INTRODUCTION

Today, the noise pollution is one of the principal types of urban natural contamination. What is more, it is responsible for the negative effects that are harmful to the Earth and the personal welfare of the people. The increase in noise pollution relies upon numerous elements and in addition, they increase in the urban population and thus the expansion in the number of development exercises and vehicles [Directive EP, 2002]. Noise pollution can be considered as one of the significant toxins present in urban areas. Its assessment, control, and decrease are among the major natural well-being concerns for specialists [Mohammadi, 2009; Zannin, et al., 2013]. Many researchers have also reported that road traffic is the most general and prominent noise pollution source in the developing countries [Mocuta, 2012]. Some researchers from different countries also investigated and characterized noise pollution under different types of traffic conditions [Boer, 2007; Stoitova and Stoilove, 1998; Zannin, et al., 2003; Piccolo, et al., 2205; Zannin, et al., 2006]. The increase in noise pollution is not sustainable because it involves direct, but also cumulative, adverse health effects. It also harmfully affects the future generations and has socio-cultural, aesthetic and economic effects. Noise monitoring under different road and environment condition is one of the best tools to discover the critical locations in residential, commercial and industrial areas [Akhter, et al., 2016]. In order to develop an acoustic model, it is necessary to know as many details as possible [IIiescui, et al., 2015]. The traffic noise prediction models are required to assist in the design of highways and roads and sometimes, in the evaluation of the existing or planned changes in the traffic noise conditions. Normally, for prediction of the sound pressure levels, the noise levels in terms of Leq are required by most of the sound prediction models [Steele, 2001]. The results from the noise prediction model may further be used for the development of 2D and 3D noise maps [Stoter, et al., 2008]. Noise mapping is the graphic representation of the sound
level distribution existing in a given region and environmental condition, for a defined period of time. Noise mapping is broadly divided into two categories i.e., 2D and 3D. The 2D mapping has been extensively and successfully used for environmental impact studies like Air pollution, Soil pollution and Noise in the existing environment. Noise monitoring, mapping, and modeling studies are interrelated. The results of noise monitoring can be used for the prediction of the sound pressure level employing different prediction models; the predicted results may further be used for the development of noise maps.

NOISE MONITORING STUDIES IN DEVELOPING COUNTRIES

Significant negative effects on the children’s blood pressure and mental health due to noise pollution have been found. Some studies show that the people who are exposed to high street traffic noise levels often suffer from hypertension [Chang, et al., 2011]. The noise monitoring studies are especially needed for monitoring the sound levels and appropriate reduction measures can be implemented to control the noise pollution [Garg, et al., 2017]. Studies on monitoring and applying noise abatement measures to ambient noise and controlling them have been conducted in various parts of the world. The advancement of developing countries is accompanied by industrialization. We see not only a higher level of noise in industry and traffic, but also a concentration of population, on the one hand, and a higher construction of high rise buildings on the other [Barrekette, 1973]. The noise monitoring studies of 22 developing countries and 25 cities for two decades were reviewed to demonstrate the current state of the investigation on the acoustic pollution in developing countries and the gaps in the studies. Table 1 shows the maximum, equivalent and minimum noise level of developing countries. A noise monitoring study was performed by [Chowdhury, et al., 2010] at Dhaka city of Bangladesh. The monitoring results show a maximum noise level of 87 dB (A) and Leq of 82 dB (A) is enough to create discomfort for the people living in the nearby areas. A study conducted in China, Brazil, Egypt, and Iraq [Bengang, et al., 2002; Henrique, et al., 2002; Zekry and Ghatass, 2009] revealed that the equivalent noise level at the study area of these countries remains in between 75.2 dB to 75.35 dB, which is also higher than the prescribed standard of these all locations. The noise study at Columbia [Danie, et al., 2014] and Poland [41] only shows the Leq noise level within the prescribed standard. However, noise monitoring in Nigeria [Awviri, and Nte., 2003] and the Philippines [Vergel et. al., 2004] shows the maximum noise level among all 22 developing countries i.e., 81.4 and 84.3 dB, respectively. The noise monitoring was carried out in three states of India by Rajiv B. Hunashala, Yogesh B. Patil, Perez Alam et al., and Ambika N. Joshi et al. The results show that the equivalent noise level remains maximum at Mumbai [72.0 dB] followed by Delhi [70.2 dB] and Kolhapur [65.3]. Thus, the noise level of these three cities of India remains higher than the prescribed standard of Central pollution Control Board (CPCB). Furthermore, it has been found that most of the study areas of the selected developing countries have been exposed to the noise levels higher than the prescribed standard of the competent authority in the respective countries.

