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Development of interrupted flow traffic noise prediction model for Dhaka City

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ABSTRACT: In the context of urbanization process, the increasing urban transport demand, growing congestion, environmental implications, the large size of investments and the impacts of urban transport on the quality of life of people. With deteriorating level of mass transport services and increased use of personalized motor vehicles, vehicular noise pollution is assuming serious dimensions in most of the metropolitan cities in view of its associated health hazards. Simulation of urban traffic noise along with a mathematical model of interrupted flow traffic noise for a road network in Dhaka city is represented in this paper. The analysis data consisted of traffic characteristics, geometrical dimensions of road sections and its noise levels at nine different sites of Dhaka city. Characteristics of noise from different types of vehicles were analyzed, including CNG driven Autorickshaws and Motorcycles. Characteristics of traffic noise levels and data on other traffic noise parameters were used to analyze and subsequently construct the interrupted flow traffic noise simulation model. The resultant models, which are separated into acceleration and deceleration lane models and their statistical goodness- of- fit tests, are presented. The collected data were used to check compatibility of different globally accepted traffic noise models e.g. FHWA model, Stop-and-Go model (Thailand, 1999), Regression model (India, 2003) and Acceleration and Deceleration Lane model (India, 2006) for Dhaka condition. After comparison of result, it was observed that separated lane models of Stop-and-Go model and Acceleration and Deceleration Lane model are more appropriate for Dhaka and could give acceptable result. In addition, statistical analysis has been done on the data between measured and predicted values and good agreement was obtained. Also, noise level was compared to the standards and the study reveals that the central part of the city e.g. Bijoy Soroni More, Bangla Motor, Poribaag has been the most affected and noise abatement of these area is nearly impossible without efficient traffic management.

1 INTRODUCTION

Noise is unacceptable level of sound that creates annoyance, hampers mental and physical peace, and may induce severe damage to the health. Along with the increasing degree of air and water pollution, noise pollution is also emerging as a new threat to the inhabitants of Dhaka City. Exposure to high level of noise may cause severe stress on the auditory and nervous system of the city dwellers, particularly the children. Although there are many sources of noise, which include industries, construction works and indiscriminate use of loud speakers, motorized traffic is the principal source of creating noise in urban areas (OECD, 1995). With the increase of in the number of motorized vehicles in the city, the hazard of noise pollution has increased and exceeded the level of tolerance. It is reported that the hearing ability of the inhabitants of the City has reduced during the last ten years. About five to seven percent of the patients admitted to the Bangabandhu Seikh Mujibur Rahman Medical University, Dhaka are suffering from permanent deafness due to noise pollution (Ahmed, 1998). Disturbances created by noise may cause hypertension, headache, indigestion, peptic ulcer, pharyngitis, atherosclosis, bradycardia and ectopic beat (Papacostas and Prevedouros, 1993; Kadiyali, 1997).

The major factors which, influence the generation of road traffic noise are traffic flow, traffic speed, proportion of heavy vehicles, gradient of the road and nature of the road surface. In addition, the following factors influence the noise level at a point distant from the highway: attenuation of sound waves due to distance between source and receiver and also due to ground absorption, obstruction due to noise barriers ,obstruction of the sound waves due to restricted angle of view of the same line from the reception point, reflection effects (Agent & Zeeger, 1980). Traffic noise prediction models have been attempted in most of the developed countries. But the effort has been limited in free flow conditions mostly. Urban planners often have to rely on road traffic noise prediction models for their assessment. The more popular ones include the CRTN model in the UK, the FHWA model in the US, the RLS90 model in Germany, the OAL model in Austria, the StatensPlanverk48 model in Scandinavia, the EMPA model in Switzerland, and the ASJ model in Japan. All these models are based on the uninterrupted traffic flow consideration. But the scenario in urban movement is very different than uninterrupted. Moving vehicles tend to accelerate and decelerate frequently due to interrupted flow occurring at closely spaced traffic signals. Recently noise prediction models are being developed for interrupted conditions. Different characteristics that are apparent throughout the noise measurement period of interrupted traffic flow conditions in urban areas make formulating a theoretical noise prediction model difficult and complex.

