Transportation Research Part C 40 (2014) 111–122

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Vehicular traffic noise modeling using artificial neural network approach

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ARTICLE INFO

Article history:
Received 27 August 2012
Received in revised form 10 January 2014
Accepted 10 January 2014

Keywords:
Artificial Neural Network (ANN)
Modeling
Vehicular traffic noise
Back propagation (BP)
Prediction capability

ABSTRACT

In India, the transportation sector is growing rapidly and the number of vehicles on Indian roads is increasing at a very fast rate leading to overcrowded roads and noise pollution. The traffic scenario is typically different from other countries due to predominance of a variety of two-wheelers which has doubled in the last decade and forms a major chunk of heterogeneous volume of vehicles. Also tendency of not following the traffic norms and poor maintenance adds to the noise generation.

In the present study, Multilayer feed forward back propagation (BP) neural network has been trained by Levenberg–Marquardt (L–M) algorithm to develop an Artificial Neural Network (ANN) model for predicting highway traffic noise. The developed ANN model is used to predict 10 Percentile exceeded sound level (L_{10}) and Equivalent continuous sound level (L_{eq}) in dB (A). The model input parameters are total vehicle volume/hour, percentage of heavy vehicles and average vehicle speed. The predicted highway noise descriptors, L_{eq} and L_{10} from ANN approach and regression analysis have also been compared with the field measurement. The results show that the percentage difference is much less using ANN approach as compared to regression analysis. Further goodness-of-fit of the models against field data has been checked by statistical *t*-test at 5% significance level and proved the Artificial Neural Network (ANN) approach as a powerful technique for traffic noise modeling.

1. Introduction

Traffic noise is a major contributor to overall noise pollution. Traffic noise from highways creates problems for surrounding areas, especially when there are high traffic volumes and high speeds. Vehicular traffic noise problem is contributed by various kinds of vehicles like heavy and medium trucks/buses, automobiles and two wheelers.

Different traffic noise prediction models have been developed by many researchers in different countries based on the field measurement of different highway noise descriptors and traffic noise parameters.

Steele (2001) has critically reviewed the most commonly used traffic noise prediction models like CORTN, FHWA and ASJ. Johnson and Saunders (1968) predicted the noise level from freely flowing road traffic on sites ranging from motorway to urban roads and showed how basic variables such as traffic density, speed and distance from road side have an effect on the observed pattern of noise. A prediction models was developed which incorporate the effects of flow rate, speed of the vehicle, composition of the traffic and adjustment for gradient and road surface for predicting L_{10} (1 h) and L_{10} (18 h) (Delany et al., 1976). This model was used by Hammad and Abdelazeez (1987) in Amman (Jordan) and found a 4 dB difference in L_{10}

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0968-090X/$ - see front matter
http://dx.doi.org/10.1016/j.trc.2014.01.006

(1 h) and a correlation coefficient of 0.91 in L_{10} (18 h) between experimental and predicted values. Pamanikabud and Vivitjinda (2002) formulated a model of highway traffic noise based on vehicles types in Thailand under free flow traffic conditions and estimated reference mean energy emission level for each type of vehicle based on direct measurement of L_{eq} (10 s). Gorai et al. (2007) have developed six different statistical relationships (models) to predict L_{eq} based on the total traffic volume per hour (Q) and percentage of heavy vehicles over total number of vehicles (P) as input parameters. The deviation between observed value and predicted value from each model at different locations was within the order of ±1.5 dB (A) except at one location. Cho and Mun (2008) considered several types of road surface and developed a highway traffic noise prediction model for environmental assessment in South Korea.

The linear regression analysis for traffic noise modeling, used in early models, was replaced by advanced modeling techniques (Cammarata et al., 1995; Givargis and Karimi, 2009; Rahmani et al., 2011). Cammarata et al. (1995) proposed the ANN model to predict the equivalent sound pressure level caused by urban traffic where the data was collected with typical features of commercial, residential and industrial area. Initially the ANN model proposed has three input parameters i.e. equivalent number of vehicles, average height of the buildings and width of the street and later on, to achieve the better prediction capability, the number of vehicles has been decomposed into the numbers of cars, motor cycles and trucks. Now the new ANN model has five inputs and one output parameter with 20 numbers of neurons in hidden layer. The result obtained using BPN based approach has been compared with classical models proposed by Burgess (1977), Josse (1972), CSTB (Bertoni et al., 1987) and a favorable agreement was observed between the predicted and measured result using ANN. Givargis and Karimi (2009) have presented the mathematical logarithmic, statistical linear regression and neural models to predict maximum A – weighted noise level ($L_{A,max}$) for Teran-karaj express train. The models have been developed on the basis of data recorded at a distance of 25 m, 45 m, and 65 m from the centerline of the track and at a height of 1.5 m while the prediction capabilities have been tested on the data associated with 35 m and 55 m. Different non-parametric tests have showed satisfactory result for all the models and none of the models outweighs the others. As far as the neural network is concern, the authors have built and tested a neural network via statistical neural networks (SNN) module of STATISTICA software (version 7.0). This network was a two layered network with no hidden layer i.e. a perceptron with two input neurons and one output neuron. The neural network input parameters were train speed and distance while output was maximum A – weighted noise level ($L_{A,max}$). The training algorithm adapted was pseudo-inverse, linear least squares optimization. The mean training and testing error were observed as 0.5 dB (A) and 0.3 dB (A) respectively, indicate a sign of good fitness between the predicted and measured values.

Even many western countries have also developed different prediction models based on L_{10}, L_{eq} and other descriptors. But the highway noise descriptors, L_{eq} (in North America, Continental Europe) and L_{10} (in United Kingdom), are increasingly being used for quantitative assessment of nuisance associated with traffic noise.

Further, these models are unreliable for predicting highway noise in India because of different traffic conditions and traffic characteristics. The traffic load on Indian road is also increasing day by day, with the introduction of varieties of new vehicle models. This paper is thus aimed to develop a more relevant and accurate free-flow traffic noise prediction model for highways in India i.e. a model which predict the output accurately by accounting the input traffic parameters, more relevant to Indian traffic conditions and characteristics. It is realized that the vehicle volume/hr, percentage of heavy vehicles and average vehicle speed are the three more relevant traffic parameters in India which affect the noise level to a large extent. Artificial Neural Network (ANN) approach has been used in the present study to develop a precise traffic noise prediction model.

2. Highway noise descriptors and traffic parameters

The different highway noise descriptors are Percentile Exceeded Sound Level (L_x), Equivalent Continuous (A-weighted) Sound Level (L_{eq}), Day Night Average Sound level (L_{dn}), Traffic Noise Index (TNI) and Noise Pollution Level (NPL). Out of the above, the two noise descriptors which have been mostly used in many countries to describe highway traffic noise are L_{10} and L_{eq} levels. The different traffic parameters normally considered are vehicle volume, vehicle mix and the average speed.

2.1. Percentile exceeded sound level, L_{10}

L_{10} is defined as the level which is exceeded for 10% of time and provides a good measure of intermittent or intrusive noise, i.e. traffic noise, aircraft flyovers, etc.

2.2. Equivalent continuous (A-weighted) sound level, L_{eq}

Equivalent continuous (A-weighted) sound level is defined as the steady sound level that transmits to the receiver the same amount of acoustic energy as the actual time varying sound over the prescribed time period. The Equivalent sound level in the time period from t_1 to t_2 is given by

$$L_{eq} = 10\,\text{Log}\left[\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2}\frac{p^2(t)}{p_{ref}^2}\text{d}t\right] \tag{1}$$