Letter to the Editor

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2-D noise maps for tier-2 city urban Indian roads

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Abstract: In today’s era, vehicular noise pollution has been identified as a serious danger that influence the attribute of the urban regions. To identify the influence of noise effects, noise maps are very useful. A noise mapping study has been carried out to study the propagation of urban road traffic noise in the areas along with field measurements. The computer simulation model (SoundPLAN software) is used to developed noise maps. In developing nations like India, traffic composition is heterogeneous. These traffic compositions contain vehicles, which have different sizes, speeds variations and operating systems. Because of fluctuating speeds, deficiency of lane disciplines, and non-authorized parking on main road lanes, honking events becomes inevitable, which changes and affects the urban soundscape of nations like India. Due to horn events (heterogeneous traffic condition), noise level (LAeq) increase by 0.5–8 dB (A) as compared to homogeneous traffic conditions.

Keywords: Heterogeneous Traffic, Noise Mapping, Prediction Models, Road Traffic Noise

1 Introduction

Environmental pollution such as air, water, hazardous waste, and noise has always been a universal alarm, which affects society’s health and the globe’s fragile ecosystems [1]. Among various forms of pollution, noise has been a major issue in urban areas due to transportation. Noise maps are very useful to identify noise sources [2]. To develop a noise map, it is essential to measure ambient noise levels and represent them on a map, which gives the impact of noise, and can support decision makers in defining action relating to its control and management [3]. In today’s era, vehicular noise is the most substantial source of environmental noise pollution in the urban area, therefore; many countries have issued noise emission limits for vehicles and legislations to optimize road traffic noise [4].

The prediction models for road traffic noise can be useful for the highways design, urban roads design and assessment of existing traffic noise conditions [5]. The prediction models are commonly required noise indices Leq, L10, L50, L90 etc., set by countries government authorities to predict sound pressure levels [6]. There are various software available for noise mapping, including some open source software. These types of software have basic tools for environment mapping. In the present study, mapping has been done by tracing polygon on top of a bitmap map [7]. This task can be suitable for a small area but leading this on a huge scale can be time-consuming. Usage of readily available data can reorganize the process of modeling and mapping large areas as fast and easily as the computing power available.

2 Study area

Surat city is situated in the state of Gujarat on the western part of India. Surat is one of the most dynamic city of India with the fastest growth rate due to immigration from several parts of Gujarat. It is famous for its diamond and textile business all over the world. Surat is the second largest city in the state of Gujarat after Ahmedabad city. Surat is observed as 4th fastest developing cities of India with a busy urban area home to about 4.6 million people according to the Census of India (2011) [8]. Surat city is nicely linked by air connectivity and road connectivity with other cities and states. Therefore, the communication system and transportation system has been developed along with the infrastructure of Surat city. There are many transportation services available in the city, including trains, public and private buses, government and private taxi, auto-rickshaw and personalized transportation including scooters, motorcycles, and cars.

There are total seven zones in Surat city name as (i) West zone (ii) East zone (iii) South zone (iv) North zone (v) Central zone (vi) South-West zone (vii) South-East zone.
These seven zones contain different activities such as business, residence, commerce, and industrial. A mixed type of traffic has been seen on these seven zones.

Different type of land-use pattern has been observed in these seven zones. Out of the seven zones, West zone was selected for the study purpose because this zone includes diversified activities of business, residence, commerce. Zone with land use involving industrial activity was kept beyond the scope of this research work.

In the west zone, three road stretches of 1 km each forming a triangle were selected Figure 1. These zones contain all type of activities, which can be affected by vehicular noise pollution. Activity refers to schools, colleges, hospitals, commercial areas, and residential areas. In the west zone, 5 locations were monitored and they are named as A₁, A₂, B₁, B₂, and C. These locations made a triangular closed loop, which has an approximate area of 1.5 sq. km.

Figure 1: Map of West zone of Surat city showing study area

Figure 2, 3, and 4 shows the image of measurement location 1, 2, and 5 which is 30 m wide road. It has two lanes in each direction and service corridors on both sides. Surrounding buildings on this road cater to the residential, hospitals and commercial zones.

Locations 3 and 4 belong to busy urban stretches surrounded by hospitals and dense commercial buildings. This road has two lanes in each direction. The nature of the traffic on this road is different as compared to the other roads. The road layouts, along with the surrounding details, road width and location of the microphone are shown in Figure 5 and 6. All the locations are under silent zone. Silence Zone is defined as areas up to 100 meters around such premises as hospitals, educational institutes and courts as per CPCB guidelines [9].
Table 1: Measured LAeq (West Zone)

| Location | Day-time Measured LAeq | CPCB limit (Silent zone) for Day-time | Night-time Measured LAeq | CPCB limit (Silent zone) for Night-time |
|----------|------------------------|--------------------------------------|--------------------------|----------------------------------------|
| A1       | 71.7                   | 50                                   | 65.3                     | 40                                     |
| B1       | 71.7                   | 50                                   | 66.4                     | 40                                     |
| A2       | 76.1                   | 50                                   | 70.3                     | 40                                     |
| B2       | 74.6                   | 50                                   | 72.6                     | 40                                     |
| C        | 72.2                   | 50                                   | 66.2                     | 40                                     |

