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Performance Evaluation of coal enterprises energy conservation and reduction of pollutant emissions base on GRD-TOPSIS

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Abstract

For the performance evaluation of coal enterprises energy conservation and reduction of pollutant emission, a new GRD-TOPSIS method is proposed. By analyzing the background of performance evaluation of energy conservation and reduction of pollutant emission, the performance evaluation system of coal enterprises is established. Three coal enterprises of Yanzhou City are selected as evaluation objects, and use the new method to evaluate their performance of energy conservation and reduction of pollutant emission. The practical example shows the feasibility and effectiveness of the proposed method.

Keywords: GRD-TOPSIS; MADM; energy conservation and reduction of pollutant emission

1. Introduction

In recent years, Chinese government has put emphasis on the resources and environmental protection, therefore, energy conservation and reduction of pollutant emission becomes an important job among government departments. Under this condition, our government has issued relevant laws and regulations, and as the policy executor, entrepreneur especially coal enterprises receive more concerns gradually for their performance evaluation of energy conservation and reduction of pollutant emission. However, up to now, our government, as for energy conservation and reduction of pollutant emission, still does not establish an authoritative performance evaluation system for coal enterprises, and still does not find out

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methods to evaluate the performance. So, coal enterprises are passive in dealing with energy conservation and reduction of pollutant emission, which is adverse to the management of energy conservation.

At the data weighting and aggregation stage, multi-attribute decision making (MADM) has recently gained much popularity in performance evaluation. MADM is a well-established technique that could guide/help decision makers to evaluate existing or potential alternatives with multiple conflict criteria (Figueira, Greco, & Ehrgott, 2005). In the past decades, MADM has been continuously studied and successfully applied in many application domains. Examples of recent MADM studies include Tzeng, Chiang, and Li (2007), Wu and Lee (2007).

TOPSIS is the most effective tool in MADM. This paper is an extension to TOPSIS. Combining the gray correlation degree (GRD) with TOPSIS, a new GRD-TOPSIS method is proposed. By this new method, this paper evaluates the performance of coal enterprises energy conservation and reduction of pollutant emission.

2. GRD-TOPSIS method

Let an alternative set be \( X = \{x_1, x_2, \ldots, x_m\} \), an index set is \( C = \{c_1, c_2, \ldots, c_n\} \) and evaluation value \([u^*_j, u^*_j]\) is interval fuzzy number. According to the standardized formula of fuzzy decision matrix, we standardize the evaluation value as follow:

For the efficiency indicators
\[
a^*_j = \frac{u^*_j - \min \{u^*_j\}}{\max \{u^*_j\} - \min \{u^*_j\}}, \quad a^*_j = \frac{u^*_j - \min \{u^*_j\}}{\max \{u^*_j\} - \min \{u^*_j\}}. \tag{1}
\]

For the cost indicators
\[
a^*_j = \frac{\max \{u^*_j\} - u^*_j}{\max \{u^*_j\} - \min \{u^*_j\}}, \quad a^*_j = \frac{\max \{u^*_j\} - u^*_j}{\max \{u^*_j\} - \min \{u^*_j\}}. \tag{2}
\]

According to algorithm of interval fuzzy numbers, we can calculate the expectations of the interval numbers \( \bar{a}_j = \frac{1}{2}(a^*_j + a^*_j) \). In order to make a better evaluation results, we use gray correlation degree (GRD) and TOPSIS method to give the order of expectations matrix.

Determine the positive ideal solution:
\[
R^+ = \{\max_{1 \leq i \leq m} a^*_j \} = (a^*_1(1), a^*_2(2), \ldots, a^*_n(n)) \tag{3};
\]

Determine the negative ideal solution:
\[
R^- = \{\max_{1 \leq i \leq m} a^*_j \} = (a^*_0(1), a^*_0(2), \ldots, a^*_0(n)) \tag{4};
\]

