Research on Arterial Highway Traffic Safety Risk Assessment Method

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Abstract: Currently, research on arterial highway traffic safety risk assessment and control techniques are limited. Back Propagation (BP) Neural Network, fuzzy logic algorithm, Principal Component Analysis (PCA) and Analytic Hierarchy Process (AHP) are the common used methods in the existing studies. These methods take into account all the risk factors without effective selection. This may lead to complicated computation and procedures and poor time effectiveness, which would hinder the wide spread and application of safety risk assessment among design engineers and operators as well as in different levels of roads. The outcome of the study makes the significant contribution to accident hazardous locations treatment measures. Therefore, based on historical traffic accident data, this proposed an applicable, ease of implementation and simplified road risk assessment method which can effectively assess hazardous locations. The paper collected the historical data of an arterial highway to verify the proposed method. The results match the actual road safety situation.

1. Introduction
The highway transportation industry in China started late but has developed rapidly. Road design mostly draws lessons from Japan, Germany and the United States and other mature relevant norms and standards. In recent years, many researchers have just started their research on the key design topics adapted to China's basic national conditions, which seriously lags behind the development of highway infrastructure construction. Therefore, the lagging research and development of road safety guarantee measures in China, together with the difficulties in traffic management and the lagging management level, have caused frequent traffic accidents, excessive casualties, huge economic and property losses, and become a serious problem in the process of realizing a well-off society in an all-round way and building a harmonious society in China[1].

At present, there are relatively few studies on risk assessment and control technology of arterial highway traffic safety. The relevant risk assessment methods mostly adopt mathematical theory methods such as BP neural network, fuzzy analysis method, principal component method, analytic hierarchy process, which cover all kinds of risk factors in an all-round way without effective screening [2-4]. The methods need to collect a large amount of data, and lead to complicated computation and procedures, and poor time effectiveness. It is difficult to extend to the design engineers and operators of arterial highway to apply to all grades of roads. Therefore, the paper focuses on the research of a risk assessment method with strong practicability, low workload, simple steps and relatively accurate evaluation results, which can identify risk segments with high efficiency.

2. Traffic safety risk assessment method
The main ideas of the paper are as follows: for high-risk sections, according to historical traffic accident
data, on the basis of optimizing the application risk model of "Technical Guidelines for the Implementation of Highway Safety and Life Protection Engineering", the influence law of each factor is studied and determined. The key sub-hazards with high risk coefficient are screened out, the design indexes are determined, and the integrated risk model is verified, so that the relevant designers and managers can quickly distinguish the traffic safety status and take timely measures [5-6].

2.1 Classification standard of traffic safety risk
According to the influence model of the alignment conditions and traffic environment of arterial highway on the probability of traffic accidents and the consequences of traffic losses, the traffic safety risk of arterial highway was quantitatively analyzed. The arterial highway was divided into two sections according to two driving directions, and the risk score was calculated according to the risk impact model combined with the traffic condition index, which represented the risk degree of the arterial highway in a certain section. Road Traffic Safety Risk is divided into five levels, which are expressed by I, II, III, IV and V respectively [7]. The risk coefficient increases in turn and is expressed by RTSR.

Table 1. Classification criteria for traffic safety risks of arterial highway.

| Risk level | Risk situation | Range of risk indicators |
|------------|----------------|--------------------------|
| V          | higher         | RTSR≥70                  |
| IV         | high           | 40≤RTSR<70               |
| III        | middle         | 20≤RTSR<40               |
| II         | low            | 10≤RTSR<20               |
| I          | lower          | RTSR<10                  |

2.2 Traffic safety risk impact model
The traffic safety risk model proposed in this paper is shown in Figure 1.

2.3 Traffic safety risk design index and standard value of risk coefficient
The data of the collected statistics are quantified. The specific values are shown in Table 2, Table 3 and Table 4.

