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Optimization Strategy of Comprehensive Evaluation Method Based on Relative Excellence Measure

Jinjian Li*

School of Business Administration, Henan Polytechnic University, Jiaozuo 45400, Henan Province, China

***Corresponding author:** Jinjian Li, lijinjian0916@163.com

Abstract: Aiming at the comparison and optimization of comprehensive evaluation methods, this paper proposes an optimization strategy of comprehensive evaluation method and constructs a relative excellence measure of the comprehensive evaluation method based on the deviation of rating value and Spearman grade correlation coefficient. On the basis of the relative excellence measure, combined with the compatibility test, the optimization strategy of the comprehensive evaluation method is given to realize the optimization of the comprehensive evaluation method. Finally, the feasibility of this strategy is verified by a case.

Keywords: Comprehensive evaluation method; Relative excellence measure; Deviation of evaluation value; Spearman rank correlation coefficient

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1. Introduction

Comprehensive evaluation refers to the objective, fair, and reasonable comprehensive evaluation of the evaluated object [1]. At present, there are hundreds of comprehensive evaluation methods established at home and abroad [2]. The most important and commonly used methods are expert evaluation method, economic analysis method, analytic hierarchy process, principal component analysis method, factor analysis method, artificial neural network method, data envelopment analysis method, grey correlation degree method, fuzzy comprehensive evaluation method, entropy weight method, and so on [3-7]. When using different evaluation methods to solve the same evaluation problem, the evaluation value vectors are often not consistent. Therefore, the comparison and optimization strategy of comprehensive evaluation methods has been a hotspot in the research field of comprehensive evaluation [8].

At present, many scholars have studied the comparison and optimization strategy of comprehensive evaluation methods. For example, Wang [9] and Niu [10] compared four comprehensive evaluation methods, respectively; the research group from Hangzhou Business School has proposed the sum of serial numbers theory, which takes the sum of serial numbers of evaluation objects under different comprehensive evaluation methods as the standard level sequence, and optimizes each method according to the correlation between the evaluation level sequence under each comprehensive evaluation method and the standard level sequence [11]; Jia [12] and Chen [13] applied the serial number synthesis theory to clinical departments in hospitals and baijiu listed companies, respectively; Bai and other researchers [14] proposed the standard rank order on the basis of sequence synthesis theory, combined with mode theory and weighted average theory;

Sun [15], Zhang [16], and other researchers analyzed the robustness and stability of various comprehensive methods, which provided a basis for the optimization of comprehensive evaluation methods; Zhang and other researchers [8] constructed a new comprehensive evaluation method for relative effectiveness measure based on three indicators: reliability, similarity and dispersion; they optimized each comprehensive evaluation method according to the measure value. In view of the above shortcomings, this paper constructs a relative excellence measure of the comprehensive evaluation method based on the deviation of evaluation value and Spearman grade correlation coefficient. This measure combines the evaluation value and evaluation grade order of the comprehensive evaluation method, and it is not unnecessary to construct the optimal evaluation result. The compatibility test of the relative excellence measure forms the optimization strategy of comprehensive evaluation results.

2. Optimization strategy of comprehensive evaluation method

2.1. Problem description and assumption

Let the evaluation question Q have n evaluation objects, where the object set is $O=\{O_1,O_2,\cdots,O_n\}$; each evaluation object has m evaluation indexes, and the index set is $I=\{I_1,I_2,\cdots,I_m\}$; the method set of c comprehensive evaluation methods to be adopted is $D=\{D_1,D_2,\cdots,D_c\}$. Set the index value of the i-th evaluation object to the index as $y_{ij}, i=1,2,\cdots,n, j=1,2,\cdots,m$, and $Y=(y_{ij})_{m\times n}$ as the index value matrix. Let the evaluation value of the t-th comprehensive evaluation method D_t of the i-th evaluation object O_i be $z_{it}, i=1,2,\cdots,n, t=1,2,\cdots,c$. $Z=(z_{it})_{n\times c}$ is the evaluation value matrix, $Z=\{Z_1,Z_2,\cdots,Z_c\}$ is the evaluation value vector set, and $Z_t, t=1,2,\cdots,c$ is the evaluation value vector of the t-th comprehensive evaluation method.

