TRAFFIC NOISE MODEL FOR ASSESSMENT OF INTERRUPTED FLOW TRAFFIC NOISE IN CENTRAL BUSINESS DISTRICT

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ABSTRACT

This paper presented a study which was aimed at the development of traffic noise model that can be used efficiently in the prediction and assessment of interrupted flow traffic noise in the central business district of the Asian city. Data for this study was collected from 20 sites in Singapore's CBD which included noise level, traffic speed, traffic volume and composition of the traffic together with various measurements of road geometry and surrounding conditions. Three existing models which were previously built in the western countries with the different environment and different traffic conditions were tested against the collected data. The modification of some significant parameters was then given to the selected model in order to improve its efficiency in traffic noise prediction. This new interrupted flow traffic noise model gave the best fit result to the measured noise in statistical test for the goodness of fit of the model, and also provided a significant improvement in the overall accuracy of traffic noise prediction when compared to the previous ones.

INTRODUCTION

Interrupted flow traffic noise from the urban area especially from the central business district has different characteristics from traffic noise generated by the freely flow traffic on highway. These differences come from the different flow characteristics of traffic in the CBD roads where the stop and go of 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 the different surrounding conditions between CBD roads and the highways such as carriage width, buildings 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 CBD of Asian city, where the characteristics of vehicle types and composition together with the 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 Asian city.

SCOPE OF THE STUDY

This study project was aimed at the development of interrupted flow traffic noise model that could be used efficiently in the prediction of traffic noise in the central business district of Singapore. Three existing models which were previously built in the United Kingdom, namely, Edinburgh model, Sheffield model, and Gilbert et al model were used in the early stage investigation of this study in order to see how effective they were in the prediction of traffic noise in Singapore CBD.

The best fitted model from this compereative analysis was then selected for further development of the new model, therefore, the overell accurucy in forecasting the interrupted flow traffic noise in this Asian CBD could be improved significantly.

THE EXISTING MODELS

The three existing models, which were previously built to predicted interrupted flow traffic noise in the United Kingdom, were used in the early stages of investigation and model development of this study. The mathematical formular of these three models can be presented as follows:

Edinburgh Model

$$L_{10} = 55.2 + 9.18 \log Q(1 + 0.09\ PH) - 4.2 \log Vy + 2.3\ T$$

where: L_{10} = traffic noise level in dBA that exceed 10% of the measuring time period (1 hour)

Q = traffic volume (veh/h)

PH = proportion of vehicles exceeding 1.5 tons (%)

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

V = mean speed of traffic (km/h)

y = carriage width (metres)

Sheffield Model

$$L_{10} = 51.51 + 10.5 \log Q(1 + 0.04\ PH) - 5.71 \log (d_k + 0.5\ y) + 2.38 \log G$$

where: d_k = distance from noise meter to edge of kerb (metres)

G = 1, or percentage gradient whichever is larger

Gilbert et al Model

$$L_{10} = 43.3 + 11.02 \log (L + 9M + 13H) - 0.43\ y + 2.42/d_f$$

where: d_f = distance from near side kerb to near side facade (metres), and $d_f > 1$

L = number of light vehicles (< 1525 kg), (veh/h)

M = number of medium goods vehicles (1525 - 4500 kg), (veh/h)

H = number of heavy goods vehicles (> 4500 kg), (veh/h)

FIELD DATA COLLECTION

Data for this study was collected from 20 signalised intersection sites in Singapore CBD which constituted about 15% of the total CBD'S signalised intersections. The CBD area and locations for data collection are shown in Figure 1. Noise levels, traffic speeds, traffic volumes, and composition of traffic flow were collected. Various measurements of the road geometry and surrounding conditions such as road widths, distances from kerbside to noise receiver, distances from receiver to facade, accelerations and decelerations of traffic flow were also taken. One-hour period traffic noise level and its corresponding volume and composition were taken during the morning peak, and off-peak hours of the day at these 20 designated sites, hence a total of 60 noise level measurements were taken for this study project.

