Modelling Of Traffic Noise Pollution

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ABSTRACT

The major contribution of the traffic noise, towards overall noise pollution scenario, is a well known established fact. 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, medium trucks/buses, automobiles and two wheelers. Many western countries have developed different prediction models based on L10, Leq and other characteristics. In India, the transportation sector is growing rapidly at more than 7.50% per annum and number of vehicles on Indian roads is increasing at a very fast rate. This has lead to overcrowded roads and various types of pollutions. Amongst, noise pollution is an important type which causes more annoyance and health problems to the human beings. So, a need is being felt to develop a noise prediction model suitable for Indian road conditions. The present work discusses the fundamentals of acoustics and analysis of vehicular traffic noise. A mathematical model is developed in Coimbatore city (Tamil Nadu) for Dindigul – Bangalore road (NH-209) (Two lane road with 7.00m BT width). A large number of sets of data were recorded at different dates in a random manner in order to account for statistical temporal variations in traffic flow conditions. The noise measurement parameters recorded were Leq. Sound level meter (SL 4010, Lutron make) was used for these measurements. A mathematical model was developed for predicting L_{10} or Leq level by considering the following parameters like 1. Total vehicle volume per hour,2. Average vehicle speed in kmph,3. Atmospheric temperature in °C,4. Surface temperature in °C, and 5. Relative humidity in %.The Noise levels Leq and L_{10} were used in regression analysis for prediction. It was concluded that value of R^2ranges from 0.1 to 0.7. The normal distribution test was also carried out successfully for goodness-of-fitness.

KEYWORDS: Modeling, Traffic,Noise, Pollution

1 INTRODUCTION TO NOISE

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 [4].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. The major concern is to study and development of a road traffic noise model.

1.1 HARMFUL EFFECTS OF NOISE ON HUMAN BEINGS

Noise is considered a serious threat to the environmental health. Some of the adverse effects of noise pollution are given below:

1. It interferes with speech. In the presence of noise we may not able to follow, what the other person is saying.
2. Noise leads to emotional and behavioral stress. A person may feel disturbed in the presence of loud noise such as produced by heating of drums.
3. Noise may permanently damage hearing. A sudden loud noise can cause severe damage to the eardrum.
4. Noise increases the chances of occurrence of diseases such as headache, blood pressure, heart failure, etc.
5. Noise leads to increased heart beat, constriction of blood vessels and dilation of pupil.
6. Noise is a problem especially for patients who need rest.
7. Noise may cause damage to liver, brain and heart.

1.2 NOISE MEASUREMENT TECHNIQUES & INSTRUMENTS

Noise measuring devices typically use a sensor to receive the noise signals emanating from a source. The sensor, however, not only detects the noise from the source, but also any ambient background noise. Thus, measuring the value of the detected noise is inaccurate, as it includes the ambient background noise. Many different type of instruments are available to measure sound levels and the most widely used are sound level meters. (Fig. 1).

FIGURE.1 SOUND LEVEL METER

1.3 ACCEPTABLE LEVELS OF NOISE

Various standards are being used in different countries regarding the acceptable levels of noise depending on the situation. Limits of acceptable noise level established by different organizations are given in Table 1.

TABLE 1. DIFFERENT STANDARDS OF NOISE LEVEL FOR VARIOUS AREAS OF A COMMUNITY.

S.No	Description of Area	Noise Level dB(A)			
		CPCB, India		FHWA	AASHTO
		Day time (6.00 AM – 9.00 PM)	Night time (9.00 PM – 6.00 AM)		
1.	Sensitive Areas such as parks, schools, hospitals, mosques and Silence area	50	40	60	55-60
2.	Residential Area	55	45	70 (Interior Max. 55)	70 Exterior 55 Interior
3.	Mixed Area	---	---	70	70
4.	Commercial Area	65	55	75	75
5.	Industrial Area	75	70	75	75

1.4 TYPICAL TRAFFIC NOISE LEVELS

- Areas with heavy traffic or close to blaring loud speakers: 80 –105 dB (A).
- Areas with over flying aircrafts: 90-100dBA.
- At Railway Stations, Traffic Junctions, Busy markets; 70 –90 dB (A).
- Residential Areas close to traffic, industries and markets: 60 –80 dB (A).
- Residential areas away from heavy traffic roads or other noisy Sources: 40 –60 dB (A).

