Journal of Advances in Science and Technology

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

COMPARISON OF FEW MODELS OF TRAFFIC NOISE REDUCTION IN URBAN AREAS

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Comparison of Few Models of Traffic Noise Reduction in Urban Areas

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Abstract – Development of transportation has greatly affected the development of the modern world and development of transport systems has polluted the environment too. Studies have shown that motor vehicles operating on highways constitute one of the major sources of noise.

Traffic noise prediction models have been developed in many industrialized countries. These models cannot, however, be applied in their original form in other countries, especially in the developing countries as the characteristics of the traffic and reference mean emission levels of the vehicles are different. Therefore, there is a need of transferability of traffic noise prediction models.

This paper includes the review of noise prediction models and geographical transferability of noise prediction models.

Key Words: Tnm 1.0, Stamina 2.0, Index of Dispersion, Variance, Attenuation, Fortran

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1. INTRODUCTION

Development of transport systems has produced both the economic and social benefits to the mankind; however it has polluted the environment too. Road transportation is first in causing irreversible damage to the environment. Effects of noise can be cumulative and its influences may cover several aspects of every day life. Road traffic noise has been reported to be cause of annoyance in many countries of the world. (1)

2. URBAN TRAFFIC NOISE SCENARIO

Noise has always been a major environmental problem for man and community. In the metropolitan cities the traffic noise is a major constituent of the environmental pollution. In some of the big cities, the noise levels have far exceeded the level of human tolerance. In 1988 about 60% of the population in Netherlands reported annoyance with road and traffic noise. About 9% of the population has had sleep disturbance due to road traffic. A quarter of the police force in Bangalore city is suffering from hearing disabilities due to increasing noise pollution levels. Noise levels of 76 dB (A) were measured in residential areas of Bangalore, and levels of 88 dB (A) measured in Calcutta (BBC 1999). Studies conducted by the state pollution control board in the city of Hyderabad have reported high noise levels at all intersections. (APPCB 2000). Reports from other countries have established the fact that almost all urban areas of the world are affected by the road traffic noise.

2.1 FACTORS AFFECTING THE GENERATION OF TRAFFIC NOISE

There are many factors, which influence the generation of traffic noise level. They are:

- Traffic flow
- Traffic speed
- Traffic composition
- Road gradient
- Road surface

It is impossible to separate the parameters completely, in particular. Traffic speed and traffic composition were found to interact and these are considered together. When estimating traffic noise levels for a road section it is important to consider that compatible values of flow, speed and composition are adopted. For noise predictions purposes, traffic composition are generally divided into two vehicles classes:

1. Light vehicle (<1525 kg unladen weight)

2. Heavy vehicle (>1525 kg unladen weight)

It is also recognized that traffic noise level is affected by the gradient of a road. The effect of gradient depends critically upon the percentage of heavy vehicles and traffic noise can be increased up to 12 dB (A) for gradient of 1 in 8.

Due to interaction between the road and tyre, road surface texture affects directly the noise level generated by traffic. The noise generated by vehicles traveling on impervious (concrete & bituminous materials) surface can be 2-3 dB (A) higher than that on pervious (open-textured materials) surface. [7] (2)

2.2 TRAFFIC NOISE CONTROL

a) Design Features

The installation of special design features such as walls or barriers can be effective as a reducer of traffic noises or noise associated with traffic. Such barriers are effective not only in reducing noise adjacent to the street and highway facilities but they can also be effectively utilized as a noise for off-street parking conditions.

Studies have shown that the erection of a five- foot masonry wall can reduce noise level by 5 dB or more. An increase in wall height or thickness will also produce a further decrease in noise level. Increasing a wall or barrier height by one foot on a six-foot wall has reduced noise levels by 8 dB and in some instances by as much as 10 dB.

b) Land Scaping

The buffer plantings of ROW as a noise control feature without the use of masonry barriers is not entirely dependent upon the width of the buffer. Almost all buffer plantings offer some noise reduction. Buffer plantings ranging from 20 to 50 feet in depth, depending upon the height and density, have produced satisfactory results. Even the noise reduction may not be considered significant; the effects of the plantings together with their aesthetic value will produce a positive influence.

c) Elevated Sections

Unlike other urban highway sections; an elevated highway section is usually provided without noise control features, as the design characteristics preclude positive noise control treatment. [1]

2.3 THE NEED FOR THE STUDY

Transportation noise has been a subject of research in many countries of the world. Most of these studies can be classified into the following groups.

