Analysis on the Investment Decision of Infrastructure Project Based on Value Engineering

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Abstract

The construction of infrastructure projects promotes economic development and enhances people’s quality of life. Based on the theory of value engineering, this paper applies the analytic hierarchy process to construct an method of investment decision for infrastructure project engineering. Compared with the traditional methods that only evaluate the economic factor, this paper takes into comprehensive account of economic, social and environmental aspects to deliver more scientific and reasonable evaluation results. At the same time, the bridge project construction plan is taken as an example to verify the decision system constructed in this paper. This investment decision-making method provides ideal plan evaluation and selection as well as a favorable reference for the investment and the decision-making of other projects.

Key words: value engineering; investment decision; analytic hierarchy process; infrastructure project

1. INTRODUCTION

A large number of infrastructure projects effectively promote the development of national economy and improve people’s quality of life. However, due to limited social resources, the demands of all project construction are impossible to be met. Therefore, a relatively reasonable project should be selected among a wide range of project investment options (Liu and Wang, 2012; Magni, 2014; Miao et al., 2015). Besides, scientific and rational project evaluations are a significant basis for making investment decisions (Bode and Hungerbuhler, 2006). In the traditional decision-making for the investment programs, the main consideration lies in the economic factor. Some scholars also consider social development, environment and other factors (Saleh and Marais, 2006; Wernz et al., 2014).

This paper puts forward an index system for the evaluation of investment decision-making, through the theory of value engineering as well as analytic hierarchy process, which provides a theoretical basis for investment decision-making. Only with comprehensive, scientific and reasonable evaluations for the project investment program, could the right investment decision and effective project management be achieved in an objective way, thereby maximizing the benefits of project investment.

2. MATHEMATICAL MODEL FOR THE INVESTMENT DECISION-MAKING OF INFRASTRUCTURE PROJECT

(1) Value engineering

Value engineering is the method and the technology that involve cooperation among various fields, which systematically analyzes the functions and the costs of the object of study, and strengthens innovation to improve the value of the object of study (Shittu and Baker, 2010; Ir, 2015). The purpose of value engineering is to achieve the desired functionality of users at the lowest lifecycle of the object, thereby achieving optimal results (Hansen, 2010; Renna and Argoneto, 2012). Value engineering is expressed as:

\[ V = \frac{F}{C} \]  

(1)

Specifically, V, F, and C represent value coefficient, function coefficient and cost coefficient, respectively.
Value engineering is introduced in the investment decision-making process of infrastructure projects, which mainly is a comprehensive consideration of the input and the output of the project. In the formula \( V = \frac{F}{C} \), \( V \) represents the investment effects; \( F \) stands for the function that the object can achieve; and \( C \) means the cost caused by the consumption of product function.

Concerning the calculation of cost coefficient \( CI_i \), in the comparison of the actual plans, the cost coefficient of an individual plan, \( C_i \), is the ratio of the cost of Plan \( i \) to the total cost of all the plans.

\[
CI_i = \frac{C_i}{\sum_{i=1}^{n} C_i} \tag{2}
\]

Concerning the calculation of function coefficient \( FI_i \):

\[
FI_i = \frac{F_i}{\sum_{i=1}^{n} F_i} \tag{3}
\]

The calculation of the value coefficient of each plan, \( V_i \), is:

\[
V_i = \frac{FI_i}{CI_i} \tag{4}
\]

The alternative plans are sorted according to the numerical magnitude of value coefficients. The greater the value coefficient is, the better the plan is.

(2) Analytic Hierarchy Process

The method of analytic hierarchy process is mainly used to calculate the weight vector of the evaluation project in the functional evaluation (Kahraman et al., 2015; Robotis et al., 2012). In the process of using analytic hierarchy process, the following steps are involved (Tang et al., 2011; Carter, 1978).

First, the hierarchy of the evaluated issue is established. Under normal circumstances, there are three levels: the highest level (object level), the middle level (rule level) and the lowest level (indicator level). The relationship among the levels are expressed as in Fig. 1.

![Hierarchical structure model](image)

Figure 1. Hierarchical structure model

Secondly, the judgment matrix is constructed (Nikolić et al., 2009; Müller et al., 2016). This paper mainly adopts the pairwise comparison method. In Table 1, the analysis is on the correlation of the B elements in the Level A. On the basis of information analysis on the Level A, the pairwise correlation of various B elements is analyzed and the following matrix is formed.