In Bangladesh, researches on traffic noise pollution are limited when compared to other developed countries. Moreover, Bangladesh does not have its own traffic noise prediction model that encompasses the Bangladeshi traffic characteristics and prevailing environmental conditions. Most of the research work on noise is limited within to check the standards. Only attempt made by Alam et al. (2001) is noteworthy. This model was developed using dataset from seven locations in Dhaka, but the main drawback of this model is the absence of interrupted flow condition and use of noise equivalence that is not consistent with traffic-noise characteristics of Dhaka city.

To deal with these drawbacks our study had focused on four specific objectives:

i. To develop traffic noise production equivalences for different vehicle types in comparison with automobiles (car/ jeep/ van).
ii. To check various noise generating factors for their correlation with noise level.
iii. To produce interrupted flow traffic noise model that is suited for Dhaka city.
iv. To evaluate various empirical and analytical models accepted globally for their suitability in the condition of Dhaka.

2 METHODOLOGY

2.1 *Determination of acoustic equivalence for vehicles*

At first, acoustic equivalence level of different vehicle types with respect to automobiles are to be generated. This value is highly needed to be determined for calculation of noise weighed flow. Equivalence is determined using Equation 1 for each of the six vehicle classes.

Equivalence, E = 10^ [(Mean Leq of any vehicle - Mean Leq of Passanger Car)/10] (1)

2.2 *Finding out suitable predictor*

All the measured parameters which were assumed to be an effect on traffic noise production are correlated with noise level and also among themselves. This is done in two ways: plotting relational graphs of individual variables with noise (in MS- Excel) and evaluating Pearson's Correlation and 1- tailed Significance Values in a form of matrix that is found from analysis.

2.3 *Development of model*

The mutually exclusive independent variables are then analyzed for model building. The analytic framework is Multiple Linear Regression Analysis (MLRA). Both forced (enter) and stepwise methods have been used. Forced entry regression model is intended to be more acceptable even if its goodness- of –fit is poor. This is because they intend to establish a relationship with previously modeled predictors globally accepted. Statistical software SPSS is used to perform this operation.

2.4 *Comparison with other models*

The suitability of some globally recognized empirical and analytical traffic noise prediction models has also been explored. They include: FHWA model, Stop- and- Go model (Thailand, 1999), Regression Model (India, 2003), Acceleration and deceleration lane model (India, 2006). A comparison of the calculated values and observed values has also been done to find out their compatibility by finding corresponding R^2 value and paired t- test.

3 DATA COLLECTION AND ANALYSIS

3.1 *Data for noise equivalence*

For convenience of measuring the effect of individual vehicle noise a long stretch of road with minimum traffic movement was needed. So, we have strategically selected Ashulia, a sub urban point of Dhaka city, which consisted of all types of vehicle that runs on Dhaka roads yet contain fairly long vehicle spacing. Traffic noise level was measured with an integrated precision noise level meter placed about 15 m away from the centerline of the roadway at a height of 1.2 m. Noise level was measured at A- weighted scale for time duration of 10 seconds. The corresponding vehicle type was also noted along with. Data for the analysis of the relationship between vehicle noise and speed of this figure consisted of 619 data sets, separated into 6 types of vehicle, which were collected from approximately a minimum of 40 vehicles/ type.

3.2 *Data for the model*

Study locations of this study include mainly the urban road network in the central part of Dhaka, the capital city of Bangladesh. Data collection sites were Shahbaag East, Shahbaag North, Poribagh, Banglamotor, Moghbazaar, Kakrail, Bijoy Shoroni More, Kakoli and Khilkhet. At the selected nine study locations 20 datasets are obtained at both acceleration and deceleration sides of the roadway during a period of March 2009 to September 2009. A usual dataset contains volume and spot speed readings at both sides of the roadway, geometric features of the roadway cross section and noise level value at a definite distance and height from roadway curb (at 1m distance, height 1.2 m).Categorized vehicle count and the counting period are noted for determination of equivalent hourly volume. We have used video-camera recordings to find out traffic volume data (Minimum 200 hours for each site). To calculate overall mean speed of the vehicle stream we have used laser gun technology by picking up spot speed of different vehicle in a random manner. The vehicle type is also noted along with their speed which was applied to find the acoustic adjustment of speed later on. Geometric measurements of roadway cross section are done with the help of an odometer. Noise level measurement was done simultaneously with volume and speed recording using a sound level meter called RION NL-32(class 1). The equivalent noise level from the collected data is used and recorded for further analysis.

