Traffic Noise Contour Mapping of Matara city, Sri Lanka

S.M.N. Sethunga *, J.A.P. Bodhika & W.G.D. Dharmaratna
Department of Physics, University of Ruhuna, Matara, Sri Lanka

Abstract

Road traffic noise in Sri Lanka is becoming a serious problem due to rapid industrialization, which could cause health problems to the civilians unless noise controlling and reduction measures are taken. "Noise contour mapping" plays a major role in planning developments of a city while maintaining the noise level at an acceptable level. Noise contour maps, have helped most developed countries to take mitigation actions to control noise levels of cities by introducing vegetation barriers, wall-type barriers, speed bumps, and by improving the conditions of the roads.

This paper presents a study aimed at preparing a noise map of Matara City, located in the Southern Province of Sri Lanka. Noise measurements were carried out using a B&K Type-2250 hand held analyzer (IEC 61672-1; 2002 Class1). L_{Aeq} *values of the diurnal sound level variation were used to produce noise contours. Internationally recommended IMMI mapping software was used for the estimation of traffic noise. The traffic volume, vehicular type, their speed, nature of road surface and meteorological conditions were considered. According to the results, in more than half the area of Matara city (suburb of A2, A24 & and B275 roads), the noise level exceeds the maximum allowed level of 63 dB of Sri Lanka National Environment Act. No. 47, 1980. The recorded* L_{Aeq} *value is around 75-80 dB at locations of traffic lights and road crossings. At some instances,* L_{Aeq} *more than 85 dB values were recorded, especially due to high power engines, poor exhaust systems of vehicles and some vehicle horns. The results suggest that necessary regulations have to be imposed to control the sound pollution and to avoid adverse health effects.*

Key Words: *Traffic noise, Traffic noise prediction, Noise contour map, Noise mitigation, Matara- Sri Lanka,* L_{Aeq}

*Corresponding Author: e-mail - nsethunga@gmail.com

1. Introduction & Literature Review

Human activities produce various sounds at different levels, especially due to transportation (air, road and rail), machines used in industries and in construction sites. Unwanted sound disturbing humans is called noise pollution. Some animals also produce noise. Noise pollution could cause annoyance, aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, and other harmful effects, disrupting physiological and psychological health conditions of humans. Especially, long term exposure to high noise levels causes adverse health effects to humans (Guidelines for community noise 1999; Ishiyama and Hashimoto, 2000; Onuu 2000; Stansfeld and Matheson, 2003).

Traffic noise, road traffic, rail traffic and air traffic, some of the most dominant sources of noise pollution in cities. It has been estimated (Guidelines for community noise, 1999) that more than half of all European Union citizens live in zones that do not ensure acoustic comfort level to residents. More than 30% are exposed to traffic noise equivalent sound pressure levels exceeding 55 dB (A) at night, which could cause sleeping disorders. The noise due to road traffic alone could cause problems in many cities. About 40% and 20% of the population in the European Union are exposed to daytime road traffic noise and sound pressure levels exceeding 55 dB (A) and 65 dB(A), respectively. The impact of road traffic noise on human health has been reviewed (Banerjee, 2012).

In Sri Lanka, the number of vehicles registered, (3.95 million in 2010), has increased very rapidly during the last few years. This increase directly contributes to the increase of road traffic noise (Tandel *et al.*, 2011). However, there is very few research published on the noise pollution in Sri Lanka. A recent study (Liyanage *et al.*, 2011) has reported that 93% of citizens in Rajagiriya suffer from road traffic noise and people living in the area more than 20 years have low hearing sensitivity. Noise maps produced in the area have indicated that schools, hospitals, offices, and a church are located within 75-80 dB sound contours. Noise is reported to be mainly due to vehicular horns, engine beat of busses, trucks and poorly maintained vehicles.

