Construction scheme comparison with comprehensive evaluation of independent perspectives

YAN Xi-kang1,2†, WANG Lei1‡, CHEN Pei1

1 College of Civil Engineering, Hebei University of Technology, Tianjin 300401, P. R. China
2 Civil Engineering Technology Research Center of Hebei Province, Tianjin 300401, P. R. China

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Abstract: Considering both the characteristics of construction scheme evaluation and the lack of consideration of index proportionality after introducing comprehensive evaluation of independent perspectives into construction scheme evaluation, a construction scheme evaluation model of independent perspectives was put forward through the study and optimization of comprehensive evaluation of independent perspectives. The feasibility and rationality of the optimized method were illustrated through a case study and the evaluation results were compared between the optimized method and non-optimized method. The optimized method has the practical value in construction scheme comparison.

Keywords: construction scheme; evaluation model; independent perspective; comprehensive evaluation

1 Construction scheme evaluation model of independent perspectives

Construction scheme comparison is an important step in engineering construction [1-3]. As far as the traditional construction scheme evaluation, evaluation units with different advantages are evaluated with a fixed weight by evaluators as an object [4-8]. This method is unrealistic and very subjective [9]. This paper puts forward a construction scheme evaluation model based on the study and optimization of comprehensive evaluation from independent perspectives.

1.1 Determine the observed value of construction scheme index system

There are n construction schemes and p experts who grade the qualitative indicators of each construction scheme. The scores are listed in Table 1, where x_{ijq} is the score of index j (j=1,2,...,m) in scheme i (i=1,2,...,n) graded by expert q (q=1,2,...,p) and x_{ij} is the average score of index j in scheme i.

<table>
<thead>
<tr>
<th>Construction scheme</th>
<th>Score of index j</th>
<th>( \frac{1}{p} \sum_{q=1}^{p} x_{ijq} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_1 )</td>
<td>( x_{1j1} )</td>
<td>( x_{1j2} ) ... ( x_{1jp} ) ( x_{1j} )</td>
</tr>
<tr>
<td>( \alpha_2 )</td>
<td>( x_{2j1} )</td>
<td>( x_{2j2} ) ... ( x_{2jp} ) ( x_{2j} )</td>
</tr>
<tr>
<td>\vdots</td>
<td>\vdots</td>
<td>\vdots</td>
</tr>
<tr>
<td>( \alpha_n )</td>
<td>( x_{nj1} )</td>
<td>( x_{nj2} ) ... ( x_{npj} ) ( x_{nj} )</td>
</tr>
</tbody>
</table>

When all the average scores of construction schemes are obtained, the determination of observed values of a
qualitative indicator is completed. For a quantitative indicator, it can be used as an observed value directly \[10\].

1.2 Principle of the optimized method

This method compares advantages and disadvantages of competitors from the view of evaluation objects. At the same time, considering both functionality and proportionality, it has four steps in construction scheme comparison.

1.2.1 Basic hypothesis

**Hypothesis 1.** Set the weight of index \(j (j=1, 2, \ldots, m)\) to \(\omega_j\) which satisfies \(\omega_1 \geq \omega_2 \geq \cdots \geq \omega_m; \omega_j \in [0.5^{m-1}, 0.5]\) is called weak weight nondictatorship condition \[11\]. This hypothesis is to create the possibility to obtain abundant evaluation information. At the same time, this hypothesis limits the competition of \(\omega_j\) which satisfies \(\omega_j \geq 0\). If we blindly emphasize the difference of indexes weight, it will increase the competition irrationally and the workload of calculation. Under this hypothesis and according to the theorem of Ref. [11], we set the optimal descending order weight vector to \(\omega_j^*\) and the poorest descending order weight vector to \(\omega_j'\), that is,

\[\omega_j^* = \left(0.5, 0.5 - (m - 2) \times 0.5^{m-1}, 0.5^{m-1}, \ldots, 0.5^{m-1}\right),\]

\[\omega_j' = \left(0.5^{m-1}, 0.5^{m-1}, \ldots, 0.5^{m-1}, 0.5 - (m - 2) \times 0.5^{m-1}, 0.5\right).\]

**Hypothesis 2.** Any construction scheme has the motivation of maximizing its own strengths while minimizing potential competitors’ weaknesses \[11\]. This hypothesis is to create the conditions of constructing a competition model of construction schemes.

