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IMPROVEMENT OF BANGKOK'S HIGHWAY NOISE FORECASTING MODEL BY MODIFICATION OF TRAFFIC NOISE SOURCES

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1. INTRODUCTION

Traffic characteristics in Bangkok, Thailand especially types of vehicle in the traffic streamm, which are quite different from those of the western countries, created an error in forecasting of highway traffic noise in Thailand when the highway traffic noise models from those of the U.S. and U.K. were used in the forecasting processes. Therefore, improvement of these traffic noise model which were previously built in the western countries by using their vehicle types and characteristics was the most important thing to be done before it can be used to predict the highway traffic noise in this capital city of Thailand with a high accuracy.

2. OBJECTIVE OF THE WORK

The objective of this study was to improve the efficiency of Bangkok's highway traffic noise forecasting model, which was built as the uninterrupted flow traffic noise model, by mean of modification of the basic traffic noise sources from each type of vehicle running in the traffic stream. Since Bangkok traffic characteristic was quite different from those traffics in Europe and the U.S.A.[1][2][3] due to the high percentage of motorcycles and tuk-tuk (motor-tricycles) in the normal Bangkok traffic stream. From the previous studies, the U.S.'s FHWA model [4] showed the better results in predicting highway traffic noise in the uninterrupted flow condition in Thailand and Asian cities than the U.K.'s model from Europe.[5] Those findings leaded to the development of the first uninterrupted flow traffic noise model for traffic characteristics in Bangkok, Thailand.[6] This study, therefore, worked toward the improvement of this Bangkok's uninterrupted flow traffic noise model in order to increase its efficiency in highway traffic forecasting.

3. STUDY MATERIALS

The traffic noise data for each vehicle type was collected in the field from real road running condition. Types of vehicles under this study project were passenger car, heavy truck (≥10 wheels truck), medium & light truck (4 - 6 wheels truck), automobile, tuk-tuk (motor-tricycle), and motorcycle. The measurement of vehicle spot-speed [7] and traffic noise generated by this particular type of vehicle were measured on simultaneous basic on the test section of road under real vehicle running conditions.[5][6][8]

4. ANALYSIS OF BANGKOK TRAFFIC NOISE SOURCES

The relationship of vehicles traffic noises in dBA were plotted against vehicle spot-speed, and then the model of this basic traffic noise was analyzed for each type of vehicle. In this analysis, the previous type of log of speed model as introduced by FHWA for U.S. vehicles as reference energy mean emission level (L_o) was tested against the linear scale of speed model in relating to traffic noise level in L_{eq} for each category of vehicle by using regression analysis technique. The results of this analysis showed that linear model between noise level and speed of vehicle were the best fitted models for every type of vehicles in Bangkok, Thailand. The final results of this reference energy mean emission level (L_o) analysis for each type of vehicle in Bangkok' traffic were shown in comparison with L_o from FHWA in Table 1 .

Table 1. Reference Energy Mean Emission Level (L_o) for Each Type of Vehicles in Bangkok in Comparison with (L_o) of FHWA

Vehicle Type	Bangkok (L_o)$_{EI}$	FHWA (L_o)$_{EI}$
Automobile	$L_{o(AU)} = 55.95 + 0.134\ S$	$L_{o(AU)} = 38.1 \log S - 2.4$
Light & Medium Truck	$L_{o(MT)} = 66.43 + 0.089\ S$	$L_{o(MT)} = 33.5 \log S + 16.4$
Heavy Truck	$L_{o(HT)} = 73.81 + 0.035\ S$	$L_{o(HT)} = 24.6 \log S + 38.5$
Motorcycles	$L_{o(MC)} = 67.85 + 0.072\ S$	-
Tuk-Tuk (Motortricycle)	$L_{o(TT)} = 72.34 + 0.036\ S$	-

5. HIGHWAY NOISE MODEL MODIFICATION

5.1 Modification by Utilizing L_o of Bangkok Vehicles

Model of L_o from each type of vehicles in Bangkok which were analyzed as previously stated were used for reference energy mean emission level

(L_o) estimation of the basic vehicle traffic noise source to be input into the overall highway traffic noise model which could be described as the following.

$$L_{eq}(\text{total}) = 10\,\text{Log}\left(10^{L_{eq(near)}/10} + 10^{L_{eq(far)}/10}\right) \qquad (1)$$

where :

$$L_{eq}(\text{near}), L_{eq}(\text{far}) = 10\,\text{Log}\left(10^{L_{eq(AU)}/10} + 10^{L_{eq(MT)}/10} + 10^{L_{eq(HT)}/10} + 10^{L_{eq(MC)}/10} + 10^{L_{eq(TT)}/10}\right) \qquad (2)$$

and $$L_{eq}(\text{1-hour})_i = (L_o)_{Ei} + 10\,\text{Log}(N_i \pi D_o / S_i T) + 10\,\text{Log}(D_o / D)^{1+\alpha} + 10\,\text{Log}[\Psi_\alpha(\phi_1, \phi_2)/\pi] + \Delta S \qquad (3)$$

where :

