

# Evaluation of University Science Technological Innovation Capability Based on Improved Grey Relational Projection Method

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**Abstract**—In order to objectively and effectively evaluate the scientific and technological innovation capability of colleges and universities, an evaluation index system including science and technology input, achievement output and transformation, and scientific and technological innovation support was established. An improved entropy weight method was used to determine the objective weight of the index, and a grey relational projection decision-making comprehensive evaluation model of scientific and technological innovation capability in colleges and universities was established. The validity and feasibility of the proposed method were verified by case analysis. The improved grey relational projection method is characterized by clear calculation steps, relatively simple calculation and strong operability and practicability.

**Keywords**—scientific and technological innovation capability; index system; grey relational projection

## I. INTRODUCTION

At present, it is of great significance to scientifically and reasonably evaluate the scientific and technological innovation ability of colleges and universities. Ornella Wanda Maietta<sup>[1]</sup> has used multiple probit model to study the driving factors of R&D cooperation between universities and enterprises, and evaluate the determinants of innovation in low-tech industries. ZHANG et al.<sup>[2]</sup> used the analytic hierarchy process to study the scientific and technological innovation ability of colleges and universities. Zhao et al.<sup>[3]</sup> have used the improved analytic hierarchy process to analyze the innovation activities of the government, universities, scientific research institutions and enterprises, and then adopted cluster analysis to analyze the four participants in each region. WANG et al.<sup>[4]</sup> used the analytic hierarchy process to carry out an empirical study on the science and technology innovation of 13 universities in Shanxi Province. Huang Jianguo et al.<sup>[5]</sup> used factor analysis to empirically analyze 24 universities in the Beijing-Tianjin-Hebei University Innovation and Development Alliance. Xiong Guojing et al.<sup>[6]</sup> have proposed the E-TOPSIS improved factor analysis method, Zhang Junting et al.<sup>[7]</sup> have adopted the subjective and objective method of entropy weight-DEMATEL method and Wang Jinguo et al.<sup>[8]</sup> have used factor analysis to study the evaluation of science and technology innovation ability in colleges and universities. Through the analysis of these documents, it is found that at present, the research on the

evaluation of the scientific and technological innovation ability of the university is focused on the construction of the evaluation index system, there is no unified standard, and it is not scientific and reasonable. Moreover, the evaluation model is established mostly by combining analytic hierarchy process with factor analysis, which seems relatively simple. However, there are some subjective factors in the process of using analytic hierarchy process to determine the weight of evaluation index. Factor analysis mostly uses the least square method to calculate the factor score, and there is a possibility of failure in the calculation process. Targeting on the shortcomings of the research, in this paper, the improved grey relational projection method is proposed to study this, and the validity and feasibility of the proposed method are further illustrated by case analysis.

## II. THE ESTABLISHMENT OF THE EVALUATION INDEX SYSTEM

According to the principles and standards established by the indicator system, the comprehensive evaluation index system of the scientific and technological innovation capability of universities, including three first-level indexes, seven second-level indexes and 17 third-level indexes, is established<sup>[9]</sup> (Figure 1).

