Construction of Environmental Impact Model for Vehicle Driving in Qinghai Tibet Plateau

Fuzhao Wang, Yi Liu*

Army Academy of Armored Forces, Bengbu, China, 233050

Keywords: Qinghai Tibet Plateau; Influencing factors; Weight score; Influence model

Abstract: The main influencing factors of vehicle driving on the Qinghai Tibet Plateau include temperature, humidity, wind speed, high altitude, sand dust, high blowing snow, road conditions, etc; The road condition can be divided into plateau ordinary gravel road, Gobi frozen land, beach pebble land, mountain washboard land and so on; The weight of environmental impact index is evaluated, and the weight value of each influencing factor is scored; Combined with the main influencing factors and weights, the driving environment impact model of vehicles in the Qinghai Tibet Plateau is established.

1. Temperature effect

Environmental temperature is one of the most important environmental factors in the use of motor vehicles on the Qinghai Tibet Plateau, which can be expressed by \([C_{\text{min}}^{\text{wd}}, C_{\text{max}}^{\text{wd}}]\). \(C_{\text{min}}^{\text{wd}}\) is the lowest temperature that has the greatest impact on motor vehicles; \(C_{\text{max}}^{\text{wd}}\) represents the highest temperature that has the greatest impact on it. That is to say, the ideal working temperature is the value between the two, when the temperature decreases or increases, it will affect its best performance. Therefore, the membership function of ambient temperature can be obtained by selecting the membership degree of normal distribution, the mean value of the constraint condition and the variance being 1/6 of the constraint condition difference is: \(C_{\text{max}}^{\text{wd}}\) represents the maximum temperature used by heavy equipment, \(C_{\text{min}}^{\text{wd}}\) is the minimum temperature used for heavy equipment, \(\mu\) average temperature of equipment in normal use, \(\sigma\) is the variance. [1]

\[
C_{\text{min}}^{\text{wd}} = 46, C_{\text{max}}^{\text{wd}} = -43, \mu = 12.5, \sigma = 17.5
\]

is known. The results are as follows:

\[
f_{\text{wd}}(x) = 1 - \frac{1}{17.5\sqrt{2\pi}} \exp\left[\frac{-1}{2} \times \left(\frac{x-12.5}{17.5}\right)^2\right] - g_{\text{wd}}(C_{\text{max}}^{\text{wd}})
\]

Suppose that the temperature range of a motor vehicle is \([C_{\text{min}}^{\text{wd}}, C_{\max}^{\text{wd}}]\), take the step size of 1. The weight in \([C_{\text{min}}^{\text{wd}}, C_{\max}^{\text{wd}}]\) range should be 2 times of other weights. The influence of temperature is calculated as follows:

\[
f_{\text{WD}}(x) = \frac{f_{\text{wd}}(C_{\text{min}}^{\text{wd}}) + \cdots + 2 \times f_{\text{wd}}(C_{\text{min}}^{\text{wd}}) + \cdots + 2 \times f_{\text{wd}}(C_{\text{max}}^{\text{wd}}) + \cdots + f_{\text{wd}}(C_{\text{max}}^{\text{wd}})}{C_{\text{max}}^{\text{wd}} - C_{\text{min}}^{\text{wd}} + 1}
\]

2. Humidity effect

It is known that [2], \(C_{\text{max}}^{\text{wd}} = 95, C_{\text{min}}^{\text{wd}} = 10, \mu = 52.5, \sigma = \frac{85}{6}\)
\[
g_{sd} (y) = \frac{1}{85/6 \sqrt{2\pi}} \exp \left[ -\frac{1}{2} \left( \frac{(y-52.5)^2}{(85/6)^2} \right) \right]
\]
\[
f_{sd} (x) = 1 - \frac{g_{sd} (x) - g_{sd} (Zs_{\text{max}})}{g_{sd} (\mu) - g_{sd} (Zs_{\text{max}})}
\]

Suppose that the humidity range of the motor vehicle used in a certain Qinghai Tibet plateau area is \([c_{\text{min}}^{sd}, c_{\text{max}}^{sd}]\), and the step size is 1, the weight in \([c_{\text{min}}^{sd}, c_{\text{max}}^{sd}]\) range should be 2 times of other weights. The influence of temperature is calculated as follows:
\[
f_{SD} (x) = \frac{f_{sd} (C_{\text{min}}^{sd}) + \cdots + 2 \times f_{sd} (c_{\text{min}}^{sd}) + \cdots + 2 \times f_{sd} (c_{\text{max}}^{sd}) + \cdots + f_{sd} (C_{\text{max}}^{sd})}{C_{\text{max}}^{sd} - C_{\text{min}}^{sd} + 1}
\]

