Appraising Enterprise Technology Innovation Project Method Based on PROMETHEE

——Taking the Iron and Steel Enterprise as an Example

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Abstract:

In view of the question on the choice of the iron and steel enterprise technology innovation project, this paper establishes the technology innovation project appraisal index system on the iron and steel enterprise, it uses the PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) method, which is a class of out ranking methods in multicriteria analysis, and it ranks various projects reasonably with the indefinite weight information. Comparing with the TOPSIS method, it illuminates that the conclusion of this method is valid and credible.

Keywords: Iron and Steel Enterprise; Technology Innovation; Project Appraisal; PROMETHEE

1. Introduction

Facing with the dynamic technology, the potential market, the massive investments, as well as a bigger risk, it is the key for the iron and steel enterprise to choose suitable project from the multitudinous innovation project. According to the research[1], the technical innovation in the ap-

plied research stage defeat rate is 75%, the development research stage is 50%~75%, the industry or the commercialized stage is 30%~50%. The correct choice at innovation technology project, is effectively to carry on controls in advance, reduces rate of the defeat and consumption of the organization resources, thus the organization's core competitive ability is strengthened.

The choice of the iron and steel enterprise technology innovation project is influenced by many kinds of factors. The question of the different project choice, in the essence, is the question of the limited project multi-attribute decision-making. It can't rely on only a few indexes to making the decision. The synthesis appraisal under many kinds of indexes has to be carried. Because of certain appraisal indexes with difficulty measures, the linguistic appraisal applied to decision-making allows a more flexible framework, where by it is possible to simulate humans' ability to deal with the fuzziness of human judgments quantitatively. This paper carries on the appraisal to 4 technology innovation projects in the iron and steel enterprise, because the new project cannot be estimated with exact numerical value. Then a more realistic approach may be to use linguistic assessments instead of numerical values.

In uncertain environments, several authors have proposed different methods in selection problems[2-4]. Here, in the condition that the importance of the attributes is not given, we will apply PROMETHEE[4-8] to choose the reasonable innovation project, in purpose to reduce the decision-making at will or blindness.

The paper is structured as follows: Section 2 shows the index to appraise the iron and steel enterprise technology innovation project; Section 3 presents a method base on PROMETHEE; Section 4 illustrates its application with some example; and finally, section 5 presents our conclusions.

2. The index system establishment

In order to make the systemic and comprehensive appraisal to the iron and steel enterprise technology innovation project, it must have a set of integrity, science and the comprehensive synthesis appraisal index system. The technology innovation alternatives appraisal, in essence, is to get full understand at the relative importance during the technology innovation projects. It also provides the important reference for the investor to make decision.

Here we present the principles of the Appraisal index system establishment: scientific, systematic, operational and so on. When establishing the index system, we must consider that the appraisal data should be easy to obtain. The iron and steel enterprise technology innovation project involves many fields, including the technology, the market, the finance, the environment, the policy and various departments, some indexes at present in theoretically do not have the strict limits, also not have the unification standard. Except for the above principle, technological advance and suitable principles, economic efficiency principle, social efficiency also should be taken. Base on different principles, referring to the technology innovation project appraisal index system, which is presented in the literature [9], according to the characteristic of the steel and iron industry, this paper proposes the appraisal index system, the details of the index system is shown in Figure 1, it divides in six main factors.

