Research on economic evaluation of a bridge construction project based on FAHP

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ABSTRACT. *The economic evaluation of a bridge construction project is carried out by using FAHP, the economic factors are analyzed, and the evaluation criteria and decision criteria are established. According to the decision-making goal of economic evaluation, the evaluation index system composed of three first-class economic factors and eleven second-class economic factors is constructed. The economic situation of the project is evaluated through expert questionnaire survey, and the probability of occurrence is determined. This paper uses FAHP to make qualitative analysis and quantitative calculation on the factor index of a bridge construction project, and obtains the economic evaluation score and economic evaluation order of the first level economic factor evaluation index. It is known that the rationality of the project cost is the main economic factor. Through the calculation of the overall economic evaluation of the project, the overall economic evaluation result of the project is good. Therefore, fuzzy AHP is an effective method for economic evaluation of a bridge construction project, which can provide a basis for decision-making of a bridge construction project.*

KEYWORDS: *FAHP, economic evaluation, decision basis*

1. Introduction

Economic index evaluation includes qualitative analysis and quantitative calculation evaluation. The subjective factors of qualitative analysis are large, and individual cognition will lead to certain deviation; however, quantitative analysis is more reliable than qualitative analysis. In the actual investigation process, specific problems should be analyzed and appropriate quantitative analysis methods should be selected. However, the quantitative analysis also has the problem of less data. The single qualitative analysis does not have certain persuasion, and the results obtained are not scientific and reasonable. Therefore, we should adopt the method of combining qualitative analysis with quantitative analysis when we evaluate the economic indicators of projects. The description of many economic indicators has certain fuzziness, so it is difficult to calculate and evaluate quantitatively, so the traditional data analysis and statistics method can not be effectively used. Therefore, the fuzzy hierarchy comprehensive evaluation method is used to calculate and evaluate. Fuzzy analytic hierarchy process (FAHP) is a kind of evaluation method which combines analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method. It can realize the qualitative and quantitative combination of economic index evaluation.

Fuzzy analytic hierarchy process (FAHP) is a kind of evaluation method which combines analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method. It realizes the qualitative and quantitative combination of economic index evaluation. When there are many evaluation indexes at a certain level (such as more than four), it is difficult to ensure the consistency of thinking, but the fuzzy comprehensive evaluation method can solve this problem well. The specific process is shown in Figure 1.
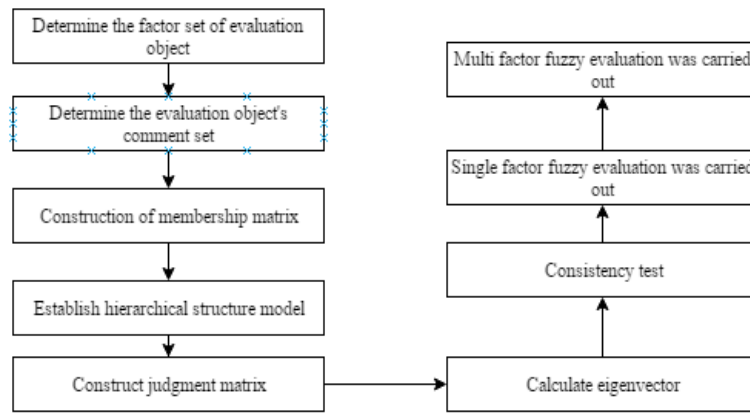
Figure. 1 Flow chart of economic index evaluation of FAHP method