In order to study the noise level in a given area, a large number of measurements have to be made. A certain number of measurements and knowledge of propagation of sound, and several attempts (Santos *et al.*, 2008; Oshino *et al.*, 2006) have been constructed to predict the noise levels in a given region. Farcas and Sivertun, (2012) have developed models to construct contours maps of noise levels. They can be developed for various zones such as cities, industrial zones, construction sites and other indoor/outdoor areas. At present, several noise prediction models and software packages (Shukla *et al.*, 2012) are available for construction of noise maps. Hence, noise maps have been used to study the noise levels in cities due to industrial sources (Santos *et al.*, 2008) as well as road traffics (Novak *et al.*, 2009**;** Akhtar *et al.*, 2012).

Noise contour maps play a major role in planning present and future developmental projects in a city and also provide indications of well being of future generation in a country. They are helpful in identifying noise affected areas and to take necessary precautions to minimize health related problems on civilians. A noise map for a city would be extremely useful in identifying suitable areas for schools, hospitals, courts, tourist hotels etc. and for comfortable residential areas. Employing noise maps, most developed countries have taken mitigation actions to control high noise levels of cities by introducing vegetation barriers, wall-type barriers, speed bumps, conditioning up the roads to suite the traffic volume and implementation of engineering methods to produce low level noise emission by vehicles (Ogata *et al.*, 2001; Boer and Schroten, 2007). Monitoring and controlling of noise pollution in a country would help environmental friendly development. Unfortunately, it is often a source of disagreement when applying standards and regulations, as there is no consensus on how to measure, estimate or present noise maps (Shukla *et al.*, 2012).

A recent study (Sethunga *et al.*, 2013) on monitoring the variation of noise levels during the day time at the Main Bus Terminal at Matara, Sri Lanka, has reported average noise level, L_{Aeq}, for the day time, from 8.00 am. to 6.00 pm., to be between 80-90 dB, which is higher than the level recommended by National Environment Act No. 47 of 1980; the Sri Lanka Government Act for Environmental Noise. It has also reported that noise from engines, horns and speakers were the dominant sources of noise at the bus terminal. This result has indicated the need for constructing a noise map for the city of Matara.

2. Methodology

The commonly used parameter for noise level analysis is the equivalent continuous sound pressure level (L_{eq}). The equivalent continuous sound pressure level is defined as the "steady sound pressure level which, over a given period of time, has the same total energy as the actual fluctuating noise". The A-weighted equivalent continuous sound level for, L_{Aeq} ('Instruction Manual' 2004) in units of dB (A) is used in this study. In general, the noise assessment studies have been done using average noise parameters such as L_{Aeq}, L_{max}, L_{min}, L_{avg}, L_{dn} L_{10}, L_{50}, L_{90}, etc (Subramani *et al.*, 2012).

2.1 Construction of noise maps

Several methods have been used by researchers in preparing noise maps (Farcas and Sivertun, 2012; Ashish *et al.*, 2005). In addition to L_{Aeq} values, traffic volume, engine power, vehicle speed, type of vehicles, nature of road surface, etc. ('User Manual' 2012) have also been used in some models in constructing road traffic noise maps. In this study, a well known software package called "IMMI", one of the most powerful packages used around the world for noise analysis and for mapping was used. IMMI is intended for carrying out noise prediction calculations based on internationally recognized guidelines ('User Manual' 2012). The software contains different algorithms for calculating noise propagation and mapping for various noise applications such as road noise, railway noise, aircraft noise, industrial noise, etc. The road and railway traffic noise simulations were adopted with the guide lines given by different countries, and therefore different elementary libraries such as RSL-90 (Germany), CRTN (Road traffic noise calculation, Great Britain), CRN (Railway noise calculation, Great Britain), XP S 31-133 (France), SRM II (Netherlands), etc. have been included in the same software ('User Manual' 2012).

As the road types and noise levels of different sources of European and Asian countries have significant differences (The Chamber of Commerce of the United States, 2006), IMMI having above features is quite suitable to adapt to situations in Sri Lanka. According to the user requirements, the XP S 31-133 elementary library facilitates with the option to change the initial parameters such as data input (daily traffic volume, dB levels), geometry input (road elevation, road surface type), driving direction input (two-way direction, one-way direction, driving on left or right, etc.), meteorological data input, etc. Further, building heights, nature of the surfaces (reflective or absorptive), number of inhabitancy and number of dwellings have to be set according to the situation.