<table>
<thead>
<tr>
<th>( A_k )</th>
<th>( B_1 )</th>
<th>( B_2 )</th>
<th>...</th>
<th>( B_n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( B_1 )</td>
<td>( b_{11} )</td>
<td>( b_{12} )</td>
<td>...</td>
<td>( b_{1n} )</td>
</tr>
<tr>
<td>( B_2 )</td>
<td>( b_{21} )</td>
<td>( b_{22} )</td>
<td>...</td>
<td>( b_{2n} )</td>
</tr>
</tbody>
</table>
As far as $A_i$ is concerned, $b_{ij}$ is the numerical representation of the relative importance of $B_i$ to $B_j$. The values of $b_{ij}$ range from 1 to 9 and their reciprocals. The specific meanings are shown in Table 2.

**Table 2** The scale of judgment matrix and its meaning

<table>
<thead>
<tr>
<th>scale</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The two factors are equally important</td>
</tr>
<tr>
<td>3</td>
<td>A factor is more important than the other factor when compared to the two factor</td>
</tr>
<tr>
<td>5</td>
<td>A factor is obviously more important than the other factor when compared to the two factor</td>
</tr>
<tr>
<td>7</td>
<td>A factor is strongly more important than the other factor when compared to the two factor</td>
</tr>
<tr>
<td>9</td>
<td>A factor is extremely more important than the other factor when compared to the two factor</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>The median value of the two adjacent judgments</td>
</tr>
<tr>
<td>reciprocal</td>
<td>Factor $i$ compared with $j$ $u_{ij} = 1/u_{ji}$</td>
</tr>
</tbody>
</table>

As seen from Table 2, as for a judgment matrix with $n$ elements, its symmetry can be obtained with the knowledge of $n(n-1)/2$ judgments of its upper or lower triangular.

Thirdly, single hierarchical arrangement is made. The largest eigenvalue of the judgment matrix and its eigenvector are calculated. The calculation steps are described as below.

(a) Calculate $M_i$ of the elements in each row of this judgment matrix $M_i = \prod_{i=1}^{n} b_{ij}, i = 1, 2, \ldots, n$

(b) Calculate the $n$th root of $M_i$, $\overline{W_i} = \sqrt[n]{M_i}$

(c) Normalize the vector $\overline{W_i} = [W_{i1} W_{i2} \ldots W_{in}]^T$: $W_i = \frac{\overline{W_i}}{\sum_{j=1}^{n} \overline{W_j}}$ the vector is obtained as follows:

$$W = [W_{11} W_{21} \ldots W_{nn}]^T$$

(d) Calculate the maximum eigenvalue of the judgment matrix $\lambda_{\text{max}}$. According to the matrix theory, it is indicated that judgment matrix $A$ has the largest eigenvalue, which is obtained by the following formula:

$$\lambda_{\text{max}} = \sum_{i=1}^{n} \frac{(BW_i)_i}{nW_i} = \frac{1}{n} \sum_{i=1}^{n} \frac{\sum_{j=1}^{n} b_{ij}W_j}{W_i}$$

Wherein, $(BW)_i$ is the $i$-th component of the vector $BW$.

After finding the maximum eigenvalue of the matrix, it is necessary to check the consistency of the matrix. The consistency index of the test judgment matrix is

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

Specifically, $n$ is the order of the judgment matrix. When $CI = 0$, $\lambda_{\text{max}} = n$, so the judgment matrix has complete consistency. The larger the value of $CI$ is, the worse the consistency of the judgment matrix is. The
specific approach is to compare CI to the average consistency index RI, that is, \( CR = \frac{CI}{RI} \). If \( CR \leq 0.1 \), the judgment matrix has satisfactory consistency. If \( CR > 0.1 \), it is necessary to adjust the judgment matrix to reach satisfied consistency.

The fourth step is the total ranking of the hierarchy. Single hierarchical arrangement results can be pushed up to obtain the higher order.

