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Research on FAHP Method Based on Highway Bridge Safety

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Abstract

Basing on highway bridge construction technique and management features, this paper conducts analysis and establishment to construction safety risk factor, index system, etc. of actual engineering, after using vague synthetic judgment method, analytic hierarchy process, implement research via integrated evaluation method, makes out argument to different safety risk factors, establishes bridge safety risk factor collection via method of comprehensive assessment, confirms bridge safety risk incidence value, judges matrix by using MATLAB construction vagueness, finally calculates concrete risk gradation sort, and gets highway bridge construction safety risk grade. Through practice it has proved that the construction safety risk assessment method is based on the method of quantification, can find out biggest influence factors on the safety of Bridges in engineering, and can also reduce the misjudgment caused by subjective factors. The safety of the bridge has a positive practical significance.

Keywords

Highway Bridge, FAHP Method, Safety Risk Assessment, Weight Sorting

1. Introduction

The safety of the bridge is a kind of ability that can still work normally under the load without causing accidents. There are many influencing factors for this ability. Generally speaking, it involves the design of the bridge structure, material selection, and construction technology. It is also affected by the degree of maintenance, maintenance, and use after completion. Most of the problems of highway bridges in China are caused by two reasons. One is overuse of bridges and overuse; the other is that maintenance is not in place during use [1]. The assessment of the safety of bridges is a means to determine that the current bridges have this capability. The safety assessment of bridges can provide scientific guidance on the safety of bridges [2].

During the construction of actual roads and bridges, all parties involved have unique security risks. If these problems are not adequately prevented, they will likely lead to casualties. Even if only property damage occurs, it will have a direct impact on the construction of the project. It can even lead to serious social negative effects [3]. With the in-depth development of bridge construction safety risks, a method combining fuzzy comprehensive evaluation and analytic hierarchy process is adopted. Through the construction of the evaluation model, specific construction safety risk factors can be identified and calculated, and specific safety can be determined according to its importance. The risk level provides important data for the following risk control.

2. Bridge Construction Safety Risk Factor Identification

China's social and economic development is fast, and the number of roads and bridges has increased year by year. However, in actual construction and use, we often find that these facilities have safety problems and their durability is poor [4]. The impact of bridge construction safety risk factors, the actual case studied in this paper, mainly involves five levels: external factors, materials, process factors, construction management factors, technical factors, supervision and maintenance factors. And complete the recognition of the importance of these five aspects [5].

The fuzzy comprehensive judgment method is based on the analytic hierarchy process, and the combination of the two can provide better accuracy for the evaluation [6].

3. The Basic Concept of FAHP Evaluation Method

The FAHP evaluation method is a combination of fuzzy comprehensive evaluation (FCE) and analytic hierarchy process (AHP). The application level can cover system evaluation, effectiveness evaluation, system optimization, etc. Quantitative and qualitative assessment model. The judging method is: using fuzzy comprehensive evaluation method to determine the results, and then use the analytic hierarchy process to divide the complex problems into multiple levels. In the structure relationship of multiple constituent factors, the relationship between the various factors can be determined, and then the hierarchical structure can be determined. Conduct the components; then, use the pairwise comparison method to determine the importance of the factors [5]. The fuzzy comprehensive evaluation method belongs to the higher level of the AHP, and the combination of the two can give a more reliable conclusion [6].

There are three levels involved in this method of judgment: Assume that the number of relevant factors for evaluating core things is n, and the set of factors is $U=\{u_1,u_2,\cdots,u_n\}$; assume that the number of possible comments is m, and that it can be judged that the set is $V=\{v_1,v_2,\cdots,v_m\}$; due to the different status of various factors, the role is not the same, usually considered to measure the weight, recorded as $A=\{a_1,a_2,\cdots,a_n\}$.

The assessment of risk factors should be made by many experts to judge things. When the same assessment factors are used to score, different expert opinions can be summed together. From this we can see that these assessment results cannot be expressed using only a single numerical value and should be described in fuzzy terms in words. Through the comprehensive use of the analytic hierarchy process and the fuzzy comprehensive evaluation method, a comprehensive judgment is made on the object to be evaluated [7].

To conduct a fuzzy comprehensive evaluation, usually follow the following steps:

1) Determine the set of factors $U=\{u_1,u_2,\cdots,u_n\}$

2) Determine the judgement set $V=\{v_1,v_2,\cdots,v_m\}$

3) Single factor assessment $r_i=\{v_{i1},v_{i2},\cdots,v_{im}\}$

4) Structural comprehensive evaluation matrix:

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}$$

Comprehensive judgment: After the weight calculation, $A=\{a_1,a_2,\cdots,a_n\}$ obtains the result of $B=A\circ R$. According to the principle of maximum subordination, a comprehensive assessment is performed, and the risk level of the evaluation object is determined [8].

