Research on application of single index membership function based on power coefficient method

Na Liu*

China National Institute of Standardization, Beijing, China

*Corresponding author e-mail: liuna@cnis.ac.cn

Abstract. The power coefficient method can determine the satisfactory value and the unallowable value of the index, quantify multiple targets, and then determine the power coefficient value of each target. Combining the distribution characteristics of the four types of membership functions, this paper innovatively proposes to solve the regional distribution problem of single-index membership functions by means of an improved efficiency coefficient method, and combined with empirical research, the application of this mathematical method in practical engineering.

1. Introduction

In high-quality energy enterprise measurement studies, the indexes involved are complex and diverse and have large differentials, such as "safety quality standardization level" (the more ideal, the more ideal), such as "accident mortality" Small indicators (the less the results of the indicator value, the more ideal). Extremeness indicators are also known as positive indicators, during production management, to improve the indicator value of positive indicators as much as possible; minimal indicators are also negative indicators, the smaller such indicates, the safer production, the higher the benefits.

In addition, there is a class of indicators that belong to the center-type indicator, optimal value taken in intermediate values, such as operating temperatures, humidity. Due to the difference between the nature and dimension of the indicator, the primary work is the consistency and quantity of the indicators in the measurement study, and this paper proposes an innovative solution to this problem by means of the efficacy method and the membership function.

2. Basic principle

2.1. principle of efficiency factor

The power coefficient method determines the satisfactory value and the disallowed value of the index, and quantifies multiple targets together, and then determines the power coefficient value of each target. This method unifies different indicators into power coefficient values by determining the upper limit (satisfactory value) and lower limit (not allowed value) for the next step of calculation and comparison [1, 2].
The calculation process of the efficiency coefficient value is as follows:

① Determine the evaluation index system.

Use the efficiency coefficient method to evaluate the index system. First, the selected indicators should have good representativeness, and the indicators must be closely related to each other and cannot be repeated. It is necessary to reflect the true situation of the evaluation index to the greatest extent.

② Determine the satisfactory value and the unallowable value of each index.

The satisfactory value is the highest level possible in the evaluation index standard; the unallowable value generally takes the worst level of each evaluation index standard.

③ Calculate the individual efficacy coefficient value of each index.

In the evaluation index system of the efficacy coefficient method, there are 4 kinds of variables. If the larger the index value (actual value), the higher the individual efficacy coefficient, which is a very large variable, it’s the greater the index value. If smaller and higher individual efficacy coefficients are very small variables; the index value at a certain point with the highest individual efficacy coefficient is a stable variable; if the individual efficacy coefficient is the highest in a certain interval, it is an interval variable [3].

The formulas for calculating the individual efficacy coefficients of the above four variables are:

a. The individual efficacy coefficients of extremely large variables

\[
d_{i} = \begin{cases} X_i - X_{sl} \times 40 + 60, & X_i < X_{hi} \\ 100, & X_i \geq X_{hi} \end{cases}
\]  \hspace{1cm} (1)

Where: \(d_{i}\) is the single-active coefficient value of the \(i\) evaluation index; \(X_{hi}\) is the satisfactory value of the \(i\)-th indicator; \(X_{sl}\) is the ousted value of the \(i\)-th indicator.

b. Single power coefficient for very small variables

Figure 1. Distribution curves of commonly subordinating degree function
\( d_2 = \begin{cases} \frac{X_i - X_{si}}{X_{hi} - X_{si}} \times 40 + 60, & X_i > X_{si} \\ 100, & X_i \leq X_{si} \end{cases} \) \tag{2}

c. Stable variable single power coefficient
\[
d_3 = (1 - |X_i - X_{hi}|) / (|X_{si} - X_{hi}|) \times 40 + 60 \tag{3}
\]
d. Interval variable single power coefficient
\[
d_4 = \begin{cases} \left(1 - \frac{X_{mi} - X_i}{X_{ni} - X_{si}}\right) \times 40 + 60, & X_i < X_{mi} \\ 100, & X_{mi} \leq X_i \leq X_{ni} \\ \left(1 - \frac{X_i - X_{ni}}{X_{ni} - X_{mi}}\right) \times 40 + 60, & X_i > X_{ni} \end{cases} \tag{4}
\]

