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Noise Pollution Mapping of Vadodara City for Assessment of Community Noise: An Underrated Health Burden

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Abstract: *Noise pollution is one of the most under rated form of pollution which possesses both auditory as well as non-auditory effects on the persistently exposed population. The best solution to minimize noise related discomfort is trying to avert exposure to their respective sources. With this reference this work estimated spatio-temporal variation of community noise levels in Vadodara, one of the fastest growing city in India. The noise levels were measured at thirty two places predominated by both commercial and residential tenements at Vadodara city and cover all important junctures throughout the all three modes of transport. Noise measurement is done with the help of calibrated M-27 logging dosimeter from 7:00 to 24:00 hours on each sampling point per day with two intervals of 13:00 to 15:00 hours and 21:00 to 22:00 hours. Result suggests that for most of the residential locations, throughout the day noise level is high but especially higher in morning and evening for a fix time slot of 09:00-11:00 and 17:00-20:00 because of the office goers. The cumulative effects of different noise emitting sources at any intersection are more hazardous and significant than that of individual one. Noise related problems are severe in these kinds of cities because of rapid growth rate well supported by slow adaptability of upgrade technology and other socio economical factors.*

Keywords: *Noise, Vadodara, Community health*

1. INTRODUCTION

Noise pollution is most underrated form of pollution posing severe threat to health and well-being. Noise is not simply a local problem, but a global issue that affects everyone and calls for precautionary action in any environmental planning situation (Babisch 2005; Lee 2002). With the rapid rate of urbanization and population growth, magnitude and harshness of noise is also continued to increase. Sustained growth in highway, rail, and air traffic are also considered as potential contributor of environmental noise. The likely health effects of noise pollution are abundant out of which some are persistent, and medically or socially important. Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources except noise at the industrial periphery. Main sources of community noise include road, rail and air traffic; outside industries premises; construction and public work; and the neighbourhood. The noise source may be point, line, or plane generating spherical, cylindrical or plane waves respectively.

Community noise generate direct and collective undesirable effects that harm human health as well as degrade residential, social, working, and learning environments with corresponding economic and elusive (i.e. well-being) losses. Though noise pollution is a slow and subtle killer, yet very little efforts have been made to ameliorate the same. It is, along with other types of pollution has become a hazard to quality of life (Singh and Davar, 2004). Persistent exposure of human body with high level of community noise may lead to nervous, hormonal, and vascular shift that have far reaching consequences (Singh and Davar 2004). Specific health effects for the general population that may result from community noise are interference with communication; annoyance responses; effects on sleep, effect on the cardiovascular and psycho-physiological systems; effects on performance; productivity; social behaviour; deficits in motivation indicative of helplessness and noise-induced hearing impairment (WHO 1995; Berglund and Lindvall 1995; Cohen et al., 1986; Evans, 2001; Ising and Braun, 2000; Medical Research Council, 1997; Nagi et al., 1993).

A typical urban neighborhood residential area in the United States ranges from 55 to 70 dBA day-night sound level (Ldn) (Kryter, 1994). Hearing damage is expected to result from both occupational

and environmental noise, especially in developing countries, where compliance with noise regulation is known to be weak (Ising and Kruppa 2004). For European Union about 20% of the population lives in areas with daytime Leq.65 dBA (Gottlob, 1995). For India, Delhi was the noisiest city in India, followed by Calcutta and Bombay (IRT 1996; Miedema HME, Vos 1998). The noise level produced by household equipment and appliances sometimes reaches up to 97 dB which is more than double the acceptable (45dB) noise level. The contribution of 2-Wheelers and 3-Wheelers in the Passenger Car Unit values are 38% and 43% respectively.

Yet there is no quantitative and qualitative assessment for noise pollution in many places especially for developing countries has been done so far which calls for scientific attention. Vadodara is one of the fastest growing cities not only in Gujarat state but also in India with no significant scientific work has been done in the area of noise mapping. Therefore this study is an attempt to create spatio-temporal noise mapping, possible health effect and preventive measures for future course of time in case of Vadodara city, India.

2. STUDY AREA

Study area (Vadodara city), is located at 22.30°N and 73.19°E in western India at an elevation of 39 metres (123 feet). It is the 18th largest city in India with an area of 148.95 km² and a population of 4.1 million according to the 2010-11 census. Vadodara is divided by the Vishwamitri river into two physically distinct eastern and western regions. The eastern bank of the river houses the old city, which includes the old fortified city of Vadodara. This part of Vadodara is characterised by packed bazaars, the clustered and barricaded pol system of shanty buildings, and numerous places of worship. Among all top urbanised cities, Vadodara has significant urbanised formation and the Vadodara Urban Development Authority (VUDA) has incorporated various revised landuse plan in 2013 to accommodate all these structure in more planned way.

