Journal of Advances in Science and Technology

Vol. IV, No. VII, November-2012, ISSN 2230-9659

APPLICATION OF DIFFERENT TRAFFIC FLOW MODELS IN REDUCTION OF NOISE IN URBAN AREAS

www.ignited.in

Journal of Advances in Science and Technology
Vol. IV, No. VII, November-2012, ISSN 2230-9659

Application of Different Traffic Flow Models in Reduction of Noise in Urban Areas

Pankaj Prasad[1] Dr. P. K. Gupta[2] Prof. (Dr.) R. K. Khitoliya[3]

[1]Research Scholar, Civil Engg. Deptt. PEC, University of Technology Chandigarh - 160012

[2]Asstt.Professor, Civil Engg. Deptt. PEC, University of Technology Chandigarh - 160012

[3]Former Head, Civil Engg. Deptt. PEC, University of Technology Chandigarh – 160012

Abstract – In a rapidly urbanizing country like India, transportation issues pose a major challenge for transportation and environmental planners. The number of vehicles is increasing at a rate of approximately 7% per annum. Consequently the quality of environment is fast deteriorating in metropolitan cities. At least 55% of the total noise is due to vehicular traffic in urban areas. In India, even the study is still at its nascent stage, the studies done abroad have been fairly comprehensive in the area of traffic noise modeling. The concept of noise prediction and abatement has been introduced long ago in developed countries.

Interrupted traffic flow in urban areas generates noise which is characteristically different from free flow traffic conditions normally occurring on highways and expressways. This characteristic difference in traffic noise requires different modeling techniques from the ones used for free flow traffic conditions. There is a need of empirical models for stop and go traffic noise for the urban areas. These models should be developed and evaluated on field so that they can be reliably used.

Many such models have been developed elsewhere and the most popular models developed so far are the FHWA (TNM) model and the CORTN model. Besides, linear models have also been developed for prediction of traffic noise.

Key Words: Passenger Car Noise Equivalence (Pcne), Tnm, Fhwa, Cortn

---------------------------♦-----------------------------

1. INTRODUCTION

Sound is created when an object moves: the rustling of leaves as the wind blows, the air passing through vocal chords, the almost invisible movement of the speakers on a stereo. The movements cause vibrations of the molecules in air in waves like ripples on water. When the vibrations reach ears, it is known as sound. Sound is quantified by a meter which measures units called decibels, dB (A). For highway traffic noise, an adjustment, or weighting, of the high- and low-pitched sounds is made to approximate the way that an average person hears sounds. The adjusted sounds are called “A-weighted levels” dB (A). The A – weighted decibel scale begins at zero. This represents the faintest sound that can be heard by humans with very good hearing. The loudness of sounds varies from person to person, so there is precise definition of loudness. However, based on many tests of large number of people, a sound level of 70 is twice as loud to the listener as a level of 60. [6]

1.1 URBAN TRAFFIC NOISE SCENARIO IN INDIA

With rapid urbanization and the corresponding increase in the number of vehicles on Indian roads, the pollution is increasing at an alarming rate in most of our Indian metropolitan cities. The main areas of concern are related to air and noise pollution [5]. More than 55% of the total noise in our environment is due to vehicular traffic. The noise levels are showing an alarming rise and infact the levels exceed the prescribed levels in most of the areas. The ambient noise standards being followed in India for different types of areas are given in table 1, the noise level standards for residential areas in India is given in table 2 and the permissible noise levels for residential areas in different countries are given in table 3. [8]

Table 1. Ambient Noise Standards (India)

Area	Leq dB (A)	
	Day Time	Night Time
1. Industrial Area	75	70
2. Commercial Area	65	55
3. Residential Area	55	45
4. Silence Zone	50	40

Table 2. Noise Level Standards for Residential Area in India

Location	Acceptable Noise Level dB(A)
1. Rural	25-35
2. Suburban	30-40
3. Rsidential	35-45
4. Urban (Residential & Business)	40-45
5. City	45-50

Table 3. Permissible Noise Level in Residential Area in Different Countries

Country	Leq Day, dB(A)	Leq Night, dB(A)
Sweden	55	45
Germany	55	40
Austria	48-51	36-43
Switzerland	60	50

1.2 CAUSES OF TRAFFIC NOISE

The level of highway traffic noise depends mainly on the following three things:

- The volume of the traffic
- The speed of the traffic
- The number of heavy vehicles in the flow of the traffic.