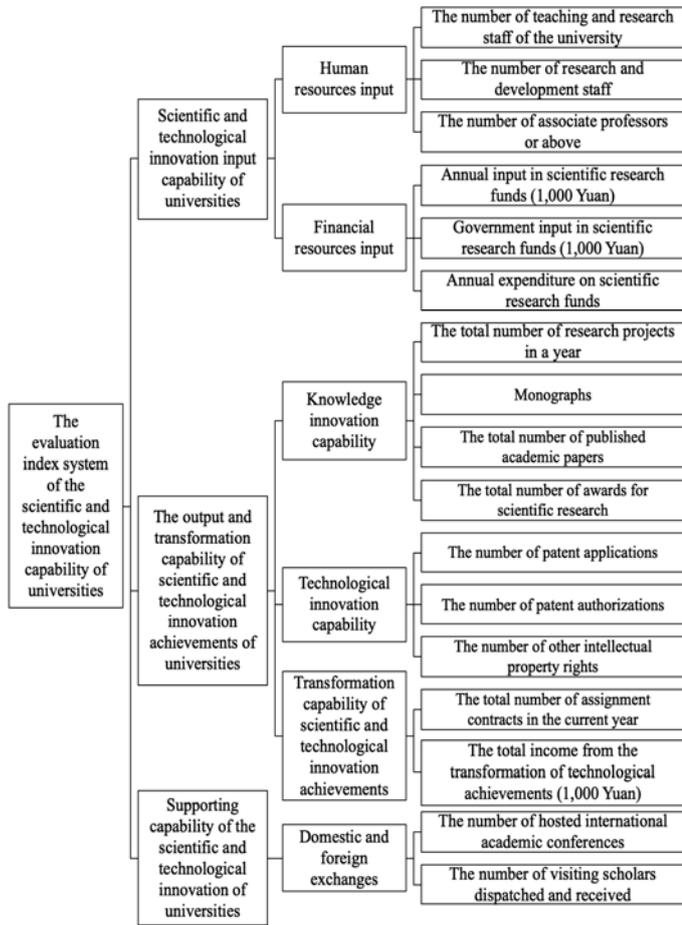


FIGURE I. THE COMPREHENSIVE EVALUATION INDEX SYSTEM OF THE SCIENTIFIC AND TECHNOLOGICAL INNOVATION CAPABILITY OF UNIVERSITIES

### III. IMPROVED GREY RELATION PROJECTION METHOD

Grey relational projection method is a multi-objective system decision method. With simple theory and good operability, it combines grey relational analysis method with vector projection principle. This method can comprehensively analyze the correlations between indexes, reflect the influence of the entire factor index space and avoid the single-direction deviation [10].

#### A. Establishing Evaluation Matrix and Dimensionless Index

Let the scheme set to be evaluated  $X = \{X_1, X_2, \dots, X_m\}$ , the index (attribute) set  $B = \{B_1, B_2, \dots, B_n\}$ , the attribute value of the evaluation scheme  $X_i$  under the index  $B_j$  be  $x_{ij}$  ( $i = 1, 2, \dots, m$ ,  $j = 1, 2, \dots, n$ ) and  $W_j$  be the weight of the index ( $W_j \in [0, 1]$  and  $\sum_{j=1}^n W_j = 1$ ). Then, the evaluation scheme set

can be represented by the matrix of eigenvalue of  $m \times n$  order index, namely

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} = (x_{ij})_{m \times n} \quad (1)$$

Where,  $x_{ij}$  refers to the  $j$ -th attribute value of the  $i$ -th evaluated scheme ( $i = 1, 2, \dots, m$ ,  $j = 1, 2, \dots, n$ ).

In order to reflect the actual situation as much as possible, eliminate the influence caused by the different dimensions of various indexes and the great disparity between their numerical orders of magnitude and avoid the occurrence of unreasonable phenomena, it is necessary to standardize and normalize the evaluation index. For the index (when the value is greater, the efficiency will be better), the standardization formula can be expressed as follows [11]:

$$r_{ij} = \frac{x_{ij} - \min_{1 \leq i \leq m} x_{ij}}{\max_{1 \leq i \leq m} x_{ij} - \min_{1 \leq i \leq m} x_{ij}} \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n) \quad (2)$$

For the index (when the value is smaller, the cost will be cheaper), the standardization formula can be presented as follows [11]:

$$r_{ij} = \frac{\max_{1 \leq i \leq m} x_{ij} - x_{ij}}{\max_{1 \leq i \leq m} x_{ij} - \min_{1 \leq i \leq m} x_{ij}} \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n) \quad (3)$$

Where,  $\min_{1 \leq i \leq m} x_{ij}$  and  $\max_{1 \leq i \leq m} x_{ij}$  refer to the minimum value and maximum value of the  $j$ -th index, respectively.