Calculate gray correlation degree (GRD) between the expected value and the positive (negative) ideal solution:
\[
\gamma(a^*_0(i), a_j(i)) = \min_{1 \leq l \leq j} \min_{1 \leq i \leq j} \frac{\min_{1 \leq l \leq j} |a^*_0(i) - a^*_j(i)| + \xi \max_{1 \leq l \leq j} |a^*_0(i) - a^*_j(i)|}{|a^*_0(i) - a^*_j(i)| + \xi \max_{1 \leq l \leq j} |a^*_0(i) - a^*_j(i)|}, \tag{5}
\]
\[
\gamma(a^*_0(i), a_j(i)) = \min_{1 \leq l \leq j} \min_{1 \leq i \leq j} \frac{\min_{1 \leq l \leq j} |a^*_0(i) - a^*_j(i)| + \xi \max_{1 \leq l \leq j} |a^*_0(i) - a^*_j(i)|}{|a^*_0(i) - a^*_j(i)| + \xi \max_{1 \leq l \leq j} |a^*_0(i) - a^*_j(i)|}. \tag{6}
\]

We can get the vector of the GRD:
\begin{equation}
V^- = (V_1^-, \cdots, V_m^-), \quad V^+ = (V_1^+, \cdots, V_m^+).
\end{equation}

At last, calculate the grey relative closeness:
\begin{equation}
C_i = \frac{V_i^+}{V_i^+ + V_i^-}.
\end{equation}

According to the value of \((C_1, C_2, \cdots, C_m)\), we know the order of \(X\).

3. Performance evaluation system for coal enterprises

As far as energy production and energy consumption are concerned, China now is the second in the world, and has had an indispensable part in the world energy market. China is playing more and more important role to protecting the safe of the world energy. Because our economy and industrialization are in the high speed, the supply and demand of the energy has appeared some contradictions. In addition, our country has the extensive mode of production, that is, high input, low output and high pollution, which leads to a large number of shortages and serious pollution of the environment. As the above, our country must adopt efficient methods of energy conservation and reduction of pollutant emission to change the status.

Energy conservation is the policy to implement our sustainable development; meanwhile, reduction of pollutant emission is the important method to realize energy conservation. Energy conservation and reduction of pollutant emission refers to conserve the energy and decrease the pollution emission, including wasted gas, wasted water and garbage. Energy conservation and reduction of pollutant emission can not only improve the efficiency of the national economy, but also decrease the fees of the environmental pollution, the greenhouse gas emission and the environmental governance, which can let existing resources lower the depletion speed maximally to safeguard national security.

In the 2009’s Climate Change Conference in Copenhagen, our premiere Wen Jiabao proposes that, from 1990 to 2005 the CO\(_2\) emission of Unit of GDP has decreased 46%. On this basis, compared with the year of 2005, in the year of 2020 the emission level will decrease from 40% to 45%. In the Twelfth Five-Year Plan proposed by the CPC Central Committee, our government significantly increases the construction of non-fossil energy sources. In 2020, our country will establish 180 million kilowatts of wind power, 20,000,000 kilowatts of solar energy, 330 million kilowatts of hydropower, and 90 million kilowatts of nuclear power. Up to then, the installed capacity of traditional coal units, its proportion will decrease from 75% to 60%. From the above, we can see energy conservation and reduction of pollutant emission is a long-term and arduous task which needs us to have a hard effort. Coal enterprises, which are the subject of energy consumption and the main source of pollution emission, shoulder the important task of energy conservation and reduction of pollutant emission. We need qualitative description and quantities analysis to evaluate a coal enterprise’s performance on energy conservation and reduction of pollutant emission. Thus, we need to establish a system to scientifically guide this performance.