Generally, the loudness of traffic noise is increased by heavier traffic volumes, higher speeds, and greater numbers of trucks. Vehicle noise is a combination of the noises produced by the engine, exhaust, and tyres. The loudness of traffic noise can also be increased by defective mufflers or other faulty equipment on vehicles. Any condition (such as a steep incline) that causes heavy labouring of motor vehicle engines will also increase traffic noise levels. In addition, there are other more complicated factors that affect the loudness of traffic noise. For example, as a person moves away from a highway, traffic noise levels are reduced by distance, terrain, vegetation, and natural and manmade obstacles. Traffic noise is not usually a serious problem for people who live more than 150 m from heavily travelled freeways or more than 30 to 60 m from lightly travelled roads. [4]

1.3 DETERMINING NOISE IMPACT

Highway traffic noise is never constant. The noise level is always changing with the number, type and speed of the vehicles which produce the noise. A more practice method is to convert the noise data to a single representative number. Statistical descriptors are almost always used as a single number to describe varying traffic noise levels. The two most common statistical descriptors used for traffic noise are L_{10} and L_{eq}. L_{10} is the sound level that is exceeded 10 percent of the time the calculation of L_{eq} is more complex. L_{eq} is the constant, average sound level, over a period of time, contains the same amount of sound energy as the varying levels of the traffic noise. L_{eq} for typical traffic conditions is usually about 3 dB(A) less than the L_{10} for the same conditions.[1,6]

2. METHODS TO REDUCE HIGHWAY NOISE

The road traffic noise in most of the urban areas is increasing at an alarming rate and this is a cause of concern for the residents living along the highways. Excess noise levels have proven to be responsible for various problems for the humans – physical, sociological and mental. The noise levels must be controlled in order to reduce the societal impacts of noise. Reduction of noise levels may be done in the following ways. [6, 12]

- Motor Vehicle Control
- Land Use Control
- Highway Planning and Design

2.1 NOISE REDUCTION ON NEW ROADS

All the measures described above can be employed on both existing roads and on new roads. [6, 12]. There are however some additional measures which can usually be used only on new roads. First a new road can be located away from noise sensitive areas such as schools or hospitals and placed near no sensitive areas such as businesses or industrial plants. New roads can also be located in undeveloped areas. Second a new road can be constructed below ground level. Much of the noise from vehicles traveling on this type of road is deflected in the air by embankments on the both side of the road. Thus these embankments function in much the same way as noise barriers. Third a new road can be designed and constructed as level as possible. The elimination of steep inclines helps to reduce traffic noise because motor vehicle engines, especially multi geared truck engines do not have to work as hard.

2.2 INTERRUPTED TRAFFIC FLOW NOISE

Interrupted flow traffic noise from the urban area has different characteristics from traffic noise generated by free flow traffic on highway. These differences come from the different flow characteristics of traffic where stop and go traffic flow is normal traffic flow condition. It also comes from the different surrounding condition such as

- Carriageway width
- Building on road side
- Road intersection

The model for prediction of interrupted flow traffic noise is therefore different in nature from that of free flow highway traffic noise. The noise generated by the traffic under interrupted flow condition may also be regards as an aggregation of individual vehicle noise output. Vehicle operating condition here is predominantly those of acceleration and breaking rather than the constant speed situation of free flow. Interrupted flow condition occurs at intersection and other road facility where acceleration and breaking maneuvers are common [2].

