A Research on Technology Project Credit Evaluation Model Based on AHP and FCEM

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Abstract *This paper analyzes the basic requirements of the technology project credit evaluation, and presents a technology project credit evaluation model based on Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation Method (FCEM). Combining with the actual situation of one scientific research center, a technology project credit evaluation index system is established, and its weight of each evaluation index is determined by AHP, and then an evaluation results is analyzed and evaluated through FCEM, also it's valuable theoretical foundation for the management of the Technology Project.*

Keywords *AHP; FCEM; Project Credit Evaluation*

1. Introduction

The technology project credit evaluation is an important part of technology project process management. In the technology project concluding, it is necessary to evaluate the technology project implementation process, which is not only the summary of project implementation process, but also the archive of credit of undertakers, which provide important historical basis for the future project application approval procedures.

Currently, the technology project credit evaluation is based on subjective qualitative assessment, there is no reasonable technology project credit evaluation index system, or the evaluation indexes are lack of scientific weight distribution. To solve this problem, this paper presents a comprehensive evaluation method based on AHP and FCEM. Combining with the actual situation of one scientific research center, this paper proposes a technology project credit evaluation index system, which evaluate the credit of project stakeholders from the contract compliance, reporting significant matters, and implementation within the stipulated time those three aspects, and determines the weight of each index by AHP and checks the consistency, then taking one credit evaluation results in a project as example, calculates the technology project credit situation through fuzzy analysis and quantitative assessment to validate this model.

2. Technology project credit evaluation index system

Technology Project credit evaluation system should be operated from the multi-level, multi-angle, which should be able to fully reflect the technology project's credit rating commitment, combined with an actual situation of R & D center, based on AHP, a three-level technology project credit evaluation index system is proposed , as shown in Figure 1.

Figure 1 show that, this system is made up of 3 respects of contract compliance, reporting significant events and implementation within the stipulated time, and has 8 indexes; of course, it can be adjusted according to actual situation. Explain the specific content of each index as follows:

(1) Completion condition of assessment indicators: refers to the completion condition of the content stipulated in the contract.

(2) Rate of progress is the completion situation of the project progress according to the contract rules.

(3) Reporting significant events is to account for the significant issues to the virtual

coordination center faithfully and timely.

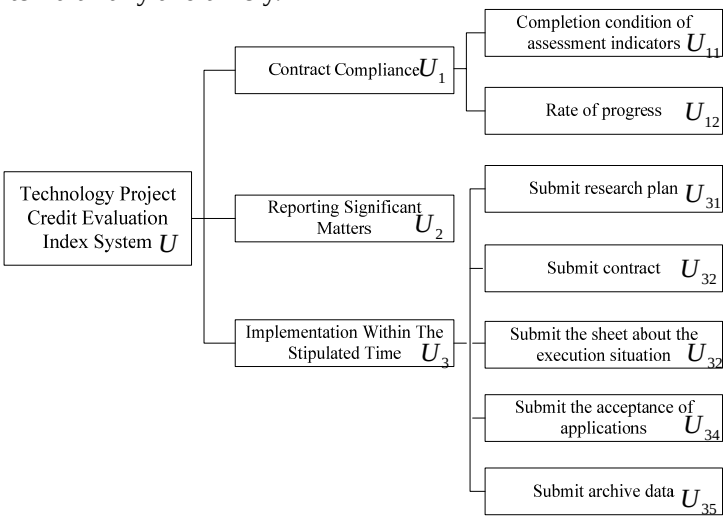

Figure 1 Technology project credit evaluation index system

(4) Submit research plan: refers to submit their work outline within the specified time, such as it is finished after being noticed in two months.

(5) Submit contract: refers to hand over contract within the specified time, such as it is finished after being noticed in three months.

(6) Submit the sheet about the execution situation: refers to submit it in scheduled time, such as finishing it on 15 of the first month of each quarter.

(7) Submit the acceptance of applications: refers to submit it before the deadline specified in the contract.

(8) Submit archive data: refers to submit it within the specified time after project acceptance, such as 1 month after the inspection (30 days) for submission.

3 The Establishment of Technology Project Credit Evaluation Model Based on the AHP and FCEM

AHP is used first to define the weight of each level index, and then use FCEM for project credit evaluation. The model is established in following steps:

1.tablishment of factors set

From the project credit evaluation index system in Figure 1 can be seen, there are two levels of evaluation indices, and now the first level is defined $U = \{U_1, U_2, U_3\}$; the second level is $U_1 = \{U_{11}, U_{12}\}$, $U_3 = \{U_{31}, U_{32}, U_{33}, U_{34}, U_{35}\}$。

2. Establishment of reviews set

According to the actual situation of the R&D center mentioned before, reviews are set to 4 levels, namely, n=4, $V = \{V_1, V_2, V_3, V_4\}$ represent {excellent, good, medium, poor}. Reviews level can be adjusted and determined according to the specific situations.