4. Case Analysis

4.1. Project Overview

The object of this study is the Dongfeng Road Trans-Beijing-Hong Kong-Macao Highway Bridge. This bridge belongs to the eastern section of Dongfeng Road in Baoding City. The role is to connect the high-speed railway bus terminal to the downtown area. The total length of the bridge is 504.660 m, including the length of the main bridge 160 m, width 48 m. The lengths of approach bridges on the east and west sides are 200 m and 140 m, respectively; the bridge width is 45 m. The bridge is one of the main trunk roads in the city and is a two-way eight-lane mode.

There are many risk factors affecting the safety of bridges, but it is not necessary to evaluate all the factors. To evaluate these factors scientifically and effectively, based on the actual situation of the project, determine the risk factors of bridge safety, and then give a reasonable evaluation system. Construction plan. First of all, a systematic analysis of the objectives of the study, determine the major factors affecting the bridge's security, and then find out the factors of each of the factors of the next level, resulting in a progressive level of impact relations, as shown in **Table 1**.

4.2. Determination of Impact Degree Value of Bridge Safety Risk

In the actual risk assessment process, according to the specification requirements, combined with the actual situation at the scene, different degrees of value are assigned to different impact conditions, indicating that the project is affected by the risk factors, and the experts score according to the degree values to determine the impact of the project. Key risk factors, such as Table 2.

4.3. Construct Fuzzy Judgment Matrix

After the completion of the safety risk factor assessment index system, the second layer elements B_1, B_2, B_3, B_4, and B_5 during the construction have a dominant effect on the lower elements C_1, C_2, C_3, ... Which risk is greater, it also needs to be expressed in numbers. According to the corresponding numerical

Table 1. Evaluation index system of bridge construction safety risk factors.

Bridge construction safety risk factors A	External factors B_1	Regulatory charters and other theoretical factors C_1
		Construction program factors C_2
		Foundation soil expansion C_3
		natural factors C_4
	Material process factors B_2	The quality of construction materials is not qualified C_5
		Material properties change C_6
		Unreasonable construction process and technology C_7
	Construction management factors B_3	Unfamiliar with drawing blind construction C_8
		Not according to plan construction C_9
		Do not comply with relevant regulations C_{10}
		Do not follow the relevant operating procedures C_{11}
		Disturbance in construction management C_{12}
	Technical factors B_4	Geological exploration factors C_{13}
		Lack of rational planning and design C_{14}
		Lack of emphasis on safety C_{15}
	Regulatory maintenance factors B_5	Completion without construction monitoring C_{16}
		Late maintenance is not in place C_{17}
		Operational stage supervision is not in place C_{18}
		Quality Warranty Insurance System C_{19}

Table 2. Bridge safety risk impact degree value.

Degree value	The degree of influence of risk factors
1	The project is minimally affected by risk factors
2	The project is very little affected by risk factors
3	The project is affected by risk factors
4	The project is less affected by risk factors
5	Works affected by risk factors
6	Project is affected by risk factors
7	Works affected by risk factors
8	The project is greatly affected by risk factors
9	The project is greatly affected by risk factors

labeling rules, the fuzzy judgment matrix can be obtained by the expert scoring the relative importance of the indicators at each level. The determination of the fuzzy judgment matrix is directly related to the quality of the evaluation.

After evaluating B_1, B_2, B_3, B_4, and B_5 in A, compare the risk size and determine the value of the factor. Specifically summarized in Table 3.

The risk fuzzy judgment matrix is established according to the scale value, which is known from the definition of the scale value of the fuzzy analytic hierarchy process:

$$a_{ij} = 0.5, i = j$$

$$a_{ji} = 1 - a_{ij}, i \neq j$$

$$A = \begin{bmatrix} B_1 & B_2 & B_3 & B_4 & B_5 \end{bmatrix}^{\mathrm{T}}$$

$$A = \begin{bmatrix} 0.5 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{1n} \\ a_{21} & 0.5 & a_{23} & a_{24} & a_{25} & a_{26} & a_{2n} \\ a_{31} & a_{32} & 0.5 & a_{34} & a_{35} & a_{36} & a_{3n} \\ a_{41} & a_{42} & a_{43} & 0.5 & a_{45} & a_{46} & a_{4n} \\ a_{51} & a_{52} & a_{53} & a_{54} & 0.5 & a_{56} & a_{5n} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 0.5 & a_{66} \\ a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{n5} & a_{n6} & 0.5 \end{bmatrix}$$