2.2. Theoretical definition of relative excellence of comprehensive evaluation method

Suppose that in the evaluation value vector set $Z=\{Z_1,Z_2,\cdots,Z_c\}$ of the evaluation problem Q, the closest to the real evaluation value of the evaluation problem is Z_t, then in a relative sense, it is considered that the comprehensive evaluation method corresponding to Z_t is the best. However, Z_t is unknown, so it is necessary to measure each comprehensive evaluation method according to the vector information based on c evaluation values and compare the relative excellence of each comprehensive evaluation method based on its measurement value. It should be noted that the excellence of comprehensive evaluation method is discussed on the basis of evaluation problem Q, method set D, and index value matrix Y. Hence, its excellence is relative.

2.3. Compatibility test of set method

Different comprehensive evaluation methods have different applicability to different problems, and some may not be applicable at all. For a specific evaluation problem, the unsuitable method is known as incompatible method, whereas the applicable method is known as compatible method [17]. In order to ensure that the set method is compatible, it is necessary to carry out a compatibility test. The compatibility test can be carried out with the help of Kendall synergy coefficient. The specific inspection methods will be discussed below [18]. When the number of evaluation objects is $n>7$, the test statistic is $\chi^2=c(n-1)W$.

$$W=\frac{12\sum_{i=1}^{n}R_i^2}{c^2n\left(n^2-1\right)}-\frac{3(n+1)}{(n-1)} \tag{1}$$

Given a significance level of a, $\chi^2\geqslant\chi_\alpha^2(n-1)$ indicates that the c evaluation results are consistent. R_i is the sum of the evaluation grades of the i-th evaluation object and c evaluation methods, $i=1,2,\cdots,n$.

2.4. Idea of measuring the relative excellence of comprehensive evaluation method

Since the c evaluation methods in method set D have passed the compatibility test, their evaluation value vector Z_t is applicable to the evaluation problem Q and can be considered as the reflection of the real evaluation value from a certain angle, so they may become the best method for this evaluation problem. The sum of the difference between the evaluation value of n evaluation objects in method D_t and the evaluation value of n evaluation objects in the other c-1 methods in method set D can be regarded as the relative excellence measure of the method. Although c methods in method set D may become the best evaluation method, it is obvious that the possibility of becoming the best varies. Therefore, when aggregating the difference between the evaluation value of method D_t and the evaluation value of the other c-1 methods, different weights should be given according to the possibility of the other c-1 methods becoming the best method.

So, how to determine the possibility of method D_t becoming the best method? At this time, the rank order of the evaluation results can be used for judgment. The consistency degree of the object level sequence reflected by any evaluation value vector Z_t in the evaluation value vector set $Z = \{Z_1, Z_2, \cdots, Z_c\}$ is different from that reflected by the other c-1 evaluation value vectors $Z_q, q = 1,2,\cdots,c, q \neq t$ as a whole. From the perspective of the law of large numbers, the consistency degree of this level sequence indirectly reflects the possibility of D_t becoming the best method [19]. The higher the degree of consistency, the more likely it is to become the best method, so the weight can be given based on this degree of consistency.

2.5. Relative excellence measure of comprehensive evaluation method

The evaluation value z_{it} must be dimensionless first, $M_t = \max_i\{z_{it}\}$, $m_t = \min_i\{z_{it}\}$.

For positive evaluation value:

$$z_{it}^* = \frac{z_{it} - m_t}{M_t - m_t} \tag{2}$$

For reverse evaluation value:

$$z_{it}^* = \frac{M_t - z_{it}}{M_t - m_t} \tag{3}$$

Let d_{itq} be the deviation between the evaluation value z_{it}^* of evaluation object O_i under evaluation method D_t and the evaluation value z_{iq}^* under evaluation method D_q, where $q = 1,2,\cdots,c$. Then, d_{itq} can be expressed as follows:

$$d_{itq} = \left| z_{it}^* - z_{iq}^* \right| \tag{4}$$

Let the Spearman rank correlation coefficient between the evaluation value vector Z_t of method D_t and the evaluation value vector Z_q of method D_q be ρ_{tq}, in which the formula is as follows:

$$\rho_{tq} = 1 - \frac{6\sum_i^n d_i^2}{n\left(n^2 - 1\right)} \tag{5}$$

Formula (4) ascertains the grade difference of samples, in which n is the number of samples. In this paper, the samples are the evaluation object.