(a) Measurement of noise due to highways, railroad and airports

(b) Modeling and prediction of transport noise

(c) Health effects of traffic noise

(d) Transport noise abatement, policies and methods

Transportation noise has been well recognized as an important pollutant especially in the urban environment of the industrialized world.

Traffic prediction models have been developed in the United Kingdom (DOT 1988), the Nordic countries (Nordic council 1980) and the United States (FHWA 1998). Federal Highway Administration (FHWA) in the United States has come up recently with a comprehensive noise model TNM 1.0 (1998) replacing STAMINA 2.0. Unfortunately these models can not be applied in their original form in other countries, especially in the developing countries as the characteristics of the traffic and mean emission levels of the vehicles are different. So far, there has been very limited work on transport noise in the developing countries.(3)

2.4 TRAFFIC NOISE MODELS

A number of studies have been conducted to develop noise prediction methodologies worldwide. Most of these studies have been conducted in the developed countries with the exception of few in the developing countries. A brief summary of these methods is represented here.

The level of noise generated by road traffic depend mainly upon the type of traffic flow, volume of traffic, the speed and composition of traffic, road gradient and the type of road surface. They are:

ANALYTICAL METHODS

One of the first traffic noise prediction methods was suggested by Scholes and Sergeant (1971). They used the following equations to predict traffic noise level. [8]

$$L_{10}\ (1h) = 10 \log (q) + 33 \log (V+40+500/V) + 10 \log (1+5p/V) - 27.6 \qquad (1)$$

$$L_{10}(18h) = 10\log (q) + 33 \log (V+40+500/V) + 10 \log (1+5p/ V) - 40.7 \qquad (2)$$

Where, q = the number of vehicles

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p = the ratio between the number of heavy vehicles and the total number of vehicles

V = vehicle speed in km/hr

THE U.K.DOE PREDICTION METHOD

The U.K.DoE Prediction method allows the calculation of both the L_{10} (18 hr) and the L_{10} (1 hr) noise values, taking into account the traffic parameters of volume, percentage of heavy vehicles, speed, road surface and grade. In this method, the reference position for each road segment is 10m from the edge of the near side lane and the reference noise level is given by [14]

L_{10}(18-hr) $=10\log^{10}(Q)+33\log^{10}(V+40+500/V)+10\log^{10}(1+5p/V)-27.6$ (3)

Where, Q = traffic volume (veh /hr)

V = mean traffic speed (km/hr)

P = percentage of heavy vehicles (4)

EDINBURGH MODEL

At present, a number of equations are available for predicting L_{10} noise levels for roads where traffic is freely flowing. These equations were derived from a consideration of the noise generally created by freely flowing traffic and cannot properly be applied to typical urban streets since intersections, traffic signals and other features often influence the traffic and the resulted in interrupted flow characteristics.

These are models developed for the prediction of noise from urban traffic under interrupted flow conditions.

This prediction model is obtained from a wide range of urban streets mainly in Edinburgh and also in London. The prediction equation from this interrupted flow conditions is [4]

$L_{10} = 55.92+9.18\log_{10}Q\ (1+0.09H)-4.2\log_{10}Vy+2.3T$ (4)

Where, Q= Volume (veh/hr)

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

H= proportion of vehicles exceeding 1.5 tons (percent)

V= mean speed of traffic (km/hr)

Y= carriageway width (meters)

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

SHEFFIELD MODEL

This prediction model is obtained from sites in Sheffield and Rotherham. The sites were chosen so that traffic and lay out characteristics were broadly similar to those surveyed in Edinburgh and elsewhere, however, the Edinburgh noise measurements were taken at the kerbside but the shuffled noise level were taken with the microphone positioned 1.5 meters above the ground and 1 meter from the building line. The prediction equation is [4]