3.3 *Calculation of noise equivalence*

Using Equation 1, we get the noise equivalence for different vehicles as shown in Figure 1.

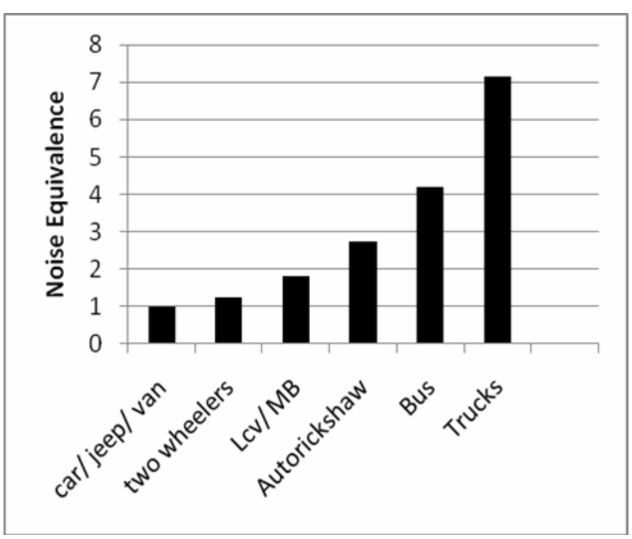

Figure 1. Noise equivalence of various vehicle types

From these calculation, Equation 2 is derived that provides us noise equivalent traffic flow.

$$Q_E = QCar/Jeep/Van + 7.161*QTru + 4.188*QBus + 2.742*QAuto + 1.811*QLCV/MB + 1.245*QTw \quad (2)$$

Where, Q_E= Equivalent Traffic Volume, QTru= Truck volume, QBus= Bus volume, QAuto = Autorickshaw volume, QLCV/MB = Light commercial vehicle /Minibus volume, QTw= Two wheeler volume.

3.4 *Single lane model analysis*

Single lane model is the simplest approach to catch the urban stop-and-go situation traffic noise. Here we use our noise measuring device at a specified height and distance from curbside in various distances from the intersection. Figure 2 describes parameters that can be used as predictors. Independent variables primarily considered are Vn, Vf= Volume of traffic for near side and far side of observer in vehicles per hour, Sn, Sf=Mean speed of traffic for near side and far side of observer, Dg= Geometric mean of the road-side section= √(Df * Dn) in meters, and Dn and Df are the distance from the observer to the central line of the near and far-side roadway in meters, J= Distance to nearest intersection stop line in meter, W= Width of the carriageway in meters, L= Queue length in meters.

