

The Comparative Study on Traffic Noise Prediction Model between Classical Algorithm and Neural Network Methods

Chen Mao

Tiangong University, No. 399, Extension Cable, Pinshui West Road, Xiqing District, Tianjin, 300387, China

Maochen@tiangong.edu.cn

Abstract. Traffic is the main noise source in urban environment, which has a significant impact on people's physical and mental health and labor productivity. To solve the problem of highway noise pollution, we should not only strengthen the prevention and control measures in the later stage but also scientifically and accurately predict and evaluate its noise impact in the early stage. The selection of the noise prediction model and the determination of its parameters is the necessary premise for the accurate prediction of highway noise. This paper introduces several traditional noise prediction algorithms based on statistical methods. Then the application of the artificial neural network method in traffic noise prediction is analyzed. The results show that artificial neural network is an effective noise prediction tool with high prediction accuracy. Compared with other statistical methods, the artificial neural network method has obvious advantages in traffic noise prediction.

Keywords: Traffic noise prediction, CoRTN, EHWA, Neural network.

1. Introduction

After many years of exploration and research, many mature road traffic noise prediction models have been formed in the world. At present, many countries have their own traffic noise prediction models. Although these models have different expressions, the basic idea of their basic models is similar, that is, to add various amendments [1-3] on the basis of a baseline sound level. The formula for calculating the model is as follows.

$$L_{Aeq} = L_0 + \Delta_Q + \Delta_v + \Delta_D + \Delta_F + \Delta_G + \Delta_\alpha + \Delta_\delta \quad (1)$$

The factor expressions in the formula are given in Table 1

Table1. Traffic noise calculation model correction factor

Correction term	Expression	Comment
Vehicle noise level	$L_0 = A_1 + A_2 \times \lg v$	A_i is constant
Traffic volume correction	$\Delta_Q = A_3 \times \lg Q$	Q is the hourly traffic volume
Vehicle speed correction	$\Delta_v = A_4 \times \lg v$	v is the average speed
Distance loss correction	$\Delta_D = A_5 \times \lg(D_0 / D)$	D_0 is the reference monitoring distance
Finite length section correction	$\Delta_F = F(\theta)$	θ is the included angle between the measuring point and the two ends of the finite length section
Longitudinal slope correction	$\Delta_G = A_6 \times G$	G is the longitudinal gradient of pavement
Ground absorption correction	$\Delta_\alpha = A_7 \times \lg(D_0 / D)^\alpha$	D is the distance from the measuring point to the sound source
Soundproof tape correction	$\Delta_\delta = F(\delta)$	δ is the sound path difference

Machine learning uses historical data to train and modify a model with an algorithm to predict future data. In practice, we usually select an algorithm based on the characteristics of the data [4]. The uncertainty and diversity of the influencing factors of road traffic noise directly lead to the

following situation. It is almost impossible to express it with established formulas when processing large-scale data using classical prediction methods. It is pointed out that combining the calculation model of acoustic theory with the information and rules mined from the measured noise data can significantly improve the accuracy of noise prediction. Hameta et al. [5] propose that the noise prediction model should be corrected according to the changes of various influencing factors such as noise source, noise propagation path, etc. With the help of machine learning, the machine learning model can be trained according to the measured road traffic noise data, so as to simulate the line sound source propagation path and predict the noise value of each point in a road segment.

2. Classical traffic noise prediction model

2.1 CoRTN model

The CoRTN noise prediction model was published in 1975 in the United Kingdom and has been tested over many years. In 1988, an improved version of the CoRTN88 model for this prediction model was published. The evaluation index of this model is peak traffic noise L10. This model is often used to predict train noise in traffic with long and smooth peak traffic or at a distance from the observer, assuming that there is a constant speed of traffic flow and line sound sources. L10 is used as the noise peak evaluation index in the model, and traffic volume and weight-to-weight ratio, traffic speed and environmental data are taken into account. This model considers the attenuation of sound waves while propagation, such as distance attenuation, sound barrier attenuation and reflection. At the same time, traffic volume, average speed, proportion of heavy vehicles and slope are corrected. The expressions are:

$$L_{10} = 10\lg q + 331\lg\left(v + 40 + \frac{500}{v}\right) + 10\lg\left(1 + \frac{5P}{v}\right) + 0.3G - 27.6 \quad (2)$$

Where: q - traffic flow;
 v - average speed;
 P - proportion of heavy vehicles;
 G - slope.