3. MATERIALS AND METHODOLOGY

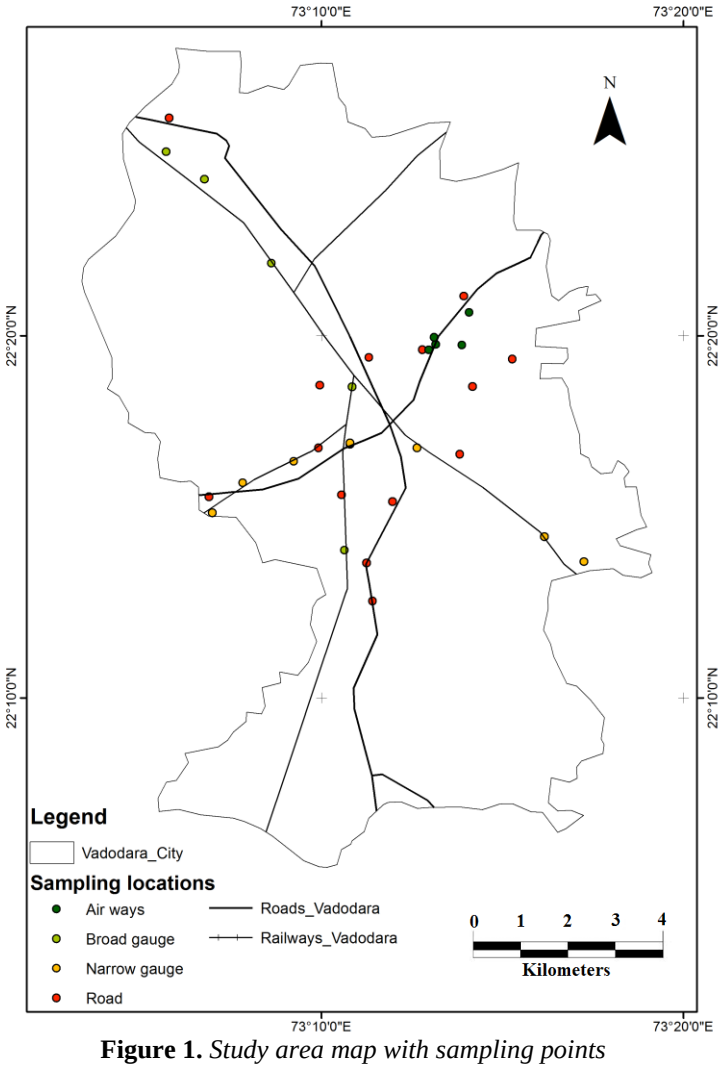

Figure 1. *Study area map with sampling points*

A total thirty two sampling site is considered within Vadodara city periphery in such a way that it cover all important junctures throughout the three modes of transport. The points have been selected on the bases of the population settlement and the relative frequency of the entity by which noise has been emitted. Selected locations and its geographical specification with relation to distribution of declared zone by Noise Pollution (Regulation and Control) Rules, 2000 is shown in figure 1. Information about each location is noted down with the help of GPS. Noise measurement is done from 7:00 to 24:00 hours on each sampling point per day with two intervals of 13:00 to 15:00 hours and 21:00 to 22:00 hours. Noise measurement is done with the help of M-27 logging dosimeter and it was properly calibrated before each measurement.

4. RESULTS AND DISCUSSION

The results have been divided in three logical manners as per its mode of generation i.e. road traffic noise, railway traffic noise and air traffic noise.

Road Traffic Noise

Observed result for road traffic noise is shown in figure 2. The graphs show the Equivalent continuous sound level (Leq), maximum value reached by the sound pressure (Peak) and maximum sound level (Lmax) values of noise pollution emitted not solely by traffic or transportation but other mix sources of community with Total Vehicular Load (TVL) per hour at various sampled locations in Vadodara. Sitewise description for the observed result is mentioned in the following section.

