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MODELLING OF ROAD TRAFFIC NOISE

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ABSTRACT

Vehicular noise is one of the most prevalent forms of pollution. Traffic noise annoyance has become a major issue with the advent of fossil fuels and development in vehicle technology. Vehicular noise is dramatically increasing with the increased number of vehicle population, especially due to speeding vehicles. Amongst all the sources of noise pollution, vehicular noise has been identified as the most annoying and health impairing one. Therefore, it had become important to check the traffic noise and enhance the environmental condition along the transportation corridor. This study attempts the development of road traffic noise model for Indian condition. A statistical regression model for predicting road traffic noise is developed based on A-weighted equivalent noise levels.

Keywords- Vehicular Noise, Noise Model, Speed

1. INTRODUCTION

Road traffic noise is the biggest corridor problem and the most intrusive and annoying form of noise pollution. The growth in vehicle population aggravated the issue. Heavy trucks, buses, auto rickshaws, two wheelers and other automobiles contribute to the vehicular noise in heterogeneous traffic conditions. In developed countries, the only concern is the homogenous traffic which can be tackled with ease. To develop a transport system which is sustainable and environmentally friendly, it is necessary to model different traffic parameters. This helps to identify various traffic problems in advance, so that preventive and mitigation measures can be adopted for improving the transportation system to make it sustainable. It is identified that vehicular noise has a supremacy over all other adverse impacts of traffic, as it affects both the physiological and psychological well-being of peoples exposed to it. Prolonged exposure to traffic noise causes acute and chronic impacts on people. Other than damaging the hearing capacity of people, it may lead to mental illness, behavioral problems and can damage heart, lungs and kidney which can be fatal.

The most interesting fact is that vehicular noise is a boon as well as a bane. Since it affects the mental and physical well-being of the people, noise is a bane. At the same time, it can be used for studying traffic characteristics, vehicle detection and for military purposes. Traffic noise can be very well correlated to many other traffic parameters like speed, volume, vehicle type etc. Vehicular noises along with ground borne noise generated by moving vehicles have a great potential to be used for studying heterogeneous traffic characteristics.

Many researches are carried out to model traffic noise so that it can be predicted in advance and preventive and mitigation measures can be taken for reducing noise impact. Traffic Noise Prediction Models aid in the design of environmentally friendly roads. Noise models can be used to determine the noise levels and its impact on an existing highway or on a proposed highway. Modelling of traffic noise dated back to 1950's. Post World War II witnessed a boom in the automobile population and this led to a serious concern in the field of traffic noise prediction. Traffic prediction models in 1950s and 60s dealt with the modelling of single vehicle [1] based on constant speeds. It is assumed that the first noise model, considering volume and distance as parameters, was given in 1952 Handbook of Acoustic Noise Control. Later developments included different parameters like percentage of heavy vehicles, speed, composition, etc., for developing noise models which can be simple or complex [2-6]. Some noise models were developed using simple regression while others used fuzzy integrals or neural network [7-8] approach with a huge input data requirements. Simulation techniques were used in other cases for noise modelling [9]. The noise models were developed for measurement and analysis of ambient noise levels on existing roadways, noise emission from vehicles and for before-after studies of infrastructure development. Dynamic models require a detailed set of database including the spatial characteristics and condition of each vehicle type. Considering the data requirement and limitation in time, multiple linear regression method was chosen for modelling traffic noise.

2.DATA COLLECTION AND ANALYSIS

2.1 Project Stretch:

The project stretch chosen for this research is a part of NH 183 which is a two lane road. This highway (NH 183) starts from the junction with NH-83 near Dindigul connecting Teni, Uttamapalayam in the State of Tamilnadu, Kumily, Peermed, Kanjirappali, Kottayam, Adoor and terminating at its junction with NH-744 near Kottarakara in the State of Kerala. The map showing the project stretch is shown in Fig 1. The selected section of NH 183 for study is from Pampady to Kottayam. The site selected represents a typical residential land use pattern. For the study, high traffic, low traffic, curves, straights and intersection were required. By considering the objectives of analysing and modelling vehicular noise, various locations enlisted below are chosen.

