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Evidence Theory in Highway Design Safety Evaluation Studies

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Abstract: Many elements interact and cause traffic accident, in which the design of the road plays an essential part. With one case in Yiwu, we take detailed assessment on safe design elements of the high way by using evidence theory. Research results indicate that interaction between the safety evaluation indexes for highway design significantly impact on traffic safety. The result is expected to be helpful to improve the current situation of highway design and safety.

Ke ywords: Evidence theory, highway design, traffic safety, evaluation

INTRODUCTION

Road safety is one of the most important problems in our society. Every year 1.2 million people are killed and 20-50 million people are injured in road accidents. If current trends continue, traffic accidents are predicted to be the third leading contributor to the global burden of disease and injury by 2020 (Huang, 2011). In China, the country involving the casualties of the road traffic accident two hundred thousand cases, approximately killed sixty thousand people in 2011. Therefore, we should strengthen the management of traffic safety, analyze the possible risk factors of road traffic through scientific methods, establish a comprehensive evaluation system of highway safety design and take effective measures to reduce the safety accidents of road traffic (Lu, 2012).

METHODS

As the complexity of the evaluation index system of highway safety design, the evaluation process will encounter random evaluation factors and a series of uncertain fuzzy problems (Peng, 2008). To overcome these shortcomings, this study presents safety evaluation system of highway safety design based on the evidence theory. The method is based on the analytic hierarchy process (ahp), using evidence theory to evaluate the highway safety design in service to determine the overall security situation of road traffic.

AHP analysis: First the practical problems faced by an in-depth analysis, the problems involved are the factors in accordance with the different properties are divided into target layer and sentenced according to level (Don *et al*., 2008), indicators, program-level and more than one level, a hierarchical model, the structure can be a framework to explain the affiliation. Secondly, starting from models of the 2nd level of the hierarchy (Yan, 2009), to compare the relative importance of elements and using the method of 1~9 and its in the bottom of the scale, constitutes a judgment matrix. Third, to determine the characteristic root of a matrix of normalized, sort by the relative importance of weight, then for which consistency test, (Zhu and Gao, 2008) required for consistent, otherwise the judgment matrix element value should be adjusted. IV, for hierarchical sorting calculated, this process is carried out in the highest level to the lowest layer-by-layer (Duan, 1993). Then sort the consistency test, conforman

Idea of evidence theory evaluation: The first step: (1) Through the analytic hierarchy process to determine the weight of each index factor. (2) The initial determination on underlying factors of safety integrity level assurance of, and the value of is generally composed of expert decision makers or industry according to the practice experience and knowledge (Ding and Hu, 2010). Basic probability function on the bottom of the elements of is, then the basic probability function key index of is, the basic probability function non critical index of is, Where is the weight of the key indicators. This article take the discount rate = 0.92.

Third step: Evidence synthesis on a layer of index in the basic probability assignment safety grade according to the basic probability assignment. Again according to the combination rule of evidence theory and recursion equation:

$$N^{q}_{i(p+1)} = k_{i(p+1}[N^{q}_{i(p)}N^{q}_{p+1} + N^{\theta}_{i(p)}N^{\theta}_{p+1} + N^{\theta}_{i(p)}N^{q}_{p+1}] \quad (1)$$

$$N^{\theta}_{i(p+1)} = k_{i(p+1)}N^{\theta}_{i(p)} + N^{\theta}_{p+1} \quad (2)$$

$$k_{i(p+1)} = 1(\sum_{i=1}\sum_{q\neq 1} N^{q}_{i(p)}N^{q}_{p+1})^{-1} \quad (3)$$

The evaluation of D-S combination rule formula synthetic index factors, obtain basic probability assignment rule layer safety degree value. Then the evaluation index of the criterion layer to synthesis, reliability distribution safety grade target layer under the value.

Fourth step: synthesis using the above formula again, can get the whole evaluation system safety degree confidence values and puts forward the corresponding improvement measures according to the result of data synthesis.

EVALUATION EXAMPLES AND DISCUSSION

Highway design traffic security evaluation indicators system: According to the system engineering theory and the structure of man, vehicle and environment, management in the modern safety science (Shafer, 1976), following the principles of scientific, rational and measurable as well as the works of domestic and foreign scholars, taking Zhejiang Province Yiwu a a highway paragraph as examples to establish the framework of risk indexes of highway design safety through surveys, interviews and questionnaires. As shown in Fig. 1 the risk assessment evaluation index system of highway design safety is a two-story structure and the second layer of indicators includes 18 factors indicators while the first layer includes highway alignment factors, roadbed factors, pavement factors and safety facilities factors four. The security situation in the first layer can be obtained from the comprehensive security of indicators in the second layer. The safety evaluation is classified as "poor", "range", "General", "good", "perfect" five, the model evaluation set is denoted as:

$$V = \{V_1, V_2, V_3, V_4, V_5\}$$

Highway design and traffic safety evaluation examples

Determination of initial weights: Extraction of the project design and management personnel, to determine the weights of all indicators using questionnaire method. A total of 4 experts in highwaymanagement of design knowledge and rich practical experience of the composition evaluation group, the weight of one class index evaluation indicators and two indicators of the judgment, the judgment matrix is established (Rong, 2008). Then check calculation for using chromatography analysis method and get the corresponding weight of each index of vector data is normalized and averages the weight of each index value, the first layer of safety evaluation index weight set.