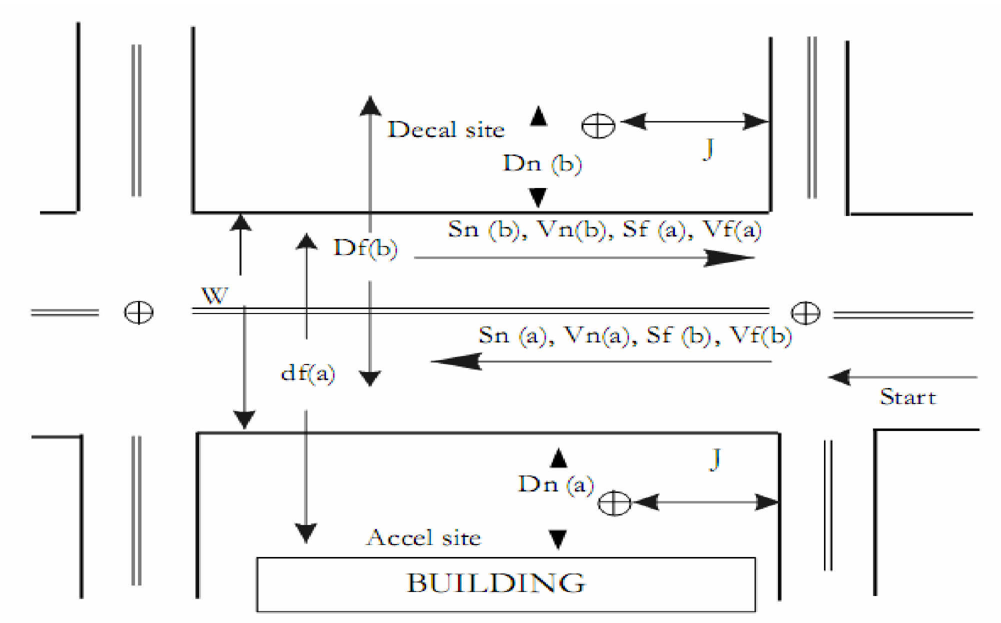

Figure 2. Parameters of Interrupted Flow Noise Model

The single lane model has provided us with Equation 3. It has an adjusted R^2 value of 0.895 and standard error of 0.75.

$$Leq\ (dBA) = 27.977 + 9.664 \log Vn + 4.375 \log Vf - 0.021\ Sn + 0.079\ Sf - 0.046\ Dg \quad (3)$$

3.5 *Separated lane model analysis*

This analysis approach acknowledges the difference in traffic noise characteristics between an acceleration lane and deceleration lane on both sides of urban road when vehicles leave an intersection on a green traffic light and come to a stop on a red traffic light.

3.5.1 *Acceleration lane model:*

The acceleration lane model was built data generated from noise level meter placed on the sidewalk near the acceleration lane of the roadway when traffic leaves the intersection. Data for nearside and farside parameters from all the locations subject to the acceleration lane condition were applied to build the model. Every parameter, which was considered to generate potentially traffic noise under acceleration condition, was tested against observed traffic noise level for its correlation with generated Leq and to observe whether any colinearity existed among noise generating parameters. From this we get Equation 4 as our acceleration lane model that has an adjusted R^2 value of 0.927 and standard error of 0.514.

$$\text{Leq (dBA)} = 60.667 + 3.755 \log \text{Vn} - 3.408 \log \text{Vf} + 0.418\text{Sn} - 0.054\ \text{Sf} + 0.042\ \text{Dg} \quad (4)$$

3.5.2 *Deceleration lane model*

In case of deceleration lane traffic noise model, the same procedure as procedure as mentioned earlier was adopted. The noise data was obtained from the roadway data collection stations, except that this time the noise level meter was set up by the side of a deceleration lane where traffic enters into an intersection. Analysis provides Equation 5 as our deceleration lane model with adjusted R^2 value of 0.977 and standard error of 0.396.

$$\text{Leq} = 35.978 + 6.357 \log \text{Vn} - 3.477 \log \text{Vf} - 0.032\text{Sn} + 0.165\ \text{Sf} - 0.067\ \text{Dg} + 2.601 \log \text{L} \quad (5)$$

3.5.3 *Decisions on separated lane model*

The highest value of R^2 obtained from the two separated lane models of the acceleration and deceleration lane were 0.927 and 0.977 respectively. These R^2 values are higher than the R^2 value obtained for the single model, which implied that the independent variables or noise generating parameters used in the two separated models provided a better explanation of the dependent variable or Leq than the parameters used in single model. The separated model thus provided a better result for forecasting traffic noise than single model. All the apparent coefficients in the acceleration and deceleration lane models also had logical meanings in reference to traffic and traffic noise characteristics. In the analysis process of separated models, parameters of distance from the observer to the nearest junction (J) together with the distances from observer to nearside and far side building facades were screened out because of the insignificant effects of these parameters to each of these two separated models.

