.3.4.1 Noise Level at Nagerjala Bus Stand

Nagerjala bus stand is one of the busiest bus stands in the city of Agartala. It is observed that noise level is showing a decreasing trend from

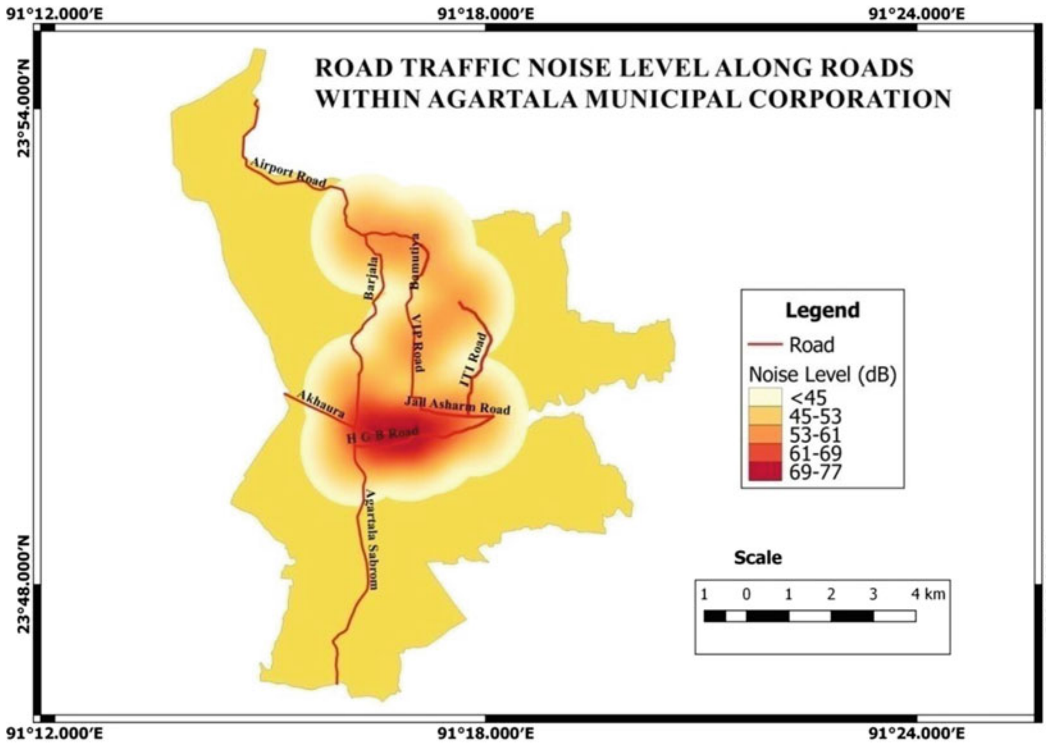

Fig. 21.4 Road traffic noise level along the roads of the Agartala Municipal Corporation

Table 21.6 Selected terminals for assessing noise level

Sector	Location	Approach roads
Road	Nagerjala bus stand	Agartala-Sabroom road Toward Battala
Rail	Agartala railway station	Toward Agartala-Sabroom road
Airway	Agartala airport	Airport road (toward Narsinghgarh) Airport road (toward Usha Bazar)

the bus stand outwards (Fig. 21.5). From the bus stand-up to a distance of 10 m, noise level is quite high, particularly toward the Battala side, as the vehicles moving out of the terminus wait here to accommodate some additional passengers, but at 15 m it is significantly reduced and the trend is followed in both the time period for the rest of the distance with the increase in distance from the bus stand.

Toward Bishalgarh road noise level also showed decreasing trend during morning peak hour, but in the case of evening peak hour noise level was higher at 5-m distance from the bus stand due to heavy congestion in this route during evening hours. However, beyond 5 m it again showed a decline in noise level.

21.3.4.2 Noise Level at Agartala Railway Station

Unlike bus terminus where congestion and honking of vehicles add to the noise pollution, in the case of rail services whistle of train, period of arrival and departure of train and hiring connecting vehicles to destinations, shouting of vendors on and off the platforms are the major causes of noise pollution. Since its inception, the

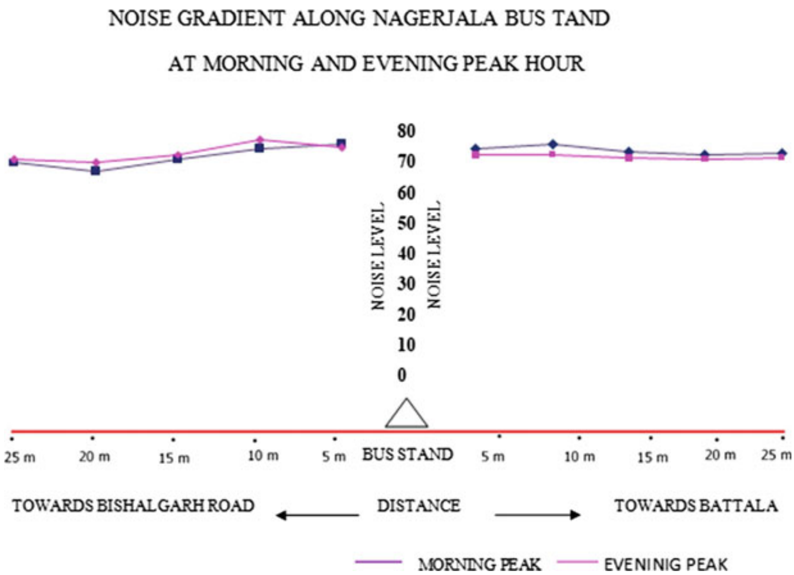

Fig. 21.5 Noise gradient along Nagerjala bus stand at morning and evening peak hour