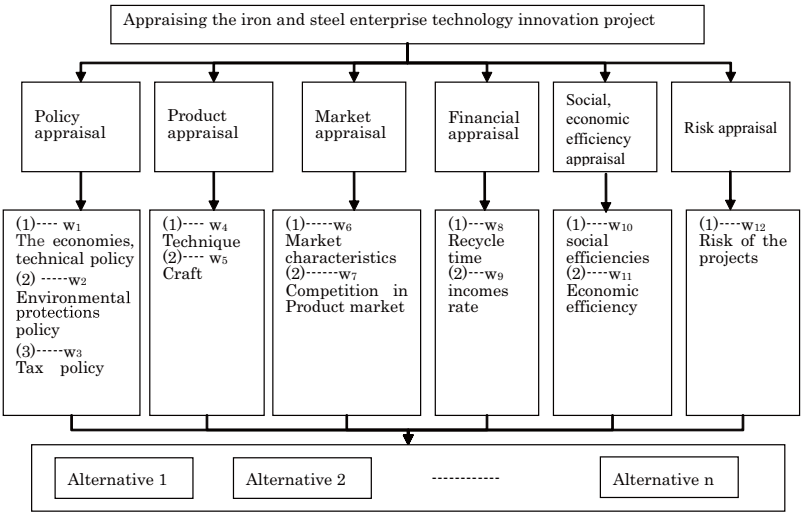

Fig.1 The index system for appraising the iron and steel enterprise technology innovation project

3. The multi-attribute decision-making method based on PROMETHEE

The PROMETHEE method firstly introduced by Brans et al. (1984) belongs to the category of outranking procedures by the help of which one is able to find the most preferable alternative among a whole set of alternatives. A big advantage of the PROMETHEE approach is its fairly low degree of mathematical complexity which should make its results transparent for decision makers and stakeholders, who are often non-experts.

There are many methods to deal with the incomplete information [2-4]. Under the condition that the weight information is incomplete, this paper uses the PROMETHEE II method to choose the best project, its concrete

application steps as follows:

(1) Constructing the appraisal matrix

Suppose we have a set of n alternatives A=$\{a_1,a_2,...,a_n\}$, and U=$\{u_1,u_2,...,u_m\}$ be the set of attributes. Let a finite and totally ordered label set S= $\{S_i\}$, $i \in H$= $\{0, \cdots, T\}$, each label set with odd cardinals, each alternative has m attributes. Then we produce the following decision-making matrix A_{nm}.

$$A_{nm} = \begin{pmatrix} a_{11} & a_{12} & ... & a_{1m} \\ a_{21} & a_{22} & ... & a_{2m} \\ ... & ... & a_{ij} & ... \\ a_{n1} & a_{n2} & ... & a_{nm} \end{pmatrix}$$

Where $a_{ij} \in S$ is the linguistic label value of i-th alternative and the j-th attribute.

(2) Selecting a preference function

Let $f_k(A_i)$ be the appraisal value of alternative A_i (i=1,2,...,n) in the attribute K(K=1,2,$\cdots$,m). for the increase index, the function $P_k(A_i, A_j)$ is expressed the preference intensity by the alternative A_i surpasses the alternative A_j. And where:

① $P_k(A_i, A_j)$ =0 indicates the indifference between A_i and A_j ;

② $P_k(A_i, A_j)$ =1 indicates the strict preference of A_i over A_j. Decrease index on the contrary.

The usual preference function has the linear, the level, the Gauss preference function and so on. In view of the fact that the unit increase of the various indexes is respectively dissimilar under the different level to the contribution in synthesis appraisal, as the linear function cannot reflect actual situation, this paper use the thought in literature [8] for reference, and selects one kind of the improved Gauss preference function. Its expression as follows:

$$p_k(A_i, A_j) = \begin{cases} 1 - \exp(-d_k^2 / 2\sigma_k^2) & if \quad d_k > 0, \\ 0 & if \quad d_k \le 0. \end{cases}$$

$$d_k = \begin{cases} f_k(A_i) - f_k(A_j) & (k \in I_1) \\ f_k(A_j) - f_k(A_i) & (k \in I_2) \end{cases}$$

Where I_1, I_2 separately represent a set of increase index and decrease index. σ_k^2 is the variance of the appraisal value f_k (A_i):

$$\sigma_k^2 = \frac{1}{n}(\sum_{i=1}^{n} a_{ik}^2 - n\overline{a_{ik}})^2 \qquad (k = 1,2,...,m)$$

(3) Calculating the synthesis preference intensity

For each pair of alternatives, the synthesis preference intensity R (A_i, A_j) can be written as

$$R(A_i, A_j) = \sum_{k=1}^{m} \omega_k P_k(A_i, A_j) \qquad (3\text{-}1)$$

where ω_k are weights associated with each criterion.