1.2.2 Competition model of construction schemes

\(N\) is defined as the number of construction schemes \((O_1, O_2, \ldots, O_n)\) and \(m\) as the number of indexes \((x_1, x_2, \ldots, x_m)\). Construction schemes and indexes construct a multiple indexes evaluation system, in which \(x_j = x_j(O_i) (i=1, 2, \ldots, n; j=1, 2, \ldots, m)\) is defined as the average score of index \(j\) in scheme \(i\). The matrix of the observed values can be expressed as follows.

\[
A = \left[ x_{ij} \right]_{n \times m} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}.
\]

We define \(x_{ij}^*\) as the dimensionless index value of each construction scheme using linear proportion method to uniformize the observed value. That is \(x_{ij}^* = \frac{x_{ij}}{\min \{x_{ij}\}}\).

Under the conditions of optimal descending order weight vector and poorest descending order weight vector, the index value of each construction scheme \(x_{ij}^*\) can be sequenced in descending order. That is \(x_{ij}^*, x_{i(2)}^*, \ldots, x_{i(n)}^*\) \((i=1, 2, \ldots, n)\). A method which considers both functionality and proportionality is used to aggregate the index values of construction schemes. The formula is as follows.

\[
y = \lambda_1 \sum_{j=1}^{m} \omega_j^{(1)} x_{ij} + \lambda_2 \prod_{j=1}^{m} x_{ij}^{(2)},
\]

where \(y\) is the index value; \(\lambda_1\) and \(\lambda_2\) \((\lambda_1 > 0, \lambda_2 \geq 0, \lambda_1 + \lambda_2 = 1)\) are the proportion of functionality and proportionality, respectively; \(\omega_j^{(1)}\) and \(\omega_j^{(2)}\) are the weights of indexes which are respectively aggregated functionally and proportionally; \(\omega_j^{(1)}\) is the optimal descending order weight vector and the poorest descending order weight vector of construction scheme. \(\omega_j^{(2)} = 1/m\) in order to consider the proportionality of construction scheme. So the range of evaluation value \(y_i\) of construction scheme \(O_i\) \((i=1, 2, \ldots, n)\) is

\[
\begin{align*}
\hat{\lambda}_1 \times 0.5 x_{iij}^* + & 0.5 - (m - 2) 0.5^{m-1} \right] x_{im}^* + \\
\sum_{j=1}^{m} \left[ 0.5 x_{ij}^* ight] + & \lambda_2 \times \prod_{j=1}^{m} x_{ij}^* ,
\end{align*}
\]

The competition intensity matrix and competitive focus coefficient matrix of construction schemes can be
calculated \[ \lambda_i y_i - \lambda_2 \sum_{j=1}^{n} \mu_i x_{ij} = z_i, \] \[ (2) \]
where \( \mu_i \) is the competitive focus coefficient; \( \lambda_1 \) is the coefficient of promoting their own advantages; \( \lambda_2 \) is the coefficient of reducing the advantages of competitors; \( \lambda_1, \lambda_2 > 0, \lambda_1 + \lambda_2 = 1, i=1,2,\ldots,n; l=1,2,\ldots,n; l \neq i; j=1,2,\ldots,m. \)

### 1.2.3 Evaluation conclusion of each construction scheme on their own perspective

According to the competition model of construction schemes, any construction scheme \( O_i \) can get a solution vector \( z=(z_1,z_2,\ldots,z_m) \), and \( \omega^i = (\omega^{i1}, \omega^{i2}, \ldots, \omega^{in}) \) is the anticipant optimal descending order weight vector of \( z_i \). A method which considers both functionality and proportionality is used to aggregate the index values of construction schemes. The method is as follows,

\[ y^{(i)}_k = \lambda_i \sum_{j=1}^{m} \omega^{i_j} x_{ij} + \lambda_2 \prod_{j=1}^{m} x_{ij}^{-1}, \] \[ (3) \]

where \( y^{(i)}_k \) is the evaluation value of construction scheme \( O_i \) \((k=1,2,\ldots,n)\) under the condition of \( \omega^i \). According to the Eq. (3), the evaluation conclusion \( y^{(i)} \) of construction schemes \( O_1, O_2,\ldots,O_n \) can be solved under the condition of \( \omega^i \), where

\[ y^{(i)} = (y^{(i)}_1, y^{(i)}_2, \ldots, y^{(i)}_n)^T. \] \[ (4) \]

This conclusion is the evaluation value of each construction scheme in the perspective of \( O_i \). Name \( y^{(i)}_k = y_{ik} \) \((k=1,2,\ldots,n; i=1,2,\ldots,n)\), and the matrix of evaluation values \( Y \) is as follows \[ (11) \]

\[ y = \begin{bmatrix} y^{(1)} & y^{(2)} & \cdots & y^{(n)} \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{nl} & y_{n2} & \cdots & y_{nn} \end{bmatrix}. \]