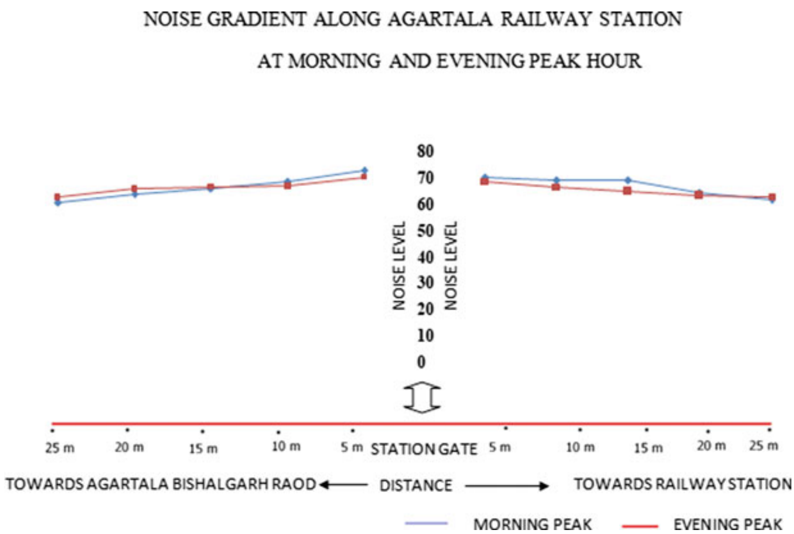

Fig. 21.6 Noise gradient at Agartala railway station at morning and evening peak hour

Agartala Railway station has seen a steady increase in the passenger numbers. But being located outside the main center of the city the approach roads show a clear decline in the noise level away from the rail station. The noise level is decreasing for both the approach roads (Fig. 21.6). The noise level at railway station is high because of noise of train, human crowd, other vehicular movements those ply as Para-transit mode of transport, but with the increasing distance the noise shows a decreasing trend from railway station.

21.3.4.3 Noise Level at Maharaja Bir Bikram Airport

Aviation sector also has its share in causing noise pollution. Those residing near an airport are well aware of the sound of takeoff and landing of an aircraft. Figure 21.7 shows the noise gradient along the roads connecting to Agartala Airport. From the diagram, it can be observed that noise level is declining from the airport toward both the approach roads toward Usha Bazar as well as toward Narsinghgarh.

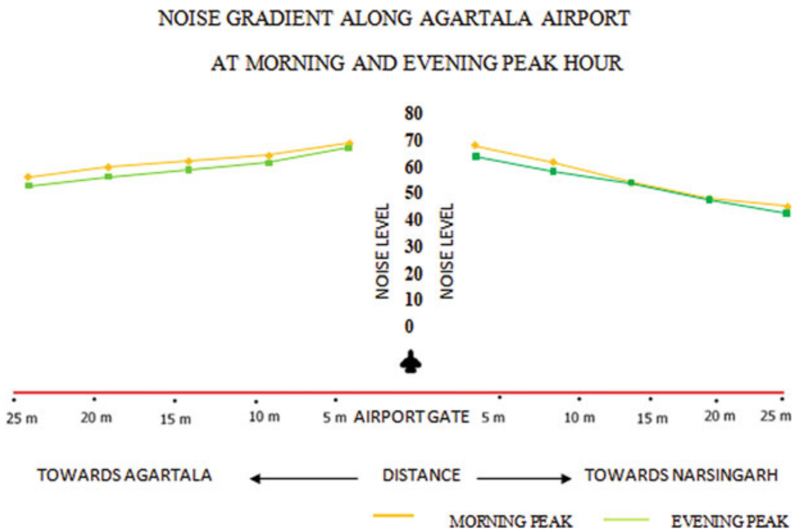

Fig. 21.7 Noise gradient at Agartala airport at morning and evening peak hour

These roads are located at the periphery of the city and therefore cater to lesser traffic numbers and encounter much less congestion therefore recording lower noise levels. Further, the noise generated from airplane decreases with the increase in distance away from airport. Contrarily human crowd and noise of other Para-transit modes of transport are responsible for increasing the noise level at airport.

21.3.5 Land Use and Traffic Noise Level

In this section, the traffic noise level has been considered at areas with different land use character, mainly industrial area, commercial area, residential area, and silent zones like hospitals and schools. There exists a standard limit for noise (Table 21.7) for each of these zones with which the present noise level of the city has been compared. Two areas from each of these land use zones have been selected for the study, i.e., for industrial zone AD Nagar and Chandinamura, for commercial zone MG Bazar and Battala Bazar, for residential zone Ramnagar 4 and Indiranagar, and two locations for silent zone selected were IGM hospital and GB hospital.

The data available from the Pollution Control Board depicts (Fig. 21.8) that in 2018, the noise level of AD Nagar industrial area is less than the standard level in both day and nighttime but the noise level is comparatively higher at nighttime, whereas in 2019, the level of noise crossed the standard level, it may be due to the increase in industrial activities. But in the case of Chandinamura industrial area, it has been observed that the noise level is very low in both the years, which is lesser than its standard level, it may be because of the lesser industrial activities in the area coupled with less movement of vehicles as this industrial area is not linked with a major road; thus, being less affected by other traffic noise or human crowd, this industrial area records lower level of noise.

In the case of commercial zone, it has been observed that noise level of two commercial zones, i.e., Battala Bazar and MG Bazar, is higher than its standard level, which may be a result of very high commercial activities in the region. Furthermore, these commercial hubs are near to the CBD of a city and lie alongside the busiest roads in the city, so that vehicular movement as well as pedestrian mobility is higher in these commercial zones. For identifying the noise pollution level in residential area, two areas, i.e., Ramnagar lane 4 and Indiranagar,

Table 21.7 Ambient air quality standards in respect of noise

Category of zone/area	Standard limit of noise (dB) (A)	
	Day time	Night time
Industrial zone	75	70
Commercial zone	65	55
Residential zone	55	45
Silent zone	50	40

Notes
1. Day time shall mean 6:00 a.m.–10 p.m.
Nighttime shall mean from 10:00 p.m.–6:00 a.m.
2. Silence zone is an area comprising not less than 100 m around hospitals, educational institutions, courts, religious places, or any other area which is declared as such by the competent authority
3. Mixed categories of areas may be declared one of the four above mentioned categories by the competent authority

