ANN Modelling of Traffic Noise in Quilon-Kochi Highway

Lekshmi.S[1], Nithya.Kurup[2], Dr.Priya.K.L[3]
[1]*Student, U.K.F College of Engineering and Technology, Paripally, Kerala, INDIA*
[2]*Asssistant Professor, U.K. F College of Engineering and Technology, Paripally, Kerala, INDIA*
[3]*Assistant Professor, T.KM College of Engineering, Kollam, Kerala, INDIA*

***Abstract*- Noise is one of the most prevalent sources of environmental pollution and is considered as the second largest pollution after air pollution. As there are many factors which contributes to noise pollution, the major contributor among all being the vehicular traffic noise. It is considered as one of the most invasive type of pollution and often the most intrusive of all. The trend of noise pollution modelling varies from the smart result of classic regressive models to the performance of many assessment models based on mathematical expression, genetic algorithms and neural networks. In this study, feed forward back propagation neural network has been developed to predict vehicular traffic noise in urban area. The study area is an ancient trade town having connections with major districts and states. NH-66 road stretch with 6 sampling locations each 500m intervals were selected for the present study. The proposed ANN model has been used to predict the equivalent continuous sound level (Leq) in dB (A). The model input parameters are the characteristics of the vehicular traffic flows (traffic volume, percentage of heavy vehicles and traffic speed). A comparison between the field measurement and the predicted Leq from neural network approach and the regression analysis was done. The results show how the neural network approach provides better performance than the classical solution based on statistical analysis.**

***Index Terms*- Back-Propogation, Model, Noise Pollution, Statistical analysis, Vehicular Traffic.**

I. INTRODUCTION

Noise can be defined as the level of sound which exceeds the acceptable level and creates annoyance. Frequent exposure to high level of noise causes severe stress on the auditory and nervous system. Extended exposure to excessive sound has been proved physical and psychological damage. Because of its annoyance and disturbance implications, noise adds to mental stress and hence affects the general well-being of those exposed to it. Noise is a major source of friction among individuals [1]. The major sources of noise are Industrial noise, Traffic noise & Community noise Out of above three parameters, the source that affects the most is traffic noise. In traffic noise, almost 70% of noise is contributing by vehicle noise. Vehicle noise is created by engine and exhaust system of vehicles, aerodynamic friction, interaction between the vehicle and road system, and by the interaction among vehicles [2]. Different traffic noise models for the analysis and the prediction of the noise levels in different urban areas have been developed by many researches based on the field measurement of different road noise descriptors and traffic noise parameters [3]. The major concern was to make a study and to develop a road traffic noise model for NH-66 road stretch.

The highway traffic is getting denser with respect to time, and with increasing traffic density noise pollution is also on the rise. Noise pollution has become a major problem in the present times; it has a long lingering negative effect on human health. Noise pollution is the root cause of many health complexities viz. hearing problem, tinnitus, high blood pressure, mental depression, heart palpitation etc. Noise including hearing impairment is the most prevalent irreversible occupational hazard and it is estimated that 135 million people worldwide have developed hearing difficulties due to heavy road traffic noise [4].

According to Road knight et.al. [5] in different countries in the past several decades many people have suffered from noise related pollution. A healthy and noise free environment is the need of the hour. Hence in order to create a healthy noise free environment we need to understand the non-linear behavior of noise, the inherent complexities, and also be able to assess and predict it.

