A Comprehensive Evaluation Approach of Road Traffic Safety Based on Grey Analysis

Qiao Lan; Yibing Li; Jun Xu
(State Key Laboratory of Automotive Safety & Energy, Tsinghua University, Beijing, 100084, China)

Abstract: Road traffic safety is a comprehensive system, which is affected and controlled by multiple factors. Analyzing the characteristics and affect factors of the traffic accidents, this paper suggests an index system which contains quantitative indexes for road traffic safety evaluation. The weights of the indexes are determined by AHP-LSDM suggested last year. Based on grey analysis, a new approach was proposed for road traffic safety evaluation, which combines the advantages of qualitative and quantitative analysis. Finally, a comprehensive evaluation of the road traffic safety condition in China is given. The results can be listed in order directly and show the accuracy and validity of the approach.
Keywords: comprehensive evaluation; traffic safety; index system; gray analysis

1 Introduction

Safety is a crucial topic in road traffic situation. The road traffic safety condition of China[1] shows that 265204 road traffic accidents happened and 73484 people were killed and 304919 people were injured in 2008. China has the largest number of people been killed in traffic accidents among the world, reflecting that the road traffic safety condition in China is not good.

To better improve the situation of road traffic safety, road traffic safety evaluation is used. Road traffic safety evaluation can describe the road safety condition and also provides important foundation for analyzing the road safety condition. To build up an index system for road traffic safety evaluation is the first step in the evaluation process. Analyzing the characteristics and affect factors of the traffic accidents, an index system which contains quantitative indexes for road traffic safety evaluation is suggested.

The generally used approaches of road traffic safety evaluation are applied statistics method, accident intensity method, time Series method and so on. However, the domestic evaluation of the road traffic safety is on very basic level. Although these approaches are useful in some evaluation, some drawbacks are very obvious such as some subjective factor may bias the conclusion or only focus on part of the safety condition. Based on grey analysis, a new approach which combines the advantages of qualitative and quantitative analysis is proposed.

2 The index system for road traffic safety evaluation

There are five characteristics for road traffic accidents shown as following: 1）cause and effect；2）chance；3）concealment；4）phases；5）complexity [2] . From these characteristics, we can analyze the factors which affect the road safety condition. Considering factors about human, vehicle, road circumstance, this paper suggests an index system for road traffic safety evaluation. This index system is mainly divided into three parts such as the happen rate of traffic accidents, the severity degree of traffic accidents and the probability of traffic accidents. And on the second index layer, the indexes are chosen to detailed describe the road traffic safety condition.

Thus, an index system for road traffic safety evaluation is founded. As table1 shows:

According to the weights determination approach AHP-LSDM [3] suggested last year, the weight vectors of the three parts are:

$$w_1 = (0.3603, 0.1759, 0.1545, 0.3094)^{\mathrm{T}}$$
$$w_2 = (0.3244, 0.3722, 0.3034)^{\mathrm{T}}$$
$$w_3 = (0.2234, 0.4218, 0.3548)^{\mathrm{T}}$$

Table1: index system for road traffic safety evaluation

Aim	first index layer	second index layer
Road traffic safety evaluation	The happen rate of traffic accidents	The happen rate count in vehicles The happen rate count in human The happen rate count in GDP The happen rate count in mileage
	The severity degree of traffic accidents	The death rate The death/injure rate The direct economic loss
	The probability of traffic accidents	The level of roads The traffic accident descend rate The death toll descend rate

And the weight for the first layer is:

$$w = (0.4, 0.26, 0.34)^{\mathrm{T}}$$

Thus, a index system for road traffic safety evaluation is found and the weights of the indexes are determined by AHP-LSDM.

3 Found the comprehensive evaluation model

Based on grey analysis, a new approach was proposed for road traffic safety evaluation, which combines the advantages of qualitative and quantitative analysis. This approach gives out specific numbers as the evaluation results which can be easily used in comparison. Combining the AHP-LSDM and the grey evaluation, a comprehensive evaluation model is given.

First we decide the evaluation object, the evaluation index and the evaluation grey kind. Then use the non-dimensional process on the original data. Assume the indexes are j=1,2,…,m, the evaluation objects are i=1,2,…,m.

$$x_{ij}=\begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}$$

The non-dimensional process [4] should also concern the direction of the data. If the larger the better of the data, we use $\frac{\max(x_i)-x_i}{\max(x_i)-\min(x_i)}$, if the smaller the better of the data, we use $\frac{x_i-\min(x_i)}{\max(x_i)-\min(x_i)}$. After these processes, we have made the original data non-dimensional and comparable.

The road traffic safety condition is divided into five levels in this paper. Assume that the range of the evaluation data is [0,10], the gray number of all the five levels are excellent [0,9,10], good [0,7,10), common [0,5,8), poor [0,3,6), very poor [0,1,3).