The fifth step is the consistency test for the total ranking of the hierarchy. The consistency check of the single hierarchical evaluation results works in the same way. CI indicates the consistency index of the total ranking of the hierarchy. RI represents the random consistency index of the total ranking of the hierarchy. CI and RI are calculated as follows:

\[
CI = \sum_{i=1}^{m} a_i Cl_i(8)
\]

\[
RI = \sum_{i=1}^{m} a_i Rl_i(9)
\]

\[
CR = \frac{CI}{RI}.
\]

If \( CR \leq 0.1 \), the results of the overall ranking of the hierarchy show satisfactory consistency. When \( CR > 0.1 \), it needs to be adjusted until the satisfactory consistency occurs.

3. CASE STUDY

This paper takes Zhuhai Bridge Construction Project as an example for case study. In this project, there are two alternatives—Plan A and Plan B. The total investment is 871.504 million Yuan and 870.098 million Yuan, respectively.

(1) Construct an index evaluation system

The evaluation index system is established according to the analytic hierarchy process. The evaluation system consists of three levels. The evaluation objective is set as the first level. In this paper, the second level is comprised of three layers—economic, social, and environmental. The specific indicators under each layer are listed as the third level. The details are demonstrated in Figure 2, Figure 3, and Figure 4.

**Figure 2.** The composition of the economic index

**Figure 3.** The composition of the social index
Based on the above analysis, we can draw the comprehensive evaluation index system for project investment, as shown in Table 3.

**Table 3 Comprehensive investment project evaluation index system**

<table>
<thead>
<tr>
<th>Object level</th>
<th>Rule level</th>
<th>Indicator level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehensive investment project evaluation(A)</td>
<td>economic index (B₁)</td>
<td>Promote the development of regional economy(C₁₁)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operating income(C₁₂)</td>
</tr>
<tr>
<td></td>
<td>Social index(B₂)</td>
<td>The impact on the regional industry development(C₂₁)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ease traffic pressure(C₂₂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The impact on the regional planning layout(C₂₃)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Impact on the rest of the transportation facilities(C₂₄)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expanding the social services capacity(C₂₅)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The impact on vulnerable groups(C₂₆)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social adaptability and acceptable for the project(C₂₇)</td>
</tr>
<tr>
<td></td>
<td>Environmental index(B₃)</td>
<td>The traffic safety(C₃₁)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The environmental pollution(C₃₂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy saving(C₃₃)</td>
</tr>
</tbody>
</table>

(2) Calculate the evaluation indexes

First, the indexes of the criterion lay are under pairwise comparisons, and a judgment matrix is established, as seen in Table 4.

**Table 4 Judgment matrix**

<table>
<thead>
<tr>
<th>A</th>
<th>B₁ (economic index)</th>
<th>B₂ (Social index)</th>
<th>B₃ (Environmental index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B₁(economic index)</td>
<td>1</td>
<td>1/5</td>
<td>1/3</td>
</tr>
<tr>
<td>B₂(Social index)</td>
<td>5</td>
<td>1</td>
<td>1/3</td>
</tr>
<tr>
<td>B₃(Environmental index)</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

The elements in the row of the judgment matrix are multiplied, and the cubic root of the product of each row is calculated. So the vector $\bar{W}$ obtained. $\bar{W} = [0.4055 \ 1.1856 \ 2.0801]^T$
Normalize the vector $\mathbf{W}$ to obtain the required eigenvector $\mathbf{W} = [0.1104 \ 0.3230 \ 0.5666]^T$

Calculate $\lambda_{\text{max}}$ and conduct the consistency check:

$$\lambda_{\text{max}} = \sum_{i=1}^{n} \left( \frac{(BW)_i}{nW_i} \right) = \frac{1}{n} \sum_{i=1}^{n} b_i \frac{W_i}{n}$$

Therein, $BW = \begin{bmatrix} 1 & \frac{1}{5} & \frac{1}{3} \\ \frac{5}{1} & 1 & \frac{1}{3} \\ \frac{3}{3} & 3 & 1 \end{bmatrix} \left[ \begin{array}{c} 0.1104 \\ 0.3230 \\ 0.5666 \end{array} \right]$, substitute it into the above formula, and $\lambda_{\text{max}} = 3.1778$

Thus $CI = \frac{\lambda_{\text{max}} - n}{n-1} = \frac{3.1778 - 3}{3-1} = 0.0889$

In terms of the third order matrix, $RI = 0.92$

CR=0.0889/0.92=0.0966<0.1, which means this matrix has satisfactory consistency.