Padra is only residential area where the 70% rural settlement found. In rural area the dispersion of noise is too high as compared to urban area because of the settlement pattern of houses and open field like farms where noise can be easily dispersed and less absorbed or reflected. The transportation mode is mixed like heavy motor vehicle (HMV) and light motor vehicle (LMV) runs on the way for whole day. The contribution of HMV is higher than LMV only because of nearest industrial zone and the road is state highway 6. Value of Leq is in range of 71 dBA to 79 dBA with average of 75.5 dBA within whole day where as Lmax reaches to 100 dBA sometimes. TVL per hour ranges in between 900 to 3200 for whole day. The result for NH8 towards Ahmedabad and NH8 towards Surat define that the vehicular movement on highway is continuous and in almost equivalent in all hours. The ratio of motor Bike: LMV per hour is 1:20 and Bike: HMV per hour is 1:30 remain almost same for whole day except office hours because bike riders also prefers highway for daily transportation which shows that the movement of bike riders and emitted noise by them is ignorable because of six lane road formation, bike riding lane, placement of dosimeter, average speed of bike and many more reasons. HMV and LMV are the maximum users in case of highway and so as for noise pollution emission. At NH8 towards Ahmedabad, maximum TVL per hour is 2300 and minimum is 1200 per hour with average value of 1900 per hour and TVL per day is 27000 because the movement of vehicles from Surat (South Gujarat) to Ahmedabad (North Gujarat) that contributes Leq maximum is 83 dBA and minimum is 78 dBA which is almost same. Whereas highest Lmax value is 109.4 dBA and lowest Lmax is 97.5 dBA with highest peak of 127 dBA within whole day. Result for NH8 towards Surat, suggests maximum TVL per day is 3900 and minimum is 2100 TVL per day with average of 3000 TVL per day and sum of 42,000 TVL per day. The average value of Leq, Lmax and peak are 82 dBA, 99.5 dBA, 118 dBA within whole day. Vehicles which move inward or outward of Vadodara from NH8 are approximately 10% of TVL per hour. There are so many accesses towards Vadodara city from NH8 but the most used and frequent access route are selected as sampling point from East-South corner of Vadodara. The selected sampling points are as follows, Sussen Circle to NH8 road result represents the sampling point specifically Makarpura area where residential and commercial area are in mixed sense Average TVL per hour 1850 vehicles and highest TVL is 2800 vehicles per hour whereas sum up TVL is 26000 vehicles per day who emits highest Leq of 73.6 dBA between 18:00 to 19:00 hours and lowest Leq of 66 dBA between 12:00 to 13:00 hours and 98.6 dBA Lmax felt during 18:00 to 19:00 hours.