NOISE MAPPING OF DEVELOPING COUNTRIES

Certain locations required more detail on the noise levels than cannot be provided by a simple noise survey. Sometimes, there may be a necessity to analyze the sound pressure levels all over the place, or around a particular piece of land and machinery of industry. Noise mapping can provide the details of the noise level around any machinery, road, house or a piece of land. A noise map is a visual depiction of noise levels for a specific area and for a specific time in the form of a contour map [Hede et al., 1998]. Contours are generally colored maps to signify the intensity of noise, as well as the occurrence of low or high frequencies of noise. The map is usually overlaid on a plan of the area or workplace for which the noise mapping is required. One of the major advantages of noise mapping is to accurately assess the adverse effect of a proposed new road on the nearby structures in order for the decision-makers to take suitable noise mitigation measures to minimize the impact. This is very important in noise action planning, where a cost-benefit study of various options can be experienced before a decision is made. The authors have reviewed the noise mapping studies of 23 developing countries and 27
cities for around two decades to demonstrate the current state of the noise mapping studies in developing countries and the gaps in the studies. Table 2 shows the assessment of 2D and 3D noise mapping of developing countries. In India [Tiwari et al., 2017; Akhtar et al., 2016] performed the 2D and 3D noise mapping for Gujarat and Delhi, using ArcView and soundPlan software, respectively. Using 2D noise mapping in Gujarat, Tiwari et al. were able to establish a critical location where remedial measures are required to reduce the adverse effect of noise on human beings. Furthermore, [Nasim Akhtar et al., 2016] has also developed 2D as well as 3D noise maps for selected locations of Delhi. Their study shows the importance of a 3D noise map, as using 3D