2. INTRODUCTION TO VEHICULAR TRAFFIC NOISE

Traffic noise will continue to increase in magnitude and severity because of population growth, urbanization, and the associated growth in the use of automobiles. It will also continue to grow because of sustained growth in of vehicles [6]. Highway noise is the sum of the total noise produced at the observer point by all the moving vehicles on the highway. Thus the fundamental component is the noise produced by the individual vehicles, which depend on the vehicle type and its mode of operation. The overall noise is also dependent on the characteristics of the vehicle flow and the relative proportions of the vehicle types included in the flow. Knowledge of these factors is thus necessary to define the characteristics of highway noise and to subsequently predict the associated noise level in the surrounding area. The amount of information required depends on the degree of accuracy desired in the predictions, which in turn is a function of the method selected to characterize the temporal variation of the noise. Thus the complexity of highway noise model will depend on the noise descriptor selected.

2.1 VEHICLE NOISE SOURCES

It is well established fact that vehicular traffic noise is a major source of community annoyance especially near highway carrying fast traffic. Many people consider the truck noise to be the principal offender. Numerous components of noise sources contribute to the overall truck noise. These sources, however, can logically be grouped into the major categories as under.

1. Power Plant and Transmission Noise Sources- engine, exhaust, intake, cooling system, drive train and so on,
2. Running gear Noise Sources – tyre road interaction, differential, propeller shaft. Noise from the power-plant increases as engine speed increases. While noise from tyre increases as vehicle speed increases. Trucks tend to operate at a nominally constant engine speed, so that engine and exhaust noise do not vary appreciably with vehicle speed. Therefore, at lower highway speeds the engine-exhaust noise is dominant, while at higher vehicle speeds tyre-pavement interaction becomes the dominant source of noise. The exact speed at which the tyre-roadway noise starts to dominate over the power-plant-associated noise is a highly complicated function of such variables as tyre characteristics, engine-exhaust characteristics, road surface, and vehicle design and condition. As a tyre rolls over a road surface, it displaces macroscopic and microscopic volumes of air. The 'macroscopic' applies to volume displacements of the same order as the volume of the tyre itself, and 'microscopic' applies to much smaller volumes. These air displacements generated pressure disturbances in the surrounding air. Pressure disturbances in the audio frequency range and of sufficient amplitude are responsible for the production of noise along the roadway.

2.2 EFFECTS OF VARIOUS FACTORS ON TRAFFIC NOISE

Rapidly changing population patterns on the national scene and developed public expectancy in terms of environmental effects have generated the requirement to furnish environmental impact statement is the noise that my result from the traffic noise is more complicated due to the facts that highways are not flat, straight or free from natural terrain variation. The factors like vehicle speed, density, traffic mix, width of median and number of lanes are not constant. Therefore, for traffic noise each of these parameters is taken into account.

A number of factors can influence the traffic noise, whose major sources are noise emission from vehicle, interaction of tyres with road surface, traffic flow conditions and driving habits. In general, these factors can be grouped under four categories namely traffic factors, road factors, vehicle factors, and human factors as listed in Table 2.

TABLE 2 FACTORS AFFECTING TRAFFIC NOISE

Traffic factors	Road factors	Vehicle factors	Human factors
(i) Traffic volume	(i) Type of payment and shoulder	(i) Engine type	(i) Experience of the driver
(ii) Traffic speed	(ii) Surface roughness	(ii) Age of vehicle	(ii) Driving habits
(iii) Vehicle composition	(iii) Grade	(iii) Type of fuel used	
(iv) Presence of heavy vehicles	(iv) Presence of pot holes	(iv) Maintenance of vehicle	
(v) Creation of traffic jams and bottle necks	(v) Presence of intersections	(v) Type of horns	
(vi) Background noise	(vi) Presence of acceleration and deceleration lanes		
	(vii) Width of road		
	(viii) Presence of road side plantations		
	(ix) Land use activities		
	(x) Presence of high rise buildings		
	(xi) Presence of noise barriers		

2.3 NOISE PREDICTION MODELS

- 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.