Definition 1: For the evaluation value vector Z_t in the evaluation value vector set $Z = \{Z_1, Z_2, \cdots, Z_c\}$, $\bar{\rho}_t$ represents the average grade correlation coefficient between Z_t and other evaluation value vectors, in which its calculation formula is as follows:

$$\bar{\rho}_t = \frac{1}{c-1}\sum_{q=1}^{c}\rho_{tq} \tag{6}$$

$\bar{\rho}_t$ indirectly reflects the possibility that D_t becomes the most effective method and normalizes ρ_t. The normalization formula is as follows:

$$w_t = \frac{\rho_t}{\sum_{t=1}^{c}\rho_t} \tag{7}$$

w_t is the weight that should be assumed when the deviation of evaluation value is aggregated.

Definition 2: For method D_t in the method set $D = \{D_1, D_2, \cdots, D_c\}$, e_t represents its relative excellence measure, in which its calculation formula is as follows:

$$e_t = \sum_{i=1}^{n}\sum_{q=1}^{c-1} d_{itq} r_q, t = 1, 2, \cdots, c \tag{8}$$

The smaller the e_t value, the better.

2.6. Steps in the optimization strategy of comprehensive evaluation method

(1) Step 1: Use formula (1) to check the compatibility of the method set to ensure that it is applicable to the evaluation problems.
(2) Step 2: Make the evaluation value dimensionless by using equations (2) and (3).
(3) Step 3: Use equations (4) to (8) to calculate the relative excellence measure e_t of each method, $t = 1,2, \cdots, c$; the smaller the value, the better.

3. Example analysis

This paper directly cites the evaluation examples from "Research on Dynamic Combination Evaluation Method Based on Drift Degree" [20] for discussion. The results of the three evaluation methods are shown in **Table 1**.

Table 1. Result of each evaluation method

Region	Evaluation method 1		Evaluation method 2		Evaluation method 3	
	Evaluation value	Sort	Evaluation value	Sort	Evaluation value	Sort
Beijing	0.56	3	0.5704	1	1.099	5
Tianjin	0.41	8	0.1454	8	0.637	9
Hebei	0.42	7	0.1467	7	0.859	7
Shanghai	0.54	4	0.4224	2	1.097	6
Jiangsu	0.7	2	0.4219	3	1.503	1
Zhejiang	0.49	6	0.2246	6	1.158	4
Fujian	0.41	8	0.1213	9	0.675	8
Shandong	0.54	4	0.2464	5	1.316	3
Guangdong	0.71	1	0.4006	4	1.468	2
Hainan	0.36	10	0.0474	10	0.188	10

Using the compatibility test of formula (1), given a significance review of a = 0.01, the temporary calculation shows $\chi^2 = 23.968 > \chi_\alpha^2(n-1) = 21.666$, and passes the compatibility test. By calculating the measure of relative excellence by using equations (3) to (9), the results are obtained as shown in **Table 2**.

Table 2. Measurement value of relative excellence of each evaluation method

Evaluation method	Evaluation method 1	Evaluation method 2	Evaluation method 3
e_t	1.0288	1.336	1.4497

It can be seen from the **Table 2** that the relative excellence of each comprehensive evaluation method is as follows: method 1 > method 2 > method 3.

4. Conclusion

Aiming at the comparison and optimization of comprehensive evaluation methods, this paper proposes a comprehensive evaluation method optimization strategy based on relative excellence measure. The first innovation is that there is no need to construct the “benchmark sequence” of evaluation results in advance, which makes the comparison and optimization of comprehensive evaluation more reasonable. Second, the measurement construction is based on the evaluation value and combined with the rank order, which retains more evaluation information than the comparison and optimization strategy solely based on the evaluation rank order.

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Disclosure statement

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