3.6 *Comparison with known models*

In this study four different models are utilized for the prediction of noise level namely FHWA, Stop- and- Go Model (Thailand, 1999), Regression (India, 2003), Acceleration and Deceleration Lane model (India, 2006). FHWA modeling is a part of empirical modeling strategy while the others are classified as an analytical model. The predicted results are then analyzed by comparing them with the observed noise model. Table 1 summarizes comparison of different accepted noise model in accordance with our observed data.

Table 1. Comparative Evaluation of Different Noise Models

Model	Variations	D.O.F.	t- statistics	Critical- t value	Correlation	R^2
FHWA model	None	19	-6.169	1.729	0.111	0.012
Stop-and- Go model (Thailand, 1999)	Single Lane	13	-2.676	1.771	-0.345	0.119
	Acceleration Lane	6	0.490	1.943	0.910	0.828
	Deceleration lane	6	-1.117	1.943	-0.499	0.249
Regression model (India, 2003)	Single lane	13	-8.525	1.771	0.025	0.000
Acceleration & Deceleration model (India, 2006)	Acceleration Lane	6	1.357	1.943	0.714	0.509
	Deceleration Lane	6	-7.842	1.943	0.332	0.110

Figure 3, 4, 5, 6, 7, 8, 9 graphically show the relationship between modeled noise level and observed noise level.

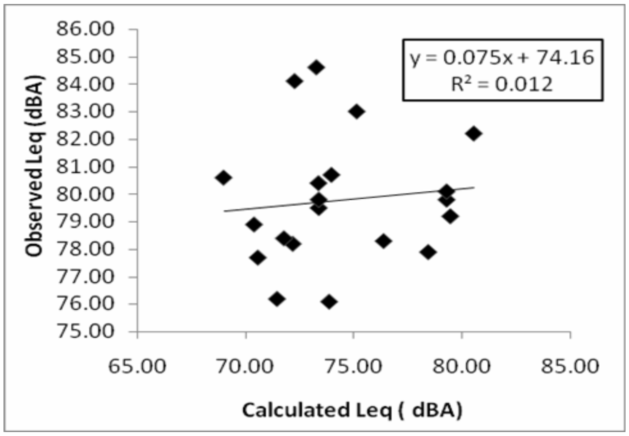

Figure 3. Comparison of FHWA noise model

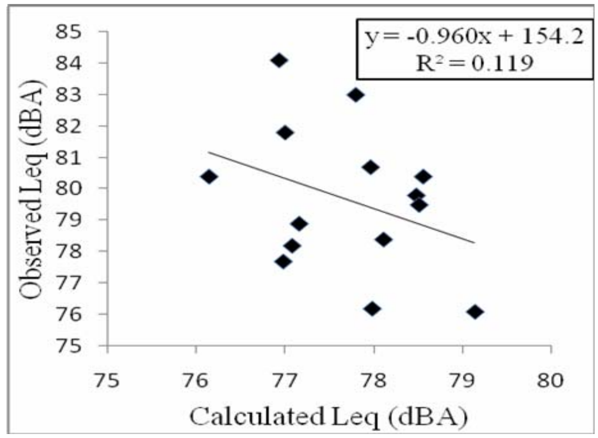

Figure 4. Stop-and-Go model (single lane)

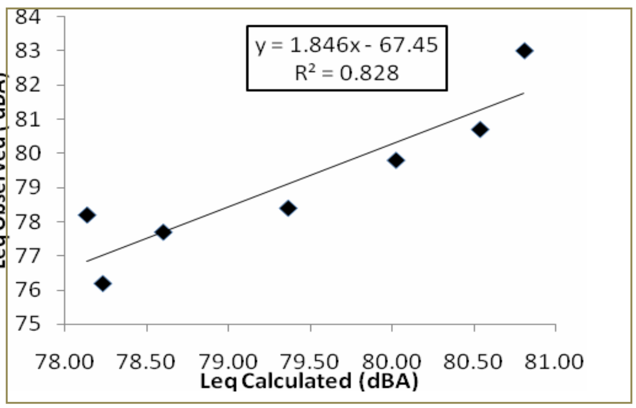

Figure 5. Stop and Go model (acceleration lane)