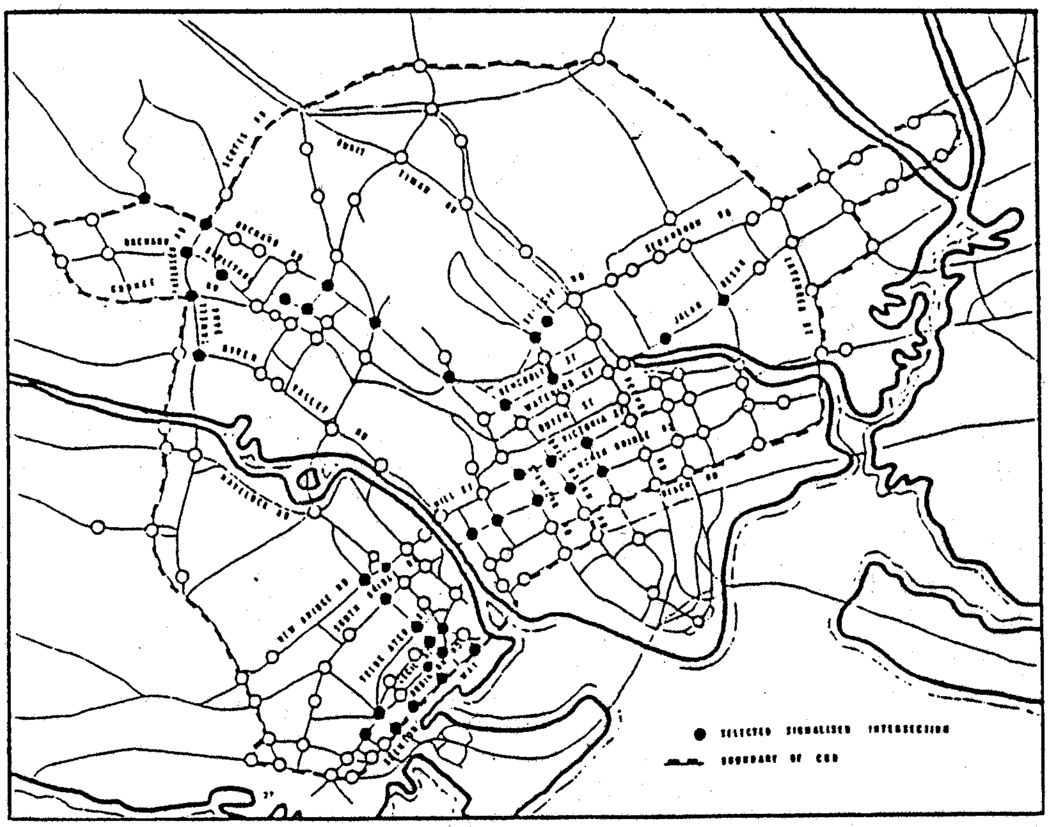

Figure 1. Central Business District of Singapore and Locations of Data Collection

COMPARATIVE ANALYSIS

Collected data on noise generating parameters was applied to calculate the predicted noise level in L_{10} (1-hour) from these 3 existing models. The comparison tests were made in order to examine the goodness of fit between the predicted L_{10} and the measured L_{10} from the collected field data. Two approaches were used to examine this relationship, namely, the graphical method and the paired t-test. The graphical method, which was the ploting of predicted noise values against the measured values to see whether how good these data points fitted into the 45 degree line or the equivalent line, This graphical test showed that all of these 3 models gave the over-estimated values of L_{10} in comparison to the field measurement values. The smallest deviation result of the predicted L_{10} values from the measured ones was from the Gilbert et al model with 97% of the data points falling within the 95% confidence interval band compared with 62% for the Edinburgh model and 2% for the Sheffield model.

The paired t-test was also carried out to provide the statistical test for the differences between the predicted results from the model and the measured result form the field. In this paired t-test, only one population about which to draw inferences that was the population of the differences between pairs of data. The difference (d) was first calculated and then using the statistical program to obtain the mean and standard deviation of the difference. The null hypothesis was $\mu_o = o$, that is the mean value of the difference between pairs of measured noise and predicted noise is equal to zero. The results from paired t-test at a significance level of 5% and 59 degree of freedom showed that the null hypothesis of these 3 models were rejected. Therefore, all of these 3 existing models could not be considered a good representation of the actual measured noise values from Singapore CBD. From this test, the Gilbert et al model gave the lowest t-value of 9.58 in comparison to 40.9 of the Edinburgh and 42.0 of the Sheffield models. The statistical testing results from this paired t-test on these 3 models were similar to those of the graphical tests. These results are shown in Table 1.