Table 1. Maximum, equivalent and minimum noise level of developing countries

| S.No | Author | Country | City | Type of study | Data Source | Noise measurement | Noise levels (dB A) |
|------|--------|---------|------|---------------|-------------|------------------|------------------|
| 1.   | Chowdhury et al., 2010 | Bangladesh | Dhaka | Field Survey | Journal | Yes | 87 | 82.0 | 53 |
| 2.   | Bengang et al., 2002 | China | Beijing | Field Survey | Journal | Yes | 87.3 | 75.2 | - |
| 3.   | Zannin, 2002 | Brazil | Curitiba | Field Survey | Journal | Yes | - | 75.6 | - |
| 4.   | Ghatass, 2009 | Egypt | Alexandria | Field Survey | Journal | Yes | 47.7 | 75.6 | 98.7 |
| 5.   | Essandoh and Frederick, 2011 | Ghana | Cape Coast | Field Survey | Journal | Yes | 87.3 | 73.5 | 51.1 |
| 6.   | Galindo, et al., 2017 | Colombia | Santa Marta | Field Survey | Journal | Yes | 76.04 | 64.0 | 54.8 |
| 7.   | Daniel et al., 2014 | Colombia | Bagota | Field Survey | Journal | Yes | 65.3 | 56.5 | 45.7 |
| 8.   | Mesfin, et al., 2018 | Ethiopia | Dire-Dawa City | Field Survey | Journal | Yes | 68.08 | - | 52.26 |
| 9.   | Abankwa, et al., 2017 | Ghana | Kumasi | Field Survey | Journal | Yes | 83.5 | 72.6 | 66.8 |
| 10.  | Hunashala and Patil, 2012 | India | Kolhapur | Field Survey | Journal | Yes | 73.7 | 65.3 | - |
| 11.  | Akhtar et al., 2016 | India | Delhi | Field Survey | Journal | Yes | 79.3 | 70.2 | 60.2 |
| 12.  | Joshi, et al., 2015 | India | Mumbai | Field Survey | Journal | Yes | 80.6 | 72.0 | 64.5 |
| 13.  | Sondakh et al., 2014 | Indonesia | Ratulangi Manado | Field Survey | Journal | Yes | 87.4 | 71.6 | 49.2 |
| 14.  | Biglari et al., 2016 | Iran | Tehran | Field Survey | Journal | Yes | 102.57 | 75.3 | 66.7 |
| 15.  | Rauf et al., 2015 | Iraq | Sulaimani | Field Survey | Journal | Yes | 75.5 | 65.3 | 55.4 |
| 16.  | Awadhi and kandani, 2017 | Kuwait | Kuwait City | Field Survey | Journal | Yes | 82.0 | 80.0 | 70.5 |
| 17.  | Aziz et al., 2012 | Iraq | Erbil | Field Survey | Journal | Yes | 85.0 | 75.2 | 69.1 |
| 18.  | Fernandez et al., 2013 | Mexico | Mexico City | Field Survey | Journal | Yes | 80.1 | 77.2 | 58.1 |
| 19.  | Awirin, and Nte., 2003 | Nigeria | Nigeria Delta | Field Survey | Journal | Yes | 93.2 | 81.4 | 68.3 |
| 20.  | Vergel et al., 2004 | Philippine | Quezon City | Field Survey | Journal | Yes | 95.6 | 84.3 | 70.1 |
| 21.  | Vasilyev et al., 2017 | Russia | Samara | Field Survey | Journal | Yes | 80.1 | 65.3 | 52.0 |
| 22.  | Zytoon, 2016 | Saudi Arabia | Jeddah | Field Survey | Journal | Yes | 70.1 | 62.3 | 50.5 |
| 23.  | Vasilyev, 2017 | Russia | Samara | Field Survey | Journal | Yes | 65.6 | 59.8 | 46.2 |
| 24.  | Çoban et al., 2018 | Turkey | Turkey City | Field Survey | Journal | Yes | 76.2 | 61.3 | 52.5 |
| 25.  | Szopinska and Rącka, 2017 | Poland | Polish City | Field Survey | Journal | Yes | 68.9 | 57.3 | 47.3 |
mapping enables to locate the effects of noise pollution in X, Y and Z direction on any residential building or setup. Most of the researchers used GIS as a tool for development of 2D noise map in different countries like Taiwan, Netherlands, Russia, Poland, Turkey, Kenya, Spain, Nigeria, Portugal and Egypt. In some countries, researchers used other tools for the development of noise maps; for instance, Nasim Akhter et al. (in India), and Zannin et al. (in Brazil) used soundPlan for the development of 2D and 3D mapping. In China, [Wu, et al., 2018] used Swallow sound for the development of a 2D noise map for the selected locations. In Latin America [Fiedler and Zannin, 2015], used Predictor 8.11 for the development of 2D and 3D noise mapping for the selected location of the Curitiba city. CAD 3D software has also been used in two countries i.e., in Spain and Brazil, in Madrid and Brasilia, respectively, for the 2D noise mapping only. Most of the researchers have developed 2D noise maps only for the selected locations of different countries such as [Kartikey Tiwari et al., 2017] for India, [Tsai et al., 2009] for Taiwan, [Paulo and David, 2011] for Brazil, [Wu, 2015] for China, [Vasilyev, 2017] for Russia, [Awadhi and Kandary, 2017] for Kuwait, [Dursun et. al., 2006] for Turkey, Brainard et al., 2004 for United Kingdom, [Wawa and Mulaku, 2009] for Kenya, [Arana et al. 2009] for Spain, [Coelho and Alarcao, 2005] for Portugal, [Eldien, 2009] for Egypt, [Nicolas et al., 2016] for Chile, [Olayinka, 2012] for Nigeria, and [Farcaş and Sivertunb, 2015] for Sweden. Few researchers have developed 3D noise maps for a selected location of some countries, such as [Nasim Akhtar et al., 2016] for India, [Stoter et al., 2008] for the Netherlands, [Kossakowski, 1990] for Poland, [Fiedler and Zannin, 2015] for Latin America. As per the above literature review of 2D and 3D noise mapping, it has been established that the 2D noise maps have been developed by most of the researchers for their respective developing countries to find out the distribution of noise along a central line of a road or along the periphery of an industry. However, the literature survey also shows that the 3D noise gives a clear picture of the noise distribution in all three directions X, Y, and Z. In one of the studies of India, 3D noise maps have been developed by [Akhtar, et al., 2016] for the selected location of Delhi which gives clear picture of noise distribution in all three directions and also provides a number of the people affected in a particular residential building. Thus, from the review of noise mapping it can be concluded that the 2D noise mapping is an effective way to show the noise level distribution along with any source of noise in X and Y direction only. The 3D noise mapping is more effective than 2D in the residential areas, as it can also provide noise exposure level in the Z direction and also gives a number of people affected in high rise residential buildings. The review also shows that very few research works has been performed in the field of 3D noise mapping. On the other hand, 2D noise mapping has been used extensively by researchers.