In the formula: \( X_{max} \) is the upper limit of the interval variable; \( X_{min} \) is the lower limit of the interval variable; \( X_{hmax} \) is the unacceptable value of the upper limit, generally 1 times the average value of all interval evaluation indicators; \( X_{smin} \) is the unallowable value of the lower limit. \( d_4 \) is the single efficacy coefficient value of the first interval evaluation index.

2.2. Determining the membership function function using the improved function factor method

The evaluation index value of the standard efficacy factor setting is \([60, 100]\), and an indicator corresponds to a set of satisfactory and not allowed values; and the energy enterprise measurement evaluation for a certain indicator, when confirming the satisfactory value and the not allowed value, different evaluations Under the grade (such as world-class, domestic advanced, domestic general) corresponding satisfactory value and unsatisfactory interval are \([90, 100]\), \([60, 90]\), \([0, 60]\), and the efficacy coefficient should be calculated. Therefore, the principle of efficiency factor is applied to \([90, 100]\), \([60, 90]\), \([0, 60]\), and recalculate the operating coefficient formula.

3. Empirical studies - Taking coal enterprises as an example

Set S1, S2 (where S1 > S2) is a different grade fractal endpoint of high quality coal enterprises. Through expert discussion, the S1 is set to 90 points, S2 positioning 60 points (high quality coal mine construction is a continuous process, The value of S1 and S2 increases with advancement of coal mine production technology), that is, the comprehensive evaluation of the world's first-class coal mine needs to reach more than 90 points, the domestic advanced coal mine is divided into 60 to 90 points, less than 60 points. The coal mine belongs to the national general level; A1, A2 (where A1 > A2) is a score endpoint of different levels of different grades. Taking the standardization level of coal mine safety quality, A1 = 90, A2 = 70, that is, the world's first-class coal mine safety standardization It is divided into more than 90 points, and the domestic advanced coal mine score is 70 to 90, the coal mine below 70 points is a domestic general rating; \( f \) is the actual evaluation value of the indicator. The linear belongings function of each indicator is as follows (listed some indicators):

(1) The indicators that meet the membership function include: coal mine safety quality standardization level.
(2) The indicators that conform to the membership function include: safe production cycle, operating profit rate, cost profit rate, mining area recovery rate, working face recovery rate, gangue utilization rate, gas utilization rate, industrial site greening rate, subsided land treatment rate, the proportion of scientific and technological research and development personnel, the number of patents granted, the contribution rate of science and technology, the number of five small achievements completed, and the average salary of employees.

\[
X = \begin{cases} 
100 & f \geq a_1 + \frac{a_1-a_2}{S_1-S_2} (100-S_1) \\
S_2 + \frac{S_1-S_2}{a_1-a_2} (f-a_2) & a_2 \leq f < a_1 + \frac{a_1-a_2}{S_1-S_2} (100-S_1) \\
0 & 0 \leq f < a_2 - \frac{a_1-a_2}{S_1-S_2} S_2
\end{cases} 
\]

(3) The indicators that conform to the membership function include: safety investment.

\[
X = \begin{cases} 
100 & f \geq a_1 + \frac{a_1-a_2}{S_1-S_2} (100-S_1) \\
\frac{(a_1-f)S_2-(a_2-f)S_1}{a_1-a_2} & a_2 \leq f < a_1 + \frac{a_1-a_2}{S_1-S_2} (100-S_1) \\
\frac{(f-1)S_2}{a_2-1} & 1 \leq f < a_2 \\
0 & f < 1
\end{cases} 
\]

(4) The indicators conforming to the membership function include: occupational disease incidence, equipment failure rate, water consumption of raw coal production, energy consumption per unit product, COD discharge of mine wastewater, COD discharge of coal washing wastewater, and noise value of workplaces.