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3. EXPERIMENTAL INVESTIGATION - NATURE OF NOISE PROBLEM

Traffic noise prediction models are required as aids in the design of 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. Several models have been developed by regression analysis of experimental data from fundamental variables such as traffic flow, vehicle speed, etc. A survey of the area revealed that the major contribution to the noise is from traffic with substantially high percentage of heavy vehicles. The average speed of the vehicles was found within range of 35-60 kmph. The noise nuisance was aggravated by the indiscriminate horn blowing, rapid accelerations and overtaking.

3.1 SITE SELECTION

To develop mathematical model for predicting the traffic noise, the first task was site selection. So, according to surveys of different areas and nature of noise problem, a two lane straight stretch where continuous uninterrupted flow of vehicles occurs, without any obstructions like speed breaker, junctions, traffic signals etc. was selected on Dindigul – Bangalore road (NH-209) at Ganesapuram, between Coimbatore and Annur (Fig.3). Also it is better to take noise measurement only in hot sunny days and it is better to avoid the rainy season. During rainy days, the level of noise due to tyre - road interaction will be more than that on normal days.

FIGURE.3 ARIAL VIEW OF THE NOISE MEASUREMENT SITE (COURTESY – GOOGLE EARTH)

3.2 MEASUREMENT PROCEDURE

For traffic noise problems it is useful to know the equivalent continuous sound level Leq and the 10 percentile exceeded sound level L10. Such information is obtained using a sound level meter (SL 4010, Lutron make). The sound level meter was suitably calibrated before taking the measurements. The sound level meter was placed on a tripod at a height of about 1.20 m above the existing road level at distance of 1.50m from the BT edge as shown in Fig. 4. The sound level meter was provided with a windscreen for minimizing the influence of wind during the measurement.

The following data were recorded at the site.

1. Location plan.
2. Atmospheric characteristics such as air temperature, humidity and surface temperature.
3. Vehicle count based on various classification of vehicles
4. Speed of vehicles
5. Noise level for different type of vehicles.

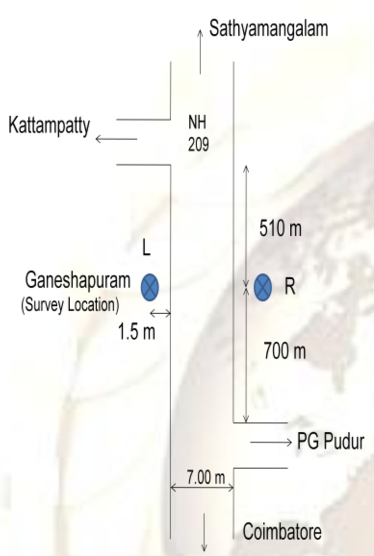

Fig. 4. Location plan of the noise measurement site

3.2.1 Location plan

The location plan was recorded in a separate sheet for showing the following details regarding the existing road.

a. Name of the road.
b. Category of the road.
c. Location of measurement.
d. Type of pavement.
e. Road width.
f. No. of lanes.
g. Type of carriageway (Divided / Undivided).
h. Width of median.
i. Height of median.

In addition to the above details, a line sketch showing the location of Km / Hm stones, their distances, distance of nearby junctions, distance of nearby culverts / bridges, north point, etc. and measured distances to the closest residences are marked in the location plan. Appendix A shows the form of location plan.

3.2.2 Atmospheric Data

Atmospheric data such as air temperature, humidity and surface temperature were measured at the time of measurement. The air temperature in °C and humidity in % were recorded using a hand held digital thermo-hygrometer and the surface temperature in °C was measured using a hand held laser thermometer.