3. Determine weights set of evaluation indexes by AHP

Using the AHP to determine weights set of evaluation indexes can be divided into the following steps:

(1) Construct Judgment Matrix

Judgment Matrix represents the relative importance between two elements in the same level to some element in the upper level, the evaluation about the importance of indexes at all levels are a subjective process, based on expert evaluation results or the result of the questionnaire. Use

$b_i, b_j (i, j = 1,2,...n)$ to represent the indexes. b_{ij} expressed the value of the importance that b_i relative to b_j, construct the judgment matrix P through 1-9 ratio scaling, and the matrix have reciprocity and basic consistency, that is, $b_{ij} > 0$, $b_{ii} = 1$, $b_{ij} * b_{ji} = 1$.

$$p = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{bmatrix} \quad (1)$$

Table 1 1-9 Description of Proportion Quotients

b_{ij}	Meaning	Explanation
1	equal importance	Both have the same importance
3	Weak Importance	b_i important than b_j slightly
5	Strong Importance	b_i important than b_j obvious
7	Very Strong Importance	b_i more important than b_j
9	Absolute Importance	b_i absolute important than b_j obvious
2、4、6、8	Between the various levels above	The importance is between the adjacent levels
1、1/2、…、1/9	Reverse comparison	The importance of b_j relative to b_i

With experience and knowledge related to credit evaluation and project management, construct judgment matrix of each level as P_1 P_2 P_3. In order to facilitate analysis and more intuitive, we graphically shows the matrix, as shown in Table 2, 3, 4.

Table 2 Judgment Matrix P_1

P_1	U_1	U_2	U_3
U_1	1	2	1/2
U_2	1/2	1	1/3
U_3	2	3	1

Table 3 Judgment Matrix P_2

P_2	U_{11}	U_{12}
U_{11}	1	2
U_{12}	1/2	1

Table 4 Judgment Matrix P_3

P_3	U_{31}	U_{32}	U_{33}	U_{34}	U_{35}
U_{31}	1	1	1	1/2	2

U_{32}	1	1	1	1/2	2
U_{33}	1	1	1	1/2	2
U_{34}	2	2	2	1	3
U_{35}	1/2	1/2	1/2	1/3	1

(2) Calculate the weight vector of each level and make consistency check

First, calculate the maximized eigenvalue and eigenvector of judgment matrix. Generally, it is to use geometric averaging (root method) or normative column average (sum method) to calculate the approximate eigenvectors [2], and then calculate the Maximized Eigenvalue.

Geometric average method: Calculate the product of each element of each row, then calculate the nth root of each product; and then normalized the obtained vector. Vector obtained above is the approximate eigenvectors, if the consistency check is passed, the vector is the relative weight vector of each index.

Calculating the maximized eigenvalue and eigenvector using geometric averaging mean is as follows:

① Calculate the geometric average of all elements of each row of the judgment matrix.

Based on $\overline{w}_i = \sqrt[n]{\prod_{j=1}^{n} b_{ij}}$, $(i = 1,2,\cdots,n)$, so $\overline{w} = (\overline{w}_1, \overline{w}_2, \cdots, \overline{w}_n)^T$ 。

② Normalize $\overline{w}$, $w_i = \overline{w}_i \Big/ \sum_{i=1}^{n} \overline{w}_i$, $i = 1,2,\cdots,n$, then $W = (w_i, w_2, \cdots, w_n)^T$ which is approximate eigenvectors, and its value of each element is the weight value of each index.

③ Calculate the largest eigenvalue $\lambda_{\max}$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(PW)_i}{nw_i} \tag{2}$$

In the formula 2, vector $(PW)_i$ is the first i component of PW .

Then check on the consistency of judging matrix. Matrix consistency test as follows:

① Calculate the inconsistent level (CI) of Judgment Matrix.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

In the formula 3, $\lambda_{\max}$ is the Maximized eigenvalue of $n(n > 1)$ order matrix.

② Calculate the Random Consistency level (RI) of Judgment Matrix, which only determined by the order of the judgment matrix. Note that, when $0 < n \le 2$, there is no inconsistency issue, matrix does not need be tested. Standards of Random consistency level shown in table 5:

③ Calculate the consistency ratio of judgment matrix (CR).

$$CR = \frac{CI}{RI} \tag{4}$$

Table 5 Random consistency level RI

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The method to determine the consistency of judgment matrix is [3]: when $CR < 0.1$, judgment matrix has satisfactory consistency, pass the consistency check; otherwise, the matrix does not pass the consistency check, degree of consistency is unacceptable, judgment matrix needs to be adjusted to your satisfaction.

