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Research on urban road traffic safety evaluation based on the combined weight topsis method

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Abstract: *In this paper, an index evaluation system on traffic safety is constructed based on accident indicators and hidden danger indicators, combined with the AHP-EMW combined weight method for index weight analysis, which effectively solves the influence of subjective extremum deviation on weight accuracy, and uses the Topsis method to conduct traffic safety evaluation on 10 urban roads, conducts case verification, and proposes suggestions and measures to improve urban road traffic safety according to the evaluation results, providing a certain reference for the research of urban road traffic safety.*

Keywords: *Traffic safety evaluation; Combined weight; Topsis; Urban roads*

1. Introduction

In recent years, due to the rapid development of road traffic, the number of motor vehicles in the city has also increased rapidly, so the road accident mortality rate has been rising in recent years, resulting in the formation of a huge safety hazard. It is urgent to build a sound and reasonable urban road traffic safety evaluation system.Based on the improved material element extensibility model and the theory of variable weight, Wang Qian et al. established a traffic safety evaluation model for urban road tunnels and concluded that the uniformity of road surface brightness and the mixing rate of models had a greater impact on the evaluation results[1]. Sun Qiuxia et al. constructed a comprehensive evaluation model of Yunwuyuan that combines the two for the evaluation of urban road traffic safety[2]. Luo Qiang et al. used fuzzy algorithms to establish an evaluation model of urban traffic conditions and verified by example that the model can be used to evaluate urban road traffic safety[3].

However, the above methods are difficult to deal with the transformation of qualitative concepts and quantitative values. Therefore, the AHP-EMW combined weight method is used to obtain the weights of each index, the topsis method is used to realize the conversion of qualitative concepts and quantitative values, and the comprehensive evaluation model of combined weight topsis traffic safety is constructed, which is used for urban road traffic safety level evaluation.

2. Establish a safety evaluation index system

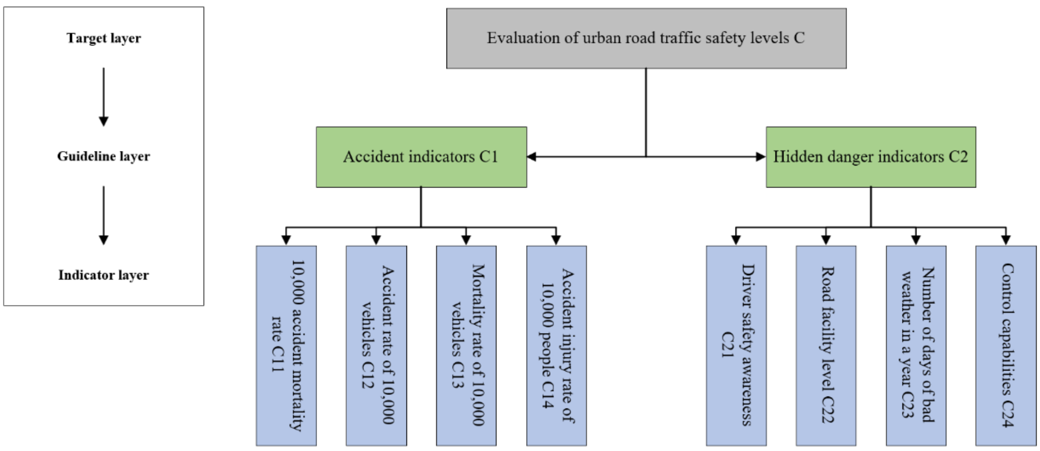

Figure 1: Urban road traffic safety evaluation index system

According to previous research, many indicators affect urban road traffic safety, so it is necessary to establish a sound and reasonable evaluation index system before making safety evaluations. Based on the principles of objectivity and scientificity, comparability and feasibility, comprehensiveness and conciseness, an urban road traffic safety evaluation index system has been established, as shown in Figure 1.