3.2.3 Vehicle count

The vehicle count was done for various classification of vehicles based on the Indian Roads Congress guidelines given in IRC:9-1972 for the full time period of 12 hours at each measurement time on both sides of the road (Figure.5)

FIGURE.5 VEHICLE COUNT MEASUREMENT

3.2.4 Speed of vehicles

The uninterrupted free flowing speed of each category of vehicles was recorded in a separate form by using a hand held speed radar gun (Bushnell make) in kmph. This speed radar gun was also placed on the berm portion of the road(Figure.6.)

FIGURE.6 MEASUREMENT OF SPEED OF VEHICLE

3.2.5 Noise measurements

The Sound Level Meter (SLM) with a wind screen was placed on a tripod at a distance of 1.50m from the existing road edge at a height of 1.20m from the existing road level. The noise levels created by each category of vehicles were recorded manually in a separate form using the sound level meter (SL 4010, Lutron make) in decibels (Figure.7). The speed of wind seriously affects the accuracy of a measurement. This wind noise can be reduced significantly by the use of wind screen. These screens are commonly spherical balls or porous foamed plastic that fit over the microphone, and have negligible effect on the frequency response of the microphone. The noise measurements were taken on both sides of the road. In every hour, the measurements were taken on the left side of road between 0 to 20 minutes (20 minutes). After that, the instrument is shifted to the opposite side (right side) and the noise measurements were taken between 30 to 50 minutes (20 minutes) of every hour. The 10 minutes time duration is considered for shifting the instrument from the left side to the right side.

FIGURE.7 MEASUREMENT OF NOISE

3.2.6 Irregular noise events

During the measurement period, the irregular noise events such as low-flying planes, dogs barking, passing of ambulances, fire service and VIP vehicles, etc. were measured and marked in red colour for easy identification of them.

4. RESULTS AND DISCUSSIONS

4.1 MODELING OF TRAFFIC NOISE

Modeling of traffic noise has several uses, including estimating current noise exposure along roadways, assessing the effect of roadway changes, and predicting the performance of noise abatement options. The basic elements of traffic noise modeling are the traffic source levels and the propagation or attenuation of sound between traffic and receiver. Typical source related inputs to traffic noise models are the speed and volume of vehicle types, operating mode of the vehicles and the length of roadway with line of sight to the receiver location. Propagation related inputs include the acoustic characteristics of the ground, the number of lanes of travel, site geometry and topography and the type of geometry of any barriers or buildings present. Most models also consider the type of pavement at the site in regard to tyre-pavement noise generation, the prevailing wind and temperature conditions and interrupted traffic flows. There are a number of resources that can be consulted for additional, detailed information about traffic noise prediction methods. To develop road traffic noise a relationship is found between two or more variables and these relationships are expressed in mathematical form. Followings are steps followed:

Step 1

Collection of various parameters for this study as follows. Date & Time, Total vehicle count, Q, Average Speed, V (kmph), Atm. Temp., Ta (°C), Surface Temp., Ts (°C), Equivalent noise level, Leq (dB)Relative Humidity, H (%)

Step 2

Analysis of the collected data using DATAFIT (Version 8.10) to find out the correlation between the various parameters and the noise level. A nominal distribution test is also applied to test the model for its goodness of fit.

Step 3

Plotting of graphs for Leq Vs Q, Leq Vs V, Leq Vs Ta, Leq Vs TsQ, and Leq Vs H.

From the scatter diagram it is possible to visualize a nature of relationship between variables. Fig 5.1-5.5.

Based on the data taken in different days between 6.00A.M. to 6.00 P.M., the data analysis was done using DATAFIT (Version 8.10). The best form of regression equation obtained is given below.

$$Leq = 75.58 + 0.0024Q - 0.0064V + 0.0469Ta - 0.00451Ts + 0.0306H \quad (R^2 = 0.523)$$

Where, Q = Total vehicle count in both directions,
V = Average speed of vehicles in kmph,
Ta = Average atmospheric temperature in °C,
Ts = Average Surface temperature in °C,
H = Relative humidity in %, and
R^2 = Coefficient of correleation.