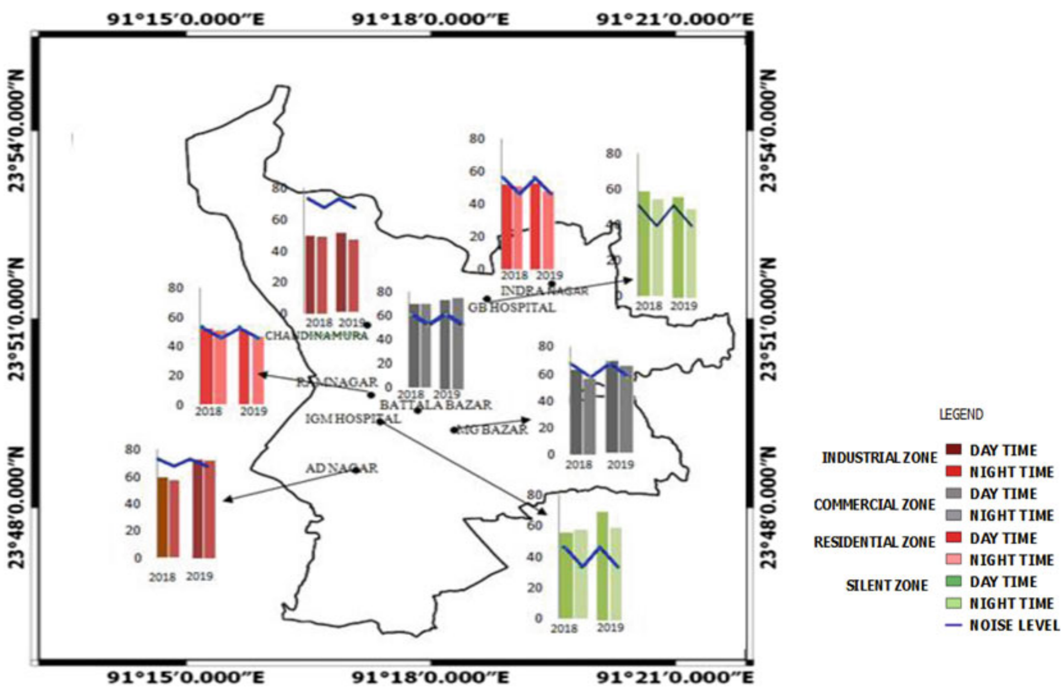

Fig. 21.8 Annual record of noise level at different zones (2018 and 2019)

area were considered and it depicted that in both the year noise level is almost equal to its standard level. The noise level is quite high in both hospital zone areas, which is more than its standard level in both the years. This may be attributed to its location at the busiest traffic intersection nodal points of the city.

21.3.6 Temporal Variation in Traffic Noise Level at Areas with Different Land Use Category

Temporal as well as spatial dimensions of noise level was monitored to identify the relation between Noise pollution and Land use pattern, at

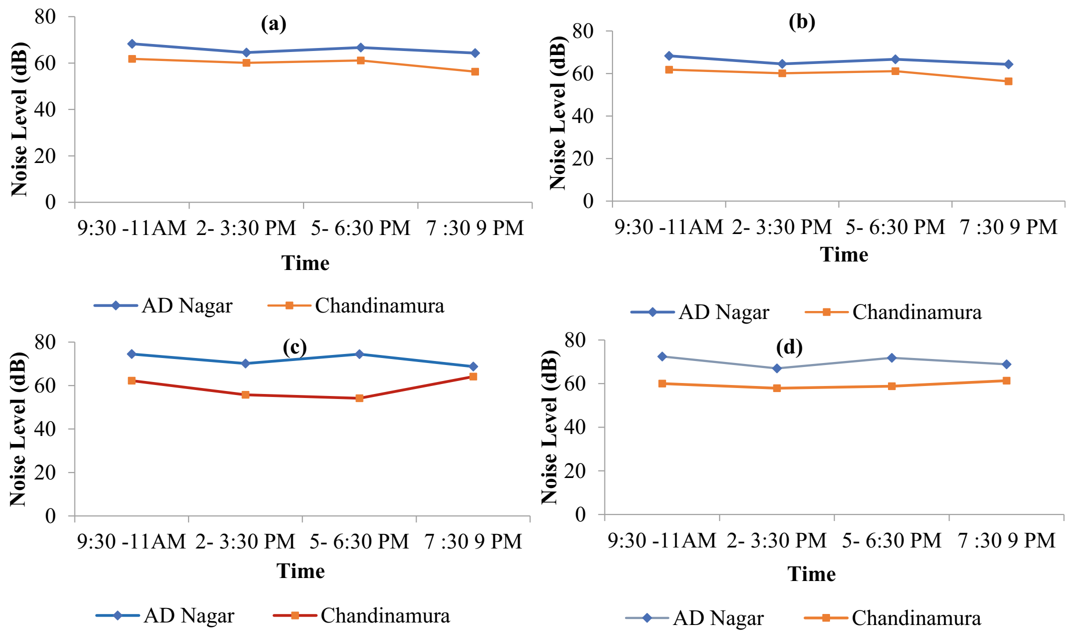

Fig. 21.9 **a** Equivalent noise level in industrial area for January; **b** Equivalent noise level in industrial area for February; **c** Equivalent noise level in industrial area for March; **d** Equivalent noise level in industrial area for April

industrial, commercial, residential, and silent zones. Areas was selected which belongs to four, i.e., A D Nagar industrial zone, Battala Bazar from commercial zone, Ramnagar road No. 5 area from residential zone, and for silent zone IGM hospital area was surveyed.

In the month of January 2019 in A.D. Nagar industrial zone, the highest noise level was recorded during 7:30–9 p.m. with 74.0 dB may be because this industrial zone lies along the NH 8/44 and trucks enter the city through this road at this hour. The lowest noise level was recorded during 2–2:30 p.m. with 69.4 dB, but the maximum equivalent level of noise 68.89 dB was recorded at the peak hour 9:30–11 a.m. (Fig. 21.9a). In Chandinamura, the highest noise level was recorded at 9:30–11 a.m. with 68.0 dB at the same time minimum noise level was 59.5 dB, and the lowest noise level record at 2–2:30 p.m. with 62.9 dB, at the same time minimum noise level was 54.9 dB much lower than the AD Nagar area, for reasons stated above. However, the equivalent noise level is high at 5–6:30 p.m. (65.90 dB). In the case of February, 2019, in A. D Nagar industrial zone the highest noise level was recorded at morning peak hour (9:30–11 a.m.) with 75.4 dB and likewise the maximum equivalent level of noise was recorded at 9:30–11 a.m. (72.34 dB). In Chandinamura, the highest noise level was recorded at 9:30–11 a.m. with 69.3 dB as well as the equivalent noise level was also high 65.40 dB (Fig. 21.9b) during the same period. It is observed that the noise level is higher for the month of February in both the industrial areas. In the month of March 2019, the highest noise level was 78.7 dB and the maximum equivalent level of noise was 674.5 dB in the morning peak hour at A. D Nagar area. While in Chandinamura the highest noise level, 65.8 dB was recorded during 9:30–11:00 a.m. but the highest equivalent noise level of 64.12 dB was seen during 7:30–9 p.m. (Fig. 21.9c), the evening lean period may be because of the movement of trucks during this time frame.