1. 8th Mile
2. 7th Mile
3. Annadivayal
4. Nedumkuzhy
5. Manarcad (Approximately 1km to Kottayam side from bus stop)
6. Manarcad Junction

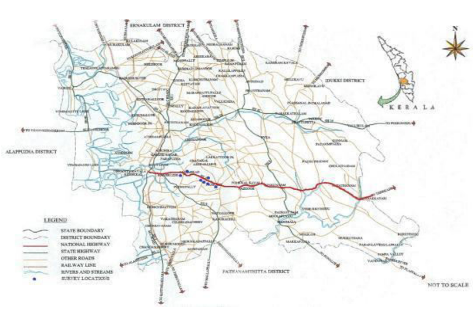

FIGURE 1. MAP SHOWING STUDY AREA(SOURCE: KERALA PWD)

2.2 Data Collection

In this study, six sites were identified for data collection. At each site noise samples, classified traffic volume count and speed of individual vehicles were collected. Data was collected from different locations during different times of the day. The sites were selected such that to obtain uncontaminated noise samples for the analysis and modelling of vehicular noise. Normally, noise data is measured using Sound Level Meter (SLM).

In this research, continuous noise recording was used instead of SLM. H4N noise recorder was used for recording the noise data continuously. The noise recorder was kept at a distance of 3m from the edge of the pavement and at a height of about 1.5m from the ground level. The height of the recorder was selected as 1.5m to account for the average position of the human ear. The continuous noise recording was carried out for one hour in each location. Simultaneously, video of the traffic stream was also recorded using Sony Handycam. The spot speed of the vehicles was found using a Falcon HR Radar speed gun. The noise and video recording was performed with perfect synchronization so that the preliminary analysis can be done with ease.

3.DEVELOPMENT OF NOISE MODEL

3.1 Software Used

The software used for modelling vehicular noise is SPSS (version 20). SPSS (originally, Statistical Package for the Social Sciences, later modified to read Statistical Product and Service Solutions) is a comprehensive and flexible statistical analysis and data management solution. In this study, the data sheets from excel is imported to SPSS and is used for conducting multiple linear regression analysis.

3.2 Noise Model

Regression method is a statistical technique which can be used to find the relationship between a dependent variable and some independent variables. The equation derived using regression method is purely empirical in nature. In modelling the vehicular noise, A-weighted Equivalent Continuous Sound Level (L_{Aeq}) is the dependent variable and the independent variables are the percentage of each category of vehicles, traffic volume and speed. The step by step procedure is given below.

Before doing any complicated statistical analysis, it is important to know how each parameter are distributed. Therefore a scatter plot was drawn between L_{Aeq} and Volume, L_{Aeq} and Speed, L_{Aeq} and traffic composition. The scatter plot shows the relationship between L_{Aeq} and other independent variables.

Next step is to develop the noise model. The collected data was divided into two parts in the ratio 1:5. 80% of the data was used for formulating the model and the remaining 20% was used for model validation. The model formulation was carried out using the software SPSS 20. The target variable is L_{Aeq} and the input variables were % of car, % of two wheelers, % of three wheelers, % of heavy vehicles, volume in PCU/min and speed in km/hr. By multiple linear regression analysis L_{Aeq} was calculated. Both forced method of variable entry and stepwise method of variable selection was chosen for regression analysis.

The goodness of fit of the developed model was tested using Chi-Square Test.

Before using the data for modelling the following tests were carried out. The data was found to be continuous and it satisfies the criteria. To check if a linear relationship exists between the variables, a scatter plot was drawn between the dependent variable (L_{Aeq}) and each of the independent variable. It was clear that there is linear relationship between the dependent and independent variables. Case-wise diagnostics was performed to check significant outliers. The independence of observations was checked using Durbin-Watson test. The value of Durbin-Watson test statistic, d, varies between 0 and 4. Closer to 0 means positive auto-correlation while closer to 4 means a negative auto-correlation. There exist a soft cushion around d = 2 where auto-correlation does exist but its intensity is not severe enough to call for some remedial measures. For a sample size of 235, the Durbin-Watson statistic was found to be around 1.4. Therefore, it can be taken that there is no much significant correlation and hence, it can be considered that observations are independent is satisfied. In regression analysis, homoscedasticity means a situation in which the variance of the dependent variable is the same for all the data. Homoscedasticity was checked using ANOVA test and found satisfied. To check if residuals of variables are normally distributed, a histogram with a superimposed normal curve was drawn. It was found that the residuals were normally distributed.