(4) Calculating the attribute weights

According to the concept of the rank relations, the ranking the alternatives is by net current of the various alternatives, the attribute weight should make the 'positive current' max, and the 'negative current' min. Namely transforms to make the net current max:

① 'positive current' :

$$R^+(A_i) = \sum_{j=1}^{n} R(A_i, A_j) \qquad (i = 1,2,\ldots,n) \qquad (3\text{-}2)$$

② 'negative current':

$$R^-(A_i) = \sum_{j=1}^{n} R(A_j, A_i) \qquad (i = 1,2,...,n) \qquad (3\text{-}3)$$

③ 'net current':

$$R(A_i) = R^+(A_i) - R^-(A_i) \quad (i = 1,2,\ldots,n) \qquad (3\text{-}4)$$

We can obtain formal 3-5 by formal 3-1,3-2,3-3,3-4.

$$R(A_i) = \sum_{j=1}^{n}\sum_{k=1}^{m} \varpi_k P_k(A_i, A_j) - \sum_{j=1}^{n}\sum_{k=1}^{m} \varpi_k P_k(A_j, A_i)$$

$$= \sum_{k=1}^{m} \varpi_k \left(\sum_{i=1}^{n} P_k(A_i, A_j) - \sum_{j=1}^{n} P_k(A_j, A_i)\right) \qquad (3\text{-}5)$$

By making the maximum value to the 'net current', then we have M-3.1

$$\begin{cases} MaxR(A_i) = \sum_{k=1}^{m} \varpi_k^i \left(\sum_{i=1}^{n} P_k(A_i, A_j) - \sum_{j=1}^{m} P_k(A_j, A_i)\right) \\ s.t. \varpi_k^i \in \Phi \\ i = 1,2,\ldots,n; k = 1,2,\ldots,m \end{cases} \qquad \text{M-3.1}$$

where ω_k^i are weights associated with the i-th alternative and the k-th criterion. Each weight is obtained by M-3.1, suppose the decision-maker has no preference on the alternatives, therefore, solving this problem we find that the optimal attribute weight:

$$w_k = \sum_{i=1}^{n} \varpi_k^i \Big/ \sum_{k=1}^{m}\sum_{i=1}^{n} \varpi_k^i \qquad (k = 1,2,\ldots,m) \qquad (3\text{-}6)$$

(5) Generating a complete ranking

Obtained weight is set in the formula 3-4, then ranking the alternatives by the 'net current'. The bigger value, the better.

4. Example of application

The decision-making data of the technology innovation project was obtained from a large-scale steel and iron enterprise in China, and was used for the model simulating. The original date is omitted due to limited space, and little influence on the model simulating.

With sum of money supposed to be invested into the steel and iron enteiprise above mentioned,there are 4 possible alternatives. Among them only the most reasonable technology innovation project can be selected due to limited resources. In view of the established index system, we use criterions U={u_1,u_2,…,u_{12}} in part 2.Let the linguistic scale S={S_0=extremely bad, S_1=very bad, S_2= bad, S_3= slightly bad, S_4= medium, S_5= slightly good, S_6= good, S_7=very good, S_8=extremely good}.

And the incomplete weight is given as follow:

$$\begin{aligned}\Phi = \{w = (w_1, w_2, \cdots, w_{12}) \mid\ & S_3 \le w_1 \le S_4, S_6 \le w_2 \le S_7, S_4 \le w_3 \le S_5,\\ & S_7 \le w_4 \le S_8, S_4 \le w_5 \le S_6, S_5 \le w_6 \le S_6,\\ & S_5 \le w_7 \le S_6, S_6 \le w_8 \le S_7, S_6 \le w_9 \le S_7,\\ & S_4 \le w_{10} \le S_5, S_6 \le w_{11} \le S_7, S_5 \le w_{12} \le S_7\}\end{aligned}$$

then constructs the appraisal table:

Tab.1 Linguistic appraisal value of each alternative

A / U	a_1	a_2	a_3	a_4
u_1	S_4	S_5	S_3	S_4
u_2	S_2	S_1	S_3	S_4
u_3	S_3	S_3	S_4	S_3
u_4	S_7	S_4	S_4	S_5
u_5	S_3	S_2	S_6	S_3
u_6	S_4	S_3	S_5	S_4
u_7	S_5	S_3	S_4	S_2
u_8	S_1	S_6	S_3	S_4
u_9	S_3	S_4	S_6	S_5
u_{10}	S_6	S_2	S_3	S_3
u_{11}	S_4	S_5	S_4	S_3
u_{12}	S_2	S_3	S_5	S_4