Table 2. Front collision risk design indicators and standard values of risk coefficient.

| Risk types | Risk                      | Key sub-hazard sources | Design indicators | Risk coefficient | Key sub-hazard sources | Design indicators | Risk coefficient |
|------------|---------------------------|------------------------|-------------------|------------------|------------------------|-------------------|------------------|
| Frontal collision risk | Possibility ≤2%          | 1                      | Number of one-way lanes | 1                | Entity central separation zone (containing guardrail) | 0.2               |
|             | Longitudinal slope        | 2%~4%                  | Intermediate zone | 1.1              | Entity central separation zone < no | 0.8               |

Figure 1. Traffic safety risk impact model ("+" means add; "x" means multiply).
Table 3. Out-of-Drive risk design indicators and standard values of risk coefficient.

| Risk types          | Risk                | Key sub-hazard sources | Design indicators       | Risk coefficient | Key sub-hazard sources | Design indicators       | Risk coefficient |
|---------------------|---------------------|------------------------|-------------------------|------------------|------------------------|-------------------------|------------------|
| Out-of-road risks   | Possibility         | Bend radius            | >1000                   | 1                | Reasonable and sufficient or signs | 1                        |
|                     |                     |                        | 700–1000                | 1.1              | Signs and markings     | Only markings or signs  | 1.1              |
|                     |                     |                        | 700–400                 | 1.3              | Sliding resistance of pavement | Poor (no or severe damage) | 1.2              |
|                     |                     | Long longitudinal slope| yes                    | 1.5              | Unprotected             | Excellent               | 1                |
|                     |                     |                        | no                     | 1.2              |                       | Good                    | 1.1              |
|                     |                     | Running speed          | 0–40                   | 0.1              |                       | Bad                     | 1.3              |
|                     |                     |                        | 40–60                  | 0.3              |                       |                         |                  |
|                     |                     |                        | 60–80                  | 0.6              |                       |                         |                  |
|                     |                     |                        | 80–100                 | 0.9              |                       |                         |                  |
|                     |                     |                        | >100                   | 1                |                       |                         |                  |
| Severity            | Roadside hazard grade| I                      | 1                       |                  |                       |                         |                  |
|                     |                     | II                     | 20                      |                  |                       |                         |                  |
|                     |                     | III                    | 50                      |                  |                       |                         |                  |
|                     |                     | IV                     | 100                     |                  |                       |                         |                  |
| Traffic             | Traffic(s) service  | Grade 1                | 0.1                     |                  |                       |                         |                  |
|                     |                     | Grade 2                | 0.2                     |                  |                       |                         |                  |
3. Application analysis of engineering example
This paper takes the road section of S328 of Zhejiang arterial highway as an example to evaluate the traffic safety risk of arterial highway. S328 provincial highway is a first-class highway. The direction of Lishui to Longquan is the direction of the pile number increasing. The range of the mileage of the research section is K6+100 ~ K6+600, the design speed is 80km/h with six-lane and two-way, and the subgrade width is 32m which is 0.75m+2.5m+3×3.75m+0.5m+1.0m) ×2. The horizontal alignment of
the research section is designed as a straight line with a longitudinal slope of 3%. The houses on both sides of the road are dense, the roadside openings are more and randomly distributed. The traffic order is chaotic which would cause greater lateral interference for the highway.

According to the risk impact model, the risks on both sides of the road can be calculated and evaluated. The traffic safety risks of the first-class highway mainly include frontal collision risk, out-of-road risk and plane intersection risk. Firstly, it could quantify the relevant data as standard values, and query the corresponding risk coefficients according to the relevant indicators in tables 2, 3 and 4. The specific results are shown in Table 5.

| Risk Types          | Risk Coefficients |
|---------------------|-------------------|
| Frontal collision   | Possibility (0.1) |
| Out-of-road risks   | Possibility (1)   |
| Traffic             | Traffic (0.2)     |
| Out-of-road risks   | Traffic (0.2)     |
| Possibility (1)     |
| Severity (70)       |
| Severity (12)       |
| Intersection risk   | Possibility (1.48)|
| Traffic (0.1)       |
| Severity (100)      |

