STUDY ON THE EFFECT OF THE LONGITUDINAL GRADIENT OF CITY TRAFFIC NOISE

Yuan Minmin, Wang Yanqin Wei Xianwei Wu Xiaoning

1. Research Institute of Highway Ministry Transport, Beijing, 10088, China
2. State Environment Protection Engineering Centre of Traffic Noise Control, Beijing, 10088, China
3. Key Lab of Traffic Environment Protection Technology Ministry of Communications, PRC, Beijing, 10088, China

e-mail: mm.yuan@rioh.cn

The noise has a great influence on the environment. Highway traffic noise is a part of environmental noise. When the car downhill, because of the change of parameters caused by the longitudinal gradient change of engine power, speed, resulting in the generation of noise is different from usual. This paper studies the Chinese part of North China area highway different longitudinal gradient effects on vehicle noise. Through the comparison with the other existing models of longitudinal slope, gradient model can get for the noise influence vehicle driving model in North China.

1. Introduction

With the more requirement of environment comfortable, traffic noise is a key factor of environment in urban area. Too many people suffer noise effects all the time. As the one factor of the many factors of traffic noise, noise caused by longitudinal gradient influence is not to be neglected. It cannot influence environment when vehicle static, but it brings even more noise as vehicle operation.

Many countries research their own traffic noise conditions and obtain their experimental models. The main international traffic noise evaluation criterion includes FHWA of American, RLS90 of Germany, ASJ Model of Japan and JRC of European. These models have different calculation methods and evaluation methods. In current stage, Chinese traffic noise evaluation standard model is mainly refer to FHWA of USA. In comparison with other models, these model is aim at equivalent sound pressure level per hour, and others are about vehicle source strength. In all models, the noise corrected value of gradient influence is only depend on environment factors, which are not related to the calculation method. So each gradient corrected value can be compared in this case.

2. Gradient modified model

In this section, 2.1 introduces sever models about gradient noise. Each of them is different. Because of Chinese models is refer to USA, so it is the same to a certain degree.
2.1 standards

2.1.1 Technical Guidelines for Noise Impact Assessment (HJ 2.4-2009) and Specifications for Environmental Impact Assessment of Highways (JTG B03-2006)

Both models are refer to FHWA\(^1\), with slightly different. In HJ 2.4-2009, the noise correction value of slope is express as:\(^2\):

Light Vehicle: \( \Delta L_{\text{grad}} = 98 \times s \quad \text{dB}(A). \) (1)

Medium Vehicle: \( \Delta L_{\text{grad}} = 73 \times s \quad \text{dB}(A). \) (2)

Heavy Vehicle: \( \Delta L_{\text{grad}} = 50 \times s \quad \text{dB}(A). \) (3)

Where \( s \) represents slope.

This model is refer to FHWA model of USA. It is equivalent hour sound pressure level for certain type vehicle. This model is different to the models which focus on single vehicle source used in Japan or European

2.1.2 Specifications for Environmental Impact Assessment of Highways\(^3\)

Light Vehicle: \( L_{\text{os}} = 12.6 + 34.73 \log V_s + \Delta L_{\text{sur}}. \) (4)

Medium Vehicle: \( L_{\text{os}} = 8.8 + 40.48 \log V_s + \Delta L_{\text{grad}}. \) (5)

Heavy Vehicle: \( L_{\text{os}} = 22.0 + 36.32 \log V_s + \Delta L_{\text{grad}}. \) (6)

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>(dB)</th>
<th>Slope (%)</th>
<th>(dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\leq 3)</td>
<td>0</td>
<td>6-7</td>
<td>+3</td>
</tr>
<tr>
<td>4-5</td>
<td>+1</td>
<td>&gt;7</td>
<td>+5</td>
</tr>
</tbody>
</table>

In this standard, the corrected value is only valid for medium and heavy vehicle, it ignore the influence by light vehicle.

2.1.3 RLS90

RLS90 is the traffic noise model used by Germany\(^4\). Commercial software Cadna/A also uses it. In this model, the correction value of gradient is express as\(^1\):

\( \Delta L_{\text{grad}} = 0.6 \times |s| - 3 \quad |s| > 5\% . \) (7)

\( \Delta L_{\text{grad}} = 0 \quad |s| \leq 5\% . \) (8)

Where, \( s \) represents as slope.