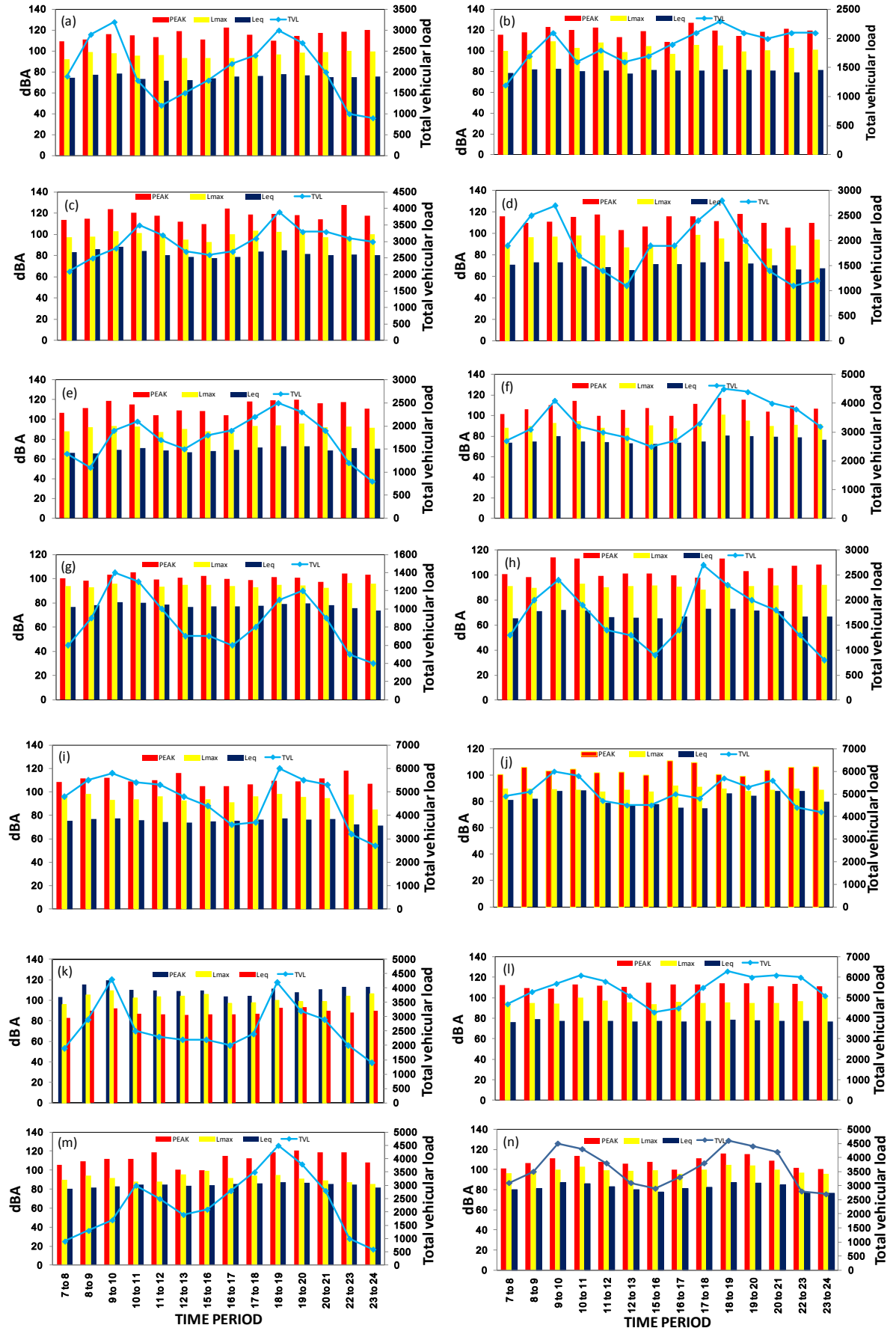

Figure 2 *Graph showing road traffic noise in terms of Leq, Peak and Lmax with Total Vehicular Load (TVL) for (a) Padra, (b) National Highway 8 towards Ahmedabad, (c) National Highway 8 towards Surat, (d) Susain to National Highway 8, (e) National Highway 8 to Vadodara Entrance at Ajwa crossing, (f) National Highway 8 at Godhra Crossing, (g) RR Danteshwar Bridge, (h) VIP Road Sardar Estate, (i) Race Course road GEB Circle,*

(j) VIP road Airport Circle, (k) Akshar Chowk, (l) Fatehgunj Circle, (m) Makarpura Bridge and (n) Sussen Circle.

Ajwa is one of the famous visiting places of Vadodara where people comes for outing from various places so, at the crossroad of Ajwa vehicular movement is from various places like inside of Vadodara and from outside of Vadodara. As observed at the Ajwa crossroad in morning hours the TVL is ranges from 1100 to 1400 vehicles per hour except the highway flyover traffic that lead to average 67 dBA Leq, 91 dBA Lmax whereas during night hours after 20:00, sum of 2000 vehicles during 2 hours emits 70.7 dBA Leq and 92 dBA Lmax. During evening time period TVL is become averagely 2300 which emits averagely 72.5 dBA Leq. The sampled spot is almost 1 km away from pure residential zone but the contributed noise emission will affect the community. Godhra crossroad also known as Halol crossroad which is used maximally by HMV and purpose of transportation due to wide industrial zone at Halol area. As observed at crossroad the HMV runs 70% whereas LMV and bikes runs 30% except the highway flyover. The generation of noise is not solely by HMV but cumulative Leq noise reaches at 80.5 dBA for an hour within a day with 76 dBA of average Leq emission by 47,300 TVL per day. The average TVL is 3400 vehicles per hour with range of 2500 to 4500 as minimum and maximum respectively. The sampled points are situated on the ring road named as, Danteshwar Bridge, Sardar Estate Circle, Airport circle, Fatehgunj circle, G.E.B. circle, Akshar chowk, Makarpura Bridge, Sussen Circle which is started from East direction anti-clock wise on map of Vadodara. The main reason behind selection of these sites is its importance in terms of noise pollution, linkage of the road to whole Vadodara, all zones are covered near by the ring road. As the points linked with inside and outside towards Vadodara city whereas inside the ring road periphery towards Eastern side of railway track old Vadodara living pattern (pol) and at Western side of railway track urbanized Vadodara can be seen and outside of the periphery chiefly under developing and urbanized Vadodara can be seen in terms of construction pattern. In this circumstances the pol area is very congested and crowded with reference to living and vehicular traffic management while on ring road 50% places having traffic management signals and 90% places having traffic management staff (Traffic Police, Home guards, traffic brigade) and outside the periphery still the development phase is going on with the less traffic management system and equipments availability.

Result for Danteswar bridge shows low traffic pattern due to the under development nearby residential and/or commercial area. The TVL value is ranges between 400 to 1400 vehicles per hour with average of 850 TVL per hour. Total sum of TVL is only 12000 per day which emits averagely 78 dBA Leq and 98.5 dBA Lmax. The highest Leq is 80.6 dBA and Lmax is 97 dBA whereas lowest Leq is 74 dBA and Lmax is 92.5 dBA. The highest peak is 105.3 dBA during whole day. Sardar Estate is defined as mixed zone with settlement of residential, commercial, small scale industrial zone and road-touch silence zone with moderate TVL of 23,500 vehicular movements that contributes for averagely 69 dBA Leq during whole day. As referred to highest TVL of 2700 per hour emits 73 dBA Leq and lowest TVL of 800 per hour generates 66.7 dBA Leq. GEB circle is situated on Racecourse Road but also a part of Ring road with residential, commercial and silence zone due to government office (Gujarat Electricity Board). The TVL is sum of 50% bike riders, 35% LMV and 15% HMV movement. It is one of the most traffic dense place of urban Vadodara and nearby railway station. The highest value of Lmax is 98.5 dBA and lowest is 85 dBA for once but continuous honking or movement of HMV made the receivers highly affected. Airport circle is also known as Harni crossroad situated on VIP road. The vehicular movement pattern is 40% bikers, 30% LMV and rest for HMV. TVL of the sampling point is 70,500 vehicles per day that contributes for 82 dBA Leq per day. The maximum noise generated as Lmax is 92 dBA within whole day.