3. Influence of wind speed

Due to dust, to meet the minimum visibility requirements, according to experience, motor vehicles can adapt to the ground wind speed of 32m/s in normal use[3]. Obviously, it has the following formula:
\[
f_{fs} (x) = \begin{cases} 
0 & 0 \leq x < 8 \\
\frac{(x+8)/2}{32} & 8 \leq x < 15 \\
\frac{(x+15)/2}{32} & 15 \leq x < 21 \\
\frac{(x+21)/2}{32} & 21 \leq x \leq 32 
\end{cases}
\]

Suppose that the wind range of motor vehicle is \([c_{\text{min}}^{fs}, c_{\text{max}}^{fs}]\), the humidity range of motor vehicle used in a certain Qinghai Tibet plateau area is \([c_{\text{min}}^{fs}, c_{\text{max}}^{fs}]\), and the step size is 0.5. The weight in \([c_{\text{min}}^{fs}, c_{\text{max}}^{fs}]\) range should be twice of other weights. The influence of temperature is calculated as follows:
\[
f_{FS} (x) = \frac{f_{fs} (C_{\text{min}}^{fs}) + \cdots + 2 \times f_{fs} (c_{\text{min}}^{fs}) + \cdots + 2 \times f_{fs} (c_{\text{max}}^{fs}) + \cdots + f_{fs} (C_{\text{max}}^{fs})}{C_{\text{max}}^{fs} - C_{\text{min}}^{fs} + 0.5}
\]

4. Degree of high altitude

Because the highest altitude that motor vehicles can adapt to is 5000m, obviously, \(\xi = 0\)
\[
f_{h} (x) = \begin{cases} 
0 & 0 \leq x < 1600 \\
1 - \frac{x-1600}{H_{\text{max}} - 1600} & 1600 \leq x \leq 5000 \\
0 & 5000 < x 
\end{cases}
\]

Suppose that the altitude range of motor vehicles is \([c_{\text{min}}^{h}, c_{\text{max}}^{h}]\), and the humidity range of motor vehicles transported to a certain Qinghai Tibet plateau area is \([c_{\text{min}}^{h}, c_{\text{max}}^{h}]\), and the step size is 10. The weight in \([c_{\text{min}}^{h}, c_{\text{max}}^{h}]\) range should be 2 times of other weights. [4]The influence of
temperature is calculated as follows:

\[
f_H(x) = \frac{f_h(C_{\min}^h) + \cdots + 2 \times f_h(C_{\min}^h) + \cdots + 2 \times f_h(C_{\max}^h) + \cdots + f_h(C_{\max}^h)}{C_{\max}^h - C_{\min}^h + 10}
\]  

(9)

5. **Solving the influence degree of sand dust and high snow blowing**

The influence of sand dust and high snow blowing on motor vehicles is as follows[5]:

\[
f_{sc}(x) = \begin{cases} \frac{x}{2} & 0 \leq x \leq 2 \\ 1 & x > 2 \end{cases}
\]

(10)

Then the dust impact is calculated as follows:

\[
f_{sc}(x) = f_{sc}(0.05) + \cdots + f_{sc}(0.3) \times 2 + \cdots + f_{sc}(0.55) + \cdots + f_{sc}(1.5) \times 2 + \cdots + f_{sc}(1.8) \times 2 + \cdots + f_{sc}(2)
\]

(11)

Calculation of influence degree of high snow blowing

\[
f_{gcx}(x) = \begin{cases} \frac{x}{573} & 0 \leq x \leq 573 \\ 1 & x > 573 \end{cases}
\]

(12)

The impact of high snow blowing is calculated as follows:

\[
f_{gcx}(x) = f_{gcx}(3) \alpha + \cdots + f_{gcx}(6) + \cdots + f_{gcx}(672)
\]

(13)

6. **Solving the influence degree of road condition**

Due to the poor road conditions in the Qinghai Tibet Plateau, the impact is serious and the vehicle vibration is strong. In the Qinghai Tibet plateau area, the road conditions causing vehicle vibration can be as follows: first, ordinary gravel road on the plateau (stones with diameter greater than 6cm < 5%); the second is Gobi frozen land (the thickness of frozen soil is generally up to 20cm ~ 50cm, mixed with stones and hard soil with a diameter greater than 8cm < 10%); the third is the pebble land on the beach (the stones are dense, and the diameter is generally 10 ~ 20cm); the fourth is the mountain washboard land (the stone is hard, uneven, the washboard road is dense, and the undulating height is more than 15cm).[6]

Considering the influence of road conditions on motor vehicles, the importance degree is determined by pairwise comparison. Calculate the combination weight of the underlying elements of the evaluation index system.

Determine the evaluation grey class. Let k = 4, i.e. "serious", "more serious", "general" and "lighter". The value of grey number represents the interval of possible distribution of scores, and the middle value represents the best score value of the grey class. In the evaluation of this index, the whitening weight functions are as follows:

\[
f_i(x_i) = \begin{cases} \frac{x_i}{8} & x_i \in [0, 8] \\ 1 & x_i \in [8, +\infty] \\ 0 & x_i \in [0, 8] \end{cases}
\]

(14)
Establish weight judgment matrix in table 1

Table 1 evaluation matrix of road condition influence degree

<table>
<thead>
<tr>
<th>index</th>
<th>Ordinary gravel road</th>
<th>Gobi frozen land</th>
<th>Pebble land on the beach</th>
<th>Security along the way</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary gravel road</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Gobi frozen land</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pebble land on the beach</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Washboard in the mountains</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The weight is obtained by analytic hierarchy process

$$\omega_{f_i(x_j)} = 0.25, \omega_{f_j(x_k)} = 0.25, \omega_{f_l(x_m)} = 0.25, \omega_{f_m(x_n)} = 0.25$$

7. Calculation of temperature difference influence degree

The temperature difference analysis is the same as the previous one

$$f_{we}(x) = \begin{cases} 
1 & 0 \leq x < 5 \\
1 - \frac{(x+5)/2}{25} & 5 \leq x < 12 \\
1 - \frac{(x+12)/2}{25} & 12 \leq x < 18 \\
1 - \frac{(x+18)/2}{25} & 18 \leq x \leq 25 
\end{cases}$$

The humidity range of motor vehicles used in a certain Qinghai Tibet plateau area is \([c^{wc}_{\min}, c^{wc}_{\max}]\), and the weight in \([c^{wc}_{\min}, c^{wc}_{\max}]\) range should be 2 times of other weights. [7] The influence of temperature is calculated as follows:
\[
I_j(x) = f_{T}^j \left(0.5\right) + \cdots + f_{T}^j \left(12\right) + \cdots + f_{T}^j \left(c^{\text{min}}_{j} \times 2\right) + f_{T}^j \left(18\right) \times 2 + f_{T}^j \left(c^{\text{max}}_{j} \times 2\right) + \cdots + f_{T}^j \left(25\right)
\]

(20)

8. Determination of environmental impact index when used in specific areas

The impact of extreme environment on vehicle \( \beta \) is calculated as follows:

\[
\beta = f_{WD} (x) \times \omega_{WD} + f_{SD} (x) \times \omega_{SD} + f_{FS} (x) \times \omega_{FS} + f_{H} (x) \times \omega_{H} + f_{SC} (x) \times \omega_{SC}
\]

\[
+ f_{GCX} (x) \times \omega_{GCX} + f_{DLQK} (x) \times \omega_{DLQK} + f_{WC} (x) \times \omega_{WC}
\]

In the calculation of weight, the sand dust and high blowing snow are taken as the whole index to evaluate the weight, and the weight value is divided equally. According to the evaluation of experts, the weight calculation matrix is given as in table 2:

<table>
<thead>
<tr>
<th>Index</th>
<th>Influence of road conditions</th>
<th>High altitude</th>
<th>Wind speed</th>
<th>Humidity</th>
<th>Dust, snow</th>
<th>Temperature</th>
<th>Temperature difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Humidity</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Wind speed</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1/3</td>
<td>1/4</td>
<td>1/3</td>
</tr>
<tr>
<td>High altitude</td>
<td>1</td>
<td>1</td>
<td>1/3</td>
<td>1/4</td>
<td>1/3</td>
<td>1/4</td>
<td>1/3</td>
</tr>
<tr>
<td>Dust, snow</td>
<td>1</td>
<td>1/3</td>
<td>1/4</td>
<td>1/3</td>
<td>1/4</td>
<td>1/3</td>
<td>1/3</td>
</tr>
<tr>
<td>Temperature difference</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

The analytic hierarchy process is used to calculate the weight

\[
\omega_{WD} = 0.1020, \quad \omega_{FS} = 0.0836, \quad \omega_{SD} = 0.1363, \quad \omega_{H} = 0.2726, \quad \omega_{SC} = 0.0418, \quad \omega_{GCX} = 0.0418, \quad \omega_{DLQK} = 0.2726, \quad \omega_{WC} = 0.1020.
\]

In the Qinghai Tibet plateau area, the speed of armored equipment maneuver is

\[
v_j = \beta v
\]

(21)

Where \( v_j \) represents the driving speed of the Qinghai Tibet Plateau, \( v \) represents the speed of the vehicle in normal environment.

9. Conclusions

In this paper, the environmental impact model was established based on the index of temperature, humidity, wind speed, dust and so on. Through the way of expert scoring, the weight of the index with score is established, and the score is given. The model is suitable for motor vehicles or large vehicles. Experience shows that the establishment of the model has a direct significance for the impact of high altitude environment on the use of vehicles.

Reference