	Model		
Statistical Functions	Edinburgh	Sheffield	Gilbert
Mean	3.69	5.53	1.27
Standard Deviation	0.70	1.02	1.02
t-Value	40.9	42.0	9.58
R	0.75	0.76	0.73
R^2	0.56	0.58	0.53

Table 1. Results of Statistical Test of the Existing Models

DEVELOPMENT OF THE NEW MODEL

Improvement of Existing Models

The improvement was made to these 3 models through the statistical modification. Each parameter and group of parameters that used in these models was investigated by the correlation test against the measured noise level. Several additional parameters were also tested to see how well they could be included into the model. The modification of these 3 existing models were then performed through the stepwise multiple regression technique, and the results showed that the inverse of distance from kerbedge to facade ($1/d_r$) was the new parameter that should be added into the Modified Edinburgh and Modified Sheffield models in order to improve their performance. No change occured in the parameters of Modified Gilbert et al model. The coefficient of multiple determination R^2 of these modified models were improved substantially to about 0.80. Comparison of the details of existing and modified models are shown in Table 2.

Model	Existing Model	Modified Model
Edinburgh	55.2 + 9.18 log Q(1 + 0.09 PH) - 4.2 log Vy + 2.3 T	54.8 + 8.13 log Q(1 + 0.09 PH) - 3.09 log Vy + 4.66/d_f
Sheffield	51.51 + 10.5 log Q(1 + 0.04 PH) - 5.71 log (1 + 0.5 y)	52.7 + 8.12 log Q(1 + 0.04 PH) - 3.81 log(1 + 0.5 y) +3.24/d_f
Gilbert et al	43.3 + 11.02 log (L + 9M + 13H) - 0.43 y + 2.42/d_f	49.6 + 7.67 log (L + 9M + 13H) - 0.07y + 4.22/d_f

Table 2. Comparison of Existing Models and Modified Models for Predicted L_{10} (1-hour) Values

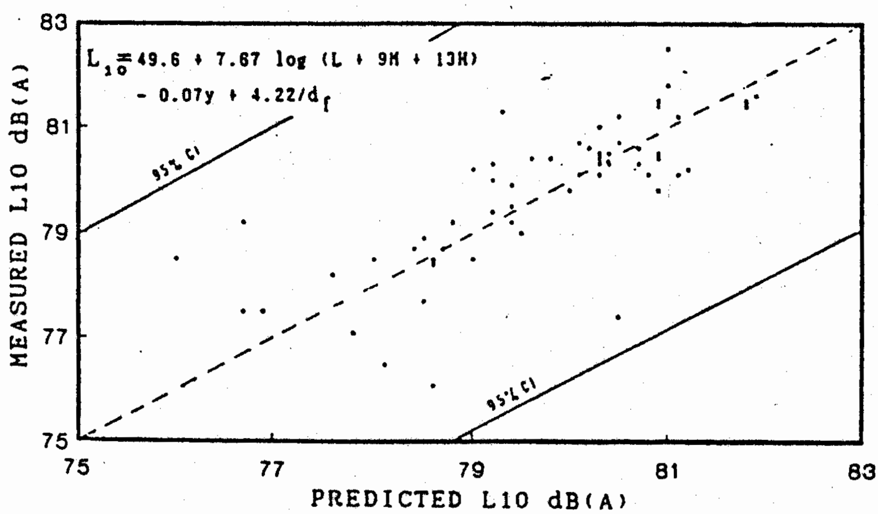

Figure 2. Plot of Measured L_{10} and Predicted L_{10} from the Modified 'Gilbert et al' Model

Modification of Selected Model

The Modified Gilbert et al model was then selected for further development in order to improve the prediction efficiency of the model. This was due to its best performance in the statistical test which provided the higheast $R^2 = 0.82$ and also the model's simplification. The plot of measured L_{10} and predicted L_{10} of the Modified Gilbert et al model from the graphical test is shown in Figure 2. Further modification was given to the Modified Gilbert et al model by the application of proportional weighting values from the Illinois Department of Transportation study into light, medium, and heavy vehicle parameters of the model together with changing the parameter of $1/d_f$ to $\log(d_f)$ which provided a higher correlation to the L_{10} noise level.