2. Construct the evaluation model of project economic index

After the discussion between the construction management personnel and the bridge engineering expert group, the relevant economic indicators of a bridge construction project are summarized, and each relevant economic index is taken as the evaluation index, and the index system of the project related economic index evaluation model is constructed. The index system includes three first-class indicators, which are the rationality of construction cost expenditure, the social benefits of the project, and the economic risk of the project; and 11 second-class indicators are the rationality of engineering project cost, the rationality of measure project cost, the rationality of safety production and civilized construction cost, the rationality of other costs, social welfare, transportation convenience and regional economic development Natural risk, social risk, construction risk and fund management risk. According to the index system, the evaluation model of economic indicators related to the project is constructed, as shown in Figure 2. The target layer is a, the criteria layer is B1 to B3, and the scheme layer is C1 to C11.
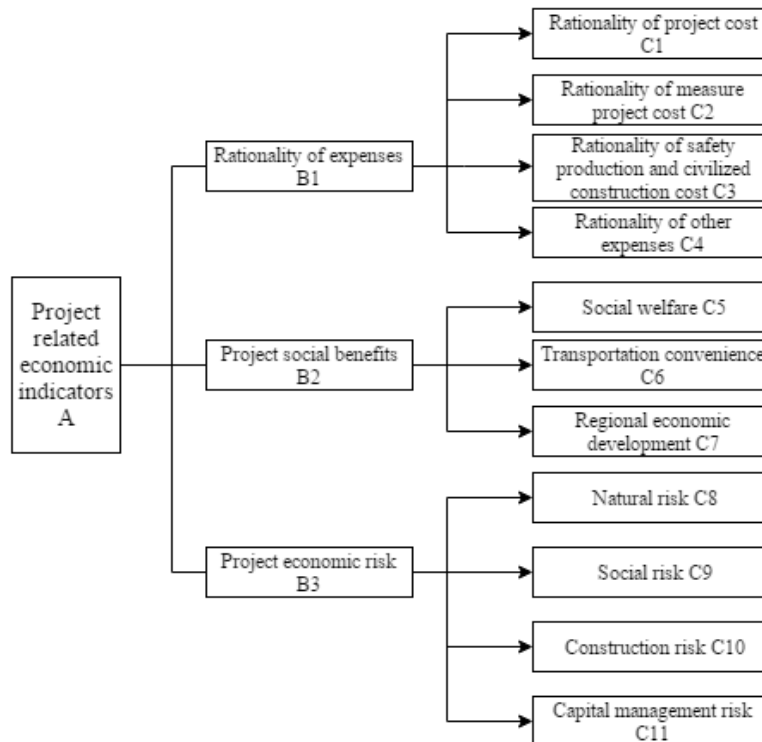
Figure. 2 Evaluation model of related economic indexes of a bridge construction project

3. Evaluation process of project economic indicators

Fuzzy AHP comprehensive evaluation method is a combination of qualitative analysis and quantitative analysis. According to the established factor set, AHP is used to determine the weight, and then fuzzy function is used to determine the evaluation result. (1) Calculation of economic index weight. Construction of judgment matrix: 1-9 scale method is used to construct judgment matrix. Through questionnaire survey and other methods, the respondents include a number of managers and staff in the construction process of bridge A. in the questionnaire survey, the survey results with large deviation are screened out, and then the relative importance ratio of each factor is summarized from the remaining questionnaire, and the judgment matrix is constructed. According to the questionnaire survey, the construction of pairwise comparison judgment matrix should be based on the scale of judgment matrix, which is shown in Table 1.

Table 1 Scale definition table of judgment matrix

Scale	Meaning
1	Compared with the two elements, they have the same importance
3	The former is slightly more important than the latter
5	The former is obviously more important than the latter
7	The former is more important than the latter
9	The former is extremely important than the latter
2, 4, 6, 8	The middle of the adjacent judgment
reciprocal	Compared to the two elements, the latter is of greater importance than the former

According to the questionnaire, the judgment matrix is as follows:

$$A = \begin{bmatrix} 1 & 1/3 & 3 \\ 3 & 1 & 5 \\ 1/3 & 1/5 & 1 \end{bmatrix} \quad B_1 = \begin{bmatrix} 1 & 3 & 5 & 7 \\ 1/3 & 1 & 3 & 5 \\ 1/5 & 1/3 & 1 & 3 \\ 1/7 & 1/5 & 1/3 & 1 \end{bmatrix}$$

$$B_2 = \begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 3 \\ 1/2 & 1/3 & 1 \end{bmatrix} \quad B_3 = \begin{bmatrix} 1 & 2 & 1/5 & 1/4 \\ 1/2 & 1 & 1/6 & 1/5 \\ 5 & 6 & 1 & 2 \\ 4 & 5 & 1/2 & 1 \end{bmatrix}$$

(2) Calculate the weight and check the consistency

Combined with the scale value of AHP, the relevant parameters of evaluation index judgment matrix were calculated, including the weight of each factor W, the maximum eigenvalue λ_{max}, and the consistency ratio CR. The available formulas are shown in formula 1.

$$\begin{cases} M_i = \prod_{j=1}^{n} a_{ij} \ (i=1,2..n) \\ \overline{W_i} = \sqrt[n]{M_i} \ (i=1,2..n) \\ W_i = \overline{W_i} / \sum_{i=1}^{n} \overline{W_i} \ (i=1,2..n) \\ W = (W_1, W_2..W_n)^T \end{cases} \quad \begin{cases} \lambda_{max} = \sum_{i=1}^{n} \dfrac{(AW)_i}{nW_i} \\ CI = \dfrac{\lambda_{max}-n}{n-1} \\ CR = \dfrac{CI}{RI} < 0.1 \end{cases} \quad (1)$$

The consistency of the calculation results and the judgment matrix of A.3 are shown in Table 2. W_i^0 is the normalized relative importance vector, and λ_{mi} is the eigenvalue of a factor. Table 3, table 4 and table 5 show the importance and consistency test results of judgment matrix B1, B2 and B3.

Table 2 Weight calculation and consistency test results of judgment matrix A

A	B_1	B_2	B_3	W_i	W_i^0	λ_{mi}
B_1	1	1/3	3	1.000	0.258	3.037
B_2	3	1	5	2.466	0.637	3.038
B_3	1/3	1/5	1	0.405	0.105	3.041
$\lambda_{max} = 3.039$ $CI = 0.020$ $CR = 0.038 < 0.1$						

Table 3 Weight calculation and consistency test results of judgment matrix B_1

B_1	C_1	C_2	C_3	C_4	W_i	W_i^0	λ_{mi}
C_1	1	3	5	7	3.201	0.564	4.128
C_2	1/3	1	3	5	1.495	0.263	4.100
C_3	1/5	1/3	1	3	0.669	0.118	4.101
C_4	1/7	1/5	1/3	1	0.312	0.055	4.139
$\lambda_{max} = 4.117$ $CI = 0.039$ $CR = 0.044 < 0.1$							

Table 4 Weight calculation and consistency test results of judgment matrix B_2

B_2	C_5	C_6	C_7	W_i	W_i^0	λ_{mi}
C_5	1	1/2	2	1.000	0.297	3.009
C_6	2	1	3	1.817	0.540	3.009
C_7	1/2	1/3	1	0.550	0.163	3.010
$\lambda_{max} = 3.010$ $CI = 0.005$ $CR = 0.010 < 0.1$						

Table 5 Weight calculation and consistency test results of judgment matrix B_3

B_3	C_8	C_9	C_{10}	C_{11}	W_i	W_i^0	λ_{mi}
C_8	1	2	1/5	1/4	0.562	0.103	4.059
C_9	1/2	1	1/6	1/5	0.359	0.065	4.065
C_{10}	5	6	1	2	2.783	0.508	4.061
C_{11}	4	5	1/2	1	1.778	0.324	4.057
$\lambda_{max} = 4.061$ $CI = 0.020$ $CR = 0.022 < 0.1$							

(3) Building a collection of comments

The establishment of the comment set: the purpose of the evaluation set is to give some evaluation rules to the above factor set, and give the specific evaluation results of the factor set under this rule.

In order to get the comprehensive evaluation value of the economic index system related to the project, it is divided into five grades by semantic scale: excellent, good, medium, general and poor. In order to calculate the aspect, the semantic scale is quantified and assigned to 90, 70, 50, 30 and 10 in turn. The quantitative criteria for design evaluation are shown in table 6.

Table 6 Evaluation of quantitative grading standards

Grade	Comment	Numerical range	Valuation
1	excellent	$80 < P \leq 100$	90
2	good	$60 < P \leq 80$	70
3	medium	$40 < P \leq 60$	50
4	genera	$20 < P \leq 40$	30
5	poor	$0 < P \leq 20$	10

(4) Construction of membership matrix

Construction of membership matrix: by contacting relevant departments, inviting managers or experts with rich experience in bridge construction, objectively evaluate each index in the index system, score them, and normalize the analysis results with formula (2). The results are shown in table 7.

$$r_{ij} = \frac{\text{The number of experts judging whether an index belongs to the corresponding level}}{\text{Total number of experts}} \quad (2)$$

Table 7 Evaluation of relevant economic indexes of a bridge construction project

Index	Proportion of relevant economic index scores				
	excellent	good	medium	genera	poor
C_1	0.5	0.3	0.2	0	0
C_2	0.3	0.4	0.2	0.1	0
C_3	0.2	0.4	0.3	0.1	0
C_4	0.2	0.1	0.5	0.1	0.1
C_5	0.7	0.2	0.1	0	0
C_6	0.8	0.2	0	0	0
C_7	0.7	0.1	0.2	0	0
C_8	0.2	0.4	0.2	0.1	0.1
C_9	0.1	0.5	0.3	0.1	0
C_{10}	0.3	0.4	0.1	0.1	0.1
C_{11}	0.1	0.5	0.2	0.1	0.1

The corresponding membership matrix can be obtained from the evaluation results in table 7. Therefore, the membership matrix of the economic index scoring degree of a bridge construction project is as follows:

$$R_1 = \begin{bmatrix} 0.5 & 0.3 & 0.2 & 0 & 0 \\ 0.3 & 0.4 & 0.2 & 0.1 & 0 \\ 0.2 & 0.4 & 0.3 & 0.1 & 0 \\ 0.2 & 0.1 & 0.5 & 0.1 & 0.1 \end{bmatrix} \quad R_2 = \begin{bmatrix} 0.7 & 0.2 & 0.1 & 0 & 0 \\ 0.8 & 0.2 & 0 & 0 & 0 \\ 0.7 & 0.1 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.2 & 0.4 & 0.2 & 0.1 & 0.1 \\ 0.1 & 0.5 & 0.3 & 0.1 & 0 \\ 0.3 & 0.4 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.5 & 0.2 & 0.1 & 0.1 \end{bmatrix}$$

(5) Single factor fuzzy evaluation

Fuzzy evaluation of single factor. According to the relative weight of each factor obtained from the scheme layer and the membership matrix of the economic index scoring degree of a bridge construction project, the evaluation results of different level indicators on each evaluation set can be obtained. For example, the evaluation results of the first level index "rationality of cost expenditure" on the relevant economic indicators of bridge a construction project are as follows:

$$B_1 = W_1 \cdot R_1 = \begin{bmatrix} 0.564 \\ 0.263 \\ 0.118 \\ 0.055 \end{bmatrix}^T \cdot \begin{bmatrix} 0.5 & 0.3 & 0.2 & 0 & 0 \\ 0.3 & 0.4 & 0.2 & 0.1 & 0 \\ 0.2 & 0.4 & 0.3 & 0.1 & 0 \\ 0.2 & 0.1 & 0.5 & 0.1 & 0.1 \end{bmatrix} = \begin{bmatrix} 0.396 \\ 0.327 \\ 0.228 \\ 0.044 \\ 0.005 \end{bmatrix}^T$$

Similarly, the evaluation results of other first level indicators can be obtained, as shown in table 8.

Table 8 A bridge construction project related economic indicators single factor fuzzy evaluation results

Index	Single factor fuzzy calculation results
B_1	(0.396, 0.327, 0.228, 0.044, 0.005)
B_2	(0.754, 0.184, 0.062, 0, 0)
B_3	(0.212, 0.439, 0.156, 0.100, 0.093)

So, the membership matrix R is as follows.

$$R = \begin{bmatrix} 0.396 & 0.327 & 0.228 & 0.044 & 0.005 \\ 0.754 & 0.184 & 0.062 & 0 & 0 \\ 0.212 & 0.439 & 0.156 & 0.100 & 0.093 \end{bmatrix}$$

(6) Multi factor fuzzy evaluation

Multi factor fuzzy evaluation. According to the single factor fuzzy evaluation results of relevant economic indicators of a bridge construction project, the multi factor fuzzy evaluation results of relevant economic indicators of bridge a construction project can be obtained.

$$B = W \cdot R = W \cdot [B_i]$$

$$= \begin{bmatrix} 0.258 \\ 0.637 \\ 0.105 \end{bmatrix} \cdot \begin{bmatrix} 0.396 & 0.327 & 0.228 & 0.044 & 0.005 \\ 0.754 & 0.184 & 0.062 & 0 & 0 \\ 0.212 & 0.439 & 0.156 & 0.100 & 0.093 \end{bmatrix} = \begin{bmatrix} 0.605 \\ 0.248 \\ 0.114 \\ 0.022 \\ 0.011 \end{bmatrix}$$

(7) Analysis on evaluation results of project economic indicators

The comprehensive fuzzy evaluation results of relevant economic indexes of a bridge construction project are calculated. According to the multi factor fuzzy evaluation results of relevant economic indexes of a bridge construction project, the comprehensive fuzzy evaluation results can be obtained.

$$B = \begin{bmatrix} 0.605 \\ 0.248 \\ 0.114 \\ 0.022 \\ 0.011 \end{bmatrix}^{T} \cdot \begin{bmatrix} 90 \\ 70 \\ 50 \\ 30 \\ 10 \end{bmatrix} = 78.28$$

Because the fuzzy evaluation result is 78.28, according to table 7, the overall evaluation result of relevant economic indicators of bridge a construction project is good, so the project has good economic expectations.

From the analysis of economic indicators and the results of fuzzy comprehensive evaluation, although the project can not obtain direct benefits, it has brought indirect economic benefits to the people of bridges on both sides of the Strait. Therefore, we can conclude that the project is feasible in economy and has a good prospect.

4. Conclusions

This chapter carries on the fuzzy comprehensive evaluation to the economic related indicators. From the analysis results, a bridge construction project benefits the people on both sides of the Strait and produces a large number of economic benefits, and the fuzzy comprehensive evaluation result of relevant economic indicators is good, so we can draw a conclusion that bridge a construction project is feasible in economic aspect. This paper provides a feasible fuzzy evaluation process for the economic evaluation of bridge projects, which has far-reaching significance.

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