Abstract: - The basic noise model is the primary noise model for each vehicle type in the traffic stream. It is used as a basic model in the development of the main highway traffic noise simulation model of the whole highway section. This basic noise model is normally different from country to country due to the characteristics of local vehicles and driving conditions of each particular country. This study aims at the developing of basic noise model for each vehicle type in Thailand. These basic noise models based on the equivalent sound pressure level in 20 seconds time period – $L_{eq}(20s)$ for free flow traffic condition. In this study, nine vehicle types on highway in Thailand are used. The $L_{eq}(20s)$ can cover the range of noise levels of all vehicle types better than the previous models, which are in form of $L_{max}$ and $L_{eq}(10s)$. Therefore, this new analysis technique of basic noise model can predict noise level of each vehicle type closely to real situation on highway. It can also be applied to build the basic noise model of vehicle in other places or countries.


1 Introduction
Road transportation plays an important role for social and economic growth in Thailand. Due to the social and economic extension to out-bound area, the construction of road network is rising. This type of road provides the high speed and continuous traffic flow condition such as highway, expressway, and motorway. Traffic noise is one of the environmental problems of highway projects affecting the communities in the vicinity of highway, which have to be seriously concerned especially for those of high speed and high volume roadways [1, 2, 3]. The efficient study of highway traffic noise impact is to find the appropriate way to predict traffic noise and select the measures for solving this problem in advance prior to the construction of highway project.

The Federal Highway Administration of the U.S. Department of Transportation developed the FHWA Highway Traffic Noise Prediction Model since 1978 [4]. The basic noise model or reference energy mean emission level (REME) of this traffic noise prediction model was based on the maximum sound pressure level (SPL) or the $L_{max}$ which provided the overestimated traffic noise level on highway in Thailand. This FHWA model also utilized only three types of vehicle, which could not represent local vehicular traffic on Thailand’s highways [5]. From this reason, the further development of basic noise model is concentrated on the average energy mean emission level of running vehicle using the Equivalent Sound Level ($L_{eq}$) instead of $L_{max}$ of each vehicle. The average noise level result from this model is much better match with existing situations of Thailand [6, 7, 8, 9]. In 1998, the John A. Volpe National Transportation Systems Center developed the FHWA Traffic Noise Model (TNM) to replace the 1978 FHWA model [10]. Basing on the 1978 FHWA model, this FHWA TNM model added in calculation details that give more accuracy, and also provided basic noise model of reference energy mean emission level for five vehicle types [4, 10]. However, reference energy mean emission level or
basic noise level have to be investigated for specific area of interest because the default basic noise level in TNM itself could not be used as the representative in every case or in the other countries. Therefore, this study is aimed at the developing of new $L_{eq}$ 20 seconds approach for each vehicle type on highways of Thailand.

2 Noise Analysis in form of $L_{eq}(20s)$

Even through the basic noise model based on equivalent sound levels in 10 seconds - $L_{eq}(10s)$ are currently applied in the highway traffic noise analysis and prediction in Thailand that can provide a good agreement with the field measuring results [8, 9], the measurement technique of vehicular noise in $L_{eq}(10s)$ may cause some errors and uncertainty. This is because a noise observer who controls a sound level meter has to approximate the time to press a record button on sound level meter at 5 seconds before the pass by vehicle reach the perpendicular position to the sound level meter. In general, each person presses the recording button not in the same time. According to field observation, observers sometimes press the button too early or too late. This will cause a measurement error in $L_{eq}(10s)$. Therefore, the novel basic noise index in form of the equivalent sound levels in 20 seconds - $L_{eq}(20s)$ is then initiated to solve the mentioned problems. In addition, the $L_{eq}(20s)$ can cover the range of noise levels of all vehicle types more than index of $L_{eq}(10s)$, especially long-body vehicular such as buses and semi-trailer trucks as shown in Fig.1.

The technique of measuring $L_{eq}(20s)$ is to eliminate the unreliable judgment of an observer. An observer will press the recording button when a vehicle passes in front of the noise meter in $L_{eq}(10s)$ as shown in Fig.2. Therefore, $L_{eq}(20s)$ that is starting from -10 s to +10 s is equal to $L_{eq}(10s)$, which get direct from mode in noise meter, since the noise characteristics are symmetric. This relationship can be mathematically described in the following equations.

$L_{eq}$ in the period $t_1$ to $t_2$ [2],

$$L_{eq} = 10 \log \left( \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p(t)^2}{p_{ref}} dt \right) \quad (1)$$

From the figure of $L_{eq}(20s)$,

For $L_{eq}(10s)$, $t_1 = 0$, $t_2 = +10$;

$$L_{eq}(10s) = 10 \log \left( \frac{1}{10} \int_{0}^{10} \frac{p(t)^2}{p_{ref}} dt \right) \quad (2)$$

Transform to 20 sec., $t_1 = -10$, $t_2 = +10$;

$$L_{eq}(20s) = 10 \log \left( \frac{1}{20} \int_{0}^{10} \frac{p(t)^2}{p_{ref}} dt \right) \quad (3)$$

Eq(3) then becomes

$$L_{eq}(20s) = 10 \log \left( \frac{1}{10} \int_{0}^{10} \frac{p(t)^2}{p_{ref}} dt \right) \quad (4)$$

Therefore,

$$L_{eq}(20s)|_{t_1=-10, t_2=10} = L_{eq}(10s)|_{t_1=0, t_2=10} \quad (5)$$

where:

$L_{eq}(10s)$ = the equivalent sound levels in 10 seconds (dBA)

$L_{eq}(20s)$ = the equivalent sound levels in 20 seconds (dBA)