**NOISE PREDICTION MODELS STUDY**

Noise prediction is one of the essential tools for decision-makers to reduce the adverse effect of noise and their control. The prediction models are generally used by three major sections of society.

1. **Acoustic Engineers**: Acoustical engineers are generally worried about the plan, investigation, and control of sound.

2. **Acoustic specialist**: They are generally part of the team to prepare an environmental impact assessment report.

3. **Decision maker**: Prediction models are generally used by decision-makers to identify the distribution of noise in the upcoming days.

This procedure is a unique way, after the directives by ministries, to control the environmental noise, wherein noise maps have been suggested for transportation sources and urban agglomerations. Consequently, many logical sound prediction models have been created as of late, focusing on this angle and presenting only source outflow and sound engendering observational details. Lots of prediction models have been developed and validated by researchers for their respective countries. They have been successfully used by various agencies for the development of noise maps. Aside from the source interpretation, progressed numerical strategies including wave condition and equation of continuity are utilized to resolve the sound engendering impacts. Thus, it is very important to logically investigate and compare these models so as to discover their reasonableness by and large and furthermore to discover the best methodology among them for traffic noise modeling. [Steele, 2001] conducted a thorough review of the major traffic noise models
in 2001, but some of them have been revised between 2007–2013 and updated by [Garg and Maji, 2014] in 2014. Now, they have been around for six years; thus, it is imperative to update the comparison done by Garg and Maji again. The present study reviews the implication and strategies of the recently developed models such as CoRTN, Start and Stop, FHWA, etc.