The gray weight functions are:

$$f_1(x)=\begin{cases} \frac{x}{9}, 0<x<9 \\ 1, x>9 \\ 0, \text{else} \end{cases},\ f_2(x)=\begin{cases} 1, 0<x<7 \\ \frac{10-x}{3}, 7<x<10 \\ 0, \text{else} \end{cases},\ f_3(x)=\begin{cases} 1, 0<x<5 \\ \frac{8-x}{3}, 5<x<8 \\ 0, \text{else} \end{cases},$$

$$f_4(x)=\begin{cases} 1, 0<x<3 \\ \frac{6-x}{3}, 3<x<6 \\ 0, \text{else} \end{cases},\ f_5(x)=\begin{cases} 1, 0<x<3 \\ \frac{3-x}{2}, 1<x<3 \\ 0, \text{else} \end{cases}$$

The definite weigh were decided by AHP-LSDM. Then we use the weight determination approach to determine the cluster weight. The clustering weight is defined as:

$$\eta_{ki}=\frac{\lambda_{ki}}{\sum_{k=1}^{m}\lambda_{ki}}$$

k=5 is evaluation grey kind, λ_{ji} is the calculation number of object i in grey k.

The clustering weight matrix for object i is:

$$R_i=\begin{pmatrix} \eta_{11} & \cdots & \eta_{1n} \\ \vdots & \ddots & \vdots \\ \eta_{k1} & \cdots & \eta_{kn} \end{pmatrix}$$

The clustering number of object i is Z_i:

$$Z_i=Z_i^{'}\times w^{\mathrm{T}}=\left[(w_1^{\mathrm{T}},w_2^{\mathrm{T}},w_3^{\mathrm{T}})^{\mathrm{T}}\times R_i\right]\times w^{\mathrm{T}}$$

The evaluate value of object i is ZR_i:

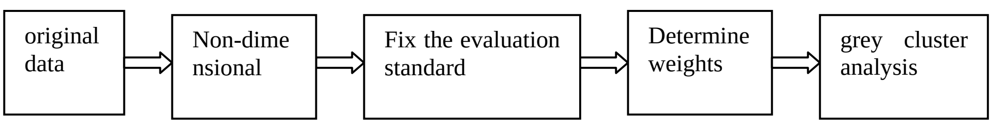
$$ZR_i=Z^{\mathrm{T}}\times E^{\mathrm{T}}=Z^{\mathrm{T}}\times(9,\ 7,\ 5,\ 3,\ 1)^{\mathrm{T}}$$

The evaluate value will be a specific number which can be easily used in comparison.

4 Comprehensive evaluation of the road traffic safety condition in China

4.1 Comprehensive evaluation process

Use the comprehensive evaluation model proposed before. The process is:



Figer1: comprehensive evaluation process

4.2 Data analysis

(1) Original data

The original data comes from Traffic Management Bureau, the Ministry of Public Security of the Peoples' Republic of China. The non-dimensional results are shown in table 2:

Table2: The non-dimensional results of the original data

Year	The happen rate count in vehicles	The happen rate count in human	The happen rate count in GDP	The happen rate count in mileage	The death rate	The death/ injure rate	The direct economic loss	The level of roads	The traffic accident descend rate	The death toll descend rate
1996	0.3223	0.9181	0.4736	0.5408	0.1537	0.0000	0.6999	0.0000	0.5858	0.3435
1997	0.4008	0.8925	0.5052	0.5262	0.2505	0.1270	0.6455	0.1639	0.5874	0.4599
1998	0.3531	0.8183	0.4637	0.4655	0.3767	0.2775	0.6102	0.3819	0.5117	0.4090
1999	0.3573	0.6757	0.3800	0.3726	0.5466	0.5270	0.5277	0.4356	0.3994	0.3119
2000	0.0778	0.3409	0.1109	0.0127	0.9137	0.8458	0.2968	0.5073	0.0000	0.1130
2001	0.0000	0.0353	0.0000	0.0000	1.0000	1.0000	0.1192	0.3522	0.0902	0.0000
2002	0.1400	0.0000	0.0766	0.0131	0.9915	0.9960	0.0190	0.3958	0.4192	0.2009
2003	0.4336	0.2486	0.3282	0.2029	0.8827	0.9107	0.0000	0.4839	0.7669	0.5415
2004	0.6572	0.5300	0.6073	0.4491	0.5141	0.8531	0.4144	0.5754	0.9815	0.5601
2005	0.8000	0.6532	0.7375	0.5659	0.4224	0.9162	0.6294	0.6488	0.9986	0.7511
2006	0.8893	0.7885	0.8492	0.8970	0.2990	0.9296	0.7966	0.8388	0.9938	0.8871
2007	0.9485	0.8855	0.9285	0.9459	0.2012	0.8935	0.9199	0.9456	0.9614	0.9705
2008	1.0000	1.0000	1.0000	1.0000	0.0000	0.7634	1.0000	1.0000	1.0000	1.0000

As $\sum_{k=1}^{5}\lambda_{k1}=\sum_{k=1}^{5}f_j(x_{i1})$ is the sum of the gray values for index 1 in object i.