$L_{eq}(\text{total})$ = Total highway traffic noise level in Leq (dBA)
$L_{eq}(\text{near}), L_{eq}(\text{far})$ = Traffic noise level from near-side & far-side of highway, respectively
$L_{eq}(\text{1-hour})_i$ = Equivalent noise level in 1 hour period for vehicle class i, (dBA)
$(L_o)_{Ei}$ = Reference energy mean emission level term
$10\,\text{Log}(N_i \pi D_o / S_i T)$ = Traffic flow adjustment term
$10\,\text{Log}(D_o / D)^{1+\alpha}$ = Distance adjustment term
$10\,\text{Log}[\Psi_\alpha(\phi_1, \phi_2)/\pi]$ = Finite roadway adjustment term
ΔS = Shielding adjustment term
i = Each class of vehicles

5.2 Modification by Application of Motorcycle and Tuk-Tuk in FHWA's L_o Classification

This part of study utilized the model of L_o for 3 categories of vehicle as given by FHWA, namely, light vehicle, medium vehicle, and heavy vehicle. The modification was then done by application of motorcycle and tuk-tuk, which were the two popular vehicles in Bangkok's normal traffic stream, into the heavy truck classification in estimating for reference energy mean emission level. This application was done according to the previous research in Singapore [5] which found that when motorcycles which were the popular vehicles in Asian city were grouped into the heavy vehicle class of FHWA's L_o, they could provide the best fit result in the prediction of highway traffic noise in Asian city.

This model could be mathematically described as the followings. The total highway noise level in L_{eq} (1-hour) was the same as shown in equation (1), and the equivalent noise level in 1 hour period for vehicle class i was also the same as in equation (2). But the terms of L_{eq}(near) and L_{eq}(far) for this modified FHWA model were applied only to 3 classes of vehicles as automobile, light & medium truck, and heavy truck with motorcycle and tuk-tuk were classified into the heavy truck group. These two terms could be stated as the following.

$$L_{eq}(\text{near}), L_{eq}(\text{far}) = 10\text{Log}(10^{L_{eq(AU)}/10} + 10^{L_{eq(MT)}/10} + 10^{L_{eq(HT)}/10}) \quad \text{\_\_\_\_\_\_ (4)}$$

6. TESTING OF THE MODELS

These two modification models were comparatively tested by using the paired t-test technique in order to see how good these two models could be fitted to the observed highway traffic noise data on Bangkok's highway. [9]

The testing result showed that the model that utilized L_o from Bangkok vehicle noise sources analysis gave the statistical significant in fitting to the highway traffic noise data in Bangkok for both of 5% and 10% significant levels in the two tails test of the paired t-test technique. In the same test, the model which utilized the base L_o from FHWA with the application of motorcycle and tuk-tuk into the heavy vehicle class could not provide any statistical significant in fitting to the observed data of Bangkok highway traffic noises. Details of this paired t-test analysis were shown in Table 2.

Table 2. Results from Paired t-test Analysis of the Models

Model with Bangkok $(L_o)_{Ei}$	Model with FHWA $(L_o)_{Ei}$ and Motorcycle and Tuk-Tuk in Heavy Truck Class
d = - 0.167 SE = 1.223 n = 62 t-value = - 1.075 (at α = 5%, DF = 61) $\pm$ t-table $_{\alpha/2, DF}$ = $\pm$ 2.00 (at α = 10%, DF = 61) $\pm$ t-table $_{\alpha/2, DF}$ = $\pm$ 1.67	d = 0.616 SE = 1.166 n = 62 t-value = 4.161 (at α = 5%, DF = 61) $\pm$ t-table $_{\alpha/2, DF}$ = $\pm$ 2.00 (at α = 10%, DF = 61) $\pm$ t-table $_{\alpha/2, DF}$ = $\pm$ 1.67

where : $(L_o)_{Ei}$ = Reference energy mean emission level of vehicle class i
i = Each class of vehicles (i = 5 classes for Bangkok L_o, i = 3 classes for modified FHWA L_o)
d = Mean of the difference values between observed and predicted noise levels
SE = Standard error of the difference values between observed and predicted noise levels

n = Number of paired samples
α = Significant level
DF = Degree of freedom (n-1)

7. CONCLUSION

From this study, it could be concluded that the linear relationship between noise level in Leq and speed of vehicle were the type of model that best fit to highway traffic noise data in Bangkok in the analysis of reference energy mean emission level (L_o) for each type of vehicles in Bangkok traffic stream which included motorcycles and tuk-tuk. Results from this research project also showed the significant improvement in the forecasting of highway traffic noise in Bangkok by utilization of these new Bangkok's reference energy mean emission level (L_o) into the highway traffic noise model. This newly modified model gave the statistical significant in fitting to the observed traffic noise data on Bangkok highway in the paired t-test for both of the 5% and 10% significant levels.

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