$p(t)$ = instantaneous sound pressure at time $t$ (N/m$^2$)

$p_{ref}$ = reference sound pressure of 2x10$^{-5}$ N/m$^2$

t$_2$ - t$_1$ = duration time interest (seconds)

\[\text{Fig.1 Diagram of } L_{eq}(20s) \text{ of a pass-by individual vehicle.}\]
### 3 Data for Analysis of Basic Noise Level

The basic noise level model is used as the first prediction of traffic noise from an individual type of vehicle on the highway. The simultaneously noise data on individual running vehicle passing by the noise level meter is collected with the spot speed of that particular vehicle for each type of vehicles. The noise level meter is placed at the reference distance of 15 m perpendicular to the centerline of traffic lane [4, 10] with the meter’s height of 1.20 m from ground surface. In this study, the vehicle types on the highway in Thailand are divided into 9 types, namely, Automobile (AU), Light Truck (LT), Medium Truck (MT), Heavy Truck (HT), Full-Trailer (FT), Semi-Trailer (ST), Motorcycle (MC), and Tri-motorcycle (Tuk Tuk - TT).

The index for this noise measurement is equivalent sound level - L\text{eq}, which is the energy mean emission level in the period of measurement. This study use the measurement period of 20 seconds - L\text{eq}(20s), which is the time that can cover the period of noise generating from individual vehicle passing by the noise meter. This technique based on the measurement of mean energy emission from a passing by vehicle during the 20 seconds period. Therefore, it can overcome the real world problem of multi-point or multi-pole sources of noise from vehicle running on highway especially those of the long body vehicles such as trucks and buses. Numbers of data collection for each vehicle type in this study are shown in Table 1.

### Table 1 Number of data collection for each vehicle type analysis

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Number of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile - AU</td>
<td>308</td>
</tr>
<tr>
<td>Light Truck - LT</td>
<td>293</td>
</tr>
<tr>
<td>Medium Truck - MT</td>
<td>193</td>
</tr>
<tr>
<td>Heavy Truck - HT</td>
<td>225</td>
</tr>
<tr>
<td>Full-Trailer - FT</td>
<td>214</td>
</tr>
<tr>
<td>Semi-Trailer - ST</td>
<td>215</td>
</tr>
<tr>
<td>Motorcycle - MC</td>
<td>196</td>
</tr>
<tr>
<td>Bus - BUS</td>
<td>194</td>
</tr>
<tr>
<td>Tri-motorcycle - TT</td>
<td>211</td>
</tr>
</tbody>
</table>

### 4 Basic Noise Equation of Each Vehicle Type in Thailand

The data on basic noise level for each vehicle type, which consist of equivalent noise level in 20 seconds - L\text{eq}(20s) and the spot speed of that vehicle is then analyzed by using linear regression technique in order to identify the relationship between L\text{eq}(20s) and log of speed. Numbers of data sets for being used in each type of vehicles analysis are ranging from 193 to 308 sets. In this study, logarithmic of speed gives the best correlation to vehicular noise level in L\text{eq}(20s) for all of vehicle types. These basic noise level equations are shown in Table 2 and the plot of relationship between L\text{eq}(20s) and speed for each vehicle type is also shown in Fig.3.

### Table 2 The basic noise model for all vehicle types in form of L\text{eq}(20s)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Basic Noise Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile - AU</td>
<td>( y = 31.108 \log(x) + 3.364 )</td>
</tr>
<tr>
<td>Light Truck - LT</td>
<td>( y = 21.549 \log(x) + 25.169 )</td>
</tr>
<tr>
<td>Medium Truck - MT</td>
<td>( y = 10.704 \log(x) + 47.086 )</td>
</tr>
<tr>
<td>Heavy Truck - HT</td>
<td>( y = 12.277 \log(x) + 49.695 )</td>
</tr>
<tr>
<td>Full-Trailer - FT</td>
<td>( y = 15.882 \log(x) + 43.820 )</td>
</tr>
<tr>
<td>Semi-Trailer - ST</td>
<td>( y = 11.349 \log(x) + 52.654 )</td>
</tr>
<tr>
<td>Motorcycle - MC</td>
<td>( y = 32.575 \log(x) + 2.546 )</td>
</tr>
<tr>
<td>Bus - BUS</td>
<td>( y = 20.977 \log(x) + 31.103 )</td>
</tr>
<tr>
<td>Tri-motorcycle - TT</td>
<td>( y = 29.181 \log(x) + 16.573 )</td>
</tr>
</tbody>
</table>

\( y : L\text{eq}(20s) \) (dBA), \( x : \) Speed (km/h)
The Basic Noise Levels as a Function of Speed (in form of $L_{eq20s}$)

From the results of this analysis, the basic noise model for nine types of vehicle on highways in Thailand can be built based on the new and more effective technique of $L_{eq}(20s)$. These basic noise models are expected to be used as the primary vehicular noise model in the further development of the more efficiency highway traffic noise prediction model for Thailand.

5 Conclusion

In this study, the new method of basic noise level analysis for each vehicle type in Thailand is applied in order to build the new set of basic noise models for nine vehicle types in Thailand. This basic noise analysis technique is based on the equivalent sound level in the time period of 20 seconds-$L_{eq}(20s)$ of vehicular noise from the highway. This $L_{eq}(20s)$ is the real time measurement of the average energy mean emission level of the entire noise path of individual vehicle that are normally not the pure single point or monopole source. Therefore, it can provide a better representation of the overall energy emission from the passing vehicle and cover the whole energy emission more than previous modek, which is in term of $L_{max}$ and $L_{eq}(10s)$. This technique can also be applied to build the basic noise and traffic noise model for highway in the other countries with similar features.

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References: