An Analysis to Determine Correlations of Highway Intersection Traffic Accidents with Specific Features in China

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Abstract: Highway intersection is the concentration of traffic accident. Evaluating traffic safety of highway intersection is an available approach for improving traffic security and reducing the amount of traffic accident, especially in China. By analysis on various causes that could impact highway intersection safety, which are:

traffic feature factors: traffic flows, speeds, ratios of truck and car;
geometric feature factors: horizontal alignment, vertical alignment, sight distance, angle of intersection and cross section structure;
Traffic control conditions: Speed limit, channelisation of intersection, traffic signals, illumination, roadside risk factor.

According to analysis these alternative affective factors and their relationship and specific distribution, traffic safety forecast model about highway intersection is made. Through establishing a better forecast model, the major factors of accident can be found out, in order to rationalize design and improve crossing safety, prevent crossing accident from occurring or prevent the dangerousness of crossing worsen. Finally, analyzed and marked an accident forecast model for class national highway section intersections can get the following conclusions: traffic flow, angle of intersection, roadside risk factor, vertical alignment and traffic disturb level are the major reasons that affect crossing safety of a national highway section.

Key words: highway intersection, traffic safety, geometric design

1. The severe situation of traffic safety of highway intersection in China

In 2007, there are 327,000 accidents happened in China and caused the death toll up to 81,600. Intersection is the most important and dangerous, caused the most accidents happening, part of highway. The motor vehicles and pedestrians in every direction must pass through the intersection, get across it and come about, then combine into the established traffic flow. Because of the mutual disturbance, weave and conflict area lead to traffic jam and speed reduction, and it makes the traffic accidents occur easier. Therefore, designing intersection and organizing traffic flow properly can improve the speed and traffic capacity, reduce delay and traffic accident, avoid traffic jam and ensure the traveling in the intersection.

In China, urban road, first class highway (except free highway) and country road can have intersections and mixed traffic, esp. in the residential area along the road side. Due to Chinese traffic management and code are not perfect, so the phenomenon of road breakage is severe. It leads to the amount of intersections increase and traffic confusion, affecting highway capacity, increasing the possibility of traffic accident. Owing to lack of statistical classify, the data we have only based on city traffic accidents: the traffic accidents in intersection account for 30% of the total accidents of the country. According to 109 National class 2 highway (Shi zuishan---Zhong ning)’s traffic accidents statistic from 1995 to 1997 by
ourselves, there are 9%(93) traffic accidents happened in the intersection. Though the research on the concentration of traffic accident occurs, there are totally 27 black spots, and 20 of them are intersections. Therefore, for intersection traffic safety study in China, proposed that right road intersection accident forecast technique of Chinese transportation characteristic, determined the hazard factors that affects the road intersection security, has important and the profound social meaning.

2. Analysis on impact factor of highway intersection safety

There are there causes that could impact highway intersection safety, human being, vehicles, highway, environment and management, which are analysis the follows:

1) Human being: driver, pedestrian, cyclist who has no consciousness about traffic safety and do their traffic behavior by themselves;

2) Motor vehicles: there are huge difference properties among motor vehicles, include trucks, cars, motorcycles and farm machine. In mixed traffic, excessive speed is serious.

3) Highway, environment and management: intersection angels have many kinds and are random, channelizations are poor, channelized highways do not consider the impact of intersection capacity. sight distance and alignment of intersection are not good, the degree of streetlism in intersection is high.

According to the system analysis above all, establishing a model, which correlated with the highway features and traffic accidents, must aim at the causes of traffic accident in the intersection and analyses the quantitative index. According to the analysis about traffic accident impact factors above, it can get some quantizing indexes, which are:

1) Traffic

Traffic volume (VN): Traffic volume is one basis for ascertaining highway class and road surface, it is an important index, which can affect highway function and importance. The traffic volume and the traffic accident become the plus correlative dependence, esp in the intersection with mixed traffic. An influx of automobile, non-power-driven vehicle and pedestrian will appear in the intersection from its leg. If drivers and pedestrians take a poor attitude or have a negative about traffic safety, it will increase the account of conflict point's .In order to reflect the influence of traffic volume to traffic safety, it uses unit length of intersection annual average daily traffic volume, which can be called VN to appraise volume, and the formula, is as follows:

$$ VN = \frac{ADT \times 365 \times seg \_ lng}{10^6} $$ (Unit: mil.vehicle\cdot kilometre) \hspace{1cm}(2.1)

Where:

\( ADT \)———annual average daily traffic volume
\( seg \_ lng \)———the length of study area, unit is kilometre.

Speed (V): speed is an index for inflect users’ expectance. The safe distance between two cars and between car and pedestrian will shorten, sometimes it even becomes double shorter than usual. Therefore, the automobiles, which arrive at the intersection, must decelerate for safe, so operating speed can be manifested speed variable.

2) Intersection geometric features

Intersection geometric features include main line and leg line. Because the traffic volume in the main lines is large and the speed is high, so the impact of feature to traffic accident is determined by main line. The vertical and horizontal curve of main line must satisfy all sorts of vehicles; vehicles can be driven comfortably, when it is near the intersection, or easy to
lead to traffic accident. Many studies manifest: There is correlation of road features and traffic safety, esp. the horizontal curve. The horizontal curve parameters determined by intersection: horizontal curve length and radii. This study uses the ratio of curvature DEG, the meaning is the degree of curve per 100 meters, the formula is as follow:

\[ DEG (i) = \frac{18000}{\pi \times \text{rad}(i)} \]  

(2.2)

Where:

- Rad (i)——horizontal curve radii, unit is meter.

The vertical parameters determined intersection is longitudinal gradient V (i). The leg alignment feature is just considered as poor or good for safety.

The form and angleθ of main road and leg road crossover: The intersection can be classed in three kinds. They are three-leg intersection, four-leg intersection and multi-leg intersection, use TYPE to show them. Right-angle crossing is the safest in intersection feature design. Shown in Figure 2.1

![Figure 2.1 INTERSECTION FLOW](image)

When the angle is more than 90°, θ is positive number; and when angle is less than 90°, θ is negative. If the leg road locates the left of main road increased direction, this angle’s a supplementary angle will become new angel, so θ can be defined as 180-angle-90=(90-angle). For four-leg intersection, θ is equal to the mean angle of two three-leg intersection.

3) Lane’s characteristic

It includes the width of lane, length of acceleration (deceleration) lane, storage length for added turning lane. Owing to the class of intersection in China is low, there is no special requirement for length of lane and the signal and channelized cross highway is few, so the number of left and right turn lane can manifest the characteristic of lane. It is expressed by n.

4) Roadside structure

Roadside structure includes shoulder, gradient of slope, location and safe precautions of obstacle in safe clearance. The security of roadside structure was mostly collected in observation. Now the index of roadside danger can be quantized it. The index of roadside danger is a variable about evaluating the intersection safety amended by Zegeer et al in 1987. It is from one to seven, all are whole numbers, and seven represents the most dangerous situation. Observers through field location usually make the value, and the observers also work out the different dangerous index for different section. The value of the whole area is the mean value of the different sections. The roadside dangerous index is shown by HAZERT.
5) Sight distance

Sight distance of intersection must make driver see the geometric feature of the intersection clearly so that they can decide how to control the vehicle and cross the intersection quickly. Sight distance includes estimation distance and brake distance. It shows the safety condition when the driver enters into the intersection. The sight condition is affected by alignment feature, environment, topography, and so on. The impact of environment for safety has already considered by roadside danger index. For reducing the interaction with variables and keeping their independence, it eliminates the impact of environment for sight distance when marking the sight distance variable. Number of modality is as follows:

\[ SIGHT = 0 \]

where: 0——sight distance satisfies safe drive, 1——sight distance unsatisfies safe drive.