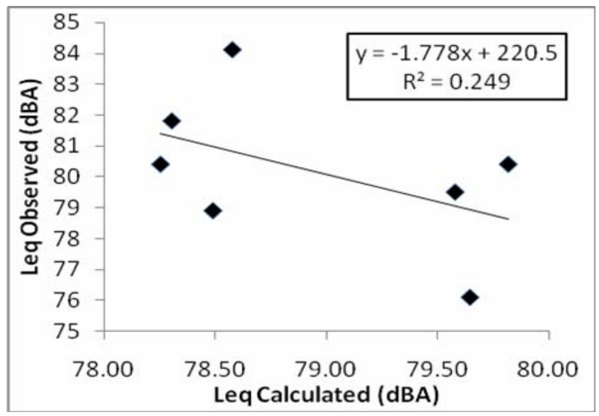

Figure 6. Stop and Go model (deceleration lane)

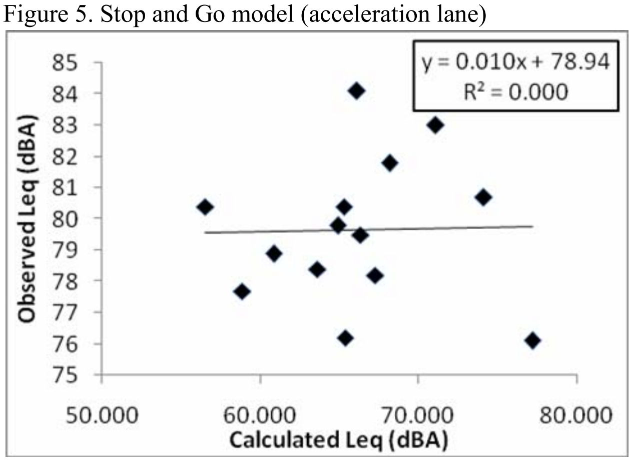

Figure 7. Comparison of Regression Model

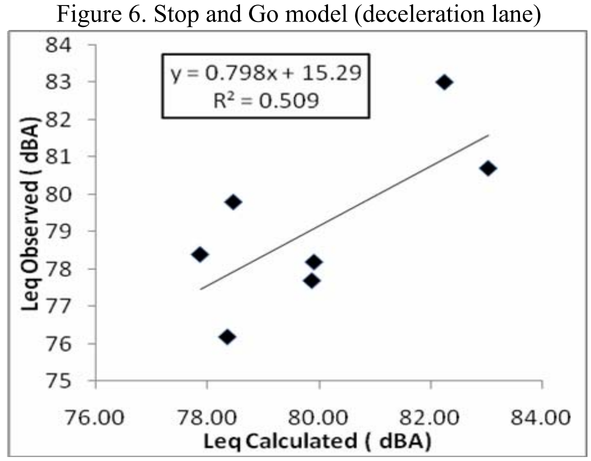

Figure 8. Acceleration lane model (India, 2006)

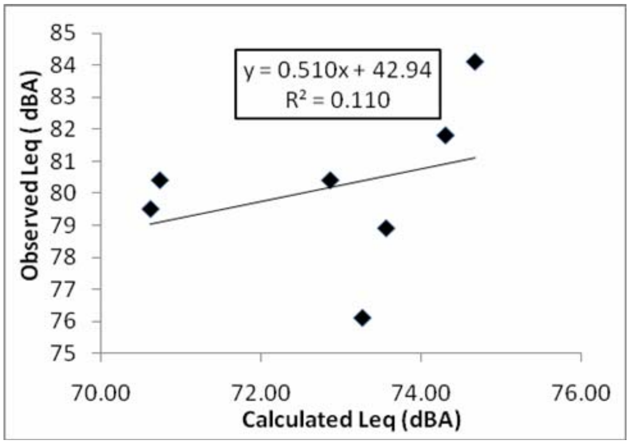

Figure 9. Deceleration lane model (India, 2006)

3.7 *Check of noise against ambient level*

Noise level against all 20 data sets is compared to their ambient noise level corresponding to their zone. All these data points have exhibited higher level of noise than their standard level. This is described in Table 2.