Now, we use the judgment matrix P_1 as example to explain the calculation.

$$P_1 = \begin{pmatrix} 1 & 2 & 1/2 \\ 1/2 & 1 & 1/3 \\ 2 & 3 & 1 \end{pmatrix} \xrightarrow{\text{Find the geometric mean}} \begin{pmatrix} 1 \\ 0.5503 \\ 1.8171 \end{pmatrix} \xrightarrow{\text{normalization}} \begin{pmatrix} 0.297 \\ 0.1634 \\ 0.5396 \end{pmatrix} = W$$

So,
$$P_1 W = \begin{pmatrix} 1 & 2 & 1/2 \\ 1/2 & 1 & 1/3 \\ 2 & 3 & 1 \end{pmatrix} * \begin{pmatrix} 0.297 \\ 0.1634 \\ 0.5396 \end{pmatrix} = \begin{pmatrix} 0.8936 \\ 0.4918 \\ 1.6238 \end{pmatrix}$$

From the formula 2, we can get $\lambda_{\max} = \frac{1}{3}\left(\frac{0.8936}{0.297} + \frac{0.4918}{0.1634} + \frac{1.6238}{0.5396}\right) = 3.0093$

Then according to the formula 3, CI =0.00465，checking the table 5, when n=3, RI=0.58, and finally, calculating according to the formula 4, $CR = 0.008$<0.1, so the judgment matrix has satisfactory consistency, the corresponding weight vector is
$A_1 = (0.297 \quad 0.1634 \quad 0.5396)$.

Similarly, the CR of judgment matrix P_3 equals 0.0022 <0.1, pass the consistency check, the weight vector is $A_3 = (0.1846 \quad 0.1846 \quad 0.1846 \quad 0.3485 \quad 0.0977)$. Because the order of judgment matrix P_2 is 2, so there is no necessary to check consistency, the corresponding weight vector is $A_2 = (0.6667 \quad 0.3333)$.

1. Build the fuzzy evaluation matrix

Evaluate the object based on the reviews set V . Build a fuzzy mapping from U to V , and determine the Fuzzy evaluation matrix formed by $r_{ij}(0 \le r_{ij} \le 1)(i = 1,2,\cdots,n;\ j = 1,2,\cdots,m)$, which is the grade of membership that u_i to v_j .

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

$r_{ij} = p_{ij} / p$; p is the total number of experts; p_{ij} is the number of experts who evaluate the index u_i by the review v_j .

To create a fuzzy evaluation matrix, firstly select a number of experts to evaluate the credit status of a project, and get the statistical data of the evaluation result, and then create fuzzy evaluation vectors of each single index, finally construct fuzzy evaluation matrix.

Construct all fuzzy evaluation vectors of the initial single indexes; so the underlying fuzzy evaluation matrix is determined, and then build the upper fuzzy evaluation matrix based on sub-level fuzzy performance matrix.

2. Calculate the result of fuzzy comprehensive evaluation

The weight of each evaluation index has been determined by AHP, using one fuzzy subset of U $A=(a_1,a_2,\cdots,a_n)$ represent weight set, namely a_i is the quantitative index of u_i. After getting R and A, the result $B=A\circ R$ can be obtained, B is the fuzzy subset of V, $\circ$ is a kind of fuzzy operator, and generally consists of 4 models, here, is the weighted average type.

$$B=AR=(a_1,a_2,\cdots,a_n)\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}=(b_1,b_2,\cdots,b_m)$$

$\sum_{i=1}^{m} b_i = 1$, according to the principle of maximum degree of membership, if b_i is the maximum number of B, corresponds to i, then the object evaluation result level is v_i.

As the project credit evaluation model is a multi-layer model, the evaluation results of indexes in previous layer can be gotten from fuzzy evaluate matrix and Weight vectors of the indexes in this layer, and then set these evaluation results as fuzzy evaluation matrixes of the previous layer, combining with weight vectors in the previous layer, the results of the project is gotten.

Another point to note is that not all the initial indexes are at the bottom, and some initial indexes are in the middle layers, such as "Reporting significant events", when conducting the initial fuzzy evaluation, only calculate the initial indexes in the bottom, then put the fuzzy evaluation vector of the single initial index in the middle layer and the initial evaluation results of the bottom layer together, so get the fuzzy evaluation matrix of the middle layer.