Create A fuzzy comprehensive judgment matrix:

$$A = \begin{bmatrix} B_1/B_1 & B_1/B_2 & B_1/B_3 & B_1/B_4 & B_1/B_5 \\ B_2/B_1 & B_2/B_2 & B_2/B_3 & B_2/B_4 & B_2/B_5 \\ B_3/B_1 & B_3/B_2 & B_3/B_3 & B_3/B_4 & B_3/B_5 \\ B_4/B_1 & B_4/B_2 & B_4/B_3 & B_4/B_4 & B_4/B_5 \\ B_5/B_1 & B_5/B_2 & B_5/B_3 & B_5/B_4 & B_5/B_5 \end{bmatrix}$$

$$= \begin{bmatrix} 0.5 & 0.6 & 0.3 & 0.4 & 0.4 \\ 0.4 & 0.5 & 0.3 & 0.4 & 0.4 \\ 0.7 & 0.7 & 0.5 & 0.6 & 0.5 \\ 0.6 & 0.6 & 0.4 & 0.5 & 0.4 \\ 0.6 & 0.6 & 0.5 & 0.6 & 0.5 \end{bmatrix}$$

Calculate the weight matrix of the fuzzy complementary matrix of risk factors

Table 3. Risk factors.

Scale value	meaning	Specific instructions
0.5	Equally important	Comparing two factors, equally important
0.6	Slightly important	The former factor is slightly more important than the latter factor
0.7	Obviously important	The former factor is obviously more important than the latter factor
0.8	Much more important	The former factor is much more important than the latter factor
0.9	Extremely important	The former factor is more important than the latter factor
0.1 - 0.4	On the contrary	Comparison of two factors $r_{ij} = 1 - r_{ji}$

using MATLAB tool to get the feature vector value:

$$A=[0.1741,0.1204,0.2801,0.1991,0.2290]^{\mathrm{T}}$$

Create a B1 fuzzy judgment matrix:

$$B_1=\begin{bmatrix} C_1/C_1 & C_1/C_2 & C_1/C_3 & C_1/C_4 \\ C_2/C_1 & C_2/C_2 & C_2/C_3 & C_2/C_4 \\ C_3/C_1 & C_3/C_2 & C_3/C_3 & C_3/C_4 \\ C_4/C_1 & C_4/C_2 & C_4/C_3 & C_4/C_4 \end{bmatrix} =\begin{bmatrix} 0.5 & 0.6 & 0.4 & 0.3 \\ 0.4 & 0.5 & 0.4 & 0.3 \\ 0.6 & 0.6 & 0.5 & 0.4 \\ 0.7 & 0.7 & 0.6 & 0.5 \end{bmatrix}$$

Using the MATLAB tool to calculate the weight matrix of the risk fuzzy consensus matrix:

$$B_1=[0.2219,0.2002,0.2632,0.3147]^{\mathrm{T}}$$

The same reason:

$$B_2=[0.3965,0.2046,0.3998]^{\mathrm{T}}$$

$$B_3=[0.1359,0.1208,0.2343,0.2429,0.2661]^{\mathrm{T}}$$

$$B_4=[0.2873,0.4221,0.2906]^{\mathrm{T}}$$

$$B_5=[0.2403,0.2437,0.3283,0.1877]^{\mathrm{T}}$$

According to the obtained B_1, B_2, B_3, B_4, and B_5, the total sorting weight of the C layer can be calculated:

$$\begin{bmatrix} 0.2219 & 0 & 0 & 0 & 0 \\ 0.2002 & 0 & 0 & 0 & 0 \\ 0.2632 & 0 & 0 & 0 & 0 \\ 0.3147 & 0 & 0 & 0 & 0 \\ 0 & 0.3965 & 0 & 0 & 0 \\ 0 & 0.2046 & 0 & 0 & 0 \\ 0 & 0.3998 & 0 & 0 & 0 \\ 0 & 0 & 0.1359 & 0 & 0 \\ 0 & 0 & 0.1208 & 0 & 0 \\ 0 & 0 & 0.2343 & 0 & 0 \\ 0 & 0 & 0.2429 & 0 & 0 \\ 0 & 0 & 0.2661 & 0 & 0 \\ 0 & 0 & 0 & 0.2873 & 0 \\ 0 & 0 & 0 & 0.4221 & 0 \\ 0 & 0 & 0 & 0.2906 & 0 \\ 0 & 0 & 0 & 0 & 0.2403 \\ 0 & 0 & 0 & 0 & 0.2437 \\ 0 & 0 & 0 & 0 & 0.3283 \\ 0 & 0 & 0 & 0 & 0.1877 \end{bmatrix}$$

4.4. Hierarchical Sorting

After the analysis above, the result is the total ranking weight of the C layer. The importance of all the factors of the C layer is compared with the importance of the top layer A and the ranking can be concluded that the total risk of the Dongfeng Road cross-bridge Beijing-Hong Kong-Macao highway bridge engineering, such as Table 4, Table 5.

