Evaluation on the Social Benefits of Power grid enterprises’ Investment Based on the Fuzzy Matter-element Model

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Abstract. Bearing the major political responsibility of constructing, operating and developing the state power grid, and the important social responsibility of optimizing the allocation of energy and resources, guaranteeing the national energy security and promoting the development of the national economy, power grid enterprises should not ignore the social benefits when evaluating their investment projects. In this paper, the evaluation indicator system for the social benefits of power grid enterprises’ investment is constructed first, then the combination weighting method is used to assign weights to the indicators and the comprehensive evaluation on the social benefits is carried out after the comprehensive evaluation fuzzy matter-element is established.

1. Introduction

With the deepening of power system reform, power grid enterprises’ investment will face significant changes in the market environment, investment benefits and recovery mechanism. Upon profound changes in the external environment and internal requirements, the comprehensive evaluation on the benefits of power grid enterprises’ investment can help the enterprises to maximize the investment benefits. The public utility attribute of power grid enterprises determines that the social benefits of their investment projects should not be ignored. The evaluation on the social benefits is more in line with the requirements for the benefit evaluation for power grid enterprises’ investment, and can reflect the investment level and value of enterprises more comprehensively.

2. Research Status at Home and Abroad

As a part of the overall investment benefit, the social benefits of power grid enterprises’ investment is an important factor that cannot be ignored when many scholars carry out research. Jiang Lin
considered the social benefits as part of the investment influence benefits, and then evaluated the investment benefits \[1\]. Liang Jian et al. only regarded the regional limited capacity as the influence benefits of investment on the society \[2\]. However, the above scholars often considered social benefits along with economic benefits, and the classification of social benefit evaluation indicators is not accurate enough.

At present, a few scholars have made a comprehensive evaluation on the social benefits of investment. Li Meng et al. conducted a comprehensive evaluation on the social benefits of power grid enterprises’ investment through the AHP method and fuzzy comprehensive evaluation, but this method was too subjective \[3\]. Xu Chao et al. constructed a full-cycle social benefit evaluation indicator system, but the objective scoring basis was lacking in the empirical analysis of the evaluation \[4\].

From the above research results, it can be seen that at present, there are few evaluations on the social benefits of power grid enterprises’ investment as the evaluation object, and the construction of the indicator system needs to be further improved, and there is still room for improvement in terms of the comprehensive evaluation method.

3. Construction of the Evaluation Indicator System for the Social Benefits of Power grid enterprise’s Investment

To evaluate the social benefits of power grid enterprises’ investment, it is necessary to construct a comprehensive and perfect evaluation indicator system. By consulting relevant literatures, this paper constructs the indicator system like the one in Table 1.

| Social benefits of power grid enterprises’ investment | Social economy                  | Additional gross production output resulting from investment |
|-----------------------------------------------------|---------------------------------|------------------------------------------------------------|
|                                                     |                                 | Additional labor remuneration resulting from investment     |
|                                                     |                                 | Additional taxes resulting from investment                  |
| Social environment                                  |                                 | Reduction of standard coal consumption resulting from investment |
|                                                     |                                 | Reduction of carbon dioxide emissions resulting from investment |
|                                                     |                                 | Improvement of environmental quality                        |
| Social stability                                    |                                 | Additional electricity consumption resulting from investment |
|                                                     |                                 | User satisfaction                                           |
|                                                     |                                 | Infrastructures                                             |
| Social production                                   |                                 | Electricity consumption per unit of GDP                     |
|                                                     |                                 | Industrial structure optimization level                     |

Table 1 Evaluation Indicator System
4. Construction of fuzzy Matter-element Model for Evaluating the Social Benefits of Power grid enterprises’ Investment

4.1 Weighting Assignment of Evaluation Indicators

In order to improve the accuracy of the evaluation results, the combination of the order relation method and the entropy weight method is used for the weighting assignment of evaluation indicators.