3. Fuzzy comprehensive evaluation of the results

The evaluation results is a fuzzy result, do not give a quantitative evaluation result or a score, generally based on the principle of maximum degree of membership [3], if the maximum number of B is b_i, corresponds to i, then the evaluation result level of the object is v_i.

Usually, in order to give a quantitative result for fuzzy evaluation result, we can assign a weight value N_i to each review, so there will be a weight value set $N=\begin{pmatrix} n_1 & n_2 & \cdots & n_m \end{pmatrix}^T$. The total score of evaluation result is $S=BN=\sum_{i=1}^{m} n_i b_i$.

Note that the determination of the weight value of reviews is a precise and seriously problem, it should be able to respond the actual situation well. General the weight value of reviews can be determined by the vote of experts or the historical data analysis, preferably both.

4 Validation of Technology Project Credit Evaluation Module Based on AHP and FCEM

The algorithm of Technology Project Credit Evaluation Module is given above, and the consistency of Judgment Matrix is verified. Now we will show a Practical example to verify this module. Table 6 shows a statistical result of project evaluation.

Table 6 A result of project evaluation

Index		Result			
		Excellent	Good	Fair	Poor
Contract fulfillment	Completion of assessment indicators	1	6	0	0
	The progress	2	4	1	0
Reporting significant events		6	0	1	0
The implementation of the stipulated time	Submitting their work plan	3	4	0	0
	Submitting the contract	2	4	1	0
	The implementation of the report	4	3	0	0
	Acceptance of applications	1	5	1	0
	Archive Information	2	3	1	1

Combining data in the table above, according to Step 4, in the bottom layer, the fuzzy evaluation matrix R_2, R_3

$$R_2 = \begin{pmatrix} 1/7 & 6/7 & 0 & 0 \\ 2/7 & 4/7 & 1/7 & 0 \end{pmatrix}$$

$$R_3 = \begin{pmatrix} 3/7 & 4/7 & 0 & 0 \\ 2/7 & 4/7 & 1/7 & 0 \\ 4/7 & 3/7 & 0 & 0 \\ 1/7 & 5/7 & 1/7 & 0 \\ 2/7 & 3/7 & 1/7 & 1/7 \end{pmatrix}$$

Weight vector A_2 A_3 have been obtained in step 3, according to $B = A \circ R$:

$$B_2 = A_2 R_2 = (0.6667 \quad 0.3333) \times \begin{pmatrix} 1/7 & 6/7 & 0 & 0 \\ 2/7 & 4/7 & 1/7 & 0 \end{pmatrix} = (0.1905 \quad 0.7619 \quad 0.0476 \quad 0)$$

Similarly, $B_3 = (0.315 \quad 0.5809 \quad 0.0901 \quad 0.014)$. The result of "the fulfillment of the contract" and "implementation within the stipulated time" can be seen from B_2 B_3. According to the principle of maximum degree of membership, the result levels of the two indicators are all good.

Then, put B_2 B_3 and the single index evaluation vector of "reporting on major issues" $(0.8571 \quad 0 \quad 0.1429 \quad 0)$ together to get the fuzzy evaluation matrix R_1, A_1 has been determined in step 3, from $B = A \circ R$, the result of this technology project credit evaluation is B_1.

$$B_1 = A_1 R_1 = (0.297 \quad 0.1634 \quad 0.5396) \times \begin{pmatrix} 0.1905 & 0.7619 & 0.0476 & 0 \\ 0.8571 & 0 & 0.1429 & 0 \\ 0.315 & 0.5809 & 0.0901 & 0.014 \end{pmatrix}$$

$$= (0.3666 \quad 0.5397 \quad 0.0861 \quad 0.0076)$$

According to the principle of maximum membership degree, the credit of this project is good. According to the actual situation of this R&D center, the weight value of each review is given, excellent 90, good 80, medium 70, and poor 50, then according to Step 6:

$$S = 90 \times 0.366 + 80 \times 0.5397 + 70 \times 0.0861 + 50 \times 0.0076 = 82.553$$

From the calculation process and the fuzzy comprehensive evaluation result, the technology project credit evaluation model based on AHP and FCEM is a scientific and reasonable, mainly fit reality. On condition that passing the consistency test of Judgment Matrix, the specific indexes of technology project credit evaluation can be adjusted flexibly, so that the model has the flexibility and scalability.

5 Conclusion

This paper introduces the relevant theory of the AHP and FCEM, presents a technology project credit evaluation model based on AHP and FCEM, establishes a credit evaluation index system of the technology project, and checks the consistency of the judgment matrix of each layer, calculates the weight vector of each layer, algorithm steps is given in detail, and finally the model and algorithm is validated by a practical examples. This model provides a scientific basis for the technology project credit evaluation.

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