6) Intersection distance

Intersection distance is a manipulative index of driving safety and comfort. Because many highways of China are mostly far away from towns, so the intersection distances are long. Because of the highway urbanization, the short intersection distance can be classified as the influencing factor of environment. Therefore, the intersection distance can not be considered.

7) Environmental management

There is short of code and law for management of right-of-highway and the management of highway property is scanty, too. That makes the highway, esp. the low class highway where have the residential area develop fast, the degree of urban of the roadside becomes more and more serious, and there is huge traffic safety hidden trouble. The store located near the intersection attracts the pedestrians and automobiles that have poor traffic safety consciousness. The drivers are not familiar with the intersection. The villagers cross the intersection at liberty. In addition, there is bad performance of car and bad driving behavior. All above make the traffic safety condition become more and more poor. Using degree of urban (DEGURB) to show environmental management.

\[ DEGURB = \begin{cases} 
0 & \text{NO BECOMING STREET} \\
1 & \text{SLIGHT EFFECT} \\
2 & \text{GENERAL EFFECT} \\
3 & \text{SEVERE EFFECT} 
\end{cases} \]
3. Establish the accident model

Setting up the intersection safety model about correlation between traffic accident and its influence factors should base on the characteristic of Chinese intersection. In order to keeping the model is valid, the datum and distribution of traffic accident should be studied.

1) Establish the model

According to the above correlation analysis about traffic accident, the traffic accident is occurring by many occasional factors. There is correlation of the mean of intersection accidents in unit time $\lambda_i$ and the characteristics of road system of given place $x_{ij}$. For insuring the different mean values of accidents for different intersection $\lambda_i \geq 0$, so it often uses power series linearity form to express the model:

$$\lambda_i = \exp(\sum_{j=0}^{n} \beta_j x_{ij}) = e^{\hat{\beta}_0 + \hat{\beta}_1 x_{i1} + \ldots + \hat{\beta}_n x_{in}}$$ (3.2)

Where:
- $\lambda_i$ — the mean value of accidents for the certain place $i$ and period;
- $x_{i0}, x_{i1}, \ldots, x_{in}$ — the variable of intersection characteristics for given place $i$ and given period;
- $\beta_j$ — the parameter of model.

The stochastic variable of the amount of highway traffic accident is dispersal and independence, traffic accident distribution has two sorts: Poisson distribution and negative binomial distribution (NB). They is all both generalized linear model which is the extension of normal linear model in value range and the type of distribution. The distributions are different, so the estimate models for $\lambda_i$ and $\beta_j$ are different.

1) Poisson distribution model: if the traffic accident distribution is discreted, the incident is infrequent and independent, we can use Poisson distribution model.

$$P(Y = y) = e^{-\lambda_i} \frac{\lambda_i^y}{y!}, y = 0, 1, 2, 3, \ldots$$ (3.3)

Where:
- $P(Y = y)$ — the probability of the value $y$ of accident happened in given place.

$$\lambda_i = \exp(\hat{\beta}_0 + \sum_{j=1}^{n} x_{ij} \hat{\beta}_j)$$ (3.4)

Where:
- $\lambda_i$ — the expected value of traffic accident of intersection $i$ or the road section $i$ in given period;
- $x_{i1}, x_{i2}, \ldots, x_{in}$ — in given period, the variable of road system of intersection $i$ or the road section $I$;
- $\hat{\beta}_0, \hat{\beta}_1, \ldots, \hat{\beta}_n$ — estimated coefficients.