1) Subjective Weight Determination for Indicators with the Order Relation Method
   1) Establishment of order relation with expert ranking: The indicator set to be subject to the comprehensive evaluation is set as \( \{x_1, x_2, \ldots, x_n\} \), experts are invited to conduct the subjective evaluation on the indicators in the indicator set \( \{x_1, x_2, \ldots, x_n\} \), and further determine the order relation of the evaluation indicators: \( x_1 \preceq x_2 \preceq \ldots \preceq x_n \).

   2) Calculation of the importance of evaluation indicators: The relative importance between adjacent evaluation indicators \( x_j \) and \( x_{j-1} \) is expressed by \( r_j \). The calculation formula of \( r_j \) is as below:

   \[
   r_j = \tau_{j-1} / \tau_j \quad (j = m, m - 1, \ldots, 2)
   \]

   3) Rational assignment for the importance of evaluation indicators: According to the order relation determined above, the importance between adjacent operational benefit evaluation indicators is calculated, and the rational assignment is carried out for \( r_j \).

   4) Subjective weight assignment of the evaluation indicators: Based on rational importance \( r_j \), the weight of the indicator \( \tau_j \) is determined as follows:

   \[
   \tau_j = \left(1 + \sum_{i=1}^n r_i\right)^{-1}
   \]

2) Objective weight determination for the indicators with entropy weight method

In the decision matrix \( D = [x_{ij}]_{m \times n} \), \( x_{ij} \) denotes the indicator value of the \( i \)th scheme under the \( j \)th indicator attribute. \( p_{ij} \) denotes the probability that the \( i \)th scheme appears under the \( j \)th indicator attribute.

\[
p_{ij} = x_{ij} / \sum_{i=1}^n x_{ij} \quad ; \quad 0 \leq p_{ij} \leq 1 \quad ; \quad \sum_{i=1}^n p_{ij} = 1
\]

\[
e_j = -k \sum_{i=1}^n p_{ij} \ln p_{ij} , k = 1 / \ln n
\]

Where, \( k \) is a constant, \( e_i \in [0,1] \).
The normalized weight coefficient is denoted as the objective weight coefficient \( v_j \):

\[
v_j = g_j / \sum_{i=1}^{m} g_j
\]

(5)

Where, \( g_j = 1 - e_j \) denotes the difference coefficient of each scheme.

(3) Combination weight determination for the investment social benefit evaluation indicators with the order relation method and the entropy value method

\[
\omega_i = \omega_j \left( \sum_{j=1}^{m} v_j \right)^{-1}
\]

(6)

4.2 Construction of the fuzzy Matter-element Model

If \( m \) objects are described by \( n \) characteristics \( C_1, C_2, \ldots, C_n \) that are the same and their corresponding fuzzy memberships \( u_1(x_{1i}), u_2(x_{2i}), \ldots, u_m(x_{mi}) \), \((i = 1, 2, \ldots, n)\), then they are taken as the \( n \) dimensional fuzzy complex matter elements of the \( m \) objects, and is denoted as:

\[
R_{mn} = \begin{bmatrix}
M_1 & M_2 & \cdots & M_m \\
C_1 & u_1(x_{11}) & u_2(x_{21}) & \cdots & u_m(x_{mi}) \\
C_2 & u_1(x_{12}) & u_2(x_{22}) & \cdots & u_m(x_{mi}) \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
C_n & u_1(x_{1n}) & u_2(x_{2n}) & \cdots & u_m(x_{mn})
\end{bmatrix}
\]

(7)

Where: \( R_{mn} \) is the \( n \) dimensional fuzzy complex matter element of \( m \) objects; \( M_j \) \((j = 1, 2, \ldots, m)\) is the \( j \)th object; \( u_j(x_{ji}) \) is the membership of the corresponding quantity value \( x_{ji} \) \((j = 1, 2, \ldots, m; i = 1, 2, \ldots, n)\) of the \( i \)th characteristic of \( M_j \). The basic steps of the comprehensive evaluation with the fuzzy matter-element model are as follows:

(1) The fuzzy complex matter element corresponding to the evaluation grade of investment social benefits is established.