In the model of RLS90, it considers that noise change value is proportion to slope when slope less than 5 angle.

2.1.4 ASJ RTN-Model 2008

In Japan ASJ model, Traffic noise power level correction value is defined as\(^5\):

\( \Delta L_{\text{grad}} = 0.14s + 0.05s^2. \) (9)

Where, \( s \) represents as slope.

Compared with other models, ASJ model is aims at heavy vehicles, it ignores influence of light vehicles.
2.1.5 JRC model

In European JRC model\(^6\), vehicle types are defined as light, medium, heavy, which have different models. The corrected values as follows:

**Light Vehicle**

\[
\Delta L_{\text{grad}} = \begin{cases} 
\frac{\operatorname{Min}(12\%; -s) - 6\%}{1\%} & s < -6\% \\
0 & -6\% \leq s \leq 2\% \\
\frac{\operatorname{Min}(12\%; s) - 2\%}{1.5\%} \times \frac{v_m}{100} & s > 2\%
\end{cases}
\]

**Medium Vehicle**

\[
\Delta L_{\text{grad}} = \begin{cases} 
\frac{\operatorname{Min}(12\%; -s) - 4\%}{0.7\%} \times \frac{v_m - 20}{100} & s < -4\% \\
0 & -4\% \leq s \leq 0\% \\
\frac{\operatorname{Min}(12\%; s)}{1\%} \times \frac{v_m}{100} & s > 0\%
\end{cases}
\]

**Heavy Vehicle**

\[
\Delta L_{\text{grad}} = \begin{cases} 
\frac{\operatorname{Min}(12\%; -s) - 4\%}{0.5\%} \times \frac{v_m - 10}{100} & s < -4\% \\
0 & -4\% \leq s \leq 0\% \\
\frac{\operatorname{Min}(12\%; s)}{0.8\%} \times \frac{v_m}{100} & s > 0\%
\end{cases}
\]

2.1.6 CRTN

In CRTN model, the corrected value is simply defined as \(\Delta L_{\text{grad}} = 0.3 \times s\).

2.2 main factors

The sources of noise caused by gradient are mainly influenced by two ways. The one is the slope of the gradient, and the other is the operation velocity.

From all the running state of traffic noise model and the auto show, the traffic noise model, correction caused by longitudinal slope values, there are two main sources: 1), longitudinal slope gradient of \(s\); 2), the speed of the vehicle \(v\).

The car engine speed rpm and speed is proportional to \(v\). When the gear unchanged, speed determines the speed. The car uphill, if the engine speed remains unchanged, the rate constant. But because the upgrade process, driving force increases for the car, so the car driving torque increased; and because the torque and the driving force is proportional to the power of engine, and provides is proportional to torque, so the power and slope is directly related to the \(s\) engine.

So the corrected value can be expressed as \(\Delta L_{\text{grad}} \propto as + bs^2\), where \(a, b\) is coefficient of polynomial, \(s\) is the slope of gradient. so the expression is

\[
\Delta L_{\text{grad}} = (as + bs^2)v.
\]

3. Test

Using the regression analysis, the basic model of gradient can be calculated through difference of velocities.
3.1 Light Vehicle

The corrected value of light vehicle is shown as Figure 1. In the figure, blue points are measurement data, red points is the average of measurement data, where red curves is regression curves of red points.

\[ \Delta L = 0.056s + 0.0197s^2. \]  \hspace{1cm} (14)

\[ \Delta L = 0.1075s + 0.0315s^2. \]  \hspace{1cm} (15)

\[ \Delta L = 0.1375s + 0.0415s^2. \]  \hspace{1cm} (16)

Where s represents slope.