The matrix R not weighted on the 'net current' of each alternative is calculated by 3-5.

$$R=\begin{pmatrix} 0 & -0.3935 & -0.0540 & 0.2155 & -0.3394 & 0 & 0.2614 & -2.8536 & -0.6468 & 0.4343 & 0 & -1.1863 \\ 0.1790 & -1.1863 & -0.0540 & -0.0979 & -0.6970 & -0.1790 & -0.0769 & 2.8536 & -0.1993 & -0.2268 & 0.1790 & -0.3935 \\ -0.1790 & 0.3935 & 0.1621 & -0.0979 & 1.3758 & 0.1790 & 0.0769 & -0.5177 & 0.6468 & -0.1037 & 0 & 1.1863 \\ 0 & 1.1863 & -0.0540 & -0.0197 & -0.3394 & 0 & -0.2614 & 0.5177 & 0.1993 & -0.1037 & -0.1790 & 0.3935 \end{pmatrix}$$

According to optimum model M-3.1,the weight of various alternatives is compose a matrix ϖ ,

$$\varpi=\{\varpi_k^i\}=\begin{pmatrix} 3 & 6 & 4 & 8 & 4 & 5 & 6 & 6 & 6 & 5 & 6 & 5 \\ 4 & 6 & 4 & 7 & 4 & 5 & 5 & 7 & 6 & 4 & 7 & 5 \\ 3 & 7 & 5 & 7 & 6 & 6 & 6 & 6 & 7 & 4 & 6 & 7 \\ 3 & 7 & 4 & 7 & 4 & 5 & 5 & 7 & 7 & 4 & 6 & 7 \end{pmatrix}$$

The final weight is obtained by formal 3-6.

$$w_k=(0.0492 \quad 0.0985 \quad 0.0644 \quad 0.1098 \quad 0.0682 \quad 0.0795 \quad 0.0833 \quad 0.0985 \quad 0.0985 \quad 0.0644 \quad 0.0947 \quad 0.0909)$$

With the weight above, the 'net current' is computed.

$$R(A_1) = -0.4445, \quad R(A_2) = 0.0376$$

$$R(A_3) = 0.2580, \quad R(A_4) = 0.1490$$

From the values of net current, we have the ranking:

$$A_3 > A_4 > A_2 > A_1$$

Namely, the project A_3 is best choice for this iron and steel enterprise, and the project A_4 is next, project A_2 is general, but the project A_1 is worst. In order to explain the choice project 3 is reasonable, we use the TOPSIS to recompute the ranking, and obtain the proximities between various projects and the ideal project:

$$T(A_1) = 0.4374, \quad T(A_2) = 0.4071,$$

$$T(A_3) = 0.5746, \quad T(A_4) = 0.4847$$

Then $A_3 > A_4 > A_1 > A_2$ is got.

Through two methods comparisons, indicates project A_3 is best one, this conclusion is consistent with the PROMETHEE method.

5. Conclusion

In order to solve the problem in the choice of the iron and steel enterprise technology innovation project, this paper has established the technology innovation project appraisal index system, and has presented one kind based on the PROMETHEE method with the incomplete weight information. Weight is solved by maximizing the 'net current'. The PROMETHEE ranking method not only considers that the positive current which represents each alternative surpasses other alternatives, and also considers the 'negative current' which is inferior to other alternatives. Then ranking of the alternatives is obtained by the size of 'net current'.

This method is utilized to the iron and steel enterprise technology in-

novation project choice. With various index analysis, it carries on the reasonable choice to the innovation project, avoiding causing the losses. In the application example from this paper, the project A_3 is superiority in the environmental protection policy, the craft index, the income rate, the overall risk and so on the important index. To be compare with the PROMETHEE method, we use the TOPSIS method and obtain the conclusion that the choice of project A_3 is reasonable, simultaneously explains it's validity and reliability.

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