According to the characteristics and connotations of coal enterprise’s performance on energy conservation and reduction of pollutant emission, we will use the methods of movement frequency statistics and expert consultation to construct the performance evaluation system in five aspects. As followed: (1) resource output. mainly reflecting the resource efficiency, refers to growth rate of GDP\((C_1)\), output rate of million tons of coal mined\((C_2)\), output rate of coal consumption\((C_3)\), output rate of land\((C_4)\) and water resources\((C_5)\); (2) Resource consumption, mainly reflecting the company’s energy saving, refers to the extraction rate\((C_6)\), unit GDP energy (water) consumption\((C_7C_8)\), mining tons of coal energy (water) consumption\((C_9C_10)\); (3) Comprehensive utilization of resources: the utilization rate of Gangue\((C_{11})\), coal\((C_{12})\) and associated minerals\((C_{13})\), fly ash\((C_{14})\), mine water\((C_{15})\), industrial water recycling\((C_{16})\), the utilization rate of methane\((C_{17})\), land reclamation\((C_{18})\); (4) pollutant emission: emission reduction rate of
gangue(C_{19}), coal gangue(C_{20}), coal ash(C_{21}), waste gas(C_{22}), waste water(C_{23}); (5) support ability: the degree of familiarity with energy conservation and reduction of pollutant emission(C_{24}), the degree of improving energy conservation and reduction of pollutant emission systems(C_{25}), the degree of implementation of emission reduction measures(C_{26}), energy conservation ratio of R&D funding(C_{27}), effectiveness of R&D activities(C_{28}).

4. Performance evaluation of coal enterprise energy conservation and reduction of pollutant emission based on GRD-TOPSIS

4.1. Survey design

Select 3 coal enterprises of Yanzhou City, Shandong Province as evaluation objects, and use sample survey approach to evaluate the performance of energy conservation and reduction of pollutant emission. The survey questionnaires of 3 coal enterprises performance evaluation covers 28 indicators of performance indicators system. Each indicator establishes two assessment items, including the actual value of energy conservation and reduction of pollutant emission performance and the maximum expectation value of energy conservation and reduction of pollutant emission performance. Assessment of the value of each item provide 7 options from low to high, including , "1" stands performance is poor, "7" stands performance is good. The greater the value is that the better the energy conservation and reduction of pollutant emission achieves. For each index, we make fuzzy evaluation of performance by combining assessed value of two items. As a result, the performance of the original results is got in the form of interval numbers.

The survey use online questionnaire survey, and the target is leaders of government departments in charge of energy conservation and reduction of pollutant emission, energy experts of universities, executives of coal enterprise and coal business technology analyst. We issued a total of 200 questionnaires, 145 were recovered, and 135 were effective, recovery of 72.5%, efficiency 93.1%. By using Cranach’s coefficient, the reliability of the questionnaire was tested. We calculated the reliability of test results was 0.8371, according to survey data, higher than 0.8. It indicated that this questionnaire is a high reliability coefficient table.

4.2. Performance evaluation

Based on three coal companies’ performance evaluation results of the questionnaire survey and by numerical integration of all assessment items, the extent of the indicators’ evaluation is given in the form of interval numbers. First, standardize the interval numbers and calculate the expectation $\bar{a}_i$ of the interval numbers. Second, determine the positive ideal solution $R^+$ and the negative ideal solution $R^-$. Draw the relationship map between coal enterprises A, B, C's performance expectations and the positive and negative ideal solution, as shown in the fig. 1. Third, calculate gray correlation between coal enterprises A, B, C's performance expectations and the positive and negative ideal solution. The value is $V^-(0.7338,0.7223,0.7232), V^+(0.7783,0.7979,0.7898)$. At last, we get the order of the 3 coal enterprises, by calculating the grey relative closeness, $C = (0.5147,0.5249,0.5220)$ , namely $B > C > A$.

5. Conclusion

In conclusion, if we want to improve its performance on energy conservation and reduction of pollutant emission, the coal enterprises must follow these points: 1. economically use coal resources, and
Fig. 1. The relationship between coal enterprises A, B, C's performance expectations and the positive (negative) ideal solution

continuously increase coal recovery rate, which includes optimizing the industrial structure, promoting the development of new energy-saving technologies, and strengthening the construction and supervision of relevant systems; 2. Positively develop the exploitation and utilization of CBM and associated minerals; 3. Improve the ratio of raw coal washed by man, and strengthen the recovery and utilization of gangue and industrial waste; 4. decrease the pollutant emissions, and promote the circular economy of coal enterprises including developing green mining technology, water saving technology, non-waste technology, and sound processing technology of mine waste; 5. Establish the system of coal polygene ration; 6. Implement staff training, enhance awareness of energy saving, and improve the quality of energy saving to really realize energy saving; 7. Increase research investment, strive for government support, and to enhance coal enterprises' ability to support energy saving.

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