### 1.2.4 Comprehensive evaluation conclusion

A comprehensive evaluation conclusion can be drawn from the matrix of evaluation values \( Y \). The basic idea is to find a vector \( y^* \) which can make the sum of the angle between \( y \) and \( y^{(1)}, y^{(2)}, \ldots, y^{(n)} \) minimum \[ (11) \]. \( y^* \) is the optimal solution given by,

\[ \max \sum_{i=1}^{n} \left[ y^T y^{(i)} \right]^2, \] \[ \text{s.t. } \|y^*\|=1. \] \[ (5) \]

The optimal solution of Formula (5) can be solved by the theorem of Ref. [13], \( \lambda_{\max} \) is the maximal characteristic root of matrix \( YY^T \). \( y^* \) is the positive eigenvector when the characteristic root is \( \lambda_{\max}^{[13-14]} \). At the same time, \( y^* \) need to meet \( \|y^*\|=1 \).

### 2 Case study

There are several construction schemes of a highway soft ground treatment \[ (15) \]. According to the construction scheme evaluation model of independent perspectives, their observed values of construction scheme index system are shown in Table 2.

This case can be solved by the optimized construction scheme comprehensive evaluation of independent perspectives. The calculated evaluation value matrix \( Y \) is

\[ \begin{bmatrix} 1.8045 & 1.6375 & 1.6995 & 1.5992 \\ 1.6550 & 1.7096 & 1.5702 & 1.6641 \\ 1.5377 & 1.1877 & 1.6474 & 1.1877 \\ 1.1478 & 1.3475 & 1.1941 & 1.3484 \end{bmatrix}, \]

\( \lambda_{\max} \) is 3.6343, and

\[ y^* = \begin{bmatrix} 0.5595 & 0.5469 & 0.4626 & 0.4169 \end{bmatrix}^T. \]

Let the values of \( Y \) and \( y^* \) be order value. Comparing the evaluation results between optimized method and non-optimized method, the results are shown in Table 3.
Table 2: Observed values

<table>
<thead>
<tr>
<th>Construction schemes</th>
<th>Engineering cost (10^6 yuan)</th>
<th>Construction period/d</th>
<th>Safety reliability</th>
<th>Technical difficulty</th>
<th>Degree of quality assurance</th>
<th>Quality assurance</th>
<th>Technological effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel pile</td>
<td>1.05</td>
<td>67</td>
<td>7.8</td>
<td>7.9</td>
<td>6.8</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Silt mixing pile</td>
<td>0.92</td>
<td>80</td>
<td>8.9</td>
<td>6.8</td>
<td>5.7</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>Two ash piles</td>
<td>2.05</td>
<td>56</td>
<td>6.8</td>
<td>9.0</td>
<td>4.5</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>Plastic drainage plate</td>
<td>1.38</td>
<td>63</td>
<td>9.0</td>
<td>3.4</td>
<td>3.5</td>
<td>8.4</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Evaluation results

<table>
<thead>
<tr>
<th>Construction scheme</th>
<th>View of GP</th>
<th>View of SMP</th>
<th>View of TAP</th>
<th>View of PDP</th>
<th>Comprehensive sequencing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel pile (GP)</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Silt mixing pile(SMP)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Two ash piles (TAP)</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Plastic drainage plate (PDP)</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Notes: A stands for non-optimized method; B stands for optimized method.

By analyzing the data in Table 3, we can conclude that the result of each construction scheme in their own perspective shows the purpose of promoting their own advantages. Each construction scheme achieves its highest ranking. At the same time, according to the different intensity of competition, each construction scheme achieves the purpose of reducing the advantages of competitors. It can also be seen through combining with the data in Table 2 and comparing the evaluation results between optimized method and non-optimized method that construction schemes with similar functionality and different proportionality can be distinguished by the optimized evaluation method. The optimized construction scheme comprehensive evaluation of independent perspectives is helpful to promote the balanced development of the whole system.

3 Conclusion

The construction scheme evaluation model of independent perspectives can make the comprehensive evaluation much more easily than the traditional evaluation method. This model makes construction schemes turn into an intelligent agent. Evaluators can easily accept the model which considers both functionality and proportionality and can ensure fairness. This model gives abundant evaluation information and changes the situation of traditional evaluation method in which construction schemes are evaluated with a fixed weight. At the same time, this model makes a breakthrough with considering the influence of the evaluation units. The case study explains that the result of optimized method is reasonable and abundant. The result also has high resolution and much more practical values in the comparison of construction schemes.

References