The expression is derived from the L10 fitting curve measured under various conditions. Although it makes the calculation easier, it reduces the accuracy of the model. The model has become the only standard prediction model accepted by national courts in the United Kingdom, New Zealand, Hong Kong, China and Australia in handling traffic noise litigation cases.

2.2 FHWA model

In December 1978, the Federal Highway Administration (FHWA) proposed and published the FHWA highway noise prediction model in the FHWA-RD-77-108 study report. The evaluation index of this model is equivalent continuous A sound level, which divides all vehicles into three categories according to certain standards, and calculates the hour equivalent A sound level of each type of vehicle at the prediction point, then superimposes each type of vehicle in the mixed traffic flow according to the corresponding formula, and finally obtains the total traffic noise equivalent continuous A sound level at the sound point. The hour equivalent continuous A sound level expression for a certain type of car is:

$$L_{eq}(h)_i = (\bar{L}_0)_{E_i} + 10\lg\left(\frac{D_0}{D}\right)^{1+\alpha} + 10\lg\left[\frac{\varphi_\alpha(\varphi_1+\varphi_2)}{\pi}\right] + \Delta S - 30 \quad (3)$$

Where: $L_{eq}(h)_i$ - Hourly equivalent A sound level for Class I car, dB(A)

$(\bar{L}_0)_{E_i}$ - Reference Energy Average Radiated Sound Level of Class I Car, dB (A)

D_0 - Reference locations for measuring radiated sound levels of vehicles in this model, 15m from road shoulders

D - Vertical Distance from Prediction Point to Driveway Centerline, m

S_i - Average Speed of Class I Cars, km/h

α - Ground vegetation coverage factor, depending on site ground conditions, 0 or 0.5

φ_α - Field Segment Correction Function

ΔS - The amount of noise attenuation caused by obstructions, including attenuation of buildings and forest belts, dB(A)

In mixed traffic flow, the equivalent sound levels of the total mixed traffic flow can be obtained by overlaying the equivalent sound levels of different traffic flows. Its expression is

$$L_{eq}(h) = 10\lg[10^{0.1L_{eq}(h)1} + 10^{0.1L_{eq}(h)2} + 10^{0.1L_{eq}(h)3}] \quad (4)$$

The applicability of the FHWA model is limited in principle and can only be used in noise prediction of single-lane highways. However, for multilane highways, the traffic noise of each lane is computed separately, and then the overlay of multiple lanes is processed. The model assumes and simplifies the traffic flow. Since the traffic on the highway is bi-directional, the traffic flow here is in two directions. This model simplifies two-way multilane traffic to one-way traffic when used.

After many years of research, the FHWA model has been continuously improved in the United States, and TNM2.5 was published in 2005, making it the latest noise prediction model. This model has a wider range of applications, and can be applied to traffic routes of different grades and pavement under continuous or intermittent traffic conditions, with more comprehensive factors considered and more in line with the latest actual road conditions.

3. Traffic noise prediction model based on neural network

The neural network structure used in Vladimir's [6] study consists of an output neuron corresponding to the L_{eq} value, two hidden layers containing eight and three neurons, and five inputs representing the number of light motor vehicles, medium trucks, heavy trucks, buses and average traffic flow (Figure 1).