In the month of April, 2019, in A. D Nagar area the highest noise level was recorded at 5–6:30 p.m. with 76.9 dB at the same time minimum noise level was 70.7 dB, which is relatively higher than all the previous months.

The maximum equivalent level of noise was also recorded at 9:30–11 a.m. (72.45 dB). In Chandinamura, the highest noise level and the equivalent noise level are was recorded at 9:30–11 a.m. with 63.7 dB and 62.05 dB values, respectively (Fig. 21.9d). From the four-month noise monitoring result, it is observed that the noise level is comparatively high in AD Nagar area than Chandinamura which may be due to industrial activities being more in AD Nagar, and the most important reason is AD Nagar industrial area is located in Agartala–Sabroom Highway, so that the movements of vehicles is more than Chandinamura, that's why AD Nagar is more noisy zone than Chandinamura. Overall, in both the industrial areas within the city limits the noise level was more or less in parity with the standard limits since heavy industries are not located here.

The two selected commercial areas are MG Bazar and Battala, the busiest commercial zones within the city. In MG Bazar commercial zone, the highest noise level was recorded at 9:30–11 a.m. with 78.6 dB while the maximum equivalent level of noise was recorded at 7:30 –9 p.m. with value74.26 dB. In the case of Battala Bazar area, the highest noise level 74.5 dB was recorded at 5–6:30 p.m. and the maximum equivalent noise level of 71.30 dB was observed during the same time frame indicating that the commercial areas in the city remain busy throughout the day. In February MG Bazar commercial zone, the highest noise level 76.0 dB was recorded between 9:30 and 11 a.m. and minimum noise level 70.9 dB was seen at 5–6:30 p.m., both being high because of the activities in the region as well as the traffic movement. The maximum equivalent level of noise was recorded at 5–6:30 p.m. (73.10 dB). In Battala Bazar, the highest noise level was recorded at 5–6:30 p.m. with 79.1 dB, but the equivalent noise level 75.05 dB was recorded between 9:30 and 11 a.m., the peak hour. In MG Bazar area, the highest noise level recorded was 78.9 dB at 9:30–11 a.m. and the lowest noise level recorded was 70.1 at 7:30–9 p.m. The maximum equivalent level of noise recorded was77.76 dB at 9:30–11 a.m. In the case of Battala Bazar, the highest noise level reading was 82.0 dB between 9:30 and 11 a.m. and the lowest noise level reading was recorded 71.3 dB between 7:30 and 9 p.m. but the equivalent noise level was also recorded highest during 9:30–11 p.m. (79.99 dB). It is observed that subsequently the noise level recorded shows an increasing trend with every month. In April, MG Bazar recorded highest noise level between 9:30 and 11 a.m., the morning peak hour, i.e., 80.3 dB, and the lowest noise level was recorded at 7:30–9 p.m. with a value of 67.3 dB while the maximum equivalent level of noise was recorded at 5–6:30 p.m. (74.20 dB). In Battala Bazar, the highest noise level observed was 80 dB during the morning peak and the minimum noise level was 65.7 dB, but the equivalent noise level recorded was highest at 5–6:30 p.m., i.e., 74.2 dB (Fig. 21.10). For the commercial areas in the city, the noise level recorded was always higher than the standard limit both for day and nighttime unlike the industrial areas.

The residential areas in all cases recorded noise level that was within the permissible limits for all the four months. While in January Indiranagar recorded the highest noise level of 62.2 dB between 5 and 6:30 p.m. lowest noise level of 58.0 dB between 2 and 2:30 p.m. for obvious reasons of it being the lean traffic period, the maximum equivalent noise level of 59.26 dB was recorded at again the evening peak hour. In Ramnagar road no 4 area, the highest noise level of 61.5 dB and the lowest noise level of 49.9 dB were recorded at the evening peak and morning lean hours, respectively, but strangely the equivalent noise level showed highest readings at 9:30–11 a.m. of 55.7 dB may be because of the festivities that occurred during the republic day celebrations in this region. In February for Indiranagar, the highest noise level was recorded evening peak hour and the lowest noise level at morning lean hour and the maximum equivalent level of noise 52.50 dB was recorded at evening peak hour. It is observed that noise level in this area decreased from the month of January. In Ramnagar road no. 4 area, except the highest noise level of 59.4 dB being recorded during morning peak hour the minimum noise level and the maximum equivalent noise level were recorded in the same time period as before with values

