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Environmental traffic noise modelling of Dhanbad township area – A mathematical based approach

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ABSTRACT

Environmental noise is an undesirable by product of industrialization and urbanization where this unwanted sound makes a significant damage to human beings viz. can cause hypertension, hearing loss, sleep disturbances and also has a hazardous impact on our environment. The present study was undertaken to analyse the spatial characteristics of road traffic noise at varying intervals viz. morning (6–9 Am) & (9 Am–12 Pm), afternoon (2–5 Pm), evening (5–8 Pm) & night (8–11 Pm) hours at different road networks of Dhanbad town by using Sound Level Meter and also noise contour maps was produced by GIS to visualize the monitoring locations. The monitored results indicated that the highest and lowest average noise levels (L_{Aeq}) were 87.2 dB(A) and 71.3 dB(A) during evening and night respectively. This study also aims to examine the accuracy of the CRTN model in predicting traffic noise in Dhanbad township from the traffic variables. The results show that the performance of the CRTN model in morning (9–12 Pm) for predicting roadside traffic noise levels, with an coefficient of determination (R^2) of 0.819 and a mean difference of +0.8 dB(A) between the measured and predicted values. Predicted traffic noise of evening (5–8 Pm) & night hours (8–11 Pm) is less accurate as with coefficient of determination (R^2) of the 45° line is less than 0.7. It is due to type of passing vehicles, the mean traffic speed and its fluctuating, and the type of road surface are the most important reasons for low accuracy in predicting level. The suggested road traffic noise model can be used as a decision support tool for predicting equivalent sound pressure level index in the cities like Dhanbad.

1. Introduction

Noise is an unwanted sound with random intensity of signals that bears no information. Noise is one of the significant factors in which produces deterioration of comfort and quality of life of people in urban areas. Traffic noise is the sum of total noise produced from all moving vehicles on the roads at the observer point of view. It is one of the most identifiable environmental problem associated with rapid urbanization, industrialization, expansion of road network and infrastructure caused severe noise pollution problem [1,2]. Noise effects may include annoyance, deterioration of sleep quality and damage to auditory mechanisms, number of health related effects like physiological disorders, disturbance of daily activities and performances, hypertensions and schematic heart diseases [2]. Prolonged exposure of high noise level causes permanent deafness hearing damage [4]. Nowadays, noise pollution is considered as one of the main problems of urban communities [5] and traffic can be considered as the main source of noise pollution in large cities [6]. In emerging country like India where roads are in bad condition, and poorly maintained and has considerable number of vehicles of out-dated technology, the traffic noise assumes much more importance. Various factors affect traffic noise viz. different traffic parameters (including traffic volume, speed), roadways characteristics (includes pavement width, gradient and roughness of the surface) and others [7].

For visualization of noise pollution, noise mapping is done which is the new way to look at noise pollution. A noise map is looks like a weather map for noise, where it shows the noisy hotspots and the cooler areas. There are several software's which is used to produce noise contours of an area e.g. LIMA, FAA, ArcGIS, etc. [8]. Noise maps provide spatial presentation of acoustic situation which can be used for analysis and management process. The effect of noise also can be determined in GIS (Geographical Information System) by combining noise levels with the location of people living in the area and their sensitivity to noise [9,10].

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The high volume, high speed and percentage of heavy vehicle on freely flowing motorways in the developing countries create a high degree of environmental noise impact on inhabitants around the motorways [11]. To create a healthy and noise pollution free environment, a noise prediction model is needed so that the noise level along a busy highway can be forecast and investigated in advance during the planning and design process [12,13]. Several models have been developed from fundamental variables such as traffic flow and speed of vehicles using regression analysis of experimental data [14]. In recent years some developed models for prediction of road traffic noise were suggested [11,15,16]. Traffic noise prediction models are commonly needed to predict sound pressure levels, specified in terms of LAeq, L10, etc., set by government authorities [14].

In traffic noise modelling, the noise level at a receptor position due to traffic emission source is usually modelled as a function of the traffic conditions (i.e., traffic volume, traffic composition, and traffic speed), road gradient, road surface nature, absorbent ground cover percentage, street configuration, and distance between the traffic emission source and the receptor [17,18]. The traffic emission source can be considered as point or line source. Traffic noise models assuming point emission source include the United States Federal Highway Administration Traffic Noise Model (FHWA) [19,20] and the model by the Acoustical Society of Japan (ASJ) [21], while those assuming line emission source include the Calculation of Road Traffic Noise (CRTN) model in the United Kingdom [22] and the RLS-90 model in Germany [23]. The CRTN model is among the first systematic schemes developed to predict noise level due to road traffic. A simulation model making use of Monte Carlo techniques was devised to incorporate the uncertainty in traffic noise estimates and traffic flow, traffic speed and traffic composition (in terms of% of heavy vehicle) were identified as key factors influencing the generation of traffic noise [5,15]. Particularly in the United Kingdom and Hong Kong, CRTN model is the sole instrument for the assessment of road traffic environmental impacts by local authorities. Some researchers have studied the reliability of traffic noise prediction using the CRTN model [22]. The aim of my study are Assessment of traffic noise status at various locations of Dhanbad Township and development of traffic noise contour maps using ArcGIS software. Also to prepare a traffic noise prediction model of Dhanbad Township.