\[
X = \begin{cases} 
100 & 0 \leq f \leq a_2 + \frac{a_1-a_2}{S_1-S_2} (S_1-100) \\
S_2 + \frac{S_1-S_2}{a_1-a_2} (f-a_2) & a_2 + \frac{a_1-a_2}{S_1-S_2} (S_1-100) < f \leq a_2 + \frac{a_1-a_2}{S_1-S_2} S_1 \\
0 & f > a_2 + \frac{a_1-a_2}{S_1-S_2} S_1
\end{cases} 
\]

(5) The indicators that meet the membership function include: death rate per million tons.
(6) The indicators that meet the membership function include: serious injury rate per thousand people, direct economic loss from accidents, and employee turnover rate.

\[
X = \begin{cases} 
100 & f = 0 \\
\frac{S_1 - S_2}{a_1} f & 0 < f \leq a_1 + \frac{a_1 - a_2}{S_1 - S_2} f \\
0 & f > a_1 + \frac{a_1 - a_2}{S_1 - S_2} f 
\end{cases} \quad (9)
\]

(7) The indicators that meet the membership function include: coal mining mechanization level, SO2 treatment rate, and industrial water recycling rate.

\[
X = \begin{cases} 
100 - \frac{100 - S_1}{a_2} f & 0 \leq f \leq a_2 \\
\frac{S_1 - S_2}{a_1 - a_2} (f - a_2) & a_2 \leq f < a_2 + \frac{a_1 - a_2}{S_1 - S_2} S_1 \\
0 & f > a_2 + \frac{a_1 - a_2}{S_1 - S_2} S_1 
\end{cases} \quad (10)
\]

(8) The indicators that conform to the membership function include: raw coal production staff efficiency, full-height mining face efficiency at one time, comprehensive unit output, tunneling face efficiency, single-entry tunneling face, and employee re-education opportunities.

\[
X = \begin{cases} 
100 - \frac{100 - S_1}{100 - a_1} (f - a_1) & a_1 \leq f \leq 100 \\
\frac{S_1 - S_2}{a_1 - a_2} (f - a_2) & a_2 \leq f < a_1 + \frac{a_1 - a_2}{S_1 - S_2} S_1 \\
S_2 S_2 & f = a_2 
\end{cases} \quad (11)
\]

(9) The indicators that meet the membership function include: industrial wastewater and domestic sewage treatment rate, and employee happiness index.

\[
X = \begin{cases} 
100 & f = 100 \\
\frac{S_1 - S_2}{a_1 - a_2} (f - a_1) & a_2 \leq f < a_1 + \frac{a_1 - a_2}{S_1 - S_2} (100 - S_1) \\
\frac{S_2 S_2}{a_2} f & f = a_2 
\end{cases} \quad (12)
\]

(10) The indicators that conform to the membership function include: return on net assets.
The indicators that meet the membership function include: R&D investment intensity.

\[ X = \begin{cases} 
100 & f \geq a_1 + \frac{a_1 - a_2}{S_1 - S_2} (100 - S_1) \\
S_1 + \frac{S_1 - S_2}{a_1 - a_2} (a_1 - a_2) & a_2 \leq f < a_1 + \frac{a_1 - a_2}{S_1 - S_2} (100 - S_1) \\
S_2 * f & 0 \leq f < a_2 \\
0 & f < 0 
\end{cases} \]  
(14)

(11) The indicators that meet the membership function include: R&D investment intensity.

\[ X = \begin{cases} 
100 & f \geq a_1 + \frac{a_1 - a_2}{S_1 - S_2} (100 - S_1) \\
S_2 + \frac{S_2 - S_1}{a_1 - a_2} (f - a_2) & f < a_1 + \frac{a_1 - a_2}{S_1 - S_2} (100 - S_1) 
\end{cases} \]  
(15)

(12) Qualitative indicators, this type of indicators are determined by experts, namely X=f.

4. Conclusion

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