The interface of XP S 31-133 elementary libraries in IMMI software has three options for input data, which are Q (Number of vehicles in vehicles/h), ADT (Average daily traffic density in vehicles/h) & L_{Aeq}/dB(A). Here, Q refers the input data calculated from the "traffic data" and ADT is input of "Average Daily Traffic density". L_{Aeq}/dB(A) could be either specified directly by the user in "direct" edit mode, or displayed as a value calculated from the traffic data specified by the user in an additional mask in Q mode. Road traffic noise guidelines are built in recommendations of 2003/613/EC ('Commission Recommendation' 2003).

2.2 Site selection

The selected site for noise mapping is the busiest area of Matara city with the highest traffic conjunction throughout the day. Detailed map of the selected area is given in Figure 1. The area includes the A2 (CGHW highway) road, A24 (Matara-Akuressa) road, B 275 (Matara-Hakmana) road and noise sensitive places like schools, hospitals, & religious places etc.

As shown in Figure 2, the area with the highest traffic conjunction is marked as the core area. All vehicles entering the city through A2, A24 and B 275 roads are passing through the core area. Two traffic lights located in main interchanges of A2 & B 275 and A2 & A24 were named as TL 1 and TL 2 respectively. Therefore it is expected that the road noise level to be highest within the core area of the noise contour map.

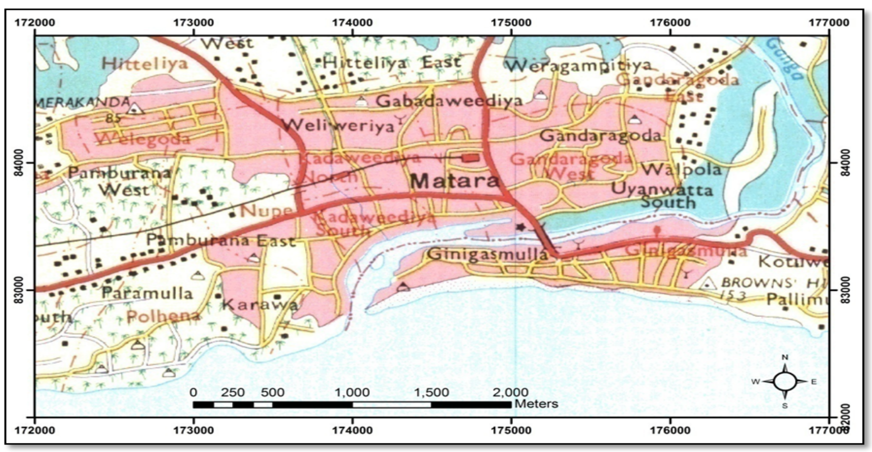

Fig. 1: Selected area for noise contour mapping (source: Survey Department of Sri Lanka)

Number of important places such as schools, churches, temples, hospitals, playgrounds, rail station, bus stand, public fair, public library, historical places, main roads, courthouse, police station, government office complex, children's parks and few industries are located in the area. The coordinates of the selected area lie from 80° 31.127' to 80° 33.295' east and from 5° 55.994' to 5° 57.352' north. The local coordinates of selected area lies from 172000 to 176000 East and from 82000 to 84500 North. The local roads network in the selected area can be seen clearly in dark colour lines in figure 2.