At Fatehgunj circle movement of bikers and LMV is almost same whereas HMV contributes 20% of TVL. The graph shows that 76,500 TVL per day that emits 77.5 dBA Leq during whole day. The sampling point is confined with 60% residential area and 35% commercial and rest for silence zone. The result for Akshar Chowk defines the maximum noise equivalent level reached at highest level in morning (8:00 to 11:00) and evening (18:00 to 20:00) hour period due to residential area and maximum movement of the regular job workers as well as irregular visitors. The overall effect of noise felt by the occupier who lives nearby of this area is intolerable in terms of Leq (A) and Lmax exposure which is 88 dBA at source. While Lmax is reached to 109.3 dBA once in a day but the continuous Lmax felt during honking of movers on the road for whole day. At Makarpura circle, range of Leq (A) noise during the whole day ranges between 80 dBA to 88 dBA however Lmax goes

in range of 85 dBA to 99 dBA only due to less honking and smooth movement and the road spacing according to TVL. Sussen Circle is the mixed zone because in Western corner industrial zone situated, in Northern corner commercial zone and Southern and Eastern corner used as residential area. During office hours bikers and LMV generate maximum noise of 85 dBA Leq per hour, 101 dBA as Lmax and in afternoon session fast movement of HMV due to open space on road generates noise in range of 79 dBA Leq to 81 dBA Leq per hour. TVL is 51,000 vehicles per day with maximum movement of 4600 TVL in 18:00 to 19:00 period.

Overall, Akshar chowk, Airport circle, NH 8 to Surat and NH 8 to Ahmedabad are the highest noise generation points whereas Sardar estate and Ajwa cross road are lowest noise generation points among all road traffic sampling points at Vadodara city during day hours. On the same hand, Makarpura bridge and Sussen circle are moderately noise generation points among selected locations for the day hours. Looking in to the finding for night hours, Akshar chowk, Makarpura Bridge and NH 8 to Surat points are the highest noise generation points whereas Sardar estate and Makarpura access point are lowest noise generation points among all sampled locations and other areas are moderately noise generation in range of 72 dBA to 80 dBA Leq in night hours within Vadodara city sampling range according to NPRCR, 2000.

Rail Traffic Noise

As per VUDA plan map of Vadodara, two types of train transportation namely broad gauge and minor gauge service are running. Result for these sections is shown in figure 3.