Table 2. Assessment of 2D and 3D noise mapping of developing countries

| S.No | Author et al., 2017 | Country | City | Type of study | Data Source | Software Used | Noise Mapping |
|------|---------------------|---------|------|---------------|-------------|---------------|---------------|
| 1.   | Tiwari et al., 2017 | India   | Gujarat | Field Study | Journal | ArcView or ArcGIS | Yes - - |
| 2.   | Akhtar et al., 2016 | India   | Delhi | Field Study | Journal | SoundPlan | Yes Yes Yes |
| 3.   | Tsai et al., 2009   | Taiwan  | Tainan | Field Study | Journal | GIS | Yes - - |
| 4.   | Stoter et al., 2008 | Netherlands | Deft | Field Study | Journal | GIS | Yes Yes Yes |
| 5.   | Paulo and David, 2011 | Brazil | Brazil | Field study | Journal | CAD and GIS | Yes - - |
| 6.   | Wu et al., 2015     | China   | Hangzhou | Field Study | Journal | Swallow sound | Yes - - |
| 7.   | Wang et al., 2018   | China   | Guangzhou | Field Study | Journal | ArcGIS | Yes - - |
| 8.   | Vasilyev, 2017      | Russia  | Samara | Field Study | Journal | GIS | Yes - - |
| 9.   | Kossakowski, 1990   | Poland  | KUT | Field Study | Journal | GIS | Yes Yes Yes |
| 10.  | Awadhi and Kandary, 2017 | Kuwait | Kuwait City | Field Study | Journal | CUSTIC 2.0 | Yes - - |
| 11.  | Dursun et al., 2006 | Turkey  | Konya | Field Study | Journal | GIS | Yes - - |
| 12.  | Casas et al., 2014  | Brazil  | Brasil | Field Study | Journal | CAD 3D | Yes - - |
| 13.  | Yilmaz and Hocanli, 2006 | Turkey | Sanliurfa | Field Study | Journal | GIS | Yes - - |
| 14.  | Zannin et al., 2013 | Barazil | Parana | Field Study | Journal | SoundPlan | Yes - - |
| 15.  | Brainard et al., 2004 | UK | Birmingham | Field Study | Journal | Lima | Yes - - |
| 16.  | Wawa and Mulaku, 2009 | Kenya | Nairobi | Field Study | Journal | GIS | Yes - - |
| 17.  | Arana et al., 2009 | Spain | Pamplona | Field Study | Journal | GIS | Yes - - |
| 18.  | Coelho and Alarcao, 2005 | Portugal | Lisbon | Field Study | Journal | GIS | Yes - - |
| 19.  | Eldien, 2009        | Egypt | Suez city | Field Study | Journal | GIS tool | Yes - - |
| 20.  | Coelho et al., 2005 | Portugal | Odivelas | Field Study | Journal | GIS | Yes - - |
| 21.  | Nicolas et al., 2016 | Chile | Valdivia | Field Study | Journal | RLS-90 | Yes - - |
| 22.  | Olayinka, 2012      | Nigeria | Ilorin metropolis | Field Study | Journal | GIS | Yes - - |
| 23.  | Klucininkas and Salunas, 2006 | UK | Kaunas | Field Study | Journal | GIS | Yes - - |
| 24.  | Kalipci and Dursun, 2009 | Turkey | Giresun | Field Study | Journal | GIS | Yes - - |
| 25.  | Merchan and Balteiro, 2013 | Spain | Madrid | Field Study | Journal | CAD and GIS | Yes - - |
| 26.  | Fiedler and Zannin, 2015 | Latin America | Curitiba’s | Field Study | Journal | Predictor 8.11 | Yes Yes Yes |
| 27.  | Farcaş and Silvertunb, 2015 | Sweden | Skane region | Field Study | Journal | ArcGIS | Yes - - |
FHWA Traffic Noise Model Version 3.0 (2016)

Federal Highway Administration (FHWA) Traffic Noise Prediction Model [Anon, 1978] was developed for the United States of America (USA) Department of Transportation Federal Highway administration by Barry and Reagan (1976); they received help from preceding National Cooperative Highway Research Program (NCHRP) [Anon, 1976]. The prediction noise model was published as a Report No. FHWA-RD-77–108 which included calculation and programmable program. The reference noise level is the maximum noise level of the vehicle, emitted by the vehicle passed at a distance of 15 m. In the FHWA model, Leq (Near) and Leq (Far) were calculated and the average of far and near were taken into consideration for noise average Leq noise level.

\[
L_{eq\, (near)} = 10 \log \left( \sum_{i} 10^{L_{eq\, (hi)\, (near)/10}} \right)
\]

where \( L_{eq\, (near)} \) = Noise level of all classes of vehicles from the near side of the road

\[
L_{eq\, (hi)\, (near)} = \text{The noise level of vehicle class-I from near side of the road}
\]

\[
L_{eq\, (far)} = 10 \log \left( \sum_{i} 10^{L_{eq\, (hi)\, (far)/10}} \right)
\]

where: \( L_{eq\, (far)} \) = Noise level of all classes of vehicles from the far side of the highway

\[
L_{eq\, (hi)\, (far)} = \text{Noise level of vehicle class I from the far side of the highway}
\]

\[
L_{eq\, (hourly)} = EL_{i} + A_{(traffic)} + A_{d} + A_{s}
\]

where: \( A_{(traffic)} \) = Correction for traffic flow

\( A_{d} \) = Correction for distance between the roadway and receiver

\( A_{s} \) = Correction for all shielding and ground effects between the roadway and the receiver.

Assumption for noise prediction (FHWA)

The following are the major assumption for the prediction of the noise level by FHWA

1. The vehicles will be represented as an acoustic source.
2. Noise emission levels will be assumed as group noise source such as (Bus, medium and heavy trucks) are normally distributed.
3. Noise propagation losses will be adequately represented by the effect of distance.