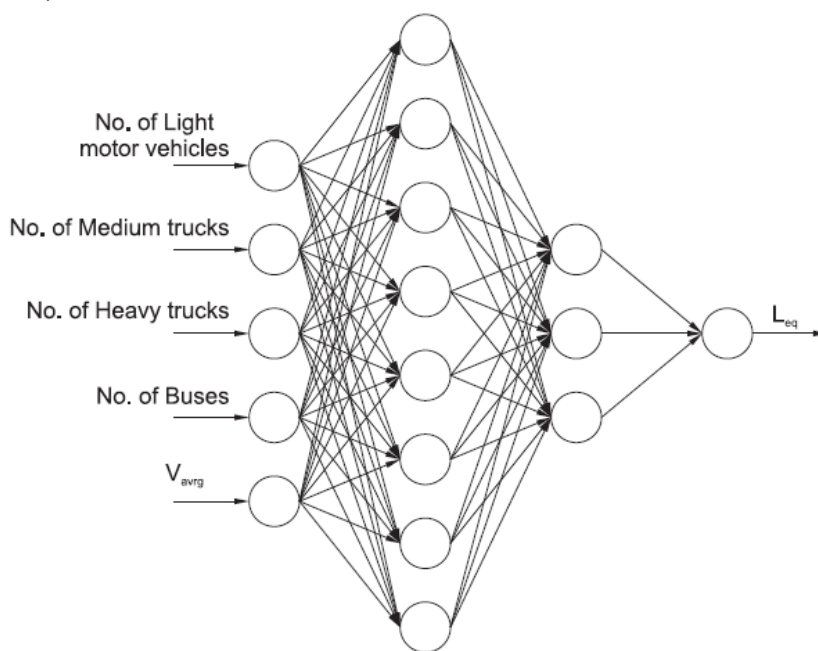


Fig. 1 Structure of proposed ANN for L_{eq} prediction.

To estimate the model's capabilities, the dataset is divided into two subsets: the training set and the test set. In this work, the training and test dataset are composed of 80 and 40 samples, respectively. Dividing the dataset into the scientific training and test subsets has a significant impact on the performance of ANN models.

To evaluate the advantages of the neural network model in traffic noise prediction, the simulation results are compared with those obtained by classical methods. The comparison results are shown in Figure 2 below. Compared with traditional noise prediction models, the statistical parameters shown in Figure 2 show that the neural network model has better prediction ability. This advantage of the

neural network is due to its greater ability to fit the non-linear relationship between traffic flow structure and equivalent noise level.

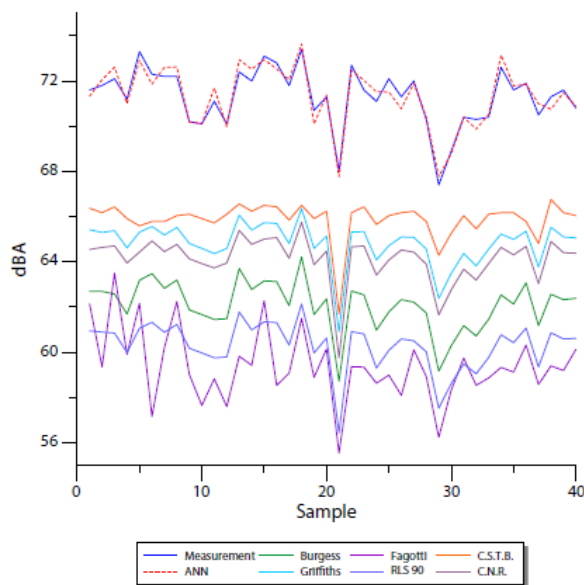


Fig. 2 Side by side comparison of ANN model and various statistical models.

4. Conclusion

There is a complex relationship between noise pollution near urban trunk roads and many influencing factors. These relationships are highly nonlinear, which makes it difficult to accurately model with classical statistical methods. The neural network road traffic noise prediction model can predict the equivalent continuous sound level of any traffic flow and any surrounding road for the road monitored by traffic noise or similar roads. Because it has high concealment, fuzziness and fault tolerance, and has the ability of self-organization and self-learning, it can provide a new means to solve the more difficult prediction task. Compared with the existing physical and mathematical prediction methods, it has more advantages when the relationship between evaluation quantity and known information cannot be expressed by general methods. It is a prediction method with good application prospects.

References

- [1] Golmohammadi R, Abbaspour M, Nassiri P, et al. (2009) A compact model for predicting road traffic noise. *Journal of Environmental Health Science & Engineering*, 6(3): 181-186.
- [2] Skarlatos D, Zakinthinos T. (2007) A simplified model for urban traffic noise prediction. *Noise control engineering journal*, 55(2): 266-274.
- [3] Mak C M, Leung W K, Jiang G S. (2010) Measurement and prediction of road traffic noise at different building floor levels in Hong Kong. *Building Services Engineering Research and Technology*, 31(2): 131-139.
- [4] Van Den Berg F. (2008) Criteria for wind farm noise: Lmax and Lden. *Journal of the Acoustical Society of America*, 123(5): 3536.
- [5] Hamet J F, Besnard F, Doisy S, et al. (2010) New vehicle noise emission for French traffic noise prediction. *Applied acoustics*, 71(9): 861-869.
- [6] Nedic V, Despotovic D, Cvetanovic S, et al. (2014) Comparison of classical statistical methods and artificial neural network in traffic noise prediction. *Environmental Impact Assessment Review*, 49: 24-30.