#### B. Determining the Ideal Scheme Reference Sequence

Relational grade analysis is the basis of analysis, evaluation and decision of grey system. Grey relational grade represents the quantitative value of the proximity between the reference sample sequence and the evaluation sample sequence. In order to conduct grey relational analysis, the reference sample sequence should be made first, and the best value of each index in each evaluation object should be taken as the index value of the ideal object, while the best value should be selected from the evaluated objects participating in the contest. For different influencing factors, the maximum values of some indexes are the best values, whereas the minimum values of some indexes are the best values [12]. In this paper, the maximum value of each index of each evaluation scheme is selected as the element of the reference sample sequence, namely

$$R_0 = (r_{01}, r_{02}, \dots, r_{0n}) \quad (4)$$

Where,  $r_{0j} = \max_{1 \leq i \leq m} r_{ij}$  ( $j = 1, 2, \dots, n$ ).

### C. Determining Weighted Grey Relational Decision Matrix

Let  $\Omega$  be the grey relational space,  $\zeta$  be the specific relational mapping and  $s_{ij}$  be the relational coefficient between the  $j$ -th index and the  $j$ -th best index of the  $i$ -th evaluation scheme<sup>[13]</sup>,  $s_{ij} = \zeta(r_{ij}, r_{0j})$ , then

$$s_{ij} = \frac{\min_{1 \leq i \leq m} \min_{1 \leq j \leq n} |r_{0j} - r_{ij}| + \lambda \cdot \max_{1 \leq i \leq m} \max_{1 \leq j \leq n} |r_{0j} - r_{ij}|}{|r_{0j} - r_{ij}| + \lambda \cdot \max_{1 \leq i \leq m} \max_{1 \leq j \leq n} |r_{0j} - r_{ij}|} \quad (5)$$

Where,  $\lambda \in (0, +\infty)$  is called the resolution coefficient, and the general value range is  $[0, 1]$ . Usually,  $\lambda = 0.5$ .

$m \times n$  grey relational coefficients  $s_{ij}$  are formed into the grey relational grade judgment matrix  $S$ , and the weight vector of the evaluation index set  $W = (w_1, w_2, \dots, w_n)^T$ . The weighted grey relational decision matrix can be obtained by weighting the grey relational grade judgment matrix  $S$ .

$$S' = \begin{pmatrix} w_1 s_{11} & w_2 s_{12} & \dots & w_n s_{1n} \\ w_1 s_{21} & w_2 s_{22} & \dots & w_n s_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1 s_{m1} & w_2 s_{m2} & \dots & w_n s_{mn} \end{pmatrix} \quad (6)$$

### D. Determining Gray Relational Projection Value

If each evaluation scheme is regarded as a row vector, the angle between the evaluation scheme and the ideal scheme reference sequence can be called grey relational projection angle<sup>[14]</sup>, and the cosine value can be calculated as:

$$\delta_i = \cos \alpha = \frac{\sum_{j=1}^n w_j s_{ij} w_j}{\sqrt{\sum_{j=1}^n (w_j s_{ij})^2} \cdot \sqrt{\sum_{j=1}^n w_j^2}} \quad (7)$$

Obviously,  $0 < \delta_i \leq 1$ , and if the value of  $\delta_i$  is greater, the results will be better, because if  $\delta_i$  is greater, it means that the change direction of  $R_i$  and  $R_0$  will be closer ( $R_i$  represents the row vector of the evaluation matrix  $R$ ). Let the modulus of  $R_i$  be  $k_i$ , and then, the grey relational projection value of evaluation scheme set  $X$  on ideal scheme reference sequence  $R_0$  can be given by the following equation:

$$\gamma_i = k_i \delta_i = \frac{\sum_{j=1}^n w_j^2 s_{ij}}{\sqrt{\sum_{j=1}^n w_j^2}} = \sum_{j=1}^n \bar{w}_j s_{ij} \quad (8)$$