$L_{10} = 51.5+10.5\log_{10}Q(1+0.04H)-5.7\log_{10}(dk0.5y)+2.38\log_{10}G$ (5)

Where, Q= Volume (veh/hr)

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

H= proportion of vehicles exceeding 1.5 tons (percent)

V= mean speed of traffic (km/hr)

Y= carriageway width (meters) (5)

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

d_k= distance to kerb from measuring point (meters)

G= 1, or percentage gradient whichever is larger

3. TRAFFIC NOISE PREDICTION SOFTWARE

TNM 1.0 replaced STAMINA 2.0 in USA for road traffic noise prediction (FHWA 1988). This program is widely used in the America.

CORTN (DOT UK 1988), calculation of traffic noise method of UK is implemented through B&K predictor type 7810 (B&K 1998) noise prediction software. These methods are explained here:

TNM 1.0

These Federal Highway Administration Traffic Noise Model (FHWA TNM) computes noise level through a series of adjustments to a reference sound level. In TNM, the reference level is the vehicle noise emission levels, which refers to the maximum sound levels emitted by a vehicle pass at a reference distance of 15m. Adjustments are then made to the emission level to account for traffic flow distance, and shielding. These factors are affected by the following equation. [8]

$L_{eq}1hr = El_i + A_{traffic(i)} + A_D + A_S$ (6)

Where, El_I = vehicle noise emission level for the ith vehicle type

$A_{traffic(i)}$ = adjustment for traffic flow, the vehicle volume and speed of the vehicle type

A_D = adjustment for distance between the roadway and the receiver

A_S = shielding and ground effects in addition to hourly equivalent noise level L_{eq} in dBA the TNM can determine the average day-night sound level given by

$L_{dn} = L_{AE} + \log_{10}(N_{day} + 3*N_{eve} + 10*N_{night}) - 49.4$ (7)

Where, L_{AE} = sound exposure level in dB

N_{day} = number of vehicles passbys between 0700 and 1900hrs. (6)

N_{eve} = number of vehicles passbys between 1900 and 2200hrs.

N_{night} = number of vehicles passbys between 2200 and 0700hrs.

TRAFFIC FLOW ADJUSTMENTS

The adjustment for traffic flow is simply a function of vehicle volume and vehicle speed. The adjustment for traffic flow is given by:

$A_{traffic} = 10 \log_{10 Vi/Si} - 13.2$ (8)

Where, V_i = vehicle volume in vehicles per hour

S_i = vehicle speed in km per hour

DISTANCE AND ROADWAY LENGTH ADJUSTMENTS

The adjustment for distance from the elemental roadway segment to the receiver and for the length of segment is given by:

$A_d = 10 \log_{10} (15/d) (\alpha/180)$ (9)

Where, d = perpendicular distance to the roadway segment in m

α = angle subtended by the road segment in degrees.

SHIELDING AND GROUND EFFECTS

It includes the effects due to the horizontal and vertical geometry. In these adjustment barriers, berms, tree zones, rows of buildings are considered.

CORTN METHOD

The CORTN (DOT UK 1988) was developed by the department of transport, UK. This method uses the following formula to calculate the noise level due to road traffic. [8]

$L_{10} = E_{road} + C_{attenuation}$ (10)

L_{10} = Noise level that is exceeded 10 percent of the period in dB (A). The period can be one hour, 18 hours (day period) or six hours (night period)

E_{road} = Emission number for a road in dB (A) (7)

$C_{attenuation}$ = Correction or attenuation for noise propagation from source to receiver in dB (A)

The emission for road is given by:

$E_{road} = E_{emission} + C_{speed} + C_{road} + C_{gradient}$ (11)

Where,

$E_{emission}$ = the noise level at a position 10 m away from the near side carriageway edge due to a defined traffic flow with a defined composition at the reference speed (75 km/h) on a horizontal road with the reference surface

C_{speed} = Speed dependent correction in dB (A)

$C_{gradient}$ = Correction for the gradient of the road dB (A)

C_{road} = Correction for the road surface dB (A)