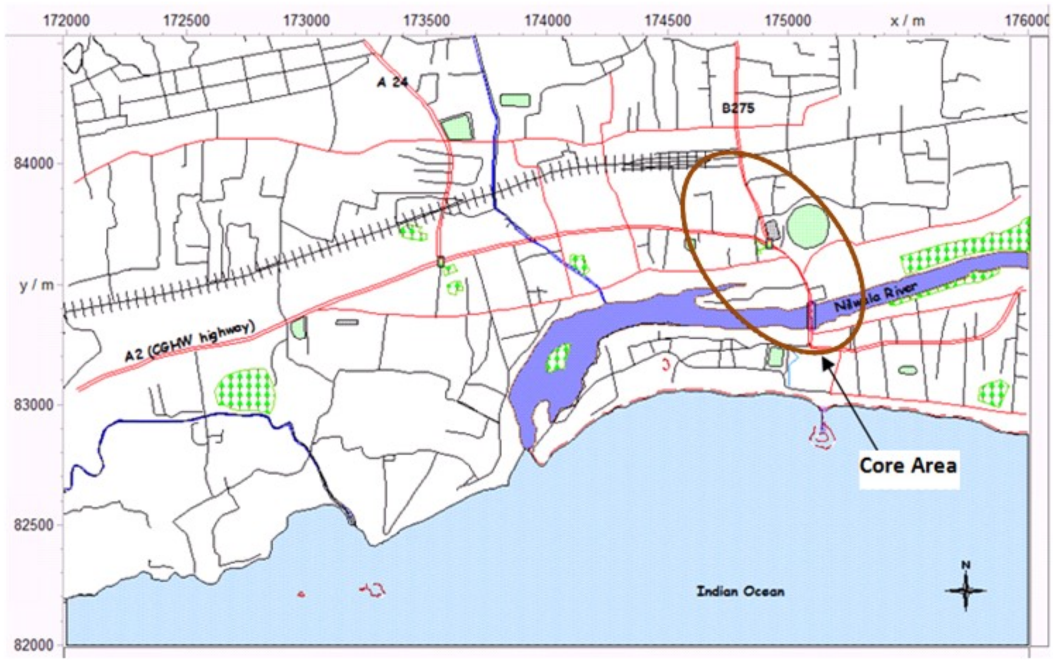

Fig. 2: Main roads and railway line in the selected area.

2.3 Field data measurement

Noise measurements were carried out using B&K Type-2250 hand held analyzer (IEC 61672-1; 2002 Class1 ('Instruction Manual' 2004) and the instrument was suitably calibrated using type 4231, B&K sound level calibrator before each measurement. The analyzer was placed on the centre line of the carriageway, 1.2 m above the ground level for road noise measurement. It was placed 1.5 m above the ground for train traffic noise measurements to overcome the effect of 0.3 m elevation of the railway track. As the wind speed could significantly affect the accuracy of data, UA 1650 90mm wind windscreen, spherical shaped porous foam plastic material, was used to minimize the wind effect. 200 m x 200 m grid scale was maintained during measurements. Atmospheric data such as wind velocity (ms^{-1}), humidity (%) and atmospheric temperature (^0C) were measured at the time of measurement using Kestrel 4500 pocket weather tracker. The noise levels created by each category of vehicles were recorded manually in a separate project using a sound level meter in decibels. Hot sunny days were used for measurements. Rainy days were avoided to disregard the noise generations due to tyre-road interactions. Garmin eTrex 20 hand held GPS navigator was used to locate the positions.

The field data was logged in one minute time periods ($L_{Aeq,\ 60s}$) in automatic mode and measurements were investigated for more than 15 minutes continuously at a single location. Noise Measurements were taken on both sides of road to obtain the mean value. Total of 120 minute time period for every location was covered during a total of three weeks period. For each day, measurements were carried out from 6.00 am to 10.00 pm and therefore busy and calm hours were investigated. The irregular noise such as passing of an ambulance, dog barking, sound of birds, low flying planes, fire service and other emergency vehicles were marked for easy identification. Especially, noise due to high power engines, poor exhaust systems of vehicles and some vehicle horns were separately marked. Finally, the A weighted equivalent noise level, L_{Aeq} was calculated for day time period.

The data on terrain height, water sources, buildings, land uses and boundaries, utilities and transport lines were obtained from the Survey Department of Sri Lanka (SDSL). Number of inhabitants and house data were obtained from the Department of Censes and Statistic (DCS). The statistics of number of industries, and other noise emission locations were obtained through the Central Environmental Authority in Sri Lanka (CEA). The necessary Arc GIS data were obtained through the Geological Survey and Mines Bureau in Sri Lanka.