Similarly, economic index, social index and environmental index are calculated. The specific results are listed in Table 5, Table 6 and Table 7.

### Table 5 Economic index judgment matrix and weight

<table>
<thead>
<tr>
<th>$B_1$</th>
<th>$C_{11}$</th>
<th>$C_{12}$</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{11}$</td>
<td>1</td>
<td>3</td>
<td>0.6834</td>
</tr>
<tr>
<td>$C_{12}$</td>
<td>1/3</td>
<td>1</td>
<td>0.3751</td>
</tr>
</tbody>
</table>

$\lambda_{\text{max}} = 2.1487$  
CI=0.053  
CR<0.1  
It has the satisfactory consistency

### Table 6 Social index judgment matrix and weight

<table>
<thead>
<tr>
<th>$B_2$</th>
<th>$C_{21}$</th>
<th>$C_{22}$</th>
<th>$C_{23}$</th>
<th>$C_{24}$</th>
<th>$C_{25}$</th>
<th>$C_{26}$</th>
<th>$C_{27}$</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{21}$</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1/3</td>
<td>4</td>
<td>2</td>
<td>1/5</td>
<td>0.231</td>
</tr>
<tr>
<td>$C_{22}$</td>
<td>1/2</td>
<td>1</td>
<td>1/2</td>
<td>1/4</td>
<td>1/3</td>
<td>1/3</td>
<td>1/4</td>
<td>0.039</td>
</tr>
<tr>
<td>$C_{23}$</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1/3</td>
<td>0.138</td>
</tr>
<tr>
<td>$C_{24}$</td>
<td>3</td>
<td>4</td>
<td>1/3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1/4</td>
<td>0.204</td>
</tr>
<tr>
<td>$C_{25}$</td>
<td>1/4</td>
<td>3</td>
<td>1/2</td>
<td>1/2</td>
<td>1</td>
<td>3</td>
<td>1/3</td>
<td>0.102</td>
</tr>
<tr>
<td>$C_{26}$</td>
<td>1/2</td>
<td>3</td>
<td>1/2</td>
<td>1</td>
<td>1/3</td>
<td>1</td>
<td>1/5</td>
<td>0.101</td>
</tr>
<tr>
<td>$C_{27}$</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0.298</td>
</tr>
</tbody>
</table>

$\lambda_{\text{max}} = 7.231$  
CI=0.072  
CR<0.1  
It has the satisfactory consistency

### Table 7 Environmental index judgment matrix and weight

<table>
<thead>
<tr>
<th>$B_3$</th>
<th>$C_{31}$</th>
<th>$C_{32}$</th>
<th>$C_{33}$</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{31}$</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0.621</td>
</tr>
<tr>
<td>$C_{32}$</td>
<td>1/3</td>
<td>1</td>
<td>3</td>
<td>0.302</td>
</tr>
<tr>
<td>$C_{33}$</td>
<td>1/3</td>
<td>1</td>
<td>1/3</td>
<td>0.163</td>
</tr>
</tbody>
</table>

$\lambda_{\text{max}} = 3.324$  
CI=0.043  
CR<0.1  
It has the satisfactory consistency
In conclusion, the values of the index weights of comprehensive investment evaluation for the urban traffic infrastructure projects are demonstrated in Table 8.