3.2 Medium Vehicle

The corrected value of medium vehicle is shown as figure 2. In the figure, blue points are measurement data, red points it the average of measurement data, where red curves is regression curves of red points.
Figure 2 The relationship between the longitudinal gradient and medium car noise changes

The expression of different velocities are:

30km/h: $\Delta L = 0.0922s + 0.0334s^2$. \hspace{1cm} (17)

70km/h: $\Delta L = 0.1487s + 0.0464s^2$. \hspace{1cm} (18)

100km/h: $\Delta L = 0.1687s + 0.0564s^2$. \hspace{1cm} (19)

Where $s$ represents slope.

3.3 Heavy Velocity
Figure 3 The relationship between the longitudinal gradient and heavy car noise changes

The corrected value of medium vehicle is shown as figure 3. In the figure, blue points are measurement data, red points are the average of measurement data, where red curves is regression curves of red points.

The expression of different velocities are:

\[ 30\text{km/h}: \Delta L = 0.1190s + 0.0392s^2. \tag{20} \]
\[ 70\text{km/h}: \Delta L = 0.1572s + 0.0694s^2. \tag{21} \]
\[ 100\text{km/h}: \Delta L = 0.1672s + 0.0794s^2. \tag{22} \]

Where \( s \) represents slope.

Through the comparisons, it known that the variables \( a \) and \( b \) of expression \( \Delta L_{\text{grad}} = \left( as + bs^2 \right) v \) are related to the velocities of operation.

4 Result

From above, the noise change value and slope of regression analysis at different speed, obtain a set of coefficient. The coefficient under different speed is not the same, and increases with the increase of velocity. Therefore, noise changes caused by longitudinal slope value associated with the vehicle running speed, and this effect is large and cannot be ignored.
Figure 4 The light car longitudinal slope noise correction coefficient

In Figure 4, blue '*' represents the coefficient at different speeds, red is the use of regression analysis of relationship between velocity and coefficient of. From the graph shows, small vehicles, the relationship between first-order coefficient and rate of about 0.00145, two order coefficient is about 0.00044. So the small vehicle longitudinal slope noise correction value can be written as:

$$\Delta L_{\text{grad},sl} = 0.00145s v + 0.00044s^2 v.$$  \hspace{1cm} (23)

In Figure 5, blue '*' represents the coefficient at different speeds, red is the use of regression analysis of relationship between velocity and coefficient of. From the graph shows, medium-sized vehicle, the relationship between first-order coefficient and rate of about 0.00190, two order coefficient is about 0.00063. So the small vehicle longitudinal slope noise correction value can be written as:

$$\Delta L_{\text{grad},sm} = 0.00190s v + 0.00063s^2 v.$$  \hspace{1cm} (24)

Figure 5 The medium car longitudinal slope noise correction coefficient

Figure 6 The heavy car longitudinal slope noise correction coefficient
In Figure 6, blue "*" represents the coefficient at different speeds, red is the use of regression analysis of relationship between velocity and coefficient of. From the graph shows, medium-sized vehicle, the relationship between first-order coefficient and rate of about 0.00198, two order coefficient is about 0.00088. So the small vehicle longitudinal slope noise correction value can be written as:

$$\Delta L_{grad,h} = 0.00198s + 0.00088s^2v.$$  \hspace{1cm} (25)

Finally, the model can be expressed as:

$$\Delta L_{grad} = \begin{cases} 
0.00145s + 0.00044s^2v & \text{Light} \\
0.00190s + 0.00063s^2v & \text{Medium} \\
0.00198s + 0.00088s^2v & \text{Heavy}
\end{cases}.$$ \hspace{1cm} (26)

Where $s$ represents slope and $v$ represents velocity.

5. Conclusion

This paper from the existing prediction models of longitudinal gradient correction model, the basic form the gradient noise correction value model is determined by fitting the model; in a large number of data obtained in Beijing city and its surrounding measurement, calculation of different speed, number system noise correction model; finally, considering the influence of velocity on correction model, the regression analysis between the vehicles of the same type, the coefficient of longitudinal slope noise correction model.

This model is applied to Beijing and its surrounding area, such as to extend to other areas, also need to test further.

REFERENCES

2 Technical Guidelines for Noise Impact Assessment (HJ 2.4-2009)
3 Specifications for Environmental Impact Assessment of Highways (JTG B03-2006)
4 Additional Technical Regulations concerning Noise Protection Walls (ZTV-Lsw 88).