Where,  $\bar{w}_j = w_j^2 / \sqrt{\sum_{j=1}^n w_j^2}$  ( $i = 1, 2, \dots, m$ ,  $j = 1, 2, \dots, n$ ), and  $\bar{W} = (\bar{w}_1, \bar{w}_2, \dots, \bar{w}_n)^T$  is called grey relational projection value vector. According to the size of grey relational projection value  $\gamma_i$  ( $i = 1, 2, \dots, m$ ), the evaluation schemes are ranked. If the grey relational projection value is greater, the corresponding scheme will be better.

## IV. CASE STUDY

The following is an example of the study in [15] for empirical analysis. A, B and C represent three universities, and Ci ( $i=1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17$ ) refers to 17 evaluation indexes. The values of each indicator are shown in Table 1.

TABLE I. THE INITIAL VALUE OF EACH EVALUATION INDEX OF UNIVERSITY A, UNIVERSITY B AND UNIVERSITY C

Index Code	University A	University B	University C
C1	5071	1385	2099
C2	3869	1200	1250
C3	1731	598	725
C4	2612051	709637	989507
C5	1561000	289170	393089
C6	1936499	590518	889671
C7	4721	2632	1646
C8	62	16	13
C9	11114	1569	2488
C10	86	6	38
C11	1450	329	379
C12	856	209	191
C13	160	237	35

TABLE I CONTINUE

C14	566	9	26
C15	306567	300	2231
C16	110	5	7
C17	2745	209	137

Due to the different initial value dimensions of various evaluation indexes and the great disparity between their numerical orders of magnitude, it is necessary to standardize and normalize the initial value of the evaluation index. According to the evaluation indexes in this paper, it is seen that the indexes are all efficiency indexes (if the values are greater, the efficiency will be better). Then, in accordance with Formula (2), the initial value of each evaluation index of University A, University B and University C is standardized. The standardization results are shown in Table 2.

TABLE II. THE STANDARDIZED DATA OF EACH EVALUATION INDEX OF UNIVERSITY A, UNIVERSITY B AND UNIVERSITY C

Index Code	University A	University B	University C
C1	1.0000	0.0000	0.1937
C2	1.0000	0.0000	0.0187
C3	1.0000	0.0000	0.1121
C4	1.0000	0.0000	0.1471
C5	1.0000	0.0000	0.0817
C6	1.0000	0.0000	0.2223
C7	1.0000	0.3207	0.0000
C8	1.0000	0.0612	0.0000
C9	1.0000	0.0000	0.0963
C10	1.0000	0.0000	0.4000
C11	1.0000	0.0000	0.0446
C12	1.0000	0.0271	0.0000
C13	0.6188	1.0000	0.0000
C14	1.0000	0.0000	0.0305
C15	1.0000	0.0000	0.0063
C16	1.0000	0.0000	0.0190
C17	1.0000	0.0276	0.0000

According to Formula (4), the ideal scheme reference sequence of University A, University B and University C can be determined.

$$R_0 = (1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1)$$

Based on Formula (5), the grey relational coefficients between University A, University B and University C and the

ideal scheme reference sequence are calculated. The calculation results are shown in Table 3.

TABLE III. THE GREY RELATIONAL COEFFICIENT OF EACH EVALUATION INDEX OF UNIVERSITY A, UNIVERSITY B AND UNIVERSITY C

Index Code	University A	University B	University C
C1	1.0000	0.3333	0.3828
C2	1.0000	0.3333	0.3375
C3	1.0000	0.3333	0.3603
C4	1.0000	0.3333	0.3696
C5	1.0000	0.3333	0.3525
C6	1.0000	0.3333	0.3913
C7	1.0000	0.4240	0.3333
C8	1.0000	0.3475	0.3333
C9	1.0000	0.3333	0.3562
C10	1.0000	0.3333	0.4545
C11	1.0000	0.3333	0.3435
C12	1.0000	0.3395	0.3333
C13	0.5674	1.0000	0.3333
C14	1.0000	0.3333	0.3403
C15	1.0000	0.3333	0.3347
C16	1.0000	0.3333	0.3376
C17	1.0000	0.3396	0.3333