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, Brown et. al. [6].
Propagation method by considering various road surfaces types was developed by Cho et. al. [7]. A statistical model of road traffic noise in an urban setting which is based on the fact that percentage of heavy vehicles plays an important role over road traffic noise emission was developed by Calixto et. al. [8] ANN was successfully employed in various environmental, analytical and engineering processes by Arora et. al. [9]. Review of the Vehicular pollution modelling using ANN technique was done by Sharma et.al. [10]. Environmental modelling for traffic noise in urban area was done by Cirianni et.al. [11].
Many models were developed to predict traffic noise emissions either for highways or urban roads in developed countries such as RLS-90 [12] in Germany and CoRTN [13] in UK. Recently, many countries such as India and Iran have started trials to develop traffic noise models that are suitable for their nature.
•Traffic noise prediction models are required as aids in the design of highways and other roads and sometimes in the assessment of existing or envisaged changes in traffic noise conditions. They are commonly needed to predict sound pressure levels, specified in terms of (Leq)L10, etc., set by government authorities.
•Environmental laws require the Environmental Impact Statement(EIS) to take into account the effect of the proposed noise on all existing and potential elements of the environment, not only statutory criteria. This calls for a variety of descriptors and criteria. Special descriptors are sometimes required for the assessment of complaints about road traffic noise.
The linear regression models are very simple; however, they do not present very accurate results. In order to improve the accuracy of the prediction outputs, researchers applied artificial neural networks to model noise with higher accuracy.
Genaro et al. [14] developed an artificial neural network to predict noise levels in Granada City and compared the mean error of the results of Leq with results of linear regression models. The mean error from the ANN was significantly less than other linear regression models. It showed how ANNs was a better tool for predicting noise.
Cirianni and Leonardi [15] in the city of Villa S. Giovanni in Italy compared the results of classical regression models that were calibrated using genetic algorithm with multilayer perceptron (MLP) neural network results. The ANNs gave better results than linear regression even after being calibrated by genetic algorithm.
Kumar et al. [16] applied a multilayer feed forward back propagation neural network trained by Levenberg-Marquardt algorithm to predict L10 and Leq in India. Then they compared the results with that of linear regression analysis. The difference between the results from ANN and regression was significantly high which assures the superiority of ANN to ordinary regression approaches.
The human brain is made up of billions of neurons that are responsible for reasoning and it transmits signals across the human body through synapses. This metamorphosis of biological neuron is used to integrate important principles of the working of real neurons into a simple artificial neuron model, which forms the basis of Artificial Neural Network (ANN). ANN is not an exact replica of human brain; it works on complete synchronous mode. ANN will give output only when input is provided. Human brain on the other hand is not completely synchronous. It will respond to input but there is no predefined time for that. Artificial Neural Network is a modelling approach that has changed the way the present machines and computer works [4].
Modelling is a powerful tool for the assessment and prediction of behavior of any system in its environment. Bousscibini et. al. [17] said that modelling is a powerful tool for assessing the environmental impact of noise but the prediction models currently available are limited in their suitability to construct noise patterns. ANN Modelling however is different in approach as it is highly successful even in such non-linear systems and environment. Chen H. [18] classified the road traffic and road side pollution concentrations for assessment of personal exposure.

II. METHODOLOGY

A. Study Area

The study area selected was Kollam city along NH-66 towards Kochi. The latitude and longitude of the area lies between (8.8870º N,76.590691ºE) in Kollam city, Kerala, India. Traffic noise measurements was done for six locations along national highway (NH-66) namely, Joyallukas shopping mall, Iron-bridge Road, Electrical section KSEB, Kollam town UP school, Almanama express road, M.K. Solutions (Fig.1).

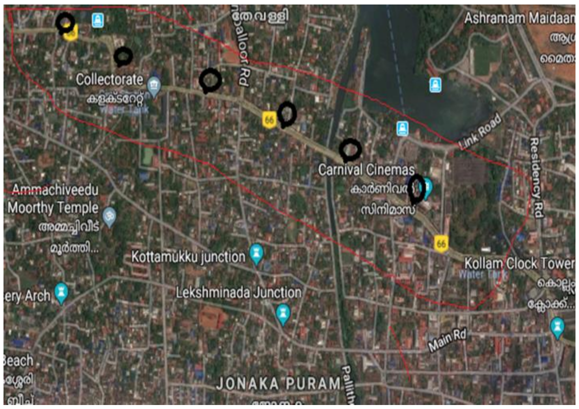

Fig.1.Map with sampling locations

B. Noise Measurement

Sound Level Meter (TYPE 4012) was used for measuring noise levels in A weighted mode, having the capacity of measuring noise from 30 dB to 130 dB and 0.1 dB resolution. Noise measurement with sound level meter was done at 1.2m height at a distance of 1m from road with A and slow weight in dB(A) scale as recommended by ISO-1996/1:2003 standard. The Leq (dB) values were directly obtained from the instrument.