Input Parameters required for prediction of noise level (FHWA)

For validating the FHWA model, traffic noise monitoring, the characteristics of traffic, including its composition and volume of traffic on the road, are required. For the FHWA model, traffic composition is normally divided into each type of vehicle such as medium truck, heavy truck and passenger car. The light vehicles included personal cars, local taxis, vans, and motorized two-wheelers, while trucks and buses are included as the heavy vehicles.

RLS-90 model

RLS-90 is an efficient model, able to determine the noise pollution level of road traffic and, in current days, is the main appropriate calculation method used in Germany. It is a German national model for the prediction of road traffic and parking noise. It is made up of two different models; the first corresponds to the determination of noise level emission (Lme) at a distance of 25 m from the center of the road and 4 m above the ground level. Lme is determined by taking into consideration traffic such as the speed of the vehicle, distribution of the vehicle, road surface condition. The sound pressure level for a street:

\[
L_{t} = L_{m} + K
\]

where: \( L_{m} \) = mean A-weighted noise level

\( K \) = Addition for increase in noise due to effect of traffic signal controlled intersections and other intersections

\[
L_{me} = L_{25} + C_{s} + C_{rs} + C_{g} + C_{r}
\]

where: \( L_{25} \) = Standardized noise level for assumption of a speed amounting to 100 km/h for cars and 80 km/h for trucks.

\( C_{s} \) = Speed correction

\( C_{rs} \) = Road surface correction

\( C_{g} \) = Gradient correction

\( C_{r} \) = Multiple reflection correction

\[
L_{25} = 37.5 + 10 \times \log_{10} \left( M \times \left( 1 + 0.082 \times P \right) \right)
\]

where: \( M \) = Number of vehicles (h⁻¹)

\( P \) = tracks exceeding 2800 kg (%)

The second model is for the transmission stage, in which, the noise level at a definite location is determined by making the suitable
addition of all the contributions carried out by the sources taking into account the length of the road, the reduction of noise due to the distance, air absorption, and sound propagation due to the temperature gradient.

**Assumption for noise prediction (RLS-90)**

The following are the major assumptions for the prediction of noise level by the RLS-90 model

1. The day and night time has been assumed as 6 AM to 10 PM and 10 PM to 6 AM, respectively.
2. It will take into account the major features which influence the noise propagation, such as obstacles, vegetation, absorption, reflections and diffraction [Quartieri et al., 2012].
3. Parking spots and the number of vehicles in parking spots will be considered for noise prediction.

**Input Parameters required for noise prediction (RLS-90)**

Prediction of the noise level by RLS-90 requires some input parameters such as the average hourly flow of traffic, separated two-wheelers, light and heavy motor vehicles, the average speed for each group of traffic, road dimension, the geometry of road and road type and any natural and artificial obstacles. This model considers the fundamental highlights which impact the propagation of noise, for example, obstacles, vegetation, reflections, and diffraction. Specifically, it makes checking the noise decrease created by obstacles conceivable and likewise considers the reflections delivered by the screens.

**Stop and Go model**

Pamanikabud and Tharasawatpipat [1999] of the Urban Transport Department in 1997 developed the Stop and Go model for the central part of Bangkok. The model gives emphasis on formulating an empirical model of the intermittent flow of traffic in Bangkok using two analytical approaches. The first is the single model analysis and the second is the separate lane analysis or dual model analysis. Traffic noises due to interrupted or stop and go flow of traffic situation on urban roads create considerably diverse noise

\[
\text{Volume of traffic} = (\text{AU}) + 1.04(\text{LT}) + 1.12(\text{MT+TT}) + 1.14(\text{HT}) + 1.09(\text{MC+BU+MB})
\]

where: 
- **MC** = Motorcycles
- **MT** = Medium truck
- **BU** = Bus
- **TT** = Tuk-Tuk
- **MB** = Minibus

The single Stop and Go model approach has been firstly applied to build a single stop and go traffic flow, noise model. This model can be used to both sides of an urban roadway. The Leq by Stop and Go single lane model can be predicted by:

\[
\text{Leq} = 71.05 + 0.10Sn + 0.95 \log Vn + 0.04Sf + 0.015 \log Vf - 0.111Dg
\]

where: 
- **Dg** = Geometric mean of road section (m); \(= \sqrt{(D_f \times D_n)}\)

In a separate lane model, the Leq noise level for acceleration and deceleration lane are taken into consideration and the average of both lanes remains the actual Leq level. The equation mentioned below is generally used for the determination of Leq by a separate lane model.