\( u_{ijk} \) denotes the membership \((i = 1, 2, \ldots, n; j = 1, 2, \ldots, m; k = 1, 2, \ldots, p)\) of \( x_{ik} \) corresponding to Grade \( j \), the \( n \) dimensional fuzzy complex matter element \( R_{mn} \) corresponding to Grade \( m \), namely:

\[
R_n = \begin{bmatrix}
M_1 & M_2 & \cdots & M_m \\
C_{11} & u_{111} & u_{211} & \cdots & u_{m11} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
C_{np} & u_{1np} & u_{2np} & \cdots & u_{mnp}
\end{bmatrix}
\]

(8)

(2) The weight matter element of the investment social benefit evaluation indicators is established.

Finally, \( R_{w1} \) and \( R_{w2} \) are set, which denote the weight complex matter elements of Grade-1 and Grade-2 indicators, namely:
The centralized fuzzy complex matter element is determined.

The main factors are weighted and averaged to achieve the centralization of the membership of the main factors, namely:

\[ R_b = R_{wa} * R_{mn} \]  

(11)

(4) The comprehensive evaluation on the objects is carried out.

1) The fuzzy complex matter element for individual evaluation is determined. Suppose \( x_R \) denotes the fuzzy complex matter element of individual evaluation indicators of the investment social benefits, namely:

\[
\begin{pmatrix}
M_1 \\
x_1 \\
x_2 \\
\vdots \\
x_n
\end{pmatrix} = \begin{pmatrix}
w_{b_1} & w_{b_2} & \cdots & w_{b_m} \\
x_{b_1} & x_{b_2} & \cdots & x_{b_m} \\
x_{b_1} & x_{b_2} & \cdots & x_{b_m} \\
\vdots & \vdots & \ddots & \vdots \\
x_{b_1} & x_{b_2} & \cdots & x_{b_m}
\end{pmatrix}
\]

(12)

2) The comprehensive evaluation fuzzy complex matter element is established. The average value, maximum value and minimum value of the fuzzy value corresponding to the weights of each major factor are taken as the evaluation indicators, denoted as \( d_{j1}, d_{j2}, d_{j3} \):

\[
\begin{align*}
  d_{j1} &= \frac{x_{j1} + x_{j2} + \cdots + x_{jn}}{n} \\
d_{j2} &= \max \left( x_{j1} + x_{j2} + \cdots + x_{jn} \right) \\
d_{j3} &= \min \left( x_{j1} + x_{j2} + \cdots + x_{jn} \right)
\end{align*}
\]

(13)

The comprehensive fuzzy complex matter elements \( R_D \) are obtained:

\[ R_D = \begin{pmatrix}
n_j \\
M_1 \\
M_2 \\
\cdots \\
M_m
\end{pmatrix} \quad R_d = \begin{pmatrix}
M_1 \\
d_{j1} \\
d_{j2} \\
\cdots \\
d_{jm} \\
M_2 \\
d_{j1} \\
d_{j2} \\
\cdots \\
d_{jm} \\
\cdots \\
M_m \\
d_{j1} \\
d_{j2} \\
\cdots \\
d_{jm}
\end{pmatrix}
\]

(14)

Where: \( d_{j} \) is the comprehensive evaluation value of the \( j^{th} \) evaluation grade, namely:

\[ d_j = \frac{1}{3} \sum_{j=1}^{3} d_{ji}, j = 1, 2, \ldots, m \]  

(15)
In Formula (15), according to the principle of maximum membership, Grade $M$ corresponding to the maximum value $d_{\text{max}}$ of the comprehensive evaluation value $d_j$ is namely the grade of the evaluation object.

5. Evaluation of the Social Benefit of Power grid enterprises’ Investment Based on the Fuzzy Matter-element Model

In this section, the fuzzy matter-element model for evaluating the social benefits of power grid enterprises’ investment is calculated based on the evaluation indicator data of power grid enterprise S in 2018.