This equation can be used for predicting traffic noise in a two lane road.

Testing the goodness of fit of the model:

As a part of this study, the statistical goodness-of-fit test is provided to test the prediction values against the field observed data. Since the total number of samples is 168, the normal distribution test was carried out to find out the goodness of fit, which shows that this model can be effectively used in analysis and prediction of highway traffic noise conditions in India.

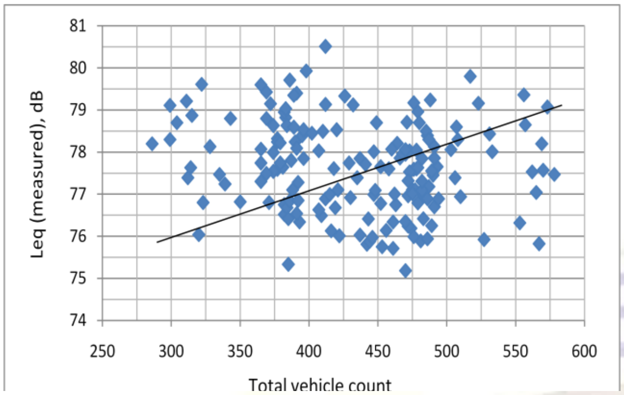

FIG. 8 TOTAL VEHICLE COUNT VS LEQ

Correlation equations have been obtained between Leq with total number of vehicles –Q (Figure.8), Vehicle speed -V(Figure.9), Atmospheric temperature- Ta (Figure.10), Surface temperature –Ts (Figure.11), and Relative humidity – H (Figure.12).