Similarly, statistical analysis of the second factors, the safety evaluation index weight set, respectively.

Sure the reliability of the initial: Select a familiar or understand the evaluation project, evaluation of the road safety situation. Still in the form of survey, invited the 10 management personnel, to give a certain score for safety grade level the score of 0-10. Through the investigation and statistical analysis to the underlying factors that degree as shown in Table 1.

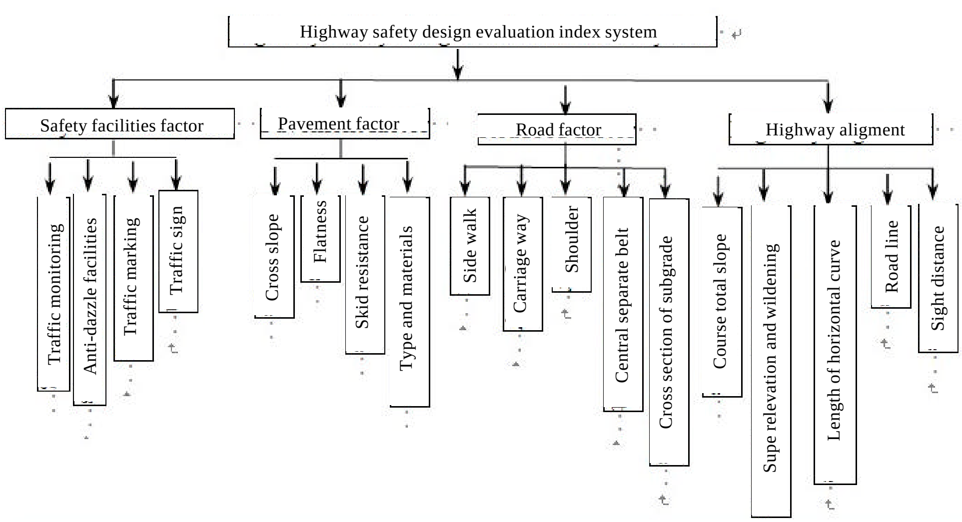

Fig. 1: Scheme diagram of the structure design of highway traffic safety evaluation index system

Table 1: Underlying factor of reliability allocation table

Criterion layer	Index	Safety grade evaluation				
		V_1	V_2	V_3	V_4	V_5
Highway alignment (U_{11}, T_{11})	Sight distance (U_{11}, ω_{11})	0.10	0.40	0.35	0.15	0.00
	Road line (U_{12}, ω_{12})	0.00	0.00	0.30	0.70	0.00
	Length of horizontal curve (U_{13}, ω_{13})	0.10	0.40	0.40	0.40	0.00
	Supe relevation and widening (U_{14}, ω_{14})	0.05	0.40	0.30	0.25	0.00
	Course total slope (U_{15}, ω_{15})	0.24	0.32	0.26	0.08	0.10
Factor of roadbed (U_2, T_2)	Cross section of subgrade (U_{21}, ω_{21})	0.13	0.24	0.30	0.18	0.07
	Central separate belt (U_{22}, ω_{22})	0.15	0.34	0.31	0.20	0.00
	Shoulder (U_{23}, ω_{23})	0.13	0.23	0.43	0.21	0.00
	Carriageway (U_{24}, ω_{24})	0.00	0.37	0.36	0.27	0.00
	Sidewalk (U_{25}, ω_{25})	0.00	0.22	0.42	0.26	0.10
Pavement (U_3, T_3)	Type and materials (U_{31}, ω_{31})	0.00	0.37	0.43	0.20	0.00
	Skid resistance (U_{32}, ω_{32})	0.16	0.31	0.33	0.05	0.15
	Flatness (U_{33}, ω_{33})	0.15	0.34	0.27	0.14	0.10
	Corss slope (U_{34}, ω_{34})	0.15	0.34	0.31	0.10	0.10
Safety facilities (U_4, T_4)	Traffic sign (U_{41}, ω_{41})	0.28	0.26	0.34	0.12	0.00
	Traffic marking (U_{42}, ω_{42})	0.13	0.23	0.43	0.21	0.00
	Anti-dazzle facilities (U_{43}, ω_{43})	0.00	0.37	0.36	0.27	0.00
	Traffic monotoring (U_{44}, ω_{44})	0.00	0.25	0.40	0.25	0.10