**Acceleration lane Stop and Go separate lane model**

\[
\text{Leq} = 56.91 + 0.09Sn(a) + 5.22 \log Vn(a) + 0.04Sf(a) + 0.02 \log Vf(a) - 0.006D(a)
\]

**Deceleration lane Stop and Go separate lane model**

\[
\text{Leq} = 71.12 + 0.07Sn(b) + 0.42 \log Vn(b) + 0.08Sf(b) + 0.44 \log Vf(b) - 0.061D(b)
\]

**Assumption for noise prediction (Stop and Go Model)**

For the prediction of noise characteristics for interrupting traffic flow, the Stop and Go model is used. This model is based on the following assumptions.

1. Two modes of vehicles motion
   a) Cruising with a steady uniform speed of traffic
   b) Stopping of traffic
2. The road is a straight, good surface condition, no variation
3. No noise barrier between the observer and the noise source
4. Traffic noise is measured in equivalent noise level (Leq)
5. Background noise should not exceed more than 10dB (A).
Input Parameters required for prediction of noise (Stop and Go Model)

Several parameters are required while predicting noise using the stop and go model. The parameters considered are vehicle volume classified into the different vehicle types appearing on the both sides of the road, average spot speed of vehicles in the traffic stream and roadway width.

CoRTN Model

The noise prediction model CoRTN has been developed by Delany, Harland, Hood, and Scholes for the United Kingdom (UK) Department of Environmental Engineering [Steele, 2001]. It is generally used as assistance for the design of the road, and also for the prediction of noise level around a noise source. CoRTN assumes a line source and constant speed of traffic, and in the UK it is the only tool for the classification of environmental impact due to the road traffic. Calculation of Road Traffic Noise (CoRTN) [Anon, 1975] has been replaced by a handier, Predicting Road Traffic Noise (PRTN) which also followed [Delany et. al., 1976] rationale for the procedure. The noise level (predicted or measured) is expressed in terms of L10 (hourly) dB (A) and L10 (18-hour) dB (A): 6:00 to 24:00 hrs. If traffic data has been available hourly, then CoRTN can be used to produce the hourly values of L(A)10 which can then be converted to Leq (A) hourly values. However, for the non-motorway roads when hourly traffic flows are below 200 vehicles per hour during the period 24:00 to 06:00 hours, the following should be used:

\[
\text{Leq(A), hourly} = 0.57 \times L10(A), 1h + 24.46 \text{ dB}
\]

For motorways Leq may be calculated using the formula below:

\[
L(\text{Day}) = 0.98 \times L_{10}^{18h} + 0.090 \text{ dB}
\]
\[
L(\text{Evening}) = 0.89 \times L_{10}^{18h} + 5.080 \text{ dB}
\]
\[
L(\text{Night}) = 0.87 \times L_{10}^{18h} + 4.240 \text{ dB}
\]
\[
L(\text{Den}) = 0.90 \times L_{10}^{18h} + 9.690 \text{ dB}
\]

For Non motorways the Leq may be calculated using below mention formula

\[
L(\text{Day}) = 0.95 \times L_{10}^{18h} + 1.44 \text{ dB}
\]
\[
L(\text{Evening}) = 0.97 \times L_{10}^{18h} - 2.87 \text{ dB}
\]
\[
L(\text{Night}) = 0.90 \times L_{10}^{18h} - 3.77 \text{ dB}
\]
\[
L(\text{Den}) = 0.92 \times L_{10}^{18h} + 4.20 \text{ dB}
\]

Assumption for noise prediction (CoRTN)

The following parameters have been assumed during noise level prediction.
1. The source height should be 0.5 m above the carriage level.
2. Source distance should be 3.5 m from the near side carriageway edge
3. Noise has been estimated at 1 meter in front of the most exposed part of an external window or door.
4. Meteorological conditions are not taken into consideration.
5. No background noise is taken into consideration.