For index 1 in object 1, the happen rate count in vehicles, the clustering weight is:

$$\eta_{k1}=\frac{\lambda_{k1}}{\sum_{k=1}^{5}\lambda_{k1}}=f_1(x_{i1})/\sum_{j=1}^{5}f_j(x_{i1})$$

For year 1996 (object 1), we have 10 indexes, so the clustering weight calculated as:

$$R_1=\begin{bmatrix} 0.0364 & 0.1137 & 0.0556 & 0.0702 & 0.0158 & 0.0000 & 0.0902 & 0.0000 & 0.0616 & 0.0384 \\ 0.1015 & 0.0310 & 0.1057 & 0.1169 & 0.0927 & 0.0727 & 0.1160 & 0.0884 & 0.0947 & 0.1006 \\ 0.1015 & 0.0000 & 0.1057 & 0.1010 & 0.0927 & 0.0727 & 0.0387 & 0.0884 & 0.0676 & 0.1006 \\ 0.0940 & 0.0000 & 0.0446 & 0.0231 & 0.0927 & 0.0727 & 0.0000 & 0.0884 & 0.0045 & 0.0860 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0678 & 0.0727 & 0.0000 & 0.0884 & 0.0000 & 0.0000 \end{bmatrix}$$

To calculate the clustering number Z_1:

$$Z_1^{'}=(w_1^{\mathrm{T}},w_2^{\mathrm{T}},w_3^{\mathrm{T}})^{\mathrm{T}}\times R_1=\begin{bmatrix} 0.0634 & 0.0325 & 0.0396 \\ 0.0945 & 0.0923 & 0.0357 \\ 0.0842 & 0.0689 & 0.0839 \\ 0.0479 & 0.0571 & 0.0521 \\ 0.0000 & 0.0490 & 0.0197 \end{bmatrix}$$

$$Z_1=Z_1^{'}\times w^{\mathrm{T}}=\left(0.0473,0.0942,0.0801,0.0517,0.0195\right)^{\mathrm{T}}$$

To calculate the evaluate value ZR_1:

$$ZR_1=Z_1^{\mathrm{T}}\times E^{\mathrm{T}}=Z_1^{\mathrm{T}}\times(9,\ 7,\ 5,\ 3,\ 1)^{\mathrm{T}}=1.661$$

Through the same process, we can calculate the evaluate value of the other objects:

$$ZR=\left(ZR_1,ZR_2,\cdots,ZR_{10}\right)$$

The final results of the evaluate value are shown below:

Table3: the final results of the evaluate value

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1.661	6.157	6.063	5.980	5.574	5.042	5.625	7.020	7.614	8.117	9.108	8.610	8.318

According to the evaluation, it is clear that in 2006 China has the best road traffic safety condition during the last 13 years. Although China's road traffic safety condition wins excellent evaluation in the last three years, the grades keep on reducing since 2006. More detailed evaluation is needed to find out the drawbacks in China's road traffic safety where we should improve to get better safety situation.

5 Conclusions

We can draw the following conclusions.

(1) Considering the factors about human, vehicle and road circumstance, this paper analyzes the factors which affect the road safety condition and an index system for road traffic safety evaluation is suggested. And the weight vectors are given out using AHP-LSDM suggested last year,

(2) This paper combines the gray analysis method and AHP-LSDM together to form a comprehensive evaluation model. A synthetic estimate of the road traffic safety can be made objectively using this comprehensive method.

(3) An evaluation of the road traffic safety condition in China is shown. The results given by this comprehensive approach is a specific number which can be easily used in comparison. This is a progress in the evaluation method and provides theoretical foundation for the road traffic safety evaluation.

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Reference

[1] The Ministry of Public Security of the People's Republic of China. The road traffic safety condition of China. http://www.mps.gov.cn/n16/n1282/n3553/1770249.html, 2008

[2] 孙伟. 城市道路交通安全评价指标体系研究[D]. 硕士学位论文，南京林业大学，2007

[3] Qiao Lan, Yibing Li, Xu Jun. Weights Determination Based on Combined Objective and Subjective method in Traffic Safety Evaluation[J]. The Sixth International Forum of Automotive Traffic Safety, 2008, 89-94

[4] 姜启源，谢金星，叶俊. 数学模型[M]. 北京：高等教育出版社，2003.8

[5] Yajing Lin, Shanjun Mao. Study of a Comprehensive Assessment Method for Coal Mine Safety Based on a Hierarchical Grey Analysis[J]. Journal of China University of Mining & Technology, 2007, 6-10

[6] EfraimTurban, DuanningZhou, JianMa. A group decision support approach to evaluating journals[J]. Information&Management, 2004, 31-44