**Table 8 Index weights of project investment evaluation**

<table>
<thead>
<tr>
<th>Rule hierarchy</th>
<th>Criteria weight</th>
<th>Indicator hierarchy</th>
<th>Indicator weight</th>
<th>total sequencing weight</th>
<th>Weight total sorts</th>
</tr>
</thead>
<tbody>
<tr>
<td>B₁ (economic index)</td>
<td>0.109</td>
<td>C₁₁ (Promote the development of regional economy)</td>
<td>0.683</td>
<td>0.073</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₁₂ (Operating income)</td>
<td>0.375</td>
<td>0.035</td>
<td>9</td>
</tr>
<tr>
<td>B₂ (Social index)</td>
<td>0.368</td>
<td>C₂₁ (The impact on the regional industry development)</td>
<td>0.231</td>
<td>0.037</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₂₂ (Ease traffic pressure)</td>
<td>0.039</td>
<td>0.014</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₂₃ (The impact on the regional planning layout)</td>
<td>0.138</td>
<td>0.050</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₂₄ (Impact on the rest of the transportation facilities)</td>
<td>0.204</td>
<td>0.041</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₂₅ (Expanding the social services capacity)</td>
<td>0.102</td>
<td>0.029</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₂₆ (The impact on vulnerable groups)</td>
<td>0.101</td>
<td>0.024</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₂₇ (Social adaptability and acceptable for the project)</td>
<td>0.298</td>
<td>0.121</td>
<td>3</td>
</tr>
<tr>
<td>B₃ (Environmental index)</td>
<td>0.498</td>
<td>C₃₁ (The traffic safety)</td>
<td>0.621</td>
<td>0.330</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₃₂ (The environmental pollution)</td>
<td>0.302</td>
<td>0.158</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C₃₃ (Energy saving)</td>
<td>0.163</td>
<td>0.076</td>
<td>4</td>
</tr>
</tbody>
</table>

The consistency check of the total ranking is: CI = Σᵢ₌₁ⁿ bᵢ(CI)ᵢ = 0.109 × 0.053 + 0.368 × 0.072 + 0.498 × 0.043 = 0.0596RI = Σᵢ₌₁ⁿ bᵢ(RI)ᵢ = 0.109 × 0.9 + 0.368 × 1.32 + 0.498 × 0.58 = 0.79683

CR = CI/RI = 0.0596/0.79683 = 0.0747 < 0.1. Therefore, the total ranking of the hierarchy is consistent.

Through the calculations of weights in Table 8, the top influencing factors include traffic safety (C₃₁), environmental pollution (C₃₂), the adaptability and the acceptability of the projects to the society (C₂₇) and energy saving (C₃₃).

(3) Determine the cost coefficient

The budget costs for Plan A and Plan B are 871.54 million Yuan and 8700.98 million Yuan respectively. Therefore, according to Formula (2), the cost coefficient of each plan is calculated:

Plan A: \( C_{IA} = \frac{C_a}{C_a + C_b} = \frac{87150.4}{87150.4 + 87009.8} = 0.5113 \)

Plan B: \( C_{IB} = \frac{C_b}{C_a + C_b} = \frac{87009.8}{87150.4 + 87009.8} = 0.4894 \)

(4) Determine the function coefficient
In the process of investment evaluation, the quality of each index is divided into five grades, namely better, good, general, poor and worse, with the corresponding scores of 10, 8, 6, 4, and 2, as seen in Table 9.

**Table 9 Index score table**

<table>
<thead>
<tr>
<th>Index evaluation</th>
<th>Better</th>
<th>Good</th>
<th>General</th>
<th>Poor</th>
<th>Worse</th>
</tr>
</thead>
<tbody>
<tr>
<td>score</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

12 experts are invited to score each index of the two plans, respectively. The specific scores are illustrated in Table 10 and Table 11.

**Table 10 Expert scoring statistics of Plan A**

<table>
<thead>
<tr>
<th>Plan A</th>
<th>Expert</th>
<th>Average</th>
<th>Weight</th>
<th>Function parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_{11}</td>
<td>8 6 8 8 10 6 10 8</td>
<td>8.17766</td>
<td>0.073</td>
<td>0.65358</td>
</tr>
<tr>
<td>C_{12}</td>
<td>8 6 8 6 8 4</td>
<td>6.66667</td>
<td>0.035</td>
<td>0.24</td>
</tr>
<tr>
<td>C_{21}</td>
<td>10 6 6 10 8 6</td>
<td>7.83333</td>
<td>0.037</td>
<td>0.28652</td>
</tr>
<tr>
<td>C_{22}</td>
<td>8 6 8 10 8 6</td>
<td>7.5</td>
<td>0.014</td>
<td>0.1235</td>
</tr>
<tr>
<td>C_{23}</td>
<td>10 8 8 8 10 8</td>
<td>8.5</td>
<td>0.050</td>
<td>0.4437</td>
</tr>
<tr>
<td>C_{25}</td>
<td>6 8 6 8 10 6</td>
<td>7.16672</td>
<td>0.029</td>
<td>0.254</td>
</tr>
<tr>
<td>C_{26}</td>
<td>6 6 8 6 8 6</td>
<td>6</td>
<td>0.024</td>
<td>0.23</td>
</tr>
<tr>
<td>C_{27}</td>
<td>10 8 6 8 10 8</td>
<td>7.66667</td>
<td>0.121</td>
<td>0.96582</td>
</tr>
<tr>
<td>C_{29}</td>
<td>10 6 6 8 10 8</td>
<td>7.16667</td>
<td>0.030</td>
<td>2.39652</td>
</tr>
<tr>
<td>C_{32}</td>
<td>10 4 8 6 6 8</td>
<td>6.66667</td>
<td>0.158</td>
<td>1.24</td>
</tr>
<tr>
<td>C_{33}</td>
<td>8 8 6 6 6 6</td>
<td>6.66667</td>
<td>0.076</td>
<td>0.57362</td>
</tr>
</tbody>
</table>