Table-1: Regression analysis for the noise model

Model type	variable	Stand. coefficients	T-Ratio >±1.96	Sig. <0.5	R^2	R^2_{adj}	Std.Error of the estimate
Leq Model	Constant		88.059				
Leq=50.844+0.662*S +0.001T.V+0.013P	S	0.710	36.427	0.000	0.842	0.708	1.04453
	T. V	0.189	9.483	0.000			
	P	0.0049	3.064	0.002			

C. Data Acquisition

The traffic noise, vehicle volume, % heavy vehicle and traffic average speed are measured at six locations. For each sampling locations, noise measurements were carried out continuously for a period of six days for six hours of monitoring per day. The measurements were taken during the working days from morning 8:00am till evening 9:00pm. The time taken for each measurement was 30 minutes. Meanwhile, a video of the passing vehicles was recorded. Later, vehicles were counted and categorized into heavy vehicles, lightmotor vehicles, light commercial vehicles for the analysis. Heavy vehicles include buses, trucks and microbuses. In order to calculate the equivalent flow in PCU units, all the counted vehicles were converted to PCU units as per [19].

III. RESULT AND DISCUSSIONS

A.Regression Model

Regression Model for the city was done using SPSS Version 25. In case of linear regression, the total flow, average traffic speed and percentages of heavy vehicles were entered and modelled using stepwise method in order to avoid co-linearity among parameters. Based on the input parameters, the linear regression model for Leq with MSE = 10.295*10-3 was given as:

Leq = 50.844 + 0.6662*S + 0.001*TV + 0.013*P (1)

Where, S is the average traffic speed in km/hr, P is the percentage of heavy vehicles and Q is the total number of equivalent traffic flow in PCU per hour. The Leq model has adjusted coefficient of determination of R^2_{adj}=0.708 which means the model offer reasonable accuracy to predict noise levels. From Table 1, the regression analysis shows the model is of significance less than 5%.

Fig. 2 shows the presentation of predicted data by linear regression model versus measured data for Leq

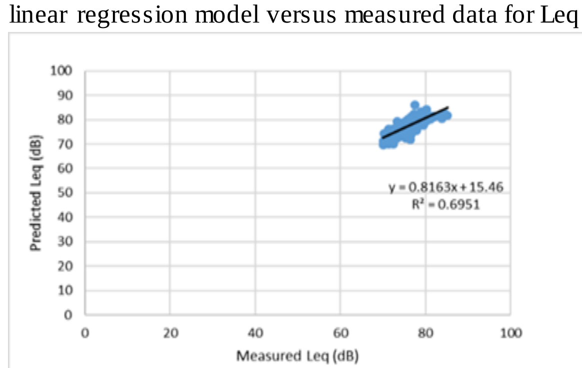

Fig 2. Plot between measured and predicted for Leq.

B.ANN Model

ANN model was developed using back propagation algorithm to predict the Leq with three input parameters as traffic volume in PCU, speed of vehicle in km/hr and percent of heavy vehicles. 80% data were used for training, 15% for testing and 5% for

Table-2: Performance results for one-hidden layer

Model	ANN model architecture	Training R^2	Validation R^2	Testing R^2	All data R^2	MAE
NN1	3*5*1	0.834	0.887	0.898	0.9021	0.00623
NN2	3*10*1	0.889	0.898	0.923	0.9110	0.00876
NN3	3*15*1	0.936	0.9368	0.9636	0.94209	0.000796
NN4	3*20*1	0.9121	0.9113	0.9232	0.922	0.000871
NN5	3*25*1	0.899	0.9002	0.9122	0.9120	0.00776

ANN model

validation. The architecture for best model was selected based on minimum Mean Square Error (MSE). Here the best model obtained was the neural network with 15 hidden neurons. The best architecture has got an MSE of 0.000796 and a regression value of 0.94 with number of epochs as 1000. Fig.3 shows the regression plot of the best model selected. Table 1 shows the performance results for one-hidden-layer ANN models for National Highway 66.

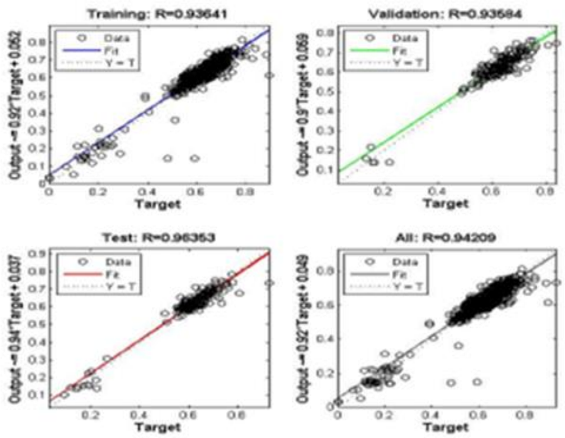

Fig .3 Regression plot for Leq

The model thus developed was validated by predicting the noise level at sampling location named Iron-bridge road for morning and off-peak hours. Thus 60 data sets were used for validation. On validation, in the developed model, actual Leq values has got coefficient of determination with predicted values as 0.88. The value of coefficient of determination nearer to 1 indicates that the model developed is good and reliable.