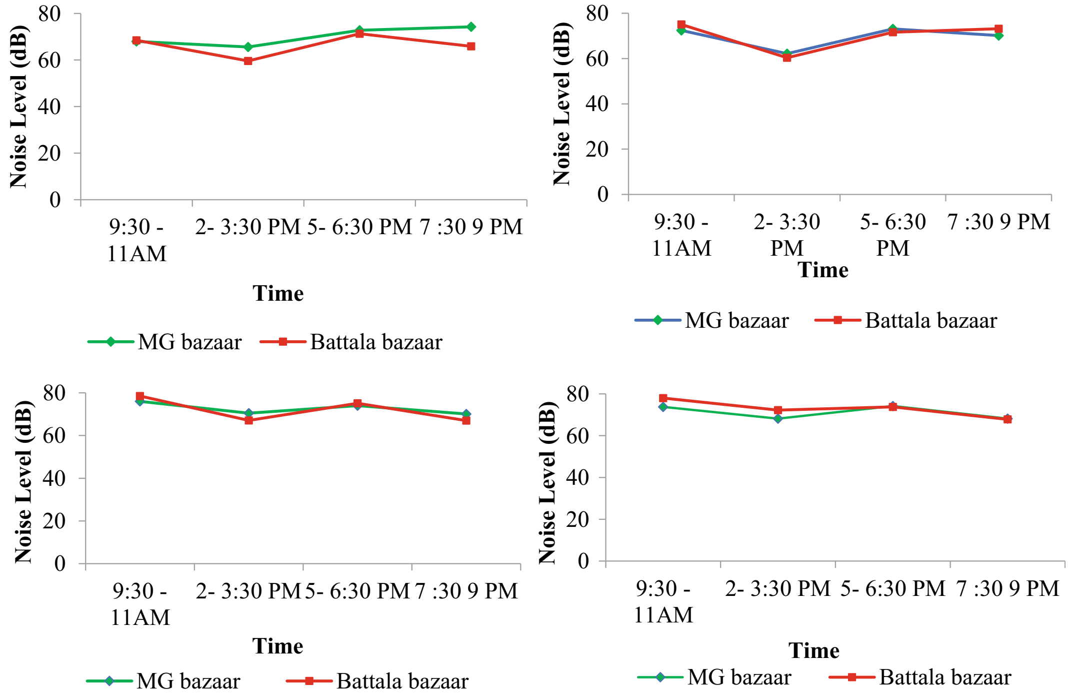

Fig. 21.10 **a** Equivalent noise level in commercial area for January; **b** Equivalent noise level in commercial area for February; **c** Equivalent noise level in commercial area for March; **d** Equivalent noise level in commercial area for April

of 47.4 dB and 56.24 dB, respectively. In the month of March, the maximum equivalent noise level recorded was during the morning peak hour for both the selected residential areas reading a value of 54.5 dB and 57.9 dB, respectively, and unlike the other cases in Ramnagar lane no. 4 area the lowest noise level in March was observed during night lean hour (Fig. 21.11).

In April however, the maximum equivalent noise level for Indiranagar was recorded during morning peak hour but for Ramnagar it was observed to be during the evening peak hours with values 55.2 dB and 57.0 dB, respectively. Comparatively, it appears that Indiranagar area is noisier than the Ramnagar area. It may be due to the presence of IT sector, Silk processing, unit, and Gomati milk dairy farm in this region.

Contrary to the industrial and residential areas, the selected silent zones are quite noisy. As GB hospital area is a multi-sector area, being a commercial area alongside a hospital zone area and also because it supports bus and auto stands, while IGM hospital is located on Akhaura road, one of the busiest road of the city as well as it connects to the Office Lane, where many of the government offices are located, resulting in higher vehicular movements, traffic noise and human crowd thus the noise level recorded in most cases are higher than the permissible limits. In GB Hospital area, the highest noise levels in January and February were witnessed during evening peak hours whereas for March and April it was in the morning peak hour. The lowest noise level on the other hand was seen in afternoon lean hour except for the month of January when it was recorded in the evening lean hour.

The maximum equivalent level of noise recorded was 75.8 dB, 76.62 dB, 78.9 dB, and 76.0 dB for January, February, March, and April, respectively, at 5–6:30 p.m. except for March when it was in between 9:30 and 11 a.m. For IGM Hospital area, the highest noise level for all the four months varied between morning peak and evening peak hours ranging from 79.0 to 80.0 dB while the lowest noise level varied between afternoon and evening lean hours

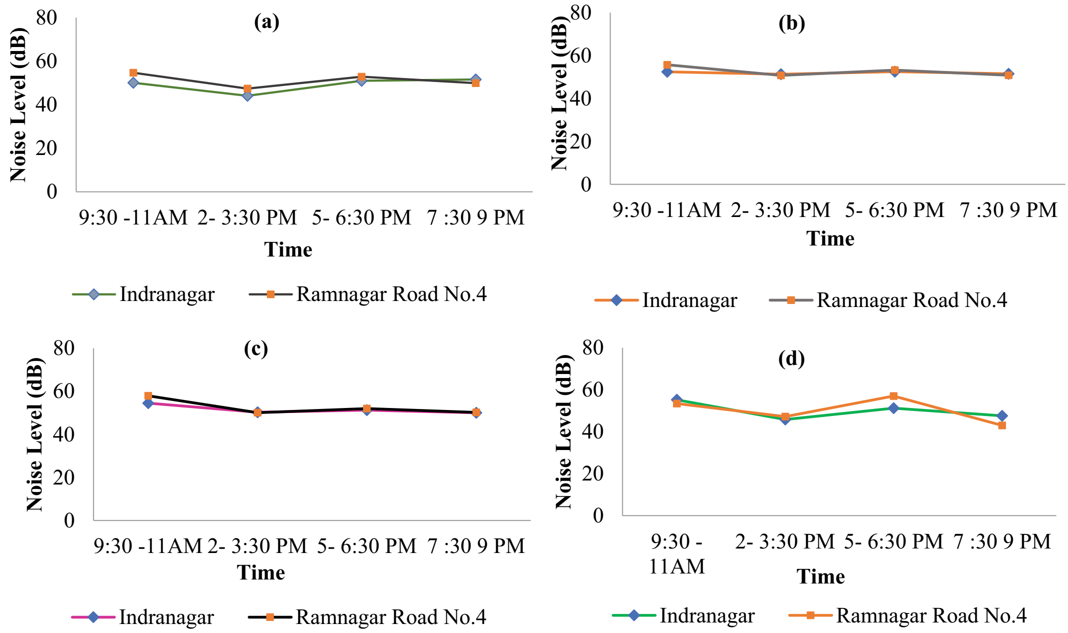

Fig. 21.11 **a** Equivalent noise level in residential area for January; **b** Equivalent noise level in residential area for February; **c** Equivalent noise level (Indiranagar and Ramnagar road no. 4); **d** Equivalent noise level (Indiranagar and Ramnagar road no. 4

ranging from 63.1 to 68.0 dB. The equivalent noise level for January and February was 76.35 dB and 77.0 dB and was recorded in the evening peak hour (Fig. 21.12a, b). However, for March and April the values were 75.56 dB and 78.9 dB and were recorded in the morning peak hour (Fig. 21.12c, d).