According to the above calculation results, this paper evaluates the engineering risk factors of Dongfeng Road across the Beijing-Hong Kong-Macao expressway bridge. The results obtained are: lack of reasonable planning and design, lack of supervision during the operation period, construction management disorder, etc. Reasonable planning and design, quality supervision throughout the life cycle of the operation stage and efficient construction organization and management have a crucial role in the project [9].

In this paper, the highway bridge project is analyzed by the risk level, and the method used is statistics. The final result of each factor weight can be calculated and the principle of maximum degree of membership can be determined. After

Table 4. Comparison of the factors of layer C and the weight of layer A.

Specific risk factors C	Various factors and weights					The weight of all factors relative to item A
	B_1	B_2	B_3	B_4	B_5	
	0.1741	0.1204	0.2801	0.1991	0.2290	
C_1	0.2219	0	0	0	0	0.038633
C_2	0.2002	0	0	0	0	0.034855
C_3	0.2631	0	0	0	0	0.045806
C_4	0.3147	0	0	0	0	0.054789
C_5	0	0.3965	0	0	0	0.047739
C_6	0	0.2046	0	0	0	0.024634
C_7	0	0.3998	0	0	0	0.048136
C_8	0	0	0.1359	0	0	0.038600
C_9	0	0	0.1208	0	0	0.033836
C_{10}	0	0	0.2343	0	0	0.065627
C_{11}	0	0	0.2429	0	0	0.068036
C_{12}	0	0	0.2661	0	0	0.074535
C_{13}	0	0	0	0.2873	0	0.057201
C_{14}	0	0	0	0.4221	0	0.08404
C_{15}	0	0	0	0.2906	0	0.057858
C_{16}	0	0	0	0	0.2403	0.055029
C_{17}	0	0	0	0	0.2437	0.055807
C_{18}	0	0	0	0	0.3283	0.075181
C_{19}	0	0	0	0	0.1877	0.042983

Table 5. Ranking of risk factor weight values.

Specific risk factors	Weights
Lack of rational planning and design	0.08404
Operational stage supervision is not in place	0.075181
Disturbance in construction management	0.074535
Do not follow the relevant operating procedures	0.068036
Do not comply with relevant regulations	0.065627
Lack of emphasis on safety	0.057858
Geological exploration factors	0.057201
Late maintenance is not in place	0.055807
Completion without construction inspection	0.055029
natural factors	0.054789
Unreasonable construction process and technology	0.048136
Construction material quality is not qualified	0.047739
Ground subsidence collapse	0.045806
Quality Warranty Insurance System	0.042983
Regulatory charters and other theoretical factors	0.038633
Unfamiliar with the blind construction of soil paper	0.038066
Construction program factors	0.034855
Not according to plan construction	0.033836
Material properties change	0.024634

evaluating the engineering risk level, this paper concludes that The result is moderate risk.

5. Conclusions

1) This paper finds out safety factors that affect bridge engineering combining reality and conduct systematic category to it, conducts category according to external factor, materials technology factor, construction supervision factor, technical factor, supervision maintenance factor and establishes bridge construction safety risk factor evaluation index system.

2) A fuzzy analytic hierarchy process was introduced to analyze the factors affecting the safety of bridges with Dongfeng Road, Beijing-Hong Kong-Macao Expressway bridge project in Baoding City. The safety risk factors were analyzed, different safety risk factors were demonstrated, and the bridge safety risk was established in a comprehensive assessment manner. Factor sets, determine the value of bridge safety risk impact, use MATLAB to construct a fuzzy judgment matrix, and finally calculate the level of specific risk factors, and obtain the Dongfeng Road cross-Beijing-Hong Kong-Macao expressway bridge construction safety risk rating. This method can display the safety risk of road and bridge more accurately and objectively, and has more feasible operational value for en-

gineering safety management and comprehensive management [10].

3) The development of bridge projects will continue to be striding forward. In order to better ensure the safety of bridges and reduce the occurrence of bridge safety accidents, bridge workers should invest more effort in the safety construction of bridge projects. When building bridge safety evaluation models, all factors should be considered as much as possible to make the evaluation result more accurate. Some current safety guidelines are relatively sketchy and only have directional guidance. They cannot provide detailed rules for different bridges. Therefore, for the current norms, more efforts should be made to establish and improve relevant regulations so as to further ensure the safety of bridge projects.

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