It is difficult to measure the sound power level of different train engines at the boundary of railway tracks. Therefore, input data was entered to the programme through the sound pressure field. Several noise measurements (more than 50 measurements) were taken out by locating the sound level meter 1.5 m above the ground level, and at a distance of 10 m perpendicularly away from the railway line. Measurements were carried out both inside and outside the railway stations.

Software has the option to select the input data field in sound pressure level, sound power level per unit length, sound power level and indoor level. The average sound pressure level calculated from the collected data was fed into the software in the field of “sound pressure level”. The input data in 1/1 octave band was entered from 16.5 Hz to 8 kHz. Since there were no estimations for building heights in Matara city, the common relative height values, 3.5m for ground floor and 3.2 m for the other floors were used for mapping.

3. Findings, Analysis & Discussion

The required initial parameters in IMMI were selected accordingly. The measured averaged meteorological parameters, ground level temperature of 30 ^{o}C, relative humidity of 70 %, were used. Ground factor (G) is set to 0.4 and reflective index was set as the 0.25 for all buildings in the selected area. The total number of 10.34 km^2 work area was divided into grids of size 15 x 15 (=225)m^2 and hence 45967 total number of grids were calculated. Vertical profile was monitored up to 50 m from the ground surface.

3.1 Area wide noise level variation in day time

This study shows that the total traffic volume in Matara city is very high and irregular. According to our investigations approximately two hundred twenty thousand vehicles (Cars, Vans, Busses, Lorries, trucks and three-wheelers only) (275*60*12) are passing through the city during the day time. Therefore, due to this high traffic volume, the expected traffic noise distribution would be very high.

To overcome the possible complications in calculating noise distribution with such an irregular high traffic volume and highly dispersed vehicle group’s, L_{Aeq} values were used through the elementary library XP S 31-133 for noise contour mapping. The library XP S 31-133 is especially designed for traffic roads in France, where the road traffic flow is more or less continuous. Therefore, the use of L_{Aeq} values in the present analysis will minimize the irregular traffic flow effects to final calculations.

The calculated noise distribution using IMMI for the particular area is shown in Figure 3.