Performance evaluation of ANN Model for Leq

a) Index of Agreement

Index of Agreement (IA) is a statistical parameter suggested by Willmott (1981) for performance evaluation of the model. It is the degree to which observed values are accurately predicted. It varies between 0 and 1. One gives perfect agreement and zero gives complete disagreement.

Here, $\sum_{i=1}^{N}(pi - oi) \leq c \sum_{i=1}^{N}(oi - o)$ with c=2

So, Index of agreement IA = 1 - $\frac{\sum_{i=1}^{N}(pi-oi)}{c\sum_{i=1}^{N}(oi-o)}$

N - Number of the data points

Oi- Observation data points

Pi - Predicted data points

O -Mean of the observed data points

Index of agreement was obtained as 0.82 for the data set of Iron bridge which was used for validation of the model of Leq by applying the equation in actual and predicted values.

b) Mean Square Error

In training of the model, the architecture with least Mean Square Error was selected as the best model. Here the data set of Iron-bridge road during morning and off peak were used for validation and had obtained a mean square error value of 2.26 x10-3.

c) Coefficient of determination

Analysis of coefficient of determination for actual and predicted values of Leq in 60 data sets during off peak and morning peak hours helps to check the reliability of model. R^2 value obtained for actual and predicted values of Leq was 0.88. Fig.4.2 shows the plot between actual and predicted values of Leq during validation at Iron-bridge during morning and off-peak hours.

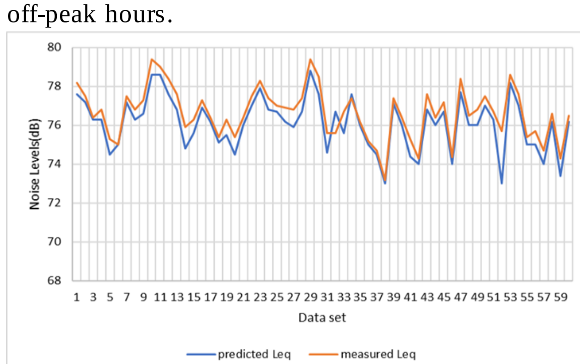

Fig .4. Plot between measured and predicted values for the data set

C.Comparison between the models

The two-model generated for the National Highway-66 was compared and founded that the R2 value for ANN model was found to be more fit compared to the

Point of comparison	Linear regression L_{eq}	ANN Model L_{eq}
Average of absolute error	0.765	0.447
Mean square error	$10.295 * 10^{-3}$	$2.26 * 10^{-3}$
Pearson correlation	0.84	0.94

Table 3. comparison table for the models regression model developed using SPSS Version25.

From Table2, it is obvious that the average absolute error and mean square error in case of ANN neural network are less than linear regression for Leq. Moreover, the results of both neural network and linear regression were tested using Pearson correlation test. The results from the linear regression model and ANN neural network showed strong correlation with measured data (more than 0.5) which assures their reliability to predict the noise levels. Meanwhile, ANN neural network correlation results are always higher than linear regression correlation results according to the test. This proves that ANN neural network gives more accurate predictions. Fig. 3 and Fig.4 shows plots for Leq of measured data with data predicted by both linear regression model and ANN neural network.

IV. CONCLUSION

In this paper, the traffic noise emissions were predicted by using both linear regression and ANN neural network approaches. This process of modelling noise showed that linear regression and artificial neural networks could be used efficiently with the least number of parameters and be based mainly on traffic flow, speed and its composition. Linear regression presents easy and simple models with reasonable accuracy, while ANN neural networks could be used to improve the accuracy, although, it seemed more complex.

Moreover, the analysis showed that some parameters that might be statistically non-significant in linear regression analysis could be efficiently used to improve the accuracy when used in neural networks. Heavy vehicles percentage is the most important variable which affected the emitted noise levels.

Moreover, other parameters such as road width, buildings heights, honks and others could be studied in order to maximize the accuracy of the modeled results. However, these models present a basic formulation for noise emissions with the least number of parameters which could be easily and accurately obtained with low probability of measurements errors.