2. Study area

The present study is covering the Dhanbad township area located in Jharkhand state of the eastern part of the country, from 85°45′E longitude to 86°30′E longitude and from 23°32′N latitude to 24°5′N latitude. The total area of Dhanbad township is around 355.77 km^2. Dhanbad has an average elevation of 227 m (745 ft.). As per the projection, the total projected population for Municipal Corporation jurisdiction is 3 million in 2036 (Source: CDP, Dhanbad, 2007). Dhanbad features climate that is transitional between a humid subtropical climate and a tropical wet and dry climate. Summer starts from last week of March and ends in mid-June. Peak temperature in summer can reach 45–47 °C and also receives heavy rainfall. In winter, the minimum temperature remains around 10 °C with a maximum of 22 °C. Fig. 1 depicts the road map with monitoring locations of Dhanbad township area. The location includes different junction points, markets, bus stations and other entry point of Dhanbad township area. In Fig. 1 yellow coding indicates the source points of traffic noise in Dhanbad township area. Green coding indicates the receiver points of sound level meter. Red coding indicates the settlements around the monitoring stations.

3. Material and methods

3.1. Sound level meter

A Bruel & Kjaer 2238 Mediator Integrating Sound Level Meter (SLM) used to measure sound levels. This instrument measures the sound pressure level in dB (A) i.e. decibels in A-weighted scale. It has the measurement range of 0–80 dB (A) to 50–130 dB (A). The dB (A) Leq denotes the time weighted average of the sound pressure level in decibels on scale A which is relatable to human hearing (Bruel & Kjaer 2238 Basic SLM Software Manual).

3.2. GPS meter

A Geographical Positioning System (Model: eTrex H, Garmin) is used to measure latitude and longitude of a location.

3.3. ArcGIS

ArcGIS version 10.3 is a state-of-art GIS software package developed by ESRI. ArcView is a well proven desktop GIS system widely known for its stability and user friendliness. GIS provides a powerful set of tools for storing and retrieving, transforming and displaying spatial data from the real world for a particular set of purposes.

4. Methodology

The noise level were measured at different locations of the Dhanbad township during September to November 2016 using B & K 2238 Mediator SLM as per the guideline given in IS: 3028:1998. Average time of 60 min was followed for measuring noise levels at each location different times of the day. The sound level meter was handled at proper orientation to receive the maximum sound intensity at 1.2 ± 0.1 m height above the ground and a distance of 7.5 ± 0.2 m from the Centre of the road. The same procedure was maintained for all the survey points in the city. The noise assessment was conducted during morning (6–9 AM) and (9–12 PM), afternoon (2–5 PM), evening (5–8 PM) and night (8–11 PM) of the day.

Based on this observation, mean L_{AFMaxP}, L_{AFMaxL}, L_{AFMinL}, L_{Aeq}, L_{CPKMax} level were determined. Besides noise monitoring, traffic density count was taken simultaneously and accordingly mean frequency of vehicular movement (heavy vehicles, automobiles and two wheelers) was computed. The latitude and longitude of each points were also collected for accurate location of the monitoring stations shown in Fig. 1.

4.1. Noise mapping

Noise mapping was prepared using ArcGIS 10.3 software for better visual information of the noise environment of Dhanbad township area and it's diurnal variations. ArcGIS 10.3 software used to plot the noise levels contours using interpolation (IDW) technique. In this interpolation technique, IDW (Inverse Distance Weighted) is done considering to assess the acoustic behaviour of the geographical area. The noise level maps were prepared in ArcGIS for different times of the day to show the diurnal variation of the noise environment in the city. ArcGIS, appropriately gives better visual information of the regions with higher noise levels and traffic accumulations and also identifies the more vulnerable areas under the noise pollution threat [4,24].

Noise map is a layer of information which is superimposed on the geographical information, which gives the idea that which part of the city is polluted by the noise. The noise maps are produced in the 0.8–1.3 dB (A) bandwidths. Each band shows different colours