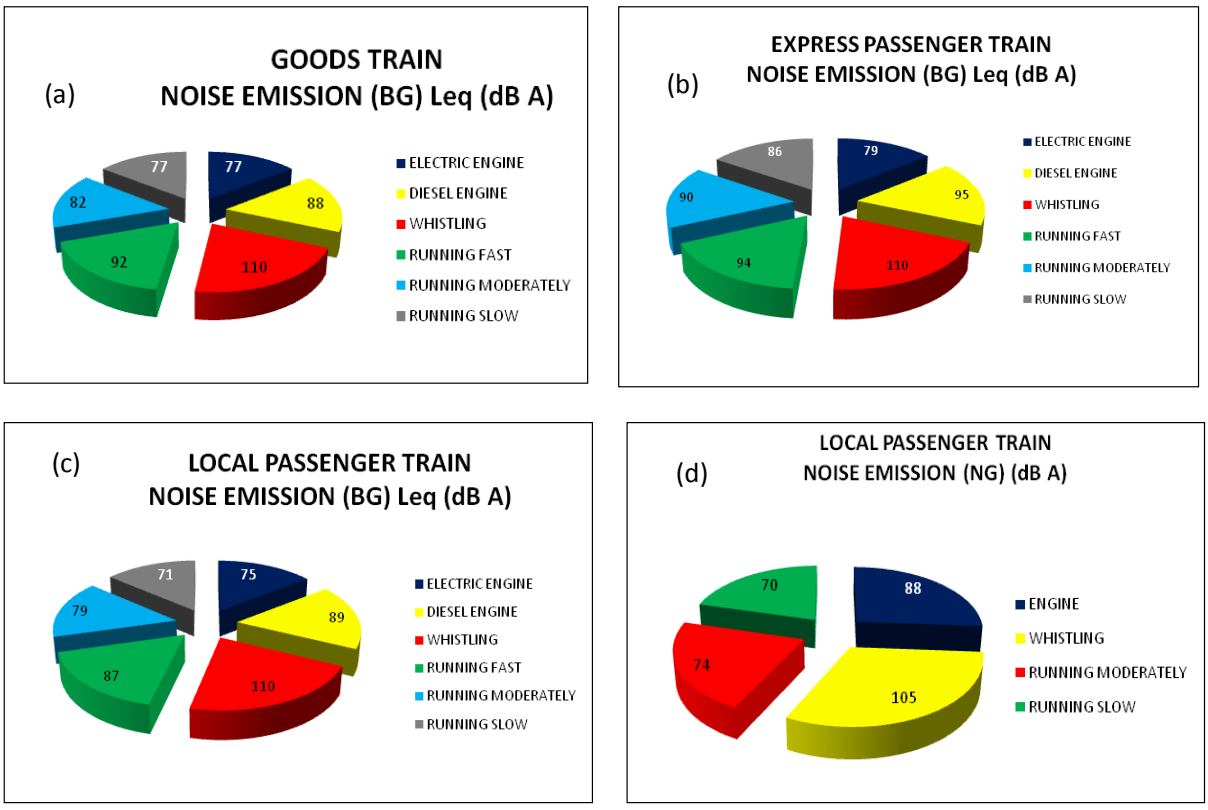

Figure 3. *Graphical presentation of noise emission in terms of LeqA of (a) Broad Guage Goods Train (BGGTs), (b) Broad Guage Express Passenger Trains (BGEPTs), (c) Broad Guage Local Passenger Trains (BGLPTs) and (d) Narrow Guage Local Passenger Trains (NGLPTs)*

Broad gauge

The broad gauge is the main train transportation service in all over India which is being used by people whereas for Vadodara city the broad gauge line is passes through middle and after Vadodara station it drifts to North-West direction. The main track joins two mega cities Ahmedabad (North Gujarat) to Surat (South Gujarat) where Vadodara comes in-between. The stations are as follows which being sampled for estimation of Noise Pollution emitted by Train transport service, 1.Makarpura Railway Station (RS); 2.Visvamitri RS; 3.Vadodara Junction; 4.Bajwa RS; 5.Ranoli RS; 6.Nandesari RS respectively from South to North direction. In case of generation of noise by all three types of train (explained in table 1), various process of trains being considered for the noise mapping.

Table 1. *General train transportation data on broad gauge*

Type of train	Goods train	Express passenger train	Local passenger train
Frequency (per day)	150	100	25
Average velocity	100 kmph	120 kmph	75 kmph
Average length of trains	650 to 750 m	550 to 600 m	550 to 600 m
Frequency at night time	High	High	Low

Goods trains are mainly used to carries goods like coal, steel sheets, groceries, courier, packed material, home appliances, etc. from departure station to destination station. They are having highest load with compare to passenger trains but due to uneven stoppage and cope with passenger trains' schedule the average velocity is not higher than express passenger trains at morning times but at night hours when passenger trains movement frequency is low the average velocity made higher to made ease and fast transportation so, the goods transportation trains more frequent in numbers at night time period. As per given value in graphical representation (figure 3), goods trains emits 77 dBA SPL from electrically driven engine whereas 88 dBA SPL from diesel driven engine. The difference between high velocity train and moderate velocity train is 10 dBA when moderate velocity emits 82 dBA Leq when passes through one cross section. In passenger express trains, the average velocity is 120 kmph and comparative load is more than all other passenger trains so the average value of noise emission is higher. The mode of engine comes under two source based one is electrically driven which emits 79 dBA SPL and second is diesel driven engine emits 95 dBA SPL. Whistling sound of express passenger trains is almost similar to all kind of trains is 110 dBA for period of 3 seconds to 7 seconds. At the time of running with high velocity generates 92 dBA to 95 dBA Leq with passing time of 20 seconds to 35 seconds whereas it reduces up to 4 dBA. Local passenger trains (LPTs) are comparatively slow in velocity, small in length and lighter in load caring condition to EPTs and Goods train.

As local passenger trains for Vadodara city railway track have to stop for total six railway stations so their average velocity is approximately 60 kmph to 90 kmph that emits 85 dBA to 89 dBA Leq for passing period from sampled cross-section. Whistling sound is almost same to EPTs and Goods trains.

Narrow gauge

Narrow gauge covers South-West corner to South-East corner as shown in figure 1. The train running is only on one track and of Diesel driven engine. The train is small in length with comparison to all types of broad gauge passenger trains. Average velocity of the train is 30 kmph to 50 kmph and length is 30 meter. The movement frequency is twice per day on the track. Whistling frequency is uneven because the train passes though area is mixed and the culture is low under stable to safety and importance of train movement. The main exposure due to uneven whistling in residential area to caution the people and children playing around the track and the living pattern which is very close to railway track is the most disadvantageous for the people. The stations within the Vadodara district are, Padra RS, Bhaili RS, Atladara RS, Vishvamitri RS, Pratapnagar RS, Kelanpur RS, Kundhela RS. Narrow Gauge Local passenger train (NGLPT) is slowest in velocity, smallest in length and lightest in load as compared to LPTs, EPTs and Goods train. Vadodara city railway track local passenger trains have to stop for total 7 railway stations so, LPTs average velocity is approximately 60 kmph to 90 kmph that emits 85 dBA to 89 dBA Leq for passing period from sampled cross-section. Whistling sound is almost same to EPTs and Goods trains but sometimes the frequency of whistling will go more due to low speed and passenger overcrowding on platform. Vadodara city railway track local passenger trains have to stop for total 7 railway stations so, LPTs average velocity is approximately 60 kmph to 90 kmph that emits 85 dBA to 89 dBA Leq for passing period from sampled cross-section. Whistling sound is almost same to EPTs and Goods trains but sometimes the frequency of whistling will go more due to low speed and passenger overcrowding on platform.