3. Comprehensive evaluation model of traffic safety

3.1 Combinatorial weight method

3.1.1 Determine subjective weights

Ordered weighted vectors v_t:

$$v_s = \frac{C_{s-1}^t}{\sum_{t=0}^{s-1} C_{s-1}^t} = \frac{C_{s-1}^t}{2^{s-1}} \quad (1)$$

The absolute weight of the jth indicator $\overline{w_j}$:

$$\overline{w_j} = \sum_{t=0}^{s-1} v_t\, p_t \quad (2)$$

The OWA operator corrects the subjective weight weights w_j:

$$w_j = \frac{\overline{w_j}}{\sum_{j=1}^{n} \overline{w_j}}, j = 1,2,\dots,n \quad (3)$$

3.1.2 Determine objective weights

First normalize the data (positive indicators):

$$x_{ij} = 0.998 \frac{x_{ij} - \min\{x_{1j},\dots x_{nj}\}}{\max\{x_{1j},\dots x_{nj}\} - \min\{x_{1j},\dots x_{nj}\}} + 0.002 \quad (4)$$

Calculates the weight of the j scheme indicator value under the jth indicator p_{ij}:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} (j = 1,2,\dots,m) \quad (5)$$

Calculates the information entropy value of the jth indicator e_j:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij} \quad (6)$$

Thereinto:

$$k = \frac{1}{\ln(n)}, e > 0 \quad (7)$$

Calculates information entropy redundancy g_j:

$$g_j = 1 - e_j \quad (8)$$

Calculate the weights of each metric h_j:

$$h_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \quad (9)$$

3.1.3 Determine the combined weights

The AHP is used to determine the subjective weights of the accident indicators C_1, hidden danger indicators C_2 and sub-evaluation indicators of urban road traffic, and the weights are corrected by OWA operators, and at the same time, the indicators are objectively empowered by EWM, and finally, the combined weighting is carried out by linear weighting method to effectively solve the impact of subjective extremum deviation on the weight accuracy, so that the calculated weight values are reliable[4-5].

Combined weights W:

$$W = \alpha w_j + \beta h_j \quad (10)$$

Where $\alpha + \beta = 1$.

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3.2 Topsis method

The normalized decision matrix b_{ij} assigned the weight W:

$$C=(c_{ij})_{m\times n}=\begin{bmatrix} b_{11}w_1 & \cdots & b_{1j}w_j \\ \vdots & \ddots & \vdots \\ b_{i1}w_1 & \cdots & b_{ij}w_j \end{bmatrix} \tag{11}$$

Determine the positive ideal solution C_j^+ and the negative ideal solution C_j^-:

$$C_j^+=\max[C_1^+,C_2^+,\dots,C_n^+],C_j^-=\max[C_1^-,C_2^-,\dots,C_n^-] \tag{12}$$

Calculate the distance d of each road to be evaluated to the positive and negative ideal solutions:

$$d_i^*=\sqrt{\sum_{j=1}^{n}(c_{ij}-C_j^+)^2},i=1,2,\dots,m,d_i^0=\sqrt{\sum_{j=1}^{n}(c_{ij}-C_j^-)^2},i=1,2,\dots,m \tag{13}$$

Calculate the relative sticker progress of each road to be evaluated (evaluation reference value) f_i:

$$f_i=\frac{d_i^0}{d_i^*+d_i^0},i=1,2,\dots,m \tag{14}$$

4. Urban road traffic safety evaluation

4.1 Line selection and indicator value determination

In this paper, 10 urban roads are selected for traffic safety evaluation, and the original data collected and sorted out are shown in Table 1:

Table 1: Values of 10 urban road traffic safety evaluation indicators

Road markings	**Indicator value**							
	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}
γ_1	0.28	6.35	2.34	0.52	73.01	71.66	193	76.15
γ_2	0.61	8.02	2.29	2.28	65.34	83.24	138	61.45
γ_3	0.32	5.13	1.76	0.85	83.21	72.01	54	79.63
γ_4	0.32	6.40	1.68	1.15	80.01	75.45	131	68.95
γ_5	0.27	8.80	2.41	0.92	79.26	73.65	222	76.15
γ_6	0.34	8.30	3.37	0.71	76.08	74.06	148	75.21
γ_7	0.51	3.04	2.53	0.29	75.93	75.61	45	77.53
γ_8	0.40	9.70	2.56	1.16	71.65	68.50	67	70.08
γ_9	0.45	15.59	3.32	1.91	69.88	79.78	168	77.06
γ_{10}	0.27	3.00	1.66	0.34	77.48	67.49	121	71.00

4.2 Evaluation index grade limits and weights

According to the provisions of the "Highway Engineering Technical Standards", this paper divides the urban road traffic safety evaluation level into five options: "excellent", "good", "average", "poor" and "extremely poor", and quantifies the answer data in combination with the Likert five-level scale, as shown in Table 2, so that the results can be evaluated later according to the evaluation table of the results of the combined weight Topsis method. In this paper, the grading limits of each evaluation index are obtained by consulting relevant experts, and the weights of each indicator are determined by using the expert scoring method, the questionnaire method, and the combined weight method as shown in Table 3:

Table 2: Road traffic safety evaluation index level limits

Grade	**Outstanding**	**Good**	**So so**	**Poor**	**Range**
Relative sticker progress limits	[1-0.6)	[0.6-0.45)	[0.45-0.35)	[0.35-0.30)	[0.30-0)

Table 3: Weights of road traffic safety evaluation indicators

Evaluation indicators	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}
Weight	0.1245	0.1253	0.1245	0.1253	0.1248	0.1252	0.1249	0.1255

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4.3 Positive and negative ideal solution for traffic safety evaluation

In this paper, 10 roads are used as alternatives, and the values of 10 urban road traffic safety evaluation indicators are normalized, and positive ideal solutions and negative ideal solutions are obtained, as shown in Table 4:

Table 4: Numerical standardization of road traffic safety evaluation indicators and positive and negative ideal solutions

Index	Positive ideal solution C_j^+	Negative ideal solution C_j^-
C_{11}	0.70501001	0.00020729
C_{12}	0.7063973	0.00000561
C_{13}	0.58043693	0.00003394
C_{14}	0.66245656	0.00003329
C_{21}	0.5559635	3.1e-7
C_{22}	0.59659007	0.00000334
C_{23}	0.49011996	0.00000311
C_{24}	0.70497341	0.00000388

4.4 Road ideal solution distance composite score

According to the numerical normalization of the road traffic safety evaluation index in Table 4 and the positive and negative ideal solution, the positive and negative ideal solution of the road and the relative sticker progress are obtained, and they are sorted according to the relative paste progress, as shown in Table 5:

Table 5: Road positive and negative ideal solution distance and relative paste progress

Road markings	Positive ideal solution distance d_i^*	Negative ideal solution distance d_i^0	Relative sticker progress f_i	Sort
γ_1	0.4497638	0.26802792	0.37340626	6
γ_2	0.27932806	0.50004148	0.64159741	1
γ_3	0.54577885	0.15158306	0.21736641	10
γ_4	0.44215937	0.23573642	0.34774728	7
γ_5	0.43741902	0.28462034	0.39418951	5
γ_6	0.39746111	0.3035237	0.43299611	4
γ_7	0.49353058	0.2386235	0.32591979	8
γ_8	0.33677822	0.33407657	0.49798641	3
γ_9	0.29385553	0.44937185	0.6046223	2
γ_{10}	0.51855487	0.23618968	0.3129399	9

5. Evaluation results

According to Table 5 and Table 6, it can be seen that road γ_2, γ_9 are "excellent" and the road safety level is the highest; Road γ_8 is "good" and has a good level of road safety; Road $\gamma_6, \gamma_5, \gamma_1$ is "general", and the road safety level is medium; Road $\gamma_4, \gamma_7, \gamma_{10}$ are "poor" road safety levels are low; Road γ_3 is classified as "extremely poor" and has the lowest road safety level. It can be seen that the current road situation is that there are very few roads in a very poor situation, but there are many roads that need to improve safety capabilities, so certain measures are needed to rectify the roads after evaluating the existing urban road traffic, so as to improve the happiness and safety of residents[6].

Table 6: Results of road traffic safety evaluation

Grade	Outstanding	Good	So so	Poor	Range
Road markings	γ_2, γ_9	γ_8	$\gamma_6, \gamma_5, \gamma_1$	$\gamma_4, \gamma_7, \gamma_{10}$	γ_3

6. Conclusion

The combined weight Topsis method applied to road traffic safety not only treats road traffic safety as a system and an integrated way of thinking for decision-making but also empowers more objective,

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theoretically based, and has higher credibility. Practical application shows that the model can reflect the road traffic safety situation more realistically. According to the research results of this paper, in order to improve the safety level of road traffic in various cities, especially in cities with "poor" and "extremely poor", the following improvement suggestions are given: (1) By increasing the traffic safety awareness of urban residents, establish traffic safety awareness, so as to achieve the purpose of reducing the traffic accident rate; (2) Improve urban air quality by reducing vehicle emissions and using clean energy; (3) By strengthening the city's control capacity, rectifying traffic order, preventing and reducing the occurrence of road traffic accidents, ensuring that the urban road traffic situation continues to be stable, and providing a certain reference for the research of urban road traffic safety.

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