(1) Determination of the combination weight of evaluation indicators

The combination weight is calculated according to Formula (6), and the final weight calculation results are shown in Table 3.

| Evaluation Objectives | Grade-1 Indicators | Grade-1 Weights | Grade-2 Indicators | Grade-2 Weights | Comprehensive Weight |
|-----------------------|--------------------|-----------------|--------------------|-----------------|----------------------|
| Social economy        | Additional gross production output resulting from investment | 0.3718 | 0.1475 |
|                       | Additional labor remuneration resulting from investment | 0.3169 | 0.1257 |
|                       | Additional taxes resulting from investment | 0.3112 | 0.1234 |
| Social environment    | Standard coal consumption saved by investment | 0.3987 | 0.1141 |
|                       | Reduction of carbon dioxide emissions resulting from investment | 0.3987 | 0.1141 |
|                       | Improvement of environmental quality | 0.2026 | 0.0580 |
| Social stability      | Additional electricity consumption resulting from investment | 0.3484 | 0.0513 |
|                       | User satisfaction | 0.3029 | 0.0446 |
|                       | Infrastructures | 0.3487 | 0.0513 |
| Social production     | Electricity consumption per unit of GDP | 0.4116 | 0.0699 |
|                       | Industrial structure optimization level | 0.5884 | 0.1000 |
(2) Determination of the evaluation grade

In this paper, five evaluation grades are used, including: excellent, good, average, pass and poor, as shown in Table 3.

| Grade-2 Indicators | Value | Evaluation Grade | | | |
|-------------------|-------|------------------|---|---|---|---|---|---|---|
| Additional gross production output resulting from investment | 393.06 | (340,400) | (280,340) | (220,280) | (160,220) | (100,160) | | |
| Additional labor remuneration resulting from investment | 200.31 | (190,220) | (160,190) | (130,160) | (100,130) | (70,100) | | |
| Additional taxes resulting from investment | 48.76 | (43, 50) | (36,43) | 29 (4) | (22, 29) | (15, 16) | | |
| Standard coal consumption saved by investment | 1398.9 | (1000140 0) | (500100 0) | (240,500) | (170,240) | (130,170) | | |
| Reduction of carbon dioxide emissions resulting from investment | 3452.24 | (1900350 0) | (1200190 0) | (600120 0) | (400,600) | (330,400) | | |
| Improvement of environmental quality | 9.37 | (9.6, 10) | (9.2, 9.6) | (8.8, 9.2) | (8.4, 8.8) | (8.8.4) | | |
| Additional electricity consumption resulting from investment | 35.89 | 32 (4) | (28, 32) | (24, 28) | (20, 24) | (16, 20) | | |
| User satisfaction | 99.86% | (99%, 100%) | (98%, 99%) | (97%, 98%) | (96%, 97%) | (95%, 96%) | | |
| Infrastructures | 9.21 | (9.4, 10) | (8.8, 9.4) | (8.2, 8.8) | (7.6, 8.2) | (7,7.6) | | |
| Electricity consumption per unit of GDP | 913.01 | (980106 0) | (1060114 0) | (1140122 0) | (1220130 0) | | | |
| Industrial structure optimization level | 9.25 | (9.2, 10) | (8.4, 9.2) | (7.6, 8.4) | (6.8, 7.6) | (6,6.8) | | |
(2) Determination of complex matter elements of main factors

According to Table 3, the complex matter elements of the four main factors of Grade-1 indicators can be established, and they are respectively set as \( r_1, r_2, r_3, r_4 \), namely:

\[
\begin{align*}
      r_1 &= \begin{pmatrix} 393.06 \\ 200.31 \\ 48.76 \end{pmatrix}, &
      r_2 &= \begin{pmatrix} 1398.90 \\ 3452.24 \\ 9.37 \end{pmatrix}, &
      r_3 &= \begin{pmatrix} 35.98 \\ 99.86\% \\ 9.21 \end{pmatrix}, &
      r_4 &= \begin{pmatrix} 913.01 \\ 9.25 \end{pmatrix}
\end{align*}
\]