Figure 5: View of location 3-A2

Figure 6: View of location 4-B2

3 Data collection

In this study, noise data, road traffic data, road width, pavement type, average building heights, meteorological data and presence of vegetation were collected. Measurements were carried out during the working days from Monday to Friday. Noise data were collected by using the KIMO DB 300/2, automatic sound level meter for 24-hour duration. Monitoring was divided into two parts as per Central Pollution Control Board (CPCB) guidelines, day-time (6.00 am to 10 pm) and night-time (10.00 pm to 6.00 am). The calibrator was used to calibrate a sound level meter for each measurement. This instrument was set for A weighting continuous 24 hours and all the readings were taken as per CPCB protocol (Ambient Air Quality Standards in Respect of Noise is notified under Noise Pollution (Regulation and Control) Rules, 2000). LAeq with a 1-sec sampling frequency was set in the sound level meter. Hence for one individual location, 57,600 readings of day time and 28,800 readings of night time were recorded and stored. Hence for such 5 locations, 432,000 reading were recorded and stored. The sound level meter was put on a tripod at 1.2 m above the floor level.

Table 1 shows that the highest Leq observed is 76.1 dBA at A2 location. The day-time Leq observed on all roads was greater than the prescribed CPCB limits during the day time, which is 50 dBA for silence zone, 55 dBA for a residential area and 65 for the commercial area. At B2 location, Maximum observed LAeq was 72.6 dBA and minimum was 66.2 dBA at location C during night-time which was greater than the prescribed CPCB limits during night time. All recorded LAeq values were higher than the prescribed CPCB limits. This indicates that the noise levels are significantly higher even during night-time in these arterial roads, thereby causing serious health impact among the human population.

The numbers of vehicles categorized as 2-wheelers, 4-wheelers, 3-wheelers, bus, and truck were counted by video-graphic; the results are reported in Table 2. The composition of vehicles namely: 2-wheeler is about 65-75 %, 3-wheeler is about 10-20%, 4-wheeler about 15-25%, and bus & truck both are about 12% during day time. During night time, the composition of vehicles namely: 2-wheeler is about 70-80 %, 3-wheeler is about 5-10%, 4-wheeler about 20-25%, and bus & truck both are about 1%

For each road stretch, the speeds of individual vehicles were taken during the day-time (6.00 am to 10 pm) and night-time (10.00 pm to 6.00 am) with a hand-held radar gun along with the noise level. The average A-weighted
Table 2: Traffic volume (West Zone)

| Location | No. of Vehicles During Day-time | No. of Vehicles During Night-time |
|----------|--------------------------------|----------------------------------|
|          | 2-Wheeler | 3-Wheeler | 4-Wheeler | Bus | Truck | 2-Wheeler | 3-Wheeler | 4-Wheeler | Bus | Truck |
| A1       | 45249     | 9668      | 10826     | 1201 | 88    | 4891      | 612       | 1148      | 45  | 14    |
| B1       | 56668     | 11246     | 15902     | 1181 | 61    | 6027      | 867       | 1335      | 73  | 8     |
| A2       | 51151     | 4741      | 11048     | 342  | 911   | 7243      | 439       | 2813      | 22  | 54    |
| B2       | 48570     | 7742      | 16672     | 496  | 930   | 8381      | 373       | 3484      | 24  | 35    |
| C        | 97759     | 22856     | 13905     | 1064 | 736   | 7935      | 1605      | 1250      | 29  | 22    |

noise emitted by vehicles traveling the roads of Surat city under actual conditions of the noise-monitoring site was determined at 5 different measurement locations in West zone when a single vehicle in each category was passing at its free speed.

The data extraction process consists of three parts: namely noise level data, traffic (count & speed). Noise levels ($L_{Aeq}$) and other noise indices ($L_{10}$, $L_{50}$, $L_{90}$, $L_{95}$) are collected and stored in the automatic precision sound level meter, which automatically generates a complete data sheet of all necessary noise data and statistics in a user-friendly way. These data sheets are then saved to high-end windows 7 operating system computer.

The speed radar gun was used for measuring the speed of the vehicle in kmph. Vehicle speed was measured at every 15-minute interval; 5 readings were taken every 15 minutes, for each category of vehicle. Residential as well as commercial buildings are located just on the roadside and these buildings are minimum 3 stories and maximum 13 stories.