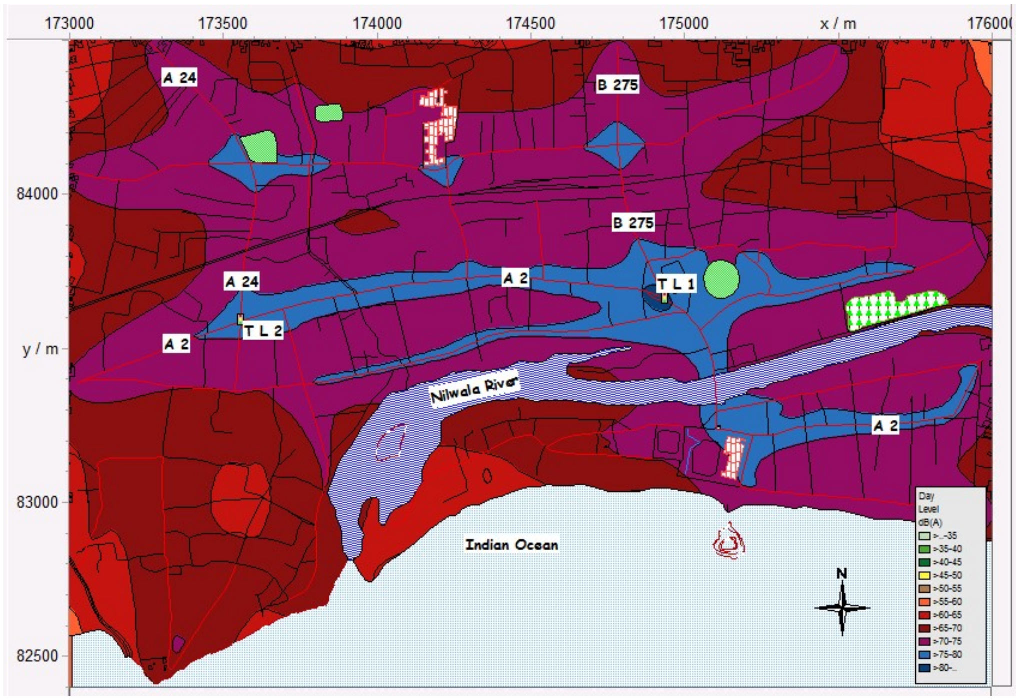

Fig. 3**:** Noise level variation in day time at the selected area in the study

Generally, the noise level variation during day time beside the A2 road varies in the range of 70-80 dB and spread up to 35-50 m on both sides from the centre line of the road. But at some road crossings in A2 road, the noise level spread out further. Beyond that region, a noise level of 70-75 dB is seen for a larger area surrounding the A2, A24 and B275 roads as seen in Figure 3. The highest noise level is seen near TL 1. The percentage of variation of noise level in the area studied was grouped as in table 2.

Table 1: The percentage of noise level variation in day time at studied area

Distribution over all scale levels											
Layer:	**Day**										
Investigated dimension:	**area /m² (Total area 103,42,400 m²)**										
Range (dB)	**>35**	**>35-40**	**>40-45**	**>45-50**	**>50-55**	**>55-60**	**>60-65**	**>65-70**	**>70-75**	**>75-80**	**>80**
Percentage of area (%)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**4.4**	**19.7**	**30.5**	**37.1**	**8.1**	**0.1**

Critically noise affected area during the day time is related mainly to the roads A2, A24 and B275. According to the Figure 3, more than 65 dB levels are occupied by total of 75.8 % of the total investigated area. Total of 95.5 % investigated area of survey lies beyond the 60 dB margin level. Especially, total of 0.1 % of area has exceeded the 80 dB noise level during day time. This study shows that the noise level observed is fairly high compared with the values given in Table 1(a) and 1(b), which could cause some adverse health effects in certain areas. Furthermore, most of the time high traffic volumes can be seen near the road interchanges. Unfortunately, some bus stops are located very closer to both traffic lights, TL 1 & TL 2, and hence high noise levels can be originated at these interchanges.

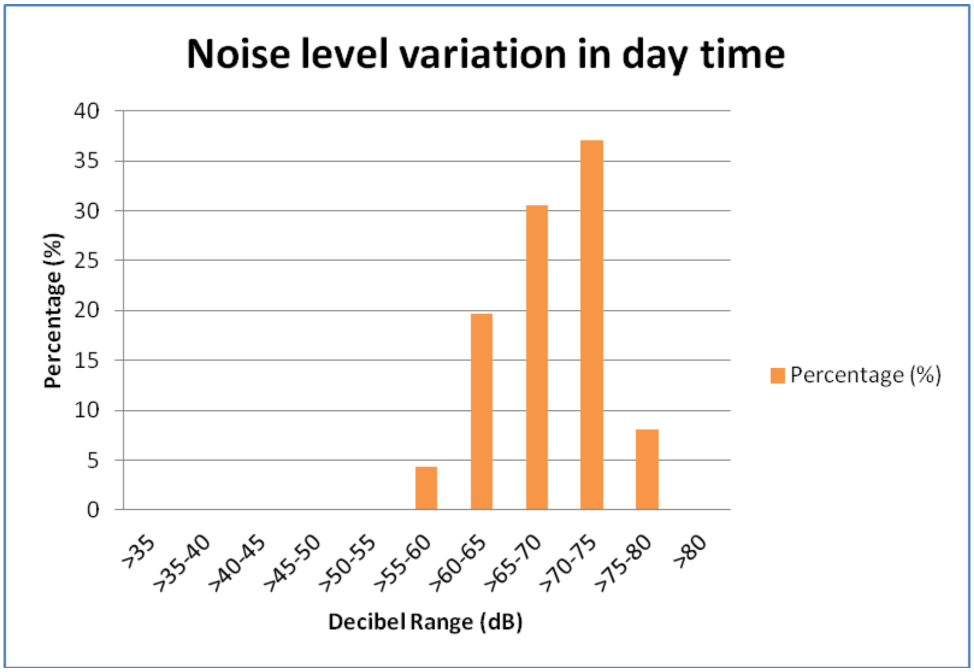

Chart 1: Noise level variation with percentage of area.