According to the traffic safety risk impact model of arterial highway, the data from the above table are substituted for calculation. It can be seen that the RTSR value of traffic safety risk of road section K6+100-K6+600 of S328 provincial highway is 21. Inquiring about the traffic safety risk grading standards for primary and secondary roads, the risk level is III, which is a medium-risk road segment, and the risk at the intersection is the largest. According to the historical traffic accident data, there are many fatalities and injuries in this section, mainly occurring at the intersection, which is consistent with the calculation results of the trunk highway traffic safety risk model.

### 4. Conclusion

According to the difference of influence degree of each hazard source in the formation process of road traffic safety risk, the paper determines the main design indexes and corresponding risk coefficients of various types of accident risk, establishes the impact model of arterial highway traffic safety risk, and adjusts the risk coefficients of the risk impact model repeatedly based on the historical traffic accident data. The established risk assessment method of arterial highway traffic safety has the characteristic of strong operability and relatively accurate results [8]. Taking the arterial highway project in Zhejiang Province as an example, the reliability and accuracy of the arterial highway traffic safety risk assessment method studied in this paper are verified.

The main road traffic safety risk studied in this paper belongs to the narrow sense of road traffic safety risk, that is the main road safety risk. The risk assessment does not involve human, vehicle, management, environment and other factors, which means that the default of the above factors does not constitute the difference of traffic safety risk [9]. This method is feasible and effective for a small area of road network. However, it should be made clear that in Zhejiang Province, the economic, population, management and other factors in different regions will lead to differences in the quality of traffic safety, vehicle performance and management functions, and then affect the difference in the size of traffic safety risks [10]. Therefore, the traffic safety risk impact model of arterial highway studied in this paper is only suitable for identifying the traffic safety risk of the arterial highway and comparing the longitudinal risk of the road. If it is used to make absolute comparison with the traffic safety risk of other highways, developing new methods of traffic safety risk assessment with consideration of other factors is necessary.
References

[1] Lifen Li. (2005) Urban Road Ventilation Risk Analysis and Its Application. Nankai University, Tianjin.
[2] Cheng Zhu. (2014) Risk Assessment of Bridge Operation Based on Analytic Hierarchy Process and Fuzzy Mathematics. Kunming University of Science and Technology, Yunnan.
[3] Muyu Liu, Ke Chen, Wu Jing. (2015) Principal Component Analysis of Construction Risk of Bridge Caisson Foundation. Journal of Wuhan University of Technology (Transportation Science and Engineering Edition), 39(01):1-4.
[4] Jing Jin, ZongHao Li, Liang Zhu et al.(2019) Application of BP Neural Network in Risk Assessment of Railway Construction. Journal of Railway Engineering Society, 36(03):103-109.
[5] Xuegang Zhao. (2010) Research on Key Technologies of Dynamic Early Warning for Regional Road Network Traffic Safety Risk. Chang’an University, Xi’an.
[6] Daocheng Sun. (2011) Research on Evaluation Method of Transportation Safety Infrastructure of Trunk Highway. Shanghai Highway, 03:54-56.
[7] Yan Wu, Zhenbang Qian, Jianjun Wang et al. (2014) Highway Traffic Safety Risk Assessment and Sensitivity Analysis. Journal of Chang’an University (Natural Science Edition), 34(04):134-141.
[8] Daoyu Zhang, Xiaowei Hu. (2016) Risk Assessment of Expressway Traffic Facilities Based on Improved Bayesian Network Model. Traffic Information and Safety, 34(05):102-107.
[9] Yanbo Huang. (2013) Discussion on Urban Road Traffic Safety Planning. Guangdong Highway Communications, 05:58-63.
[10] Xuejun Nu, Yin Zhu, Tao Lou. (2008) Countermeasures for Pre-control Management of Road Traffic Safety Risks. Integrated transportation, 10:42-46.