21.3.7 Spatial Variation in Traffic Noise Level at Areas with Different Land Use Category

In order to identify the nature of land use along the approach roads to each of the zones, which is in turn indicative of any external noise that may impact the total noise level of the zones, field survey was conducted for one selected area under each type of zones. Under industrial zone A.D. Nagar industrial area, commercial zone Battala Bazar area, Residential zone Ramnagar area and for Silent zone IGM hospital area was chosen.

21.3.7.1 Industrial Zone (A.D Nagar Industry)

A.D. Nagar industrial zone mainly comprises industrial units, zones of commercial activities, and major parts of police ground and police quarter. From the land use map (Fig. 21.13), it can be observed that the noise level decreases from Industry gate toward Battala, indicating that the distance decay effect occurs for distances away from the industry. Further, most part toward Battala till 100 m is occupied by police quarter, so that the noise level is lower at this region toward Battala. In the case of toward Bishalgarh, the noise level is also showing a decreasing trend. It may be due to the presence of a Montessori school; however, between 80- and 100-m distance noise level was quite high maybe due to the presence of CNG station, so the vehicular noise is more.

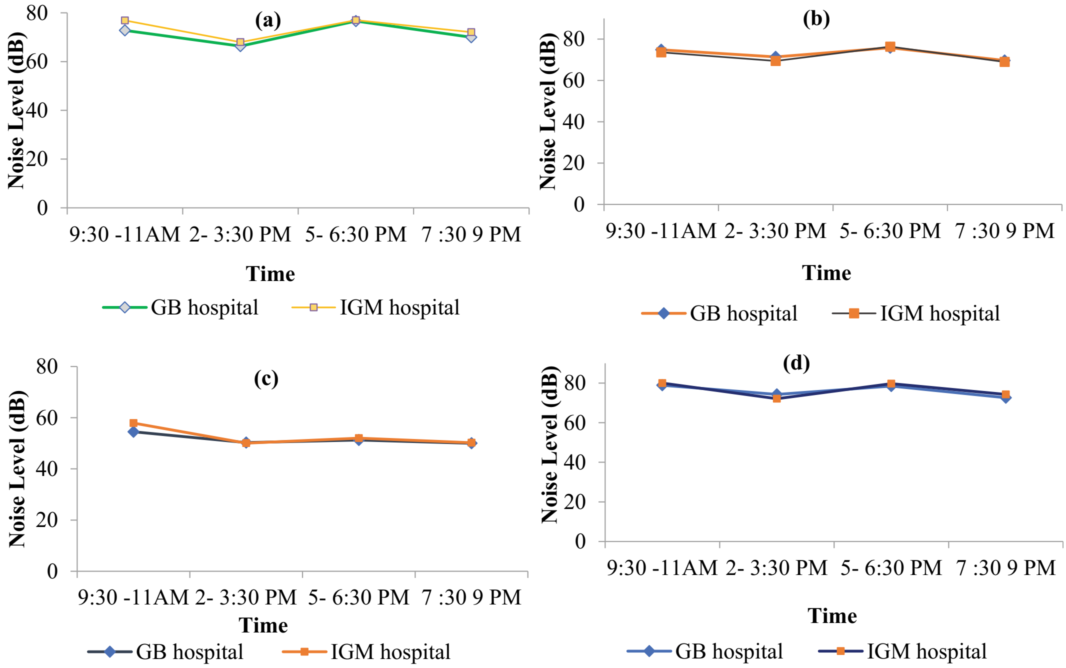

Fig. 21.12 **a** Equivalent noise level in silent zones for January; **b** Equivalent noise level in silent zones for February; **c** Equivalent noise level in silent zones for March; **d** Equivalent noise level in silent zones for April

21.3.7.2 Commercial Zone (Battala Bazar)

From the conducted survey and the prepared land use map, it was observed that 90 percent of the area in Battala Bazar is dominated by commercial activities, and the level of noise is showing slightly increasing trend away from the center, which may be because of the high number of mixed traffic movement in the area. Toward H.G. B. road, the noise level recorded increased from 60-m to 100-m distance. H.G.B road houses all the retail shops of electronics and other essential items because of which human crowd in this area remains high throughout the day (Fig. 21.14).

21.3.7.3 Residential Zone (Ramnagar Road no. 4 Area)

Ramnagar road no. 4 being a residential area is mainly dominated by human settlement. From Fig. 21.15, it can be observed that the noise level of Ramnagar road no. 4 changed with its land use pattern, here noise level increases from the first noise monitoring point toward main road, because of commercial activities toward main roads, and vehicular movement on the main roads, but toward the interior though noise level was high up to 40 m distance, it slightly goes down up to 80 m.

However, from 80 to 100 m, may be due to the presence of some shops slight increase in noise level is documented. In the case of the road toward Ramnagar road 3 noise level showing quite a fluctuating trend, here the higher noise level is observed from 80- to 100-m distance. In the case of the road toward Ramnagar road no. 05, the noise level is showing decreasing trends from the first monitoring point toward the interior, and it may be due to lesser human crowd and lesser vehicular movement.

21.3.7.4 IGM Hospital (Silent Zone)

IGM hospital area is the one of noisy area of Agartala City. From the survey, it was seen that the noise level of IGM hospital area is much more than any other traffic intersection point and other crowded areas. The land use map (Fig. 21.16) of the existing land use pattern and noise level observed that the noise level was high at IGM gate, but showed a slightly decreasing