Overall for the railway traffic noise, whistling at various station is same almost and at the time of running between the stations it reduces accordingly while in case of running or movement the noise generation is highest between the stations due to high velocity and very less at noise emission at station due to nil velocity of local trains, high velocity of express and goods trains. The specific range

of train movement is almost 200 trains per day from one single stop on the track but sometimes due to the type of trains the noise emission varies in range of 80 dBA to 90 dBA and for whistling of trains the range is between 105 dBA to 110 dBA at various sampling locations. The noise emission status of NG railway line is relatively low with reference to BG railway line sampling points status. The effect of noise is felt highest at Vishvamitri and Atladara railway stations whereas Kundela railway station and Padra railway station is relatively low in case of noise emission with reference to other sampled railway station on BG railway track within Vadodara city range. The noise emission ranges between 104 dBA to 110 dBA for NG railway track of Vadodara city. The maximum noise emission occurs at Atladara RS and Bhaili RS whereas Padra, Kelanpur and Kundhela RS are relatively low to the other areas within whole track and among all 7 sampling points.

Air Traffic Noise

Air traffic noise is generated due to aircraft movement above ground level and in all direction and the observed result is shown in figure 4. Noise generated from the aircraft is considered responsible to pollute environment to a large extent. Mainly noise is contributed by aircraft type, height, track and wheel friction, meteorological variation and operating procedures. An aircraft flying overhead produces a substantially high noise levels on the ground above the ambient level which reaches a maximum when the aircraft is near to above head. There are total 16 national or international flights take off or arrive at the airport of Vadodara. Normally at the time of departing and landing it makes highest noise but the noise made at height when flying is also considerable, which is intolerable for the community who exposed by that. The graphical representation shows that different concentration of noise from various activities.

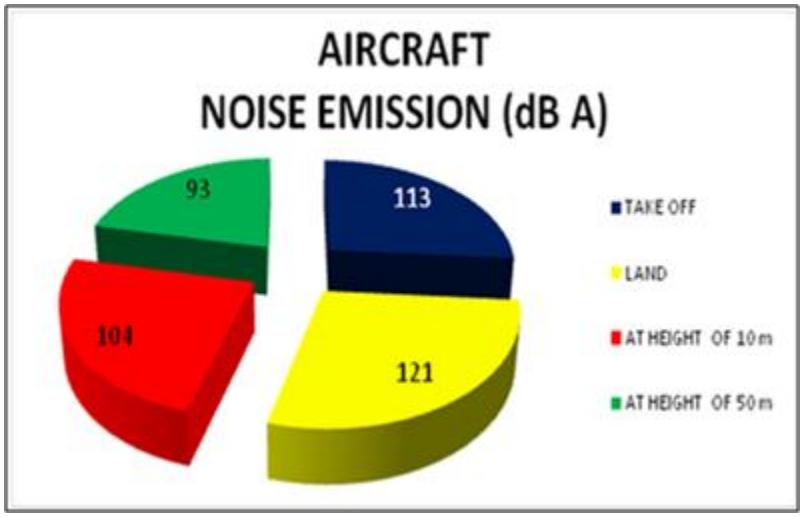

Figure 4. *Graphical presentation of noise emission in terms of LeqA from Air traffic movement nearby airport area*

Finally it can be said that, air traffic is significant but less frequent noise generation source as compare to whole area of Vadodara city. The noise generation is occurred in range of 90 dBA to 120 dBA at various points of airport, nearby area and air traffic route area within Vadodara city range. The other areas except the route area of air traffic is remain unaffected due to nil movement of air traffic but the areas where the air traffic passes are highly noisy with range of 90 dBA to 100 dBA noise generation during pass time of air traffic within Vadodara city.

Noise Mapping of Vadodara City at Spatial Scale

Result for cumulative noise mapping on the basis of Leq of Vadodara city with a total 14 road traffic points, 6 B.G.R.S. points, 7 N.G.R.S. points and 5 airport traffic observation points is shown in figure 5. It defines the maximum generation of noise in some area and very less generation of noise pollution in various spots and affected community as per NPRCR, 2000. The cumulative effects of noise pollutants (sampling points witnessing all three modes of transport) will be more hazardous than the individual one. The figures on the map will tell the real exposure scenario of Vadodara community and the possible and adverse effects of health on individual. This will help to take necessary precautionary action by local government and residents to curb and manage the noise at point source.