Statistical Analysis of the New Model

The stepwise regression approach of the linear multiple regression analysis was given to this new set of parameters, and the result of this "New" Modified model was as follows:

$$L_{10} = 51.5 + 8.51 \log(L + M + 3H) - 0.081\, y - 0.421 \log(d_f)$$

where: L_{10} = predicted traffic noise level in L_{10} (1-hour)

- L = volume of light vehicles (< 1525 kg), (veh/h)
- M = volume of medium goods vehicles (1525 - 4500 kg), (veh/h)
- H = volume of heavy goods vehicles (> 4500 kg), (veh/h)
- y = carriage width of road (metres)
- d_f = distance from kerbedge to facade (metres)

This New Modified model gave the R^2 of 0.84 for the ANOVA test of the model which was the highest value in comparison to those of other models. Results of this ANOVA test are shown in Table 3.

The graphical test and paired t-test of these 4 modified models were also investigated, and the results showed that the New Modified model gave the best fitted result to the 45 degree equivalent line in the graphical test, and also gave the smallest standard deviation of 0.57 and the t-value of 0.10 in the paired t-test. Results of these graphical test and paired t-test of the New Modified model are shown in Figure 3. and Table 4. respectively.

R^2	R	SE	F-Statistic	Prob.> F
0.84	0.92	0.6	2.21	0.1429

Table 3. Results of the ANOVA Test of the 'New Modified' Model

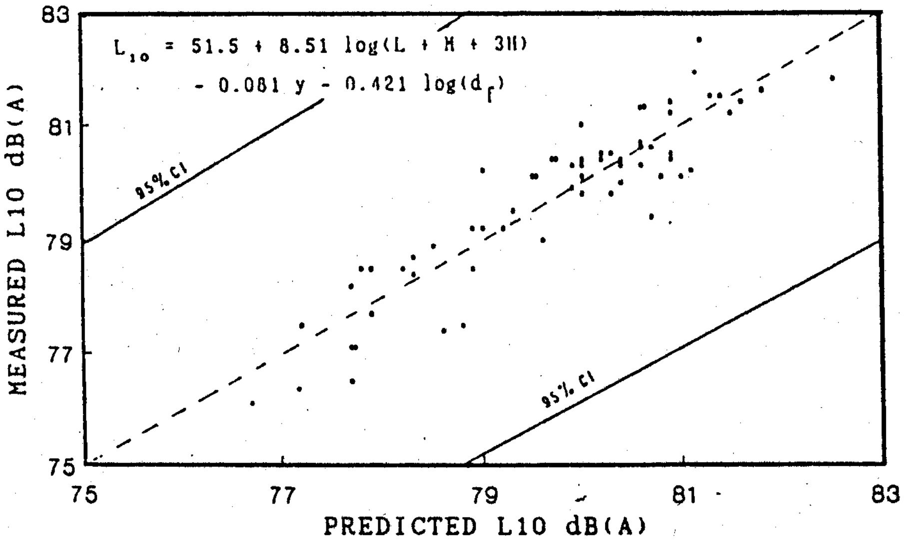

Figure 3. Plot of Measured L_{10} and Predicted L_{10} from the 'New Modified' Model

	Modified 'Gilbert et al' Model	'New' Modified Model
Mean	-0.02	0.007
Std Dev	0.76	0.57
t-Value	0.20	0.10

Table 4. Results of the Paired t-Test of the 'New Modified' Model

CONCLUSION

From the results of this study, it could be concluded that the "New" model which was developed in this study was the most suitable interrupted flow traffic noise forecasting model for the traffic in the central business district of Singapore. This model also provided a significant improvement in the overall accuracy of interrupted flow traffic noise prediction in comparison to the performance of the existing models.

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