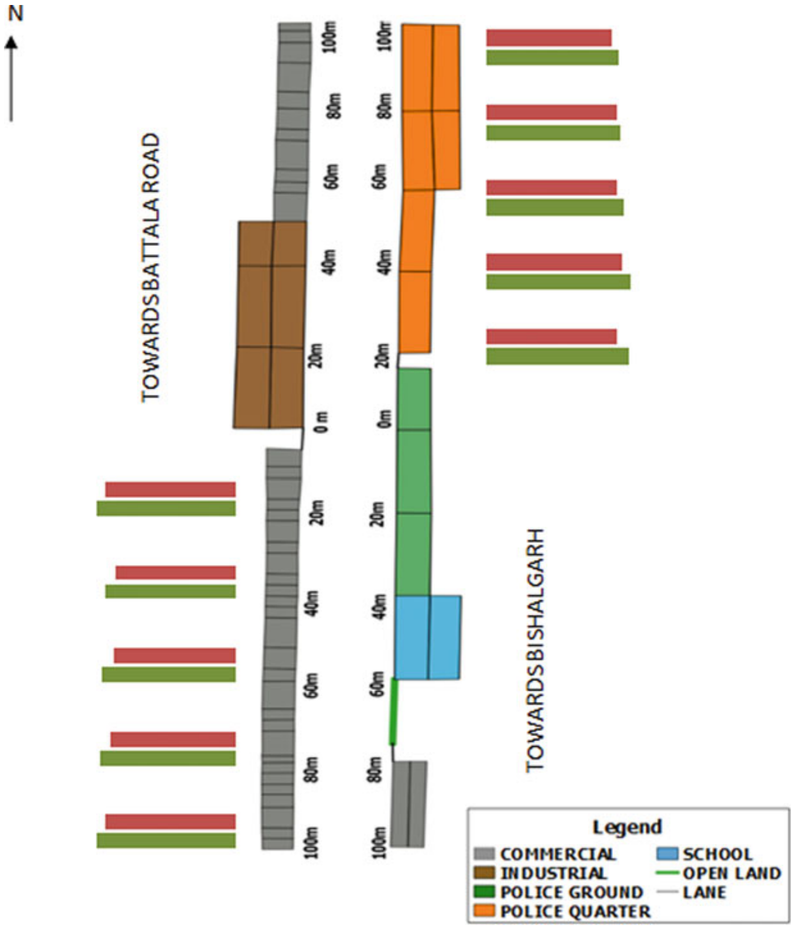

Fig. 21.13 Spatial variation in traffic noise level at industrial zone with different land use category

trend, till 80 m after which up to 100 m the noise level was quite high (Fig. 21.16). It may be attributed to the presence of IGM traffic intersection point, where heavy vehicular movement is recorded. Contrarily toward Paradise crossing noise level shows a decreasing trend, which may be due to the presence of administrative offices along the road. However, on the first 20 m along this road the noise is quite high because of the human crowd at the hospital gate as well as due to the entry and exit of vehicles and ambulance from the hospital premises. In the case of the road toward Office Lane from the hospital gate, the noise level was reduced during peak hour quite obviously because of the presence of most of the administrative offices in the area like the Agartala Municipal Corporation, Higher Education Department, etc.

21.3.8 Population Affected by Noise Level in AMC

The detrimental effects of exposure to noise pollution are well established, ranging from annoyance, hearing loss to cardiovascular diseases (Banerjee et al. 2008). Apart from these diseases hypertension, high-stress levels and sleep disturbances have been experienced by local people around the highways. Negative impact of road traffic noise on psychological and physiological health of humans have established in many studies (Anees et al. 2017; Helbich 2018; Klompmaker et al. 2019).

Road traffic noise pollution has a harmful impact on human work efficiency at Agartala city, Tripura (Pal and Bhattacharya 2012). An attempt had been made to estimate the percentage

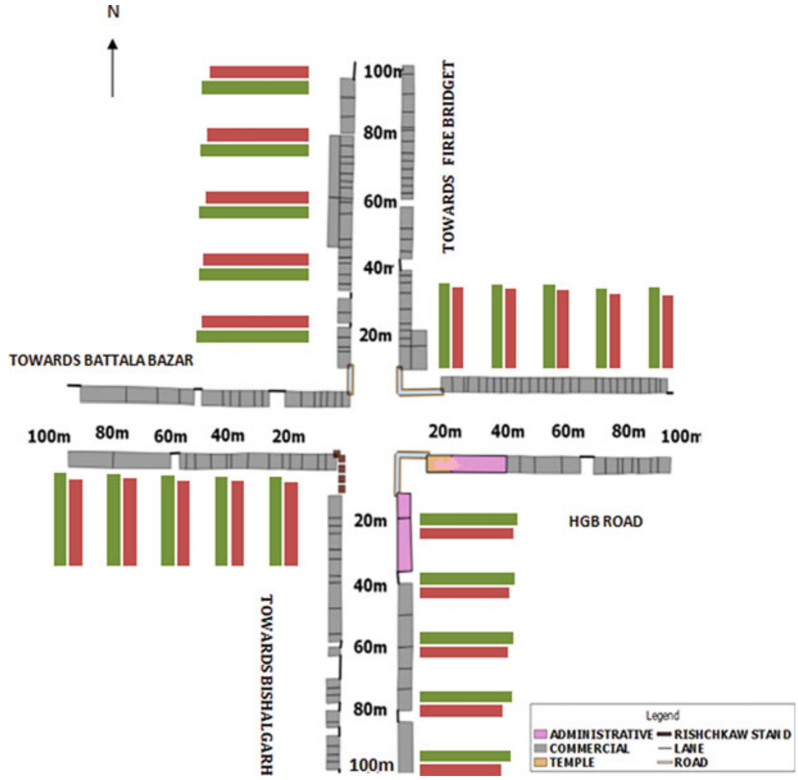

Fig. 21.14 Spatial variation in traffic noise level at commercial zone with different land use category

of population affected by this vehicular noise along the selected roads with the help of the land use of the area and target group discussion. Each of the selected roads has distinct land use along them, and thus, the population affected are of different age groups, gender, income levels, etc. Akhaura road has the highest level of noise where 40% office goers, 30% school students and teachers, and 20% hospital visitors are likely to be affected (Table 21.8). Similar is the case for VIP road where the most affected sections are office goers and residential population and comparatively less affected are shop-owners and school children. While in HGB road, Motorstand road, Agartala-Sabroom road, T.G road, and Dhaleswar A.A road, shop owners are the most exposed section, for that of Barjala road vehicle noises mainly cause problem to the residential population. In the case of Airport road, GB-ITI road, and Bamutia road where noise pollution is comparatively less, shop owners are mainly affected, but hospital visitors, individuals going to office, and educational institutions also confirmed their discomfort with the noise pollution in the area.