5. CONCLUSION

The overall community of Vadodara is being affected by various range of noise level at different time period. For day and night time, Akshar chowk followed by NH 8 are the highest noise generation points whereas Sardar estate is lowest noise generation points among all road traffic sampling points at Vadodara city. For railway traffic, the noise emission status of narrow guage railway line is relatively low with reference to broad guage railway line. The effect of noise is felt highest at Vishvamitri and Atladara railway stations whereas Kundela railway station and Padra railway station is relatively low in case of noise emission with reference to other sampled railway station on broad guage railway track within Vadodara city range. In case of air traffic, noise generation is significant but less frequent for Vadodara city. Noise at higher level generated mainly in the areas nearby to the airport and air traffic route area within Vadodara city range. The other areas except the route area of air traffic is remain unaffected due to nil movement of air. Implementation at both regulatory expert at the policies front and awareness for abiding community with regards to strict reduction as well as adaptation is the need of this time.

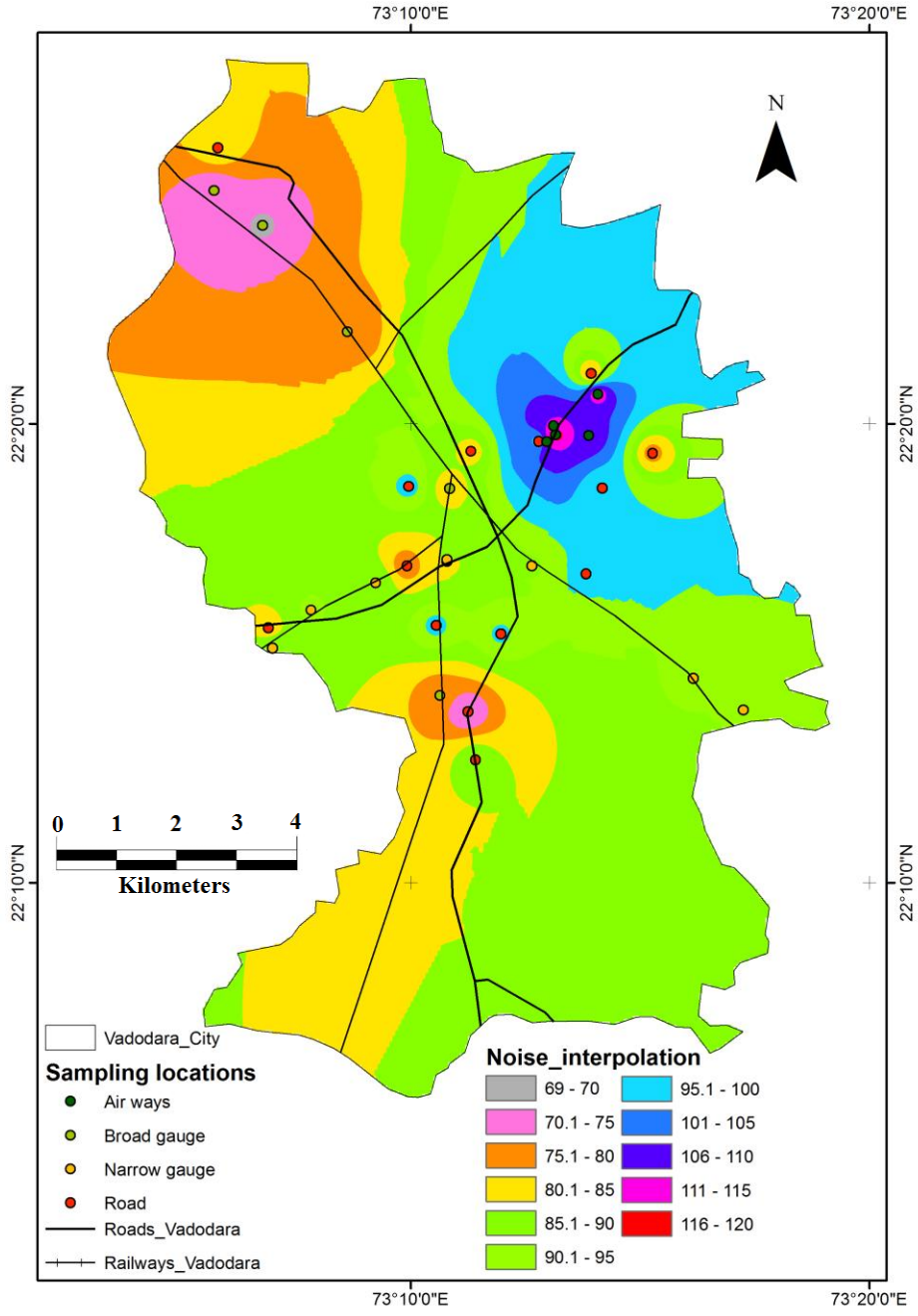

Figure 5. *Spatio-temporal va*

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