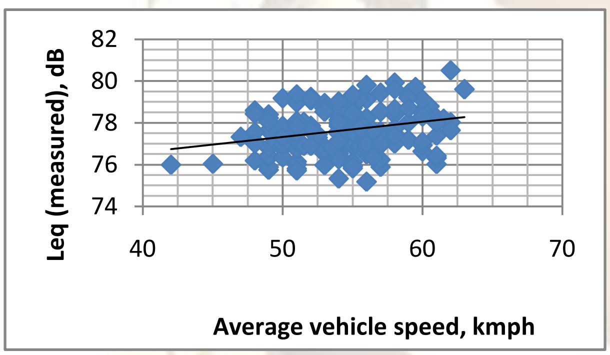

FIGURE.9 AVERAGE VEHICLE SPEED VS LEQ

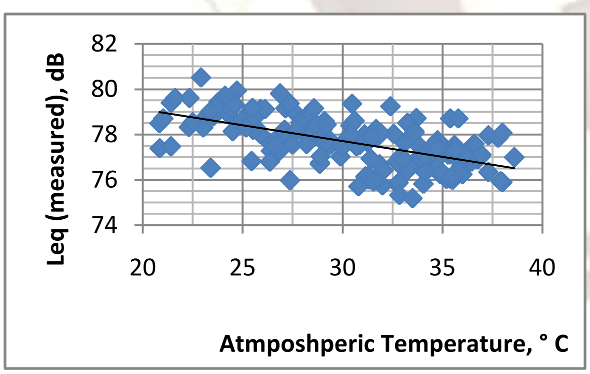

FIGURE.10 ATMOSPHERIC TEMPERATURE VS LEQ

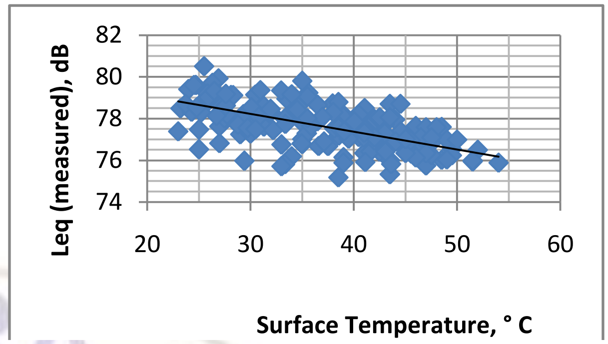

FIGURE.11 SURFACE TEMPERATURE VS LEQ

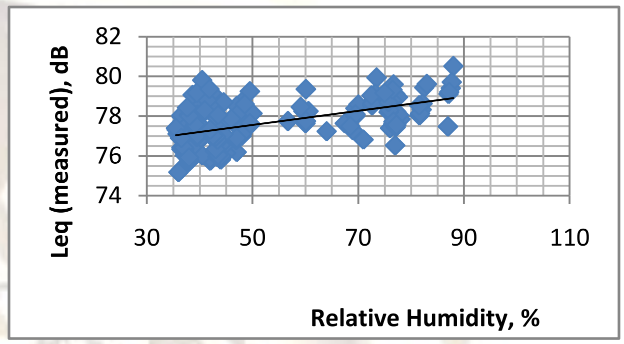

FIGURE.12 RELATIVE HUMIDITY VS LEQ

5. CONCLUSION

Collected data on noise generating parameters was applied to calculate the predicted noise level with the help of regression analysis. The comparison tests were made in order to examine the goodness of fit, between the predicted and measured noise level from the collected field data and to suggest a suitable model for Indian conditions. From the present study following conclusions are drawn:

1. Correlation equations have been obtained between Leq with total number of vehicles (Q), Vehicle speed (V), Atmospheric temperature (Ta), Surface temperature (Ts), and Relative humidity (H). Percentage errors between the measured and predicted volumes are of negligible amount.
2. R^2 value for the equation was found to be 0.523. The value of R^2 can be improved by incorporating variations by taking number of different locations and taking more data sets.
3. Since the number of data are 168, the goodness of fit for large samples was applied to study about the fitness of the equation. The null hypothesis, $\mu=0$, that is the mean value of the differences between pairs of measured noise and predicted noise is equal to zero. The results of nominal distribution at 5% level of significance shows that the null hypothesis is accepted, that is the mean value of difference between measured and predicted noise level is zero.
4. The scatter plots of Leq Vs Q, Leq Vs V, Leq Vs Ta, Leq Vs Ts, and Leq Vs H were plotted to determine the influence of the parameter on the level of noise. In the above plots, if there are more data sets of different locations and timings are

adopted then it may have better correlation. The following results conclusions were arrived from that plots.

a) The noise level increases with increased total number of vehicles.
b) The noise level increases with increase in speed of vehicles.
c) The noise level decreases with increased atmospheric temperature.
d) The noise level decreases with increased surface temperature.
e) The noise level increases with increased humidity.

6. SCOPE FOR FUTURE WORK

1. In this work, vehicle speed was measured using hand held speed radar gun. The speed of vehicles only in the measured direction was considered in this study. The results may be improved if the speed of vehicles plying the opposite direction is also considered.

2. All the measurements were taken at single location on seven week days. If different locations and timings are adopted, then better results can be obtained.

3. In the present work only three parameters like, total number of vehicles (Q), Vehicle speed (V), atmospheric temperature (Ta), Surface temperature (Ts) and relative humidity (H) are only considered in this study. If more parameters are included in the prediction and it may give better results.

4. In this study only two lane road is considered for the modeling. The noise predicting model for different category of roads with different lane widths may be more realistic.

5. In this study the stretch is selected without the presence of median. But now-a-days, the four laning and six laning works are carried out with sufficient medians. Hence the presence and width of median may be considered for further study.

6. This study is done for uninterrupted free flow traffic. But the nature of noise level may differ in an uninterrupted traffic flow condition. Hence that traffic flow condition may be considered in future study.

7. This study was carried in flexible pavement. The characteristics of noise will be totally different in rigid pavements. Hence it is wide open to explore the level of noise in rigid pavements.

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