2.3 CHARACTERISTICS OF URBAN TRAFFIC NOISE

1. Urban roadways occur in region of high population density.
2. Urban roadways are lined with building.
3. Intersection with other similar urban roadway occurs regularly and these intersections are frequently controlled by traffic lights or stop lines.

Urban traffic flow generally is limited to low speed, usually below 72 km/hr. Speeds frequently occur as a result of changing traffic condition and traffic control devices at intersection. [9]

2.4 PASSENGER CAR NOISE EQUIVALENTS

Each vehicle in the stream having mixed traffic system has different noise generation characteristics than other vehicle and the fact makes the road traffic noise problem little complex. In order to understand the behavior of road traffic noise, or to understand the various relationships, it is necessary to convert all vehicles into some equivalence based on their noise generation characteristics. The passenger car noise equivalence (PCNE) of particular vehicles represents that, how many times the vehicle is noisier than car. [8]

The intensity I of sound corresponding to L, dB (A) is

$I = 10^{L/10} \times I_o$

Where I_o = Reference intensity

Now corresponding to L_C dB(A) of sound level produce by car intensity is given by

$I_C = 10^{Lc/10} \times I_o$

corresponding to L_T dB(A) of sound level produce by a particular vehicle intensity is given by

$I_T = 10^{Lt/10} \times I_o$

Also $I_T = n \times I_C$

Considering total intensity due to n car is equal to intensity due to one particular vehicle

$N = 10^{(L_T - L_C)/10}$

Where n is PCNE of any particular type of vehicle whose noise level is L_T dB (A)

2.5 CALCULATION OF WEIGHTED FLOW (Q_W)

To find out the weighted flow Q_w for each sample of one hour, the number of vehicle passing the section in the same time is multiplied by the corresponding PCNEs and summed up.

$Q_w = N_c + 7.08N_B + 2N_T + 1.26\, N_{2\text{-}W} + 7.8\, N_{3-W} + 0.08\, N_{R\text{-}CY}$

Where Q_w = EPCNE per hour

N = number, veh/hr

C, B, 2-w, R-Cy denotes car, bus, truck, 2w, 3w and rickshaw – cycle respectively.

2.6 THE MATHEMATICAL MODEL

A common form of mathematical model for traffic noise prediction is as follows:

$Y = a_0+a_1X_1+ a_2X_2+ a_3X_3+\ldots\ldots\ldots\ldots\ldots+ a_nX_n$

Where Y is traffic noise parameter i.e. L_{eq}, a_0 is constant.

X_1, X2, $X_3, \ldots\ldots\ldots\ldots\ldots$ X_n, are the variables affecting the road traffic noise like volume, flow, speed and other factors like surface texture, gradient, road condition etc.

$a_1, a_2 \ldots\ldots\ldots$ a_n are the coefficients to be determined adopting multiple linear regression method.

2.7 CONCEPT OF PREDICTIVE MODEL

The purpose of impact analysis is to evaluate the likely result of implementing purpose transportation function. We can predict future highway noise level for the area. This is accomplished through use of algorithm prediction model. The prediction on traffic noise can prove to be a very vital tool for transportation planners and environmental engineers because the predicted noise values can be used both during the design and planning stage as well as the regulatory and enforcement stages. [1, 4]

(I) FEDERAL HIGHWAY ADMINISTRATION (FHWA) MODEL

It is the only method currently approved for use on federal funded highway project in USA (4). FHWA model is an energy based model which adds a series of adjustment to the single vehicle reference energy mean emission level to produce hourly equivalent level L_{eq} each vehicle travelling at a uniform speed.FHWA model is intended to serve primary in case of expressway free flow condition usually at receivers distance greater than 15 m from roadway side. This model simulate the traffic flow stream as a series of discrete moving source each travelling at a uniform rate of speed. FHWA model is valid for a very low or very high volume as long as traffic is free flowing. The FHWA noise standards are shown in table 4.