The noise modelling was done considering various factors affecting the highway noise. The factors considered were speed, volume and traffic composition. The model generated using stepwise method of variable entry for maximum number of available sample is taken as the Road Traffic Noise Model. The explanatory variables in the model are speed, percentage of three wheelers, percentage of heavy vehicles and traffic volume. The model generated by enter method is rejected since it includes the entire requested variable while the stepwise method gives a refined model.

The Road Traffic Noise Model is given by the regression equation shown below.

$$\bar{L}_{Aeq} = 22.255 + 1.418 * S + 0.060 * T + 0.046 * V + 0.032 * H \quad (1)$$

Where, S is the average speed of the vehicles in kmph
T is the percentage of three wheelers

H is the percentage of heavy vehicles V is the traffic volume (PCU/min)

For calculating the noise at a curve, the roadway is divided into small straight sections. The noise level from these sections are calculated and superimposed to get the noise level of the curvature. The angles subtended at the receiver by the straight subsection contribute to the noise level. A schematic diagram is shown in Fig 2. The correction to be applied for the noise level is given by

$$\Delta L = 10 \log \frac{\alpha}{180}$$

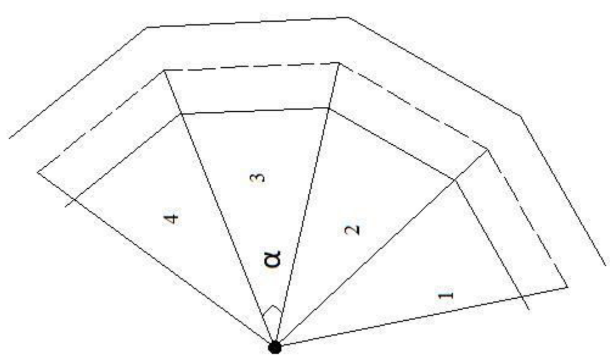

FIGURE 2. SCHEMATIC REPRESENTATION OF SEGMENTATION AT CURVES

For determining the noise level at curves, the above correction factor must be added with the noise level of straight road.

Unlike the curves, the characteristics of an intersection are a complex one. The intersection selected was a T-junction on a plain terrain. The parameters used to formulate the intersection noise model are average time headway, the near and far side traffic factors like volume, speed and percentage of heavy vehicles. The output of the regression equation is given below.

The regression equation can be written as

$$L_{Aeq(Intersection)} = 69.117 - 0.77NH + 0.165NV - 0.204NS + 0.071FH + 0.092FV - 0.058FS + 0.0592AH \quad (2)$$

With R^2 value of 0.804.

Where, NH is the near side percentage of heavy vehicles
NV is the near side traffic volume in PCU/min
NS is the near side speed of the traffic stream in kmph
FH is the far side percentage of heavy vehicles
FV is the far side traffic volume in PCU/min
FS is the far side speed of the traffic stream in kmph
AH is the average headway in seconds.

At the intersection, the vehicle speed is slow and therefore the contribution of near side and far side speed has a negative sign in the model.

3. 3 Chi-Square Test for Goodness of Fit

Chi-square is a statistical test commonly used to compare observed data with data predicted by a mathematical model. This test gives the goodness of fit of the developed model. For 57 degrees of freedom and at 5% level of significance the calculated value of chi- square is 22.517 and the tabled value is 75.6089. Since, 22.517< 75.6089, there is no significant difference between the observed data and predicted data. Therefore, it is concluded that the model is a having a good fit.

4. CONCLUSION

In this study, the negative effects of vehicular noise were considered. Considering the negative effect of noise, a road traffic noise model was developed. In Indian Scenario, the major share of noise is made by heavy vehicles and three wheelers. The noise model developed in this study, considered the effect of the shares of different category of vehicles and it was found that the contribution of three wheelers and heavy vehicles are more than that of four wheelers and two wheelers. The model developed was in conformation with the characteristic of the area.

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