The Attenuation A is calculated as follows:

$A = A_{distance} + A_{ground} + A_{barrier} + C_{reflection} + C_{angle} + C_{low}$ (12)

Where, $A_{distance}$ = Distance attenuation in dB (A)

A_{ground} = Ground effect in dB (A)

$A_{barrier}$ = Screening in dB (A)

$C_{reflection}$ = Correction due to reflection effect in dB (A)

C_{angle} = Correction for the angle of view in dB (A)

C_{low} = Correction for low traffic flow in dB (A)

3.1 NOISE STUDIES CONDUCTED AROUND THE WORLD

In 1980, Jacobs.et al developed a computer model for predicting traffic noise in built-up situations for free flow traffic conditions and for a flow interrupted by a traffic light. The stream of vehicles is stimulated by a given time headway distribution, and a transfer function obtained from a 1: 100 scale model is used to stimulate the specific built-up situation. [6] (8)

In 1974, Nelson and Godfrey studied road traffic noise in rural environment. In this study, traffic noise measurements have been made along side 26 miles of the A66 within the Lake District national park and in the towns of Keswick and Coker mouth and they constructed a 50dB (A) L_{10} contour for road traffic noise. [9]

In 1977, Nelson and Piner classified road vehicles for the prediction of road traffic noise. Measurements of speed, noise level and vehicles had made in road conditions ranging from fairly congested urban situations with speeds around 20 kmph to free flow on motorways with speeds over 100 kmph. The measurements had used to construct approximate vehicle noise levels and speed characteristics over the speed range 20-100 kmph for upto 6 vehicle categories, and used as input in the TRRL computer model of traffic noise. [10]

In 1978, Samuels and Thomas studied the measurement and analysis of road noise. In this study, they measured roadside noise levels as a vehicle passes by test track under various conditions of speed, load, and engine operation and so on. [13]

In 1985, Fawcett and Samuels developed an interactive traffic noise prediction program at the Australian Road Research Board (ARRB) to predict road traffic noise. It is based on the U.K.Department of the environment for predicting the noise indices L_{10} (1hr) and L_{10} (18hr). [2]

3.2 NOISE STUDIES CONDUCTED IN INDIA

Gupta, Nigam and Hansi (1986) analyzed the traffic noise pollution for mixed traffic flow for various land uses. A computer program was developed in FORTRAN IV to evaluate the noise parameters. From this study it was found that value of 'K' reported by Robinson does not match for mixed traffic flow and varies between 2.37 to 3.54 as against reported value of 2.56.[5]

Rao and Rao (1991) the first comprehensive traffic noise study took place in the city of Vishakapatnam. In this study, noise was measured for different types of land use areas and prediction equations are developed. [12]

Srivastava (1994) evaluated the environmental noise pollution on NH – 58 and models were developed to predict noise levels. [15]

Kumar Vimal (1997) carried out a study in Delhi to study the urban noise scenario and has developed equation for equivalent sound level L_{eq}. The developed prediction equation for the noise level L_{eq}(1hr) is given below.[16]

$$L_{eq}(1hr) = 47.45+8.58\log(Q_w)-0.14d \text{ dB(A)} \quad (13)$$

Where Q_w= traffic flow in PCU/hr (9)

3.3 TRANSFERABILITY OF NOISE PREDICTION MODELS

Interrupted flow traffic noise from the urban area especially from the central business district has different characteristics from traffic noise generated by the freely flowing traffic on highway. These differences come from the different flow characteristics of traffic in the CBD roads where the stop and go off traffic flow is the normal traffic condition. This is in contrast to traffic on highway, where the continuous flow traffic generally occurs. It also comes from different surrounding conditions between CBD roads and the highways such as carriage width, building by the road side, and road intersections in the vicinity. The model for prediction of interrupted flow traffic noise is therefore, different in nature from that of the free flow highway traffic noise.

Very few studies were done in the area of interrupted flow traffic noise prediction model, and all of these models were built and tested in the western countries. The efficiency of these models when they are applied to predict the interrupted flow traffic noise in central business district of any Asian city, where the characteristics of vehicle types and composition together with surrounding conditions are generally different, is the interesting point to be investigated together with the building of any effective interrupted flow traffic noise prediction model for the CBD in the Asian city.