It is recommended that these models be used in "Noise Road Pricing" in order to keep the traffic, at most, up to specific limits that ensure a safe threshold of noise levels especially in case of roads where hospitals and schools are located. In addition, based on the traffic count and traffic composition, mobile software could be developed to provide users with real- time maps with noise levels. These maps might help people who suffer from cardiovascular diseases, children or bike riders to take alternative routes away from noise-polluted roads. According to the models, traffic speed and the percentage of heavy vehicles should be monitored and regulated inside the city in order to minimize the noise pollution emitted [20].

ACKNOWLEDGMENT

The authors would like to thank the management and the government authorities who helped and supported during the data collection.

REFERENCES

[1] Jobair Bin Alam. Md., Rauf. A.F.M.A and Ahemed. M.F (2001), "Traffic Induced Noise Pollution in Dhaka", Journal of Civil Engineering, The Institute of Engineers, Vol.1, pp.55-63

[2] T. Subramani, M. Kavitha and K.P. Sivaraj (2012), "Modeling of Traffic Noise Pollution", International Journal of Engineering Research and Applications (IJERA), Vol.2, pp.3175-3182

[3] Francis Cirianni and Giovanni Leonardi (2015), "Artificial Neural Network for Traffic Noise Modelling", ARPN Journal of Engineering and Applied Sciences, Vol.10, pp.1819-6608

[4] Jyoti Kumar Arora and Ponnala Vimal Mosahari (2012), "Artificial Neural Network Modelling of Traffic Noise in Agra-Firozabad Highway", International Journal of Computer Applications, Vol.56, pp.0975-8887

[5] Roadknight C.M., Balls G.R., Mills G.E. & Palmer Brown D (1997), "Modeling Complex Environmental Data" IEEE Transactions of Neural Networks, Vol. 8, pp.211-221

[6] Brown A.L. and Mcdonald G.T. (2003) "Environmental Impact to Environmental

Management 2", Australian Journal of Environmental Management 2. pp 65-77
[7] Cho D.S. and Mun S. (2008). "Development of a highway traffic noise prediction model that considers various road surface types". Applied Acoustics 69 (11) pp1120-1128.
[8] Calixto A, Dinitz FB and Zannin PHT (2003). "The statistical modeling of road traffic noise in some urban setting cities "20 (1) PP 23-29.
[9] Arora J.K., Singh S.P. (2011). "ANN Modelling of Road Traffic Noise for Environment Impact Assessment".
[10] Sharma N., Chaudary K.K., Chalapati Rao C.V(2005), "Vehicular Pollution Modelling using Artificial Neural Network Technique: A Review". Journal of Scientific & Industrial research Vol. 64, pp 637-647.
[11] Cirianni F., Leonardi G (2012) "Environmental Modelling for Traffic Noise in Urban Area". American journal of Environmental Science, vol 8147, pp 345-351
[12] Der Bundesminister Fur Verkehr (1990), DBV. RLS/90: Richtlinien fur den Larmschutz an Strapen,
[13] Department of Transport, CoRTN Calculation of Road Traffic Noise, London, Her Majesty's Stationery Office (HMSO), 1988
[14] N. Genaro, A. Torija, A. Ramos-Ridao, I. Requena, D. P. Ruiz, and M. Zamorano (2010), "A neural network-based model for urban noise prediction," The journal of the Acoustical Society of America, vol. 128, pp. 1738-1746.
[15] F. Cirianni and G. Leonardi (2012) "Environmental Modeling for Traffic Noise in Urban Area," American Journal of Environmental Science, vol. 8, pp. 345-351
[16] P. Kumar, S. Nigam, and N. Kumar (2014), "Vehicular traffic noise modeling using artificial neural network approach," Transportation Research Part C, Emerging Technologies, vol. 40, pp. 111-122
[17] Bousscibine A.H(1997), "Artificial neural networks for predicting Noise from construction sites", Building Acoustics, Vol.4(3), pp.211-221
[18] Chan H., Namdev A and Bell M (2008), "Classification of Road Traffic and Road Side Pollution Concentrating for Assessment of Personal Exposure". Journal of Science Direct 23, Vol.66, pp.-282-287
[19] Guidelines for Traffic Prediction on Rural Highways, IRC 108-1996
[20] K. Habib, D. Said and H. Hozayen (2016), "Modeling of urban traffic noise in Giza city based on traffic characteristics", Journal of intelligent Transportation and Urban Planning, vol. 4, pp. 12-21