Table 2. Noise checking against standard value

Location	Zone	Noise Level, Leq (Average)	Ambient Level, Leq (DOE)	Improvement Chance*
Shahbaag East	Commercial	76.15	70	Attainable
Shahbaag North	Silent	78.30	45	Nearly Impossible
Poribaag	Mixed	81.70	60	Do
Bangla Motor	Commercial	82.40	70	Very Difficult
Moghbazar	Commercial	80.00	70	Attainable
Kakrail	Mixed	79.53	60	Nearly Impossible
Bijoy Soroni More	Mixed	81.15	60	Very Difficult
Kakoli	Commercial	78.1	70	Nearly Impossible
Khilkhet	Residential	79.50	50	Do

* improvement with noise barrier (OECD,1995 & Harris, 1979)

4 CONCLUSION

Increasing use of motorized private vehicles and deterioration of mass transport facilities has lead to an enormous problem of noise pollution in urban and semi urban areas of Dhaka city. This problem has been multiplied due to positioning of closely spaced intersection and accelerating- decelerating noise of motorized vehicles resulting from them. This study attempted to assess the impact of various predictors on traffic noise generations and develop an analytical tool to be used for the purpose of predicting interrupted traffic flow noise. Equation 3, 4 and 5 consist of set of predictors that have been used to develop several globally accepted interrupted flow traffic noise models (TNM). Suggestion of the study is to use separated lane models rather than single lane. A comparison of some globally accepted noise models with prevailing noise data revealed that they have a very low level of predictability of the actual situation. Used all around the world the FHWA noise model, is an empirical model based on free flow condition , has shown a very poor correlation with the observed noise level and paired t- test revealed a very high t- statistics (negative value suggest this model under predicts the actual noise). As far as the analytical models are concerned Stop and Go Model and Acceleration and Deceleration Lane Model (India, 2006) had shown a good correlation with the observed noise level with the difference of observed and predicted noise being minimum for their acceleration lane models. The Regression Model (India, 2003) is a single lane model which seems to have almost no correlation with the observed noise values and decided unsuitable for use in Bangladeshi conditions. Moreover, the existing severity of noise pollution of Dhaka city has soared to a position that at some places it has become nearly impossible to lessen the level of severity within acceptable limit with only structural abatement measures (Table 2). Therefore it has become very urgent to apply various traffic management strategies to control this noise pollution. Some important findings of our study are:

1. At all other studies previously done noise levels have been found to have directly correlated with nearside and farside volumes and speeds of the roadway. But in our study we have found that with the increase of decelerating lane speed noise level tends to decrease. This phenomenon may be better explained by effect of horns because at interrupted flow condition vehicle drivers tend to use horns more frequently as the regulations concerning use of horn are not properly enforced.
2. For developing deceleration lane model a new parameter, Queue Length has been introduced than those were previously used in stop- and- go noise model. Logarithmic value of this predictor has shown a very good correlation with the deceleration lane noise level and therefore it is introduced into the forced regression predictors (Equation 5).
3. Observations include motorcycles, heavy vehicles (trucks and buses), and vehicles with faulty exhaust systems tend to produce high noise levels. Older diesel engines tend to be the noisiest, followed by gasoline and natural gas, hybrid, and electric vehicles being quietest.
4. It has been found studying the acceleration lane speeding that Lower speeds tend to produce less engine, wind and road noise. Aggressive driving, with faster acceleration and harder stopping, increases noise as engine noise is greatest when a vehicle is accelerating or climbing an incline.
5. Effect of horn is by far the most notorious and complex one which has yet to be explained into the predictors of TNM. The study revealed that horn tends to increase the level of noise to an extent of 7 to 10 dBA.

All in all, we think result of this study will assist the urban planners and traffic mangers of Dhaka city in a great way by providing them an analytical tool to select proper noise abatement and control procedure.

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