Table 4. FHWA Noise Standards

Land use category	Design noise level	Description of land use category
A	60 dB(A) (exterior limit)	For park and open space where quietness is of primary importance
B	70 B(A) (exterior limit)	Residential, hotel, school, libraries, hospitals
C	75 dB(A)	Developed area
D	-	For requirement on undeveloped land
E	55 dB(A)	Residential area, hotel

(II) TRAFFIC NOISE MODEL (TNM)

In 1998, the FHWA released new generation of highway traffic noise prediction model called the traffic noise model or TNM [3]. TNM is entirely new state of art, computer program that uses advances in personal hardware and software to improve upon the accuracy and modeling of traffic generation highway noise. TNM has the ability to model both constant and interrupted traffic flow. It can also account for the effect of roadway grade on vehicle acceleration and declaration of heavy truck on highway upgrade. TNM takes into account such factor as atmospheric absorption, sound divergence, acoustical characteristic, the type and topography of intervening ground, rows of buildings and area of vegetation when modelling.

The Salient Features of FHWA (TNM) are given below:

- Modelling of five standards vehicle type, included automobiles, medium trucks, heavy trucks, buses and motorcycle as well as user defined vehicles.
- Modelling of both constant flow and interrupted flow traffic using a 1994/1995 field measured database.
- Modeling of effects of different pavement types, as well as the effect or graded roadway.
- Sound level computation based on one third octave band database and algorithms.
- Multiple diffraction analysis.
- Parallel barrier analysis.
- Graphically interactive noise barrier design and optimization.

(III) LINEAR MODELS

A number of linear models have been developed for the prediction of interrupted flow traffic noise. The details of these models are given below:

EDINBURGH MODEL

This model is build to predict interrupted flow traffic noise in the UK used in the early stage of investigation and model development of this study [10]. The mathematical formula of the model:

L_{10} = 55.2+9.18logQ (1+0.09PH)-4.2logV_y+2.3T

Where L_{10} = Traffic noise level in dB (A) that exceed 10% of the measuring time period (1hour)

Q = Traffic volume (veh/hr)

PH = proportion of vehicles exceeding 1.5 tons

T = index of dispersion (ratio of variance to the mean of number of the vehicle arriving in each 10 second interval)

V = mean speed of traffic (km/hr)

y = carriageway width (meters)

SHEFFIELD MODEL

The mathematical formula of the model [10]

L_{10} = 51.51+10.5logQ(1+0.04PH)-5.71log(d_k+0.5y)+2.38logG

Where, L_{10} = Traffic noise level in dB(A) that exceed 10% of the measuring time period (1hour)

Q = Traffic volume (veh/hr)

PH = proportion of vehicles exceeding 1.5 tons

T = index of dispersion (ratio of variance to the mean of number of the vehicle arriving in each 10 second interval)

V = mean speed of traffic (km/hr)

y = carriageway width (meters)

d_k = distance from noise meter to edge of kerb (meters)

G = 1, or percentage gradient whichever is larger

2.8 URBAN NOISE STUDIES CONDUCTED AROUND THE WORLD

2.8.1 MODELLING EFFORTS AROUND THE WORLD

In 1929 first noise survey was carried out in New York. In 1947 a noise survey was carried out in Chicago, covering vehicular traffic, industrial area and residential area. In 1961 the London noise survey may be regarded as the most comprehensive study on urban noise. [11]

In 1968 British prediction methods for the road traffic noise as developed by building research establishment have been based on the observation of freely flowing traffic noise made by Johnson and Saunders together with the research establishment and national physical laboratory. [7]

In 1969, Galloway et al. develop a computer simulation model to account for these factors in developing a model of noise level produce by freely flowing traffic. The model assumes a random distribution of vehicles distributed along a highway of any number of lanes.

The basic difference between Galloway's computer models from that of Johnson & Saunders is that the previous takes the acoustic power generated by traffic of a function of a three degree of velocity where as the later one assumed to be a function of first degree.[4]

In 1988 Pearson & Sabir conducted noise level survey for community noise & peak noise emission. The survey was conducted in six sites in the eastern province of Saudi Arabia, at two sites in New Delhi, India.