The Chart 1 shows the result of figure 3 as percentage of area for different decibel ranges. It clearly shows that the average noise level in this area at day time is above 55 dB and below 85 dB. Therefore, actions have to be taken to control the noise level. According to WHO guidelines adverse health effects could take place if the noise level is above 85 dB.

Unfortunately, there are some schools in the area with 65-75 dB sound levels. The recommended value for the region of schools, courts, and churches are below the 55 dB level. Therefore, special attention has to be given to reduce the noise levels in such areas. As already discussed, it is possible to build noise reduction barriers at least in these sensitive areas. Some poor urban planning, such as side-by-side industrial and residential buildings, in the residential areas may give rise to noise pollution.

3.2 Core area and other heavily affected areas in the noise map

The core area was confined near the traffic colour lights, main road crossings and the main bus stand. The high noise level can be seen near the traffic colour light 1 (TL 1) as in Figure 4. Several reasons conduce to high noise level at this junction. In particular, two bus stops at TL 1 make a significant contribution. This effect can be decreased if busses leave quickly without waiting long time at the bus stop. The municipal council, general hospital, pilgrimage places, police station, play ground, historical place, fire rescue camp, and a considerable number of shopping complexes, several banks, etc. are located in this core area. As a result, many people get exposed to higher noise levels in this area during the day time.

Moreover, loud noise produced by horns and engines of buses near TL 1 while waiting to collect more passengers contributes significantly to high noise level in the core area. Implementation of local regulations for buses certainly would reduce the noise level in this area.

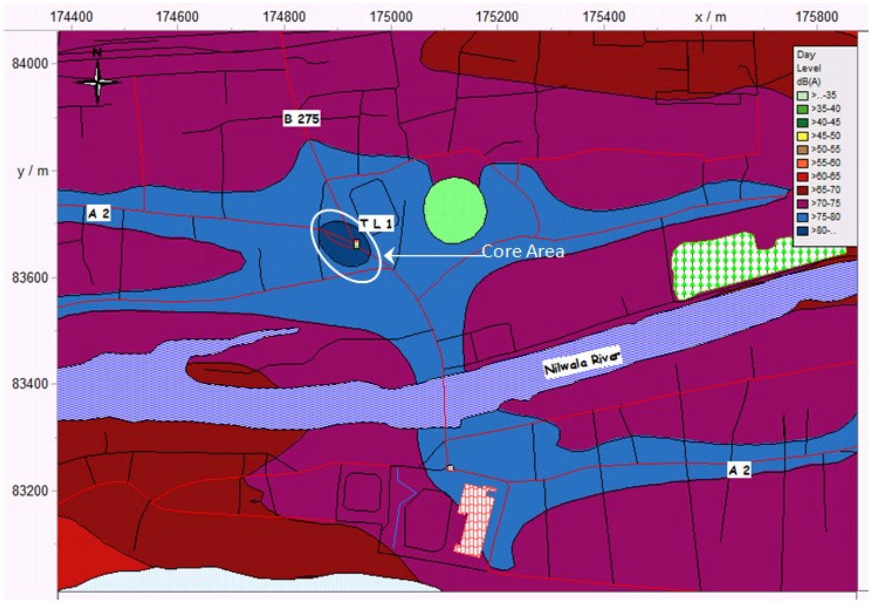

Fig. 4: Core area with critically high noise levels.

As some sensitive places like hospitals and schools are located here, noise reduction barriers have to be implemented in this area. According to the literature it was observed that around 10-15 dB noise level can be reduced using noise reduction strategies such as barriers.

3.3 Effect of the sea

According to the measurements, 60-63 dB continuous background noise level from the sea has been observed along the beach line in the area studied. Ambient noise of 50-55 dB could be observed at lands near the sea. This is mainly due to the tidal noise and therefore it would be the background noise level at the vicinity of beach. Even at some distance away from the sea, a noise level of low frequency spectrum which is similar at the beach has been observed. This confirms the low attenuation of low frequency components of noise.