3.4 CASE STUDIES OF TRANSFERABILITY

Limited interrupted noise prediction models are developed by western countries. Therefore, transferability of this traffic noise prediction model is necessary to the site conditions.

A CASE STUDY OF HONG KONG

STUDY AREA

In Hong Kong, four road sites were selected for measuring the road traffic noise at both peak and off-peak hours. The sites reflect local characteristics which consist of undivided carriageway with and without tramway, impervious and pervious road surfaces.

MODEL USED FOR TRANSFERABILITY

The traffic noise model currently used in Hong Kong is the one developed in U.K. by Department of Transport (Department of Transport, welsh office, 1988).

The new equations for estimating the traffic noise levels are calibrated using this survey data of four road sites in Hong Kong. The noise descriptor L_{10} will be applied for analysis because it is commonly used in the evaluation of highway projects.

The equation being used in practice for predicting the basic traffic noise level at the reference distance of 10 meters in terms of hourly L_{10} is the CORTN model

(Department of Transport, Welsh office, 1988) (10)

L_{10} = 10logQ + 33log (V+40+500/V) + 10log (1+ 5P/V) – 276 (14)

MODIFIED TRAFFIC NOISE MODEL

The validation of Eq (14) was carried out by comparing the estimated L_{10} values with the corresponding L_{10} values observed in Hong Kong. The estimated L_{10} values are calibrated by Eq (14) in which the data of Q, V and P was collected on sites. Using the linear regression model, the accuracy of the estimated L_{10} to the observed values (directly collected from the surveys) was examined. It was found that the CORTN model is over estimated traffic noise level by 1.2 dB (A) on the average.

The coefficient of determination (R^2) of the 45^0 line is 0.892 with taking into account the effects of local environment and conditions, the equations for estimating the Hong Kong traffic noise levels are re-calibrated.

Regression analysis was used to carry out on the four observed noise descriptors L_{10}, L_{50}, L_{eq} and L_{90}, with traffic noise estimates from Eq 14

After re-calibration, the equations are

L_{10} = 10.534 logQ + 34.762log(V+40+500/V) + 10.534log(1+5P/V) – 34.409 (15)

L_{eq} = 10.548 logQ + 34.808log(V+40+500/V) + 10.548log(1+5P/V) – 36.796 (16)

L_{50} = 10.976 logQ + 36.221log(V+40+500/V) + 10.976log(1+5P/V) – 42.377 (17)

L_{90} = 10.047 logQ + 33.155log(V+40+500/V) + 10.047log(1+5P/V) – 34.934 (18)

The new estimated noise descriptors were compared with the observed values to investigate the accuracy of the revised equations. Regression analysis was also performed to compare the noise descriptor L_{10} estimated by eq (15) against the observed data. It was found that the coefficient of determination (R^2) is 0.964 which is comparatively higher than that of 0.892. [7]

3.5 CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. A number of models are available for interrupted flow conditions; the most popular models used for prediction are FHWA (TNM) model, CORTON model. Analytical models like Edinburgh, Sheffield and Gilbert models are also developed.

2. This prediction models are very useful for planning and enforcement. (11)

3. Transferability of noise prediction models for another flow conditions is very useful for predicting traffic noise at that site. In this, the models of abroad are re-calibrated with the data of that site.

4. Transferability increases significant improvement in the overall accuracy in traffic noise prediction in comparison to the performance of the existing models.

5. In case of Hong Kong, by transferring the CORTON noise prediction model, R^2 is increased from 0.892 to 0.964.

6. Existing models tends to overestimate the traffic noise as compared to the noise levels on sites. By transferability of noise prediction models it can be reduced.

7. For transferability, models developed for heterogeneous traffic conditions cannot be used for homogenous traffic conditions.

RECOMMENDATIONS

1. There has been a limited study on transferability of traffic noise models. There is a need to test transferability of noise prediction models under Indian conditions. (12)

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