12 experts give scores to each index. Formula (3) indicates that the function score of Plan A is calculated as follows: \( F_A = 7.4328 \)

**Table 11 Expert scoring statistics of Plan B**

<table>
<thead>
<tr>
<th>Plan A</th>
<th>Expert</th>
<th>Average</th>
<th>Weight</th>
<th>Function parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_{11}</td>
<td>6 4 10 8 6 8</td>
<td>7.25673</td>
<td>0.073</td>
<td>0.52763</td>
</tr>
<tr>
<td>C_{12}</td>
<td>6 4 6 8 4</td>
<td>5.43722</td>
<td>0.035</td>
<td>0.198</td>
</tr>
<tr>
<td>C_{21}</td>
<td>10 6 8 8 4</td>
<td>6.74444</td>
<td>0.037</td>
<td>0.246542</td>
</tr>
<tr>
<td>C_{22}</td>
<td>6 6 8 6 6</td>
<td>6.5</td>
<td>0.014</td>
<td>0.0892</td>
</tr>
</tbody>
</table>
12 experts give scores to each index. According to Formula (3), the function score of Plan b is calculated as: $F_b = 6.3947$.

Thus, the function coefficients of the two plans are calculated.

$$F_A = \frac{7.4320}{7.4320 + 6.3947} = 0.5375$$

$$F_B = \frac{6.3947}{7.4320 + 6.3947} = 0.4625$$

(5) Determine the value coefficient

Based on the above calculation results, the value coefficients of the two plans are calculated according to the formula $V = \frac{F_A}{C_A} = 1.0512$ and $V_b = \frac{F_B}{C_B} = 0.9449$.

The calculations indicate that the value coefficient of Plan A is higher than that of Plan B. Therefore, the final choice is Plan A. In the selection process of the alternatives, it is found that the investment cost of Plan A is higher than that of Plan B. However, in the application of the analytic hierarchy process, the factors with great influence on the project decision include traffic safety ($C_{11}$), environmental pollution ($C_{32}$), the adaptability and the acceptability of the projects to the society ($C_{27}$), energy efficiency ($C_{33}$) and the impact on the regional economy ($C_{11}$). Plan A has a better performance than Plan B in terms of the promotion of regional economic development ($C_{11}$), the adaptability and the acceptability of the projects to the society ($C_{27}$), environmental pollution ($C_{32}$) and other aspects. Thus, Plan A receives a higher performance score than Plan B, which effectively compensates for the cost disadvantage of Plan A. This is the reason why the value coefficient of Plan A is higher than that of Plan B, and why Plan A is the preferred plan.

4. CONCLUDING REMARKS

(1) In the traditional investment decision-making method, the main consideration is the economic factor, and the plans are compared by means of financial indicators. In the evaluation process of investment projects, this paper is not limited to economic benefits. Environmental, social and other factors are under comprehensive consideration. How various factors influence the project investment evaluation is under full analysis.

(2) In the selection process of project investment plan, this paper mainly uses the theory of value engineering as well as the method of analytic hierarchy process and forms a decision model for the system.

(3) In case study, comparative analysis is conducted on the two alternative plans. Although the final choice is at the higher cost, but it is the preferred plan from the comprehensive perspective of economic, social, environmental and other factors. It is effectively proved that the combination of the value engineering theory and the analytic hierarchy process is able to scientifically and reasonably evaluate the project and it provides a good reference for the evaluation of the investment of other projects.

5. REFERENCES