21.4 Conclusion

Noise pollution is a major environmental pollution. It is a major source of disturbances in daily life of people particularly living in a congested and crowded area. So, assessment of the noise pollution of an area is important to understand the environmental condition of a particular place. Further, the GIS-based noise map has great

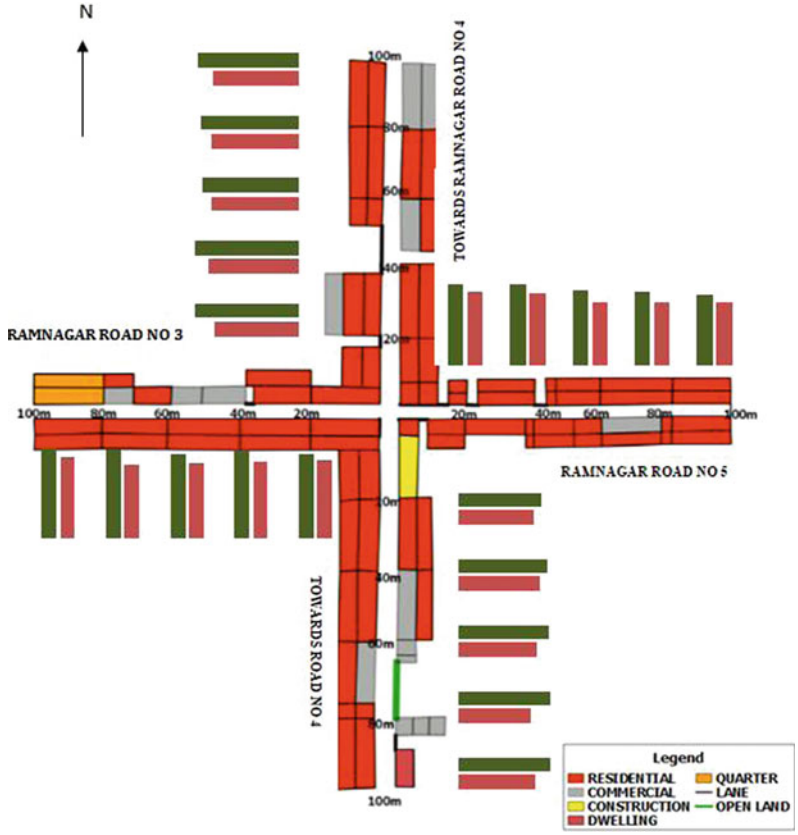

Fig. 21.15 Spatial variation in traffic noise level at residential zone with different land use category

potentiality mapping traffic noise levels. The study revealed that roadside noise level in AMC is mainly dependent on total vehicular volume and category of vehicles. The spatial contour map generated based on collected field data shows that noise levels read maximum values at or near major traffic intersections and are relatively high all along the busiest roads in the central part of the city, i.e., Motor stand road, T.G road, HGB road, Agartala-Sabroom road, etc., while the noise level decreases toward peripheral areas. In the case of some roads, numbers of vehicles movement are less but recorded noise level is high which may be due to other sources of noise in the area like the presence of market or commercial activities along the road. It may be mentioned that most of the major roads in AMC have a mixed land use pattern along them; therefore, vehicular noise level is amplified at many areas because of other activities. Therefore, strict enforcement of existing law is necessary not only to prohibit unnecessary use of horns particularly around the silence zones and at traffic intersections but also to ensure that

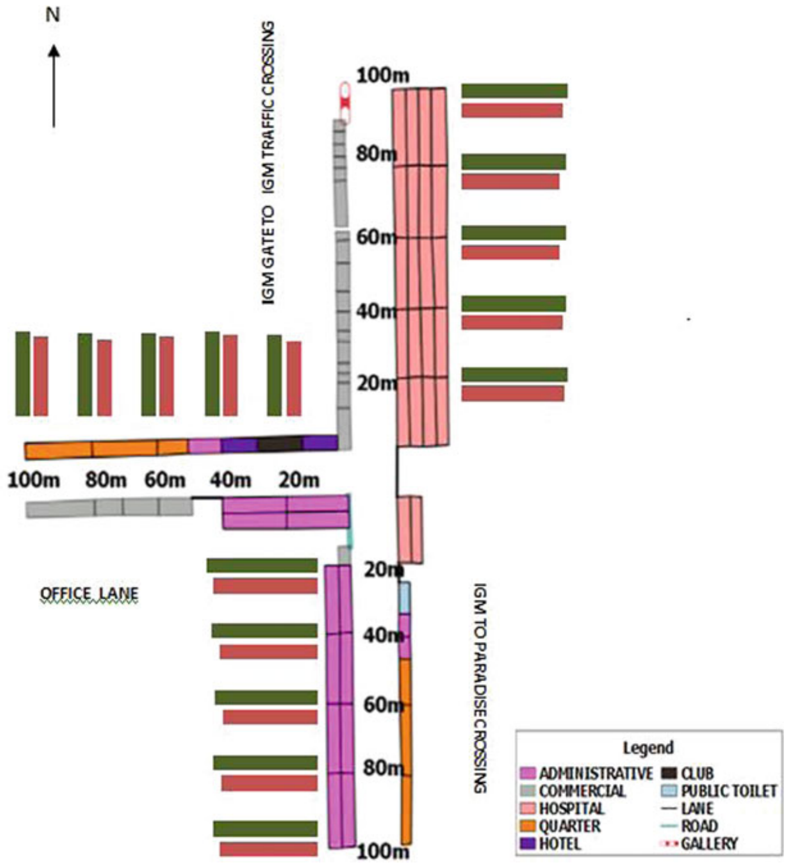

Fig. 21.16 Spatial variation in traffic noise level at Indira Gandhi memorial hospital with different land use category

Table 21.8 Impact of noise pollution along different roads in AMC

Road name	Average noise level of a day (dB)	Estimated affected population (in percent)				
		Settlement	Shop owner	Office	Educational institute	Hospital
VIP road	64.52	20	10	40	5	0
GB-ITI road	53.33	10	50	15	5	20
Airport road	58.00	30	40	20	0	10
Bamutia road	59.84	20	40	10	30	0
Jail-Ashram road	57.14	40	50	0	10	0
Dhaleswar A.A road	60.00	40	60	0	0	5
Barjala road	65.34	60	40	0	0	0
TG road	72.60	30	70	0	0	0
HGB road	67.67	0	100	0	0	0
Akhaura road	69.67	0	10	40	30	20
Motorstand road	65.84	0	100	0	0	0
Agartala-Sabroom road	68.68	10	80	5	5	0

people are aware about the hazards of loud sound so that total noise pollution levels are under control within a growing city like Agartala where vehicular population is inevitably intended to rise.

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