(3) Determination of the fuzzy complex matter element

The decreasing semi-trapezoidal method is introduced to construct the membership function, and the fuzzy complex matter element is established:

\[
\begin{align*}
      R_1 &= \begin{pmatrix} 0.8834 & 0.1157 & 0 & 0 & 0 \\ 0.3437 & 0.6563 & 0 & 0 & 0 \\ 0.8229 & 0.1771 & 0 & 0 & 0 \end{pmatrix}, &
      R_2 &= \begin{pmatrix} 0.9973 & 0.0027 & 0 & 0 & 0 \\ 0.9702 & 0.0299 & 0 & 0 & 0 \\ 0 & 0.4250 & 0.5750 & 0 & 0 \end{pmatrix}, \\
      R_3 &= \begin{pmatrix} 0.9725 & 0.0275 & 0 & 0 & 0 \\ 0.8600 & 0.1400 & 0 & 0 & 0 \\ 0 & 0.6833 & 0.3167 & 0 & 0 \end{pmatrix}, &
      R_4 &= \begin{pmatrix} 0.1626 & 0.8374 & 0 & 0 & 0 \\ 0 & 0.9375 & 0 & 0 & 0 \end{pmatrix}
\end{align*}
\]

(4) Determination of the weight complex matter element

According to the weights of evaluation indicators in Table 2, the weight complex matter elements of each grade of indicators are calculated as follows:

\[
\begin{align*}
      R_{w1} &= \begin{pmatrix} 0.3718 & 0.3169 & 0.3112 \end{pmatrix}, &
      R_{w2} &= \begin{pmatrix} 0.3987 & 0.3987 & 0.2026 \end{pmatrix}, \\
      R_{w3} &= \begin{pmatrix} 0.3484 & 0.3029 & 0.3487 \end{pmatrix}, &
      R_{w4} &= \begin{pmatrix} 0.4116 & 0.5884 \end{pmatrix}, &
      R_w &= \begin{pmatrix} 0.3966 & 0.2863 & 0.1472 & 0.1699 \end{pmatrix}
\end{align*}
\]

Where, \( R_{w1}, R_{w2}, R_{w3}, R_{w4} \) is the weight complex matter elements of Grade-2 indicators under each of Grade-1 indicators, and \( R_w \) is the weight complex matter element of Grade-1 complex matter elements.

(5) Comprehensive evaluation on the fuzzy matter-elements

According to Formulas (12) to (15), the fuzzy complex matter elements for the investment social benefit evaluation of power grid enterprise from 2015 to 2018 can be calculated, and they are respectively denoted as \( R_{D1}, R_{D2}, R_{D3}, R_{D4} \):

\[
\begin{align*}
      R_{D1} &= \begin{pmatrix} M_1 & M_2 & M_3 & M_4 & M_5 \end{pmatrix}, &
      R_{D2} &= \begin{pmatrix} M_1 & M_2 & M_3 & M_4 & M_5 \end{pmatrix}, \\
      R_{D3} &= \begin{pmatrix} M_1 & M_2 & M_3 & M_4 & M_5 \end{pmatrix}, &
      R_{D4} &= \begin{pmatrix} M_1 & M_2 & M_3 & M_4 & M_5 \end{pmatrix}
\end{align*}
\]

According to the maximum membership principle, the evaluation grades of the social benefits of power grid enterprise S’ investment from 2015 to 2018 include poor, pass, good and excellent.
6. Conclusion
In this paper, the evaluation indicator system of the social benefits of power grid enterprises’ investment, where the social benefits involves social economy, social environment, social stability and social production; then, the combination weighting method is used to perform weight assignment to the indicators and the comprehensive evaluation on the social benefits is carried out after the comprehensive evaluation fuzzy matter-element is established. Finally, the feasibility of the model is analyzed and demonstrated with an example.

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