Samuels from Australia road research board attempted to analyses the problem of many cases when traffic flow was interrupted for example in the vicinity of intersection. [13]

2.8.2 EFFORTS MADE IN INDIA

In India, the earliest noise surveys were conducted by Prabhu et al [11], during the sixties. The result of these surveys found application in compiling the section on acoustics, sound insulation and noise control in national building code.

Kumar Vimal carried out a study in Delhi to study the urban noise scenario and has developed various useful correlations between the various traffic parameters like traffic volume, traffic speed and distance from pavement edge and the equivalent sound level L_{eq}. From the correlations developed, it is possible to predict the impact of traffic developments in terms of noise pollution in future and timely measure for control can be implemented.(8). The developed prediction equation for the noise level $L_{eq}(Ih)$ is given below.

$$L_{eq}(Ih) = 47.45+8.58xLog(Q_W)-0.14d \qquad dB(A)$$

Where Q_W = traffic volume in EPCU/hr.

3.0 COCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

(i) The major contributor to the total noise is vehicular traffic. Approximately 65% of the total noise pollution is due to vehicles.

(ii) The concept of noise prediction modeling is yet to be fully explored in India and only a few isolated attempts have been made.

(iii) The modelling of traffic noise for free flow is totally different compared to the modelling of traffic noise for interrupted flow and the urban traffic conditions require that modelling be done separately for interrupted flow.

(iv) Many popular models for interrupted flows have been developed abroad, the most popular being the FHWA (TNM) model, COORTN model and linear models.

(v) Predictive models can prove to be a very useful tool for engineers both for planning and enforcement.

(vi) The models developed abroad cannot be directly used for prediction in Indian conditions and need to be calibrated for the existing conditions.

RECOMMENDATIONS

(i) There is a need to develop a simplified prediction model for interrupted traffic flow conditions incorporating the various correction factors which can be directly applied in all parts of India.

(ii) The model must be tested for its reliability by comparing it with field data.

REFERENCES

1. Agent, K.R. (1981), "Evaluation of Federal Highway Administration procedure for highway noise prediction" Transportation Research Record No.789, Transportation Research Board, USA.

2. Cohn, L.F, Harish, R.A. (1987), "Environmental planning in urban transportation", ASCE Journal of Transportation Engineering, Vol. 113. No.3.

3. Dutta, N., Mohan, S., Batra, V. S., Kumasr, P. (2001)," Development of a prediction model for road traffic noise in a city of Punjab" Proc.Seminar of the Indian National Academy of Engineers, Hyderabad.

4. Federal Highway Administration home page http://www.Tac.Net/Users?Aifo4/Tnm

5. Hothersall D.C., Salter, RJ. (1997),"Transportation and the Environment"Granda publishing Limited, London.

6. Harris C.M. (1979),"Handbook of Noise Control" Pub: McGraw Hill, USA.

7. Harmelink M.D. (1970), "Noise and Vibration Control for Transportation System" Road Research Report, Vol. 108, Toronto.

8. Kumar Vimal (1997), "Analysis of urban traffic noise", M.E. Dissertation, Department of Civil Engineering, UOR, Roorkee.

9. Murugesan, R. (1997)," Noise Nusiance By Road Traffic Assessment and Control", Indian Highways, Indian roads Congress, New Delhi, Vol.25 No.7.

10. Pamanikabud, P (1991), "Traffic Noise Model for Assessment of interrupted flow traffic noise in central business district" Proc. Asian Federation of Engineering Organization, Bangkok, Thailand.

11. Prabhu, B.T.S and Krishna Veni (1994), "A review of traffic noise studies related to the environment planning" Indian Highways, New Delhi.

12. "Roads and the Urban Environment", Edition II, Proc. Symposium on Roads and the Urban Environment, Madrid, Spain, 1974.

13. Samuels, S.E. (1988), "Some consideration of traffic noise generation under interrupted flow condition", Proc. 14th Australian Road research Board Conference, Australia, Vol. 14, Part-3.