In this paper, the weight information of each evaluation index in University A, University B and University C is totally unknown. Therefore, in order to obtain the grey relational projection value of the evaluated universities, it is necessary to first obtain the weight or gray relational projection value vector of each evaluation index. The traditional entropy method has certain drawbacks and shortcomings, For example,  $r_{ij} = 0$  and  $r_{ij} \cdot \ln(r_{ij}) = 0$  is the special agreement, and at the same time, when  $r_{ij} = 0$  and  $r_{ij} = 1$ ,  $r_{ij} \cdot \ln(r_{ij}) = 0$ , this assumption is obviously unreasonable both in theory and in objective practical problems [13]. Since the normalized data of each evaluation index contains 0, in order to overcome the limitations and drawbacks of the special agreement of the entropy weight method, it is improved in this paper. The specific calculation steps of this method are as follows:

- (1) Calculating the attribute entropy value

$$e_j = -k \sum_{i=1}^m r_{ij} \ln(r_{ij}) \tag{9}$$

Where

$$r_{ij} = \frac{y_{ij} + 1}{\sum_{i=1}^m (y_{ij} + 1)} \left( k = \frac{1}{\ln(m)}; j = 1, 2, \dots, n \right)$$

(2) Calculating the attribute difference coefficient

$$g_j = 1 - e_j \quad (j = 1, 2, \dots, n) \quad (10)$$

(3) Determining the weight

$$\omega_j = \frac{g_j}{\sum_{j=1}^n g_j} \quad (11)$$

According to the above method, the weights of 17 evaluation indexes can be obtained based on Formula (9), Formula (10) and Formula (11). The calculation results are as follows:

$$W = \begin{pmatrix} 0.0533, 0.0664, 0.0586, 0.0561, 0.0609, 0.0518, 0.0476, 0.0626, 0.0597, 0.0453, \\ 0.0640, 0.0656, 0.0434, 0.0653, 0.0676, 0.0664, 0.0656 \end{pmatrix}$$

Since  $\bar{w}_j = w_j^2 / \sqrt{\sum_{j=1}^n w_j^2}$ , the gray relational projection value vector can be obtained by substituting the obtained index weight value into the formula.

$$\bar{W} = (0.0116, 0.0180, 0.0140, 0.0129, 0.0152, 0.0109, 0.0093, 0.0160, 0.0146, 0.0084, 0.0168, 0.0176, 0.0077, 0.0174, 0.0187, 0.0180, 0.0176)$$

According to Formula (8), the grey relational projection values of University A, University B and University C can be obtained, respectively.

$$\gamma_A = 0.2413, \gamma_B = 0.0879, \gamma_C = 0.0857$$

$\gamma_A > \gamma_B > \gamma_C$ , so  $A \succ B \succ C$ . Therefore, University A has the strongest scientific and technological innovation capability, followed by University B and University C. In order to further explain the method in the text, the methods in Literature [3] and Literature [6] are applied to the examples in this paper. Through calculation, it can be concluded that  $\gamma_A > \gamma_B > \gamma_C$ , and the scientific and technological innovation capability of University A, University B and

University C is ranked as  $A \succ B \succ C$ , which is consistent with the results of this paper.

## V. CONCLUSION

This paper proposes a new gray relational projection decision method. The method combines the improved entropy weight method with the grey relational analysis method and the vector projection principle. This paper establishes a suitable evaluation index system of the scientific and technological innovation capability of universities, by using the improved entropy weight method, the weight of the evaluation index is obtained, and the application of the example shows that the calculation steps of the method are clear, the calculation is relatively simple, the operability and the practicability are strong.

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