Table 2: Road alignment factor under the factor of reliability allocation table

Factor of road alignment	Weight normalized value ω_{1j}	Basic probability assignment					
		V_1	V_2	V_3	V_4	V_5	Θ
U_{11}	0.920	0.920	0.368	0.322	0.138	0.000	0.080
U_{12}	0.875	0.000	0.000	0.630	0.613	0.000	0.124
U_{13}	0.716	0.072	0.286	0.286	0.072	0.000	0.284
U_{14}	0.671	0.034	0.268	0.201	0.168	0.000	0.329
U_{15}	0.887	0.213	0.284	0.231	0.071	0.089	0.156
Synthesis of credibility $U'_{ij}(V_q)$		0.108	0.262	0.465	0.140	0.020	0.005

Table 3: Subgrade factor under the factor of reliability allocation table

Subgrade factor	Weight normalized value ω_1	Basic probability assignment					
		V_1	V_2	V_3	V_4	V_5	Θ
U_{21}	0.482	0.063	0.116	0.145	0.087	0.034	0.555
U_{22}	0.920	0.138	0.313	0.285	0.184	0.000	0.080
U_{23}	0.887	0.115	0.204	0.381	0.186	0.000	0.114
U_{24}	0.628	0.000	0.232	0.226	0.170	0.000	0.372
U_{25}	0.405	0.000	0.089	0.170	0.105	0.041	0.595
Synthesis of credibility $U'_{ij}(V_q)$		0.044	0.279	0.465	0.158	0.003	0.051

Table 4: Road factor under the factor of reliability allocation table

Road factor	Weight normalized value ω_1	Basic probability assignment					
		V_1	V_2	V_3	V_4	V_5	Θ
U_{31}	0.299	0.0000	0.111	0.129	0.060	0.000	0.700
U_{32}	0.904	0.0145	0.280	0.298	0.045	0.024	0.208
U_{33}	0.920	0.1380	0.313	0.248	0.129	0.092	0.080
U_{34}	0.495	0.0740	0.168	0.153	0.050	0.050	0.505
Sunthesis of credibility $U'_{ij}(V_q)$		0.1040	0.408	0.349	0.068	0.040	0.310

Table 5: Traffic safety facility factor under the factor of reliability allocation table

Traffic safety facilities factor	Weight normalized value ω_1	Basic probability assignment					
		V_1	V_2	V_3	V_4	V_5	Θ
U_{41}	0.920	0.258	0.239	0.313	0.110	0.0000	0.0800
U_{42}	0.918	0.119	0.275	0.395	0.193	0.0000	0.0180
U_{43}	0.290	0.000	0.107	0.104	0.078	0.0000	0.7110
U_{44}	0.298	0.000	0.075	0.119	0.075	0.0300	0.7010
Synthesis of credibility $U'_{ij}(V_q)$		0.105	0.275	0.506	0.112	0.0002	0.0018

Data synthesis: By Eq. 1-3 followed bybasic probability assignment of index layer under the $U_{ij}'(V_q)$ and then to synthesize data, finally get the fact standard layer under the basic probability assignment is $U_i'(V_q)$, as shown in Table 2-5. And then a comprehensive evaluation, comprehensive evaluation of highway design can be safe

Table 6: Road safety evaluation of comprehensive reliability allocation table

		Basic probability assignment					
One class index	Weight normalized value ω'$_1$	V_1	V_2	V_3	V_4	V_5	Θ
U_1	0.920	0.099	0.241	0.423	0.129	0.018	0.090
U_2	0.273	0.012	0.076	0.127	0.143	0.001	0.741
U_3	0.576	0.060	0.235	0.201	0.039	0.004	0.461
U_4	0.262	0.028	0.072	0.133	0.029	0.000	0.738
Synthesis of credibility $U'_i(V_q)$		0.074	0.278	0.502	0.014	0.010	0.122

credibility distribution, as shown in Table 6. Therefore, the safety evaluation of the highway trust 50.2% (mediuml)>27.8 (better)>12.2% (fail)>7.4% (good)>1.4% (pass), in accordance with the principle of maximum degree of membership, the safety evaluation for the general.

According to the results of data analysis, the design of highway safety performance in general, need to be further improved.

CONCLUSION

The evaluation results can be seen:

- The assessment of highway section line length design is appropriate, the plane curve is reasonable, but more sections by critical value, poor coordination. The longitudinal gradient can meet the design requirements, but there are also part of the road freight climbing difficult, extremely easy to cause the traffic jam. The evaluation section of part of high rationality
- There is a contradiction between traffic and the number of lanes, the lane width meet the standard requirements, but the section of large trucks accounted for a large proportion, coupled with the evaluation of road through the village more, pedestrians crossing the road is pervasive and there is a certain amount of agricultural vehicle driving, have a certain impact on traffic safety

Measures to improve:

- Without undue increase in the case of quantity, the maximum radius of vertical curve of limit, ensure the longitudinal slope does not meet the requirements of the road not too long
- Improve visibility, increase the chevron alignment sign, make driving people take the initiative to reduce speed in advance; the speed limit signs, set the decelerating oscillatory line, forcing motorists passive deceleration; increase the curve superelevation, reduce the speed of vehicle with high risk

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