Input Parameters required for noise prediction (CoRTN)

For validating the CoRTN model, traffic noise monitoring, characteristics of traffic including its composition, the volume of traffic, and vehicle speed on the road have been recorded. In the process of validation, the CoRTN model and traffic composition are normally divided into the light and heavy vehicles. For this study, the light vehicles included personal cars, local taxis, vans, and motorized two-wheelers, while trucks and buses are included as the heavy vehicles.

COMPARISON OF MODELS

A comparison of different aspects of principal traffic noise prediction models was shown in Table 3. The main aspects of FHWA-TNM, RLS-90, Stop and Go (Single Lane Model) and Stop and Go (Separate Lane Model) were discussed in the table. Only the Stop and Go model is predicting noise level for interrupting traffic flow. In turn, all remaining models are designed to predict the noise level for uninterrupted traffic flow. In India, the traffic flow is usually interrupted. Thus, the traffic noise model able to predict the noise level in such a complex scenario is still pending to design.

CONCLUSION

This paper reviews the literature on noise monitoring, noise mapping and noise modeling studies carried out in different countries by many researchers. Accordingly, the following conclusions were drawn.
1. 90% noise monitoring studies focused on the traffic noise, the remaining 10% focused on the residential, commercial and industrial areas.

2. The 2D noise maps were developed by 95% of researchers only 5% developed 2D as well as 3D noise maps.

3. Most of the noise prediction models use uniform traffic flow for the prediction of noise levels, only a few predict the noise levels for uniform as well as interrupted flow.

4. On the basis of the above-mentioned literature survey, it has also been concluded that the noise monitoring has not been carried out in different seasons and 24 X 7 and the 3D noise maps have not been developed for the assessment of noise level. However, the 2D noise maps are readily developed for noise assessment.

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Table 3. Comparison of noise prediction models

| Model | FHWA- TNM | RLS-90 | Stop and Go (Single Lane Model) | Stop and Go (Separate Lane Model) | CoRTN |
|-------|-----------|--------|---------------------------------|----------------------------------|-------|
| Country | United State of America | Germany | Thailand (Bangkok) | Thailand (Bangkok) | United Kingdom |
| Equation | \( L_{eq,\text{near}} = 10 \log \left( \frac{1}{10} \sum a_i \right) \) | \( L_{eq} = \frac{10 L_{eq,\text{near}}}{10 (10) \text{ hi}} \) | \( L_{eq} = L_m + K \) | \( L_{eq} = 56.91 + 0.095 S_n(a) + 5.22 \log V_n(a) + 0.045 S_f(a) + 0.02 \log V(a) - 0.006 D(a) \) | \( L_{eq}(A), \text{hourly} = 0.57 L_{eq}(A), 1h + 24.46 \text{ dB} \) |
| Traffic Condition | Constant, Grades | Acceleration, Uniform speed, intermittent | Uniform Speed | Acceleration, Uniform speed, | Uniform Speed |
| Data Requirement | Speed of Traffic, Traffic Flow, Environment Condition and Local characteristics | Traffic type, Traffic Flow, Road data, and Environment Condition and Local characteristics | Type of traffic, Detail of interrupted flow, speed of traffic and road geometry | Type of traffic, Detail of interrupted flow, speed of traffic(Acceleration and deceleration lane) and road geometry | Heavy to Light vehicle Ration, Low, speed, road and environs data. |
| Mapping | Grid | Point | Point | Point | Grid |
| Application | Prediction road traffic noise, | Prediction road traffic noise | Urban road traffic, uninterrupted traffic flows (Leq) | Urban road traffic, interrupted traffic flows (Leq) | Prediction of Single traffic noise |
| Limitations | Leq only | No local characteristics take cares. | Not take care traffic flow of both lanes | On the basis of \( L_{eq} \), is being determine that is obsolete |
| Noise Data requirement | Equivalent Noise Level and \( L_{eq} \) noise level | Equivalent Noise Level | Leq, Equivalent Noise Level | Equivalent Noise Level | \( L_{eq} \), noise level |
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