3.4 Validity of the prediction

The validity of the predictions of the model was tested by comparing the measured values of the noise level at 23 randomly selected locations. Same procedure was followed initially, as mentioned in data collection under methodology. The result is shown in Figure 5. As can be seen from the Figure 5, 18 measurements out of 23 (78%) agree with the predictions. Three measurements are slightly lower and two are slightly higher than the predictions which are closer to contour boundaries. This could be expected as the present model has used only averaged L_{Aeq} measured along the roads.

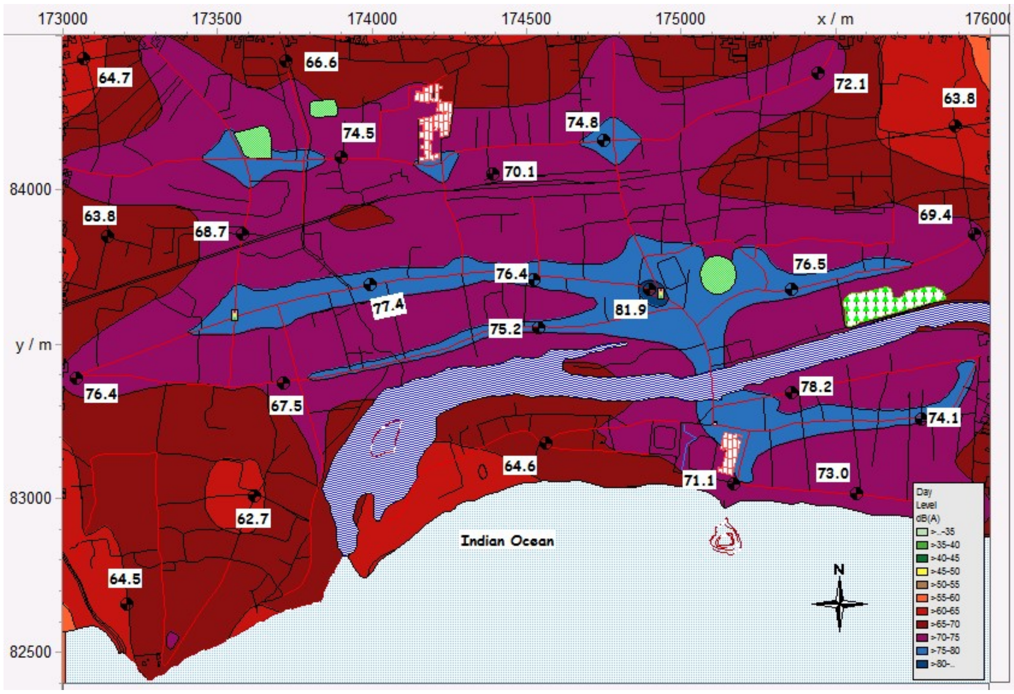

Fig. 5: Comparison of predictions of the model with measured values at 23 randomly selected locations.

4. Conclusions

The diurnal noise variation at the selected area of Matara city exceeds the acceptable level given by the National Environment Act 47, 1980, by around 10 to 20 dB in a larger area of the city. For more than half of the area of Matara city (suburb of A2, A24 & and B275 roads), the noise level exceeds the maximum allowed level of 63 dB. The recorded L_{Aeq} value is around 75-80 dB at locations of traffic lights and road crossings. At Some instances, L_{Aeq} more than 85 dB values were recorded, especially due to high power engines, poor exhaust systems of vehicles and some vehicle horns. The results suggest that necessary regulations have to be imposed to control the sound pollution and to avoid adverse health effects. Furthermore, the result could be used for future planning of the city and the local authorities have to take necessary mitigation actions such as imposing vegetated barriers, and wall-type barriers, and develop the road network to suite the traffic volume, introduction of new regulations and implementation of awareness programs.

It is certain that the initial noise map produced here must be updated after the completion of the extension of the Southern Express Way up to Matara as traffic volumes in certain roads passing through the core area would be significantly changed. Furthermore, this study has to be extended to other parts of the city with some more measurements. The results could be improved further by tuning the parameters of the model used. In addition, the effect of high noise pollution on the citizens living in the core area of the city for a long period of time has to be investigated.

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