In the Poisson distribution model, coefficient rector $\beta$ can be calculated by maximum likelihood estimation. The formula is as follows:
\[ L(\beta) = \sum_i (y_i \log \lambda_i - \lambda_i - \log y_i) \]  

(3.5) \hspace{1cm} (3.5)

Where:

\[ \beta = (\beta_0, \beta_1, L, \beta_n) \quad \text{—coefficient rector} \]

\[ y_i \quad \text{—the amount of accidents in intersection } i \]

\[ \lambda_i \quad \text{—expected value of intersection } i \]

(2) Negative binomial distribution model: When the accident is not independent-sample, the data of traffic accidents often has big variation, it more than mean, called super-separated. NB distribution model can describe this super-separated data of accidents. The variance of the data of intersection accident is based on the assumption as follow:

\[ \lambda + K\lambda^2 \]

Where K is a parameter, it can be called distribution parameter. Therefore, the variance of data of the accidents has two parts. One is the variable by Possion distribution variable, the other is made by the deviations of the data. And every intersection has the same accident distribution.

The probability function is as follows:

\[ P(Y = y_i) = \frac{\Gamma(y_i + (1/K))}{y_i!\Gamma(1/K)} \left( \frac{K\lambda_i}{1 + K\lambda_i} \right)^y \left( \frac{1}{1 + K\lambda_i} \right)^{1/K} \]  

(3.6)

Where:

\[ K \quad \text{—over-discrete parameter of the model} \]

The model parameter \( \beta_j \) and the over-discrete parameter K is gained by maximum likelihood estimation. When the accident distribution doesn’t in obedience to Poisson Distribution or NB negative binomial distribution, it must be demarcated the mean value of the accidents \( \lambda_i \) and the road system variable parameter of the intersection \( \beta_j \).

2) The Model test

Besides the test requirement, the model test must accord with the actual situation and the standard of the common estimation.

(1) The significance testing of regression equation

The significance testing of regression equation estimates the chosen assumption whether come into existence, formula 5—11. If

\[ H_0 : \beta_1 = \beta_2 = L = \beta_p = 0 \]  

(3.7)

come into existence, it proves whatever the independent variable changes, y will not change with them. If \( H_0 \) not come into existence, it proves that there are not all zero in \( \beta_1, \beta_2, L, \beta_p \), so y can change with one of the \( x_1, x_2, x_3, L, x_p \). Therefore, the significance testing of regression equation tests whether y and \( x_1, x_2, x_3, L, x_p \) have linear relation on the whole. There are two kinds of the significance testing of regression equation: LR tests and Wald tests.

(2) The significance testing of regression coefficient

The practical issue dealt with multiple regression can estimate the significance of regression equation. Because if the regression equation is significance, that is the assumption of
\( \beta_i = \beta_j = \ldots = \beta_p = 0 \) rejected, but it doesn’t mean the all the \( \beta_i \) are not equal to zero. If one of \( \beta_i \) equal to zero, the change for independent variable \( x_j \) has no influence to \( y \), \( x_j \) is not significance. To ensure the quality of predict and control for \( y \), it must test every regression coefficient.

\[
H_0 : \beta_j = 0
\]  

(3.8)

(3) Test of goodness of fit of regression equation

It is the test of goodness of fit between sample regression equation

\[
\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \ldots + \hat{\beta}_k X_k
\]

and sample \((X_1, X_2, \ldots, X_k, Y)\) \((i = 1, 2, \ldots, n)\).

4. A case study for intersection traffic accident model

This case is studied about mountainous class highway section—Yutong Highway in Guizhou. The segment length is 55Km, there are 22 intersections. Two of them are four-leg intersection, one is abnormal intersection and 19 of them are three-leg intersections, all the intersections have stop signs in the leg road. The distances between intersections are from 759m to 6324m. According to the rule of automobile achieving the intersection, it based on the length of acceleration lane ruled by “Specification of the highway route design”, and added 100m to the acceleration lane in two directions with the intersection center. That area is the intersection study area.

There are 180 accidents during the years between 2002~2004, the fatal accident is 54, the injury accident is 77, and there are 49 accidents with property damage only and 54 accidents happened in the intersections. The structure is shown in Figure 4.1.