4 Noise mapping process

In this research study, SoundPLAN essential 4.0 was used to develop noise maps. It can create noise contour maps in cities and the open environment from basic 3D geometry and traffic information. Figure 7 depict the methodology used to develop a noise map. Data required for mapping are noise data ($L_{Aeq24hr}$, $L_{10}$, $L_{90}$, $L_{den}$, $L_{max}$, $L_{min}$), road inventory data, geometric features of mapping area, category wise traffic counts, category wise vehicles speed, meteorological data such as wind velocity, humidity, temperature, air pressure. The geometry features of road and buildings were measured manually. All the features of buildings were drawn and identified using tools available in SoundPLAN such as road making tool, building making tool, receiver tool, calculation selection area tool etc.

Around 1600 building in South-West zone and 400 buildings in West zone of Surat city were drawn manually and ground elevation height for all buildings was taken from Google Earth. These buildings were minimum 3 stories and maximum 13 stories. The height of one floor considered was 3.50 meter so the minimum building height is 10.5 meter and the maximum is 45.5 meter.
The traffic data was acquired by site studies for traffic counts. The speed of the vehicle was taken using the radar gun and the average values of speed observed were between 35-45 kmph. A further assumption in the computation was that all road and motorway surfaces are constructed of impervious bitumen and that all the measurement were taken only during i.e. Monday to Friday.

To develop noise map, country wide road calculation models such as RLS-90 from Germany, CORTN:88 from the UK, NMPB:2008 from France, TNM2.5 from the US, etc. are available in SoundPLAN software. Out of these, two calculation models namely RLS-90 and CoRTN:88 are used in SoundPLAN to generate noise maps.

Two noise propagation models such as RLS-90, and CORTN:88, are useful to develop road traffic noise map because these two noise models have urban road inventory features. Both day-time and night-time maps (Figure 8, 9, 10, and 11) were developed using RLS-90 and CORTN:88 models. These noise maps generated by SoundPLAN software are LAeq predicted values of the West zone. These predicted LAeq values, given by RLS-90 and CORTN:88 are presented in Table 3.

Figure 12 & 13 show a difference of up to 8 dB (A) when compared to measured data. The results show (e.g. Figure 12 & 13) a significant difference from the measured noise levels, which are due to the fact that these standards inherently assume homogeneous traffic conditions with higher speeds and wider roads, whereas Indian traffic conditions are heterogeneous. Due to the widely varying vehicular dimensions, speeds, lack of lane disciplines, in heterogeneous traffic conditions horn honking becomes inevitable. It changes the soundscape of the city considerably as compared to other cities of developed countries. Therefore, RLS-90 and CORTN:88 are thought of considering factors such as heterogeneity, horn honking conditions, and non-authorize parking.

5 Results and discussion

In this study, all the measured LAeq values were higher than the prescribed CPCB limits. This indicates that the
Table 3: Predicted LAeq by SoundPLAN (West Zone)

| Location | Day-time Predicted LAeq by SoundPLAN | Night-time Predicted LAeq by SoundPLAN |
|----------|--------------------------------------|---------------------------------------|
|          | RLS-90 | CORTN:88 | RLS-90 | CORTN:88 |
| A1       | 66.3   | 65.6     | 58.6   | 57.1     |
| B1       | 68.3   | 65       | 60.6   | 57.4     |
| A2       | 68     | 65.1     | 62.6   | 59.2     |
| B2       | 70.8   | 67.3     | 64.9   | 61.5     |
| C        | 68.9   | 66.4     | 60.4   | 58.1     |

Figure 12: Chart showing a comparison between different standards for day-time

Figure 13: Chart showing a comparison between different standards for night-time

noise levels are significantly higher even during night-time in these arterial roads, thereby causing serious health impact among the human population. The difference between measured LAeq and predicted LAeq by CORTN:88 and RLS-90 model, are up to 8 dBA. CORTN: 88 model is used for bituminous road surface having vehicle speed greater than 75 kmph, whereas on Indian urban roads such vehicles speed is never observed. This is reflected in the prediction values given by CORTN: 88, where Leq values are underpredicted by up to 8 dBA as compare to actual values. RLS-90 model is used for bituminous road having vehicular speed up to 60 kmph and its predicted LAeq values are underpredicted by up to 6 dBA as compared to actual values. The results show a significant difference from the measured noise levels which are due to the fact that these inbuilt models of SoundPLAN inherently assume homogeneous traffic conditions with higher speeds, wider roads, and no conjunction, whereas Indian traffic conditions are heterogeneous, lesser speeds and narrow roads. Therefore, the correction will be needed to apply and develop a new model for Indian traffic condition.

In India, residential, as well as commercial buildings, are located just on the roadside and enough parking space is not available. Therefore, people park vehicles on the main road in a non-authorized manner. Also, due to the widely fluctuating vehicular dimensions, the composition of vehicles, the speed of vehicles, lack of lane disciplines, and non-authorized parking on main road lane in heterogeneous road traffic conditions, horn honking becomes imperative. It changes the soundscape of the city considerably as compared to other cities of developed countries. Therefore, a model considering the factors of Indian urban condition such as heterogeneity, non-authorize parking, horn-honking conditions should be developed, which probably may bring down the difference between predicted and measured values.

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