**FIGURE 4.1 The composition of traffic accidents in different level**

Due to the restrictions of collecting information and statistics of traffic accidents in China, so the basic information of accident severity and type of accident loses badly. Therefore, there is no classification and statistic of different type and severity accidents in this paper. The intersection accident model by establishing model and coefficient of correlation and test is as follows:

\[
\ln \lambda = -4.007 + 12.587 V N + 0.303 H A Z E R T - 0.025 \theta + 2.985 V I
\]

\[ \square 4.1 \square \]

Where:

\( \lambda \) —— expected value of intersection accident
According to the model, the traffic volume is the most important factor of traffic safety. The table 4.1 is shown the change range of traffic volume variable and the effect for accident expectation value.

**TABLE 4.1 THE EFFECT OF TRAFFIC VOLUME TO TRAFFIC ACCIDENT**

<table>
<thead>
<tr>
<th>Variable VOL</th>
<th>800</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>The effect to $\ln \lambda$</td>
<td>2.202</td>
<td>2.757</td>
<td>4.135</td>
<td>5.513</td>
<td>8.270</td>
<td>11.026</td>
</tr>
</tbody>
</table>

The table shows that the change of traffic volume makes obvious effect for accident, the more the traffic volume, the more accidents. With the experience, when the traffic volume becomes large, the index of accidents increases quickly. But when the traffic volume reaches the maximum highway capacity (traffic jam), the amount of accidents is decreasing. So, this accident model is restricted by maximum highway capacity.

Compared with traffic volume, the effect of other variables is little. The table 4.2~4.4 are shown the effect of the other three variables to expectation of traffic accidents.

**TABLE 4.2 The effect of Roadside dangerous index to traffic accident**

<table>
<thead>
<tr>
<th>HAZERT</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln \lambda$</td>
<td>0.303</td>
<td>0.606</td>
<td>0.909</td>
<td>1.212</td>
<td>1.515</td>
<td>1.818</td>
<td>2.121</td>
</tr>
</tbody>
</table>

**TABLE 4.3 The effect of variable of intersection angel to traffic accident**

<table>
<thead>
<tr>
<th>$\theta$</th>
<th>0</th>
<th>5</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>75</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln \lambda$</td>
<td>0</td>
<td>-0.125</td>
<td>-0.75</td>
<td>-1.125</td>
<td>-1.5</td>
<td>-1.875</td>
<td>-2.25</td>
</tr>
</tbody>
</table>

**TABLE 4.4 The effect of change of vertical curve to traffic accident**

<table>
<thead>
<tr>
<th>Variable VI</th>
<th>0</th>
<th>0.00235</th>
<th>0.05</th>
<th>0.1</th>
<th>0.3</th>
<th>0.5</th>
<th>0.7</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln \lambda$</td>
<td>0</td>
<td>0.0070</td>
<td>0.15</td>
<td>0.300</td>
<td>0.900</td>
<td>1.500</td>
<td>2.090</td>
<td>2.985</td>
</tr>
</tbody>
</table>

**5. Conclusion**

Through the system analysis to the factors that may possibly affect the intersection’s safety, this disquisition worked over to establish the evaluative index of highway intersection’s traffic safety, and discussed to make the accident forecast model and methods to check up and demarcate the model. Through establish a better forecast model, the major factors of accident cause can be found out, in order reasonable design or improvement crossing safety, prevent crossing accident occur or prevent the crossing dangerousness worsen further. Finally, analysis and marked an accident forecast model for mountainous class highway section intersections, then get the following conclusions: traffic flow, angle of intersection, roadside risk factor, vertical alignment and traffic disturb level are the major reasons that affect crossing safety of the highway section.

Due to china’s accident statistic system is not perfect, it could increase the risk of demarcating the accident forecast model.
Reference


5. Huang Xiaojuan, Xu Yaguo, Traffic Accident Forecast Model for Guangzhou City, Transportation Management, pp. 56-60.