Risk Evaluation Method of High-technology Based on Uncertain Linguistic Variable and TOPSIS Method

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Abstract—**There are many characteristics in high-technology project investment, such as needing a lot of capital, having so many unsure factors and so on. There are full of risks in the investment process. Some corporations were disastrous in investment because of ignoring the risk evaluation or using the inapposite valuation methods. So it is necessary to use a scientific evaluation method in the investment of high-technology. This paper attempts to structure a risk evaluation model of high-technology project investment based on the uncertain linguistic variable and TOPSIS method. Firstly, this paper discusses the current situation of the research of the high-technology project investment. Then a evaluation indicators system is constructed and the evaluation procedures based on the uncertain linguistic and TOPSIS method. At last, this evaluation method is used to a practical example.**

Index Terms—**high-technology project, risk evaluation, linguistic variable, TOPSIS method**

I. INTRODUCTION

In the era of knowledge economy, the high-technology industry is the principal part that promotes the development of the country's economy. It has many characteristics such as needing a lot of capital, having so many unsure factors and so on. And its investment processes have many unexpected risks. Because some enterprises ignore the risk evaluation or the evaluation methods they adopt are improper, the loss is very big. Thereby, the evaluation of the high-technology project using scientific evaluation method of project investment risk is very necessary.

II. THE CURRENT SITUATION OF THE RESEARCHES

There are many risk evaluation methods of the high-technology project investment, and they can be divided into two kinds: traditional method and new method. The theory of the cash flow and its application are tend to become mature[1]. Among the new methods, Analytic Hierarchy Process(AHP) method provides a structure frame for the risk evaluation method of the high-technology project investment. Clustering analytical method and fuzzy synthetical evaluation method are concrete operations to deal with the AHP data during the evaluation process. The consistency check of judgment matrix in the Analytic Hierarchy Process plays a key role in calculating the eigenvector of a matrix(the weight coefficient of the indicators). But the judgment matrix that experts proposed doesn't always meet the consistency demand. There are some deficiencies in the conventional consistency test of AHP[2,3]. Wanli Liu proposed common rules of rectifying judgment matrix using the vector concept[4]. And MaWY used eigenvector of the judgment matrix to do entirely correction[5]. Zening Wu proposed a kind of method to modify the judgment matrix's consistency using the statistical identifying method as standard[6]. Otherwise, AHP method does not eliminate the disturbance of the experts' individual opinions that have big devition, so the result is made distort. When the synthesis weights are calculated, the simple arithmetic mean does not accord with the majority principle and the result is discrete. Guotai Chi *ea.tl* used the theory of the cluster analysis to do two times of convergences to the AHP method. How to gain the scientific and reasonable weight becomes a problem worth discussed. The indicators and weights in the traditional risk evaluation method of the high-technology project investment are always subjective. The processes of evaluation are too long, so it can not be used cosmically. Recently, the artificial neural network model is used in the area of risk evaluation. There are mainly two arithmetics: the classical BP algorithm model[7] and the improved BP algorithm model. The later models are many, such as the additional momentum method and adaptive learning rate method and so on. Zhengou Wang ea.tl proposes a high generalization of radial basic function neural network and uses it to the risk evaluation of high-technology project investment[8]. Tao Song eatl proposes the evaluation method of the investment risk of high tech projects based on the neural network model[9].

Rita Gunthe MeGrath eatl and Martha introduced the option theory to risk evaluation of high-technology project investment[10][11]. Hongjiang Li proposes a evaluation method of real option of high-technology project[12].

In general, among the new methods, AHP method is always used in risk evaluation of high-technology project investment. The implication of the artificial neural network in the area of risk evaluation of high-technology project investment is at the beginning. The real options evaluation method is a new method in the area of risk evaluation of high-technology project investment.

The above evaluation methods are all quantitative methods. But things are complex and uncertain. The thought of people is fuzzy and the person who makes evaluations is always be restricted by some objective factors. So it is hard to use the quantitative method in the area of risk evaluation of high-technology project investment. Using linguistic way to evaluate the problem is an easy method. This paper introduces a evaluation method based uncertain linguistic variable and TOPSIS method to the risk evaluation of high-technology project investment.

III. THE INDICATORS SYSTEM

A reasonable indicator system of the evaluation is the foundation of the risk evaluation of the high-technology project investment. A scientific indicator system can reflect the constitution of the risk factors of the high-technology project investment. On the foundation of the literatures[13][14][15][16], this paper constructs the following indicator system:

TABLE 1 THE RISK EVALUATION INDICATORS SYSTEM OF THE HIGH-TECHNOLOGY PROJECT INVESTMENT

Contents	Indicators
A1 Financial risk	B1 Financing ability B2 The supply ability of the production capital
A2 Technical risk	B3 The advantagement of the technology B4 The substitutability of the technology B5 The reliability of the technology
A3 Production risk	B6 The standardization degree of the production equipment and process B7 The employee's makings B8 The supply capability of the raw material
A4 Market risk	B9 The product life cycle B10 The capacity of acceptance and time B11 Product competitiveness B12 The effect of the potential competitors B13 Marketing ability
A5 Management risk	B14 The quality and experience of the managers B15 The convenience degree of obtaining the related information B16 The usage degree of the scientific decision means B17 The project management mechanism
A6 Environment risk	B18 The favorable degree of the policy and legal environment B19 The favorable degree of the macro economic environment B20 The favorate degree of the social environment

IV. THE RISK EVALUATION MODEL OF THE HIGH-TECHNOLOGY PROJECT INVESTMENT BASED ON THE UNCERTAIN LINGUISTIC VARIABLE AND TOPSIS METHOD

A. Tthe description and operation rules of the uncertian lingustic information

Suppose dthe linguistic scale are $S = \{s_\alpha \mid \alpha = -L, -L+1, \cdots, L-1, L\}$, where s_α denotes the linguistic variable. S has the following characters[17][18][19]:

(1) if $i > j$, then $s_i \succ s_j$ (s_i is better than s_j).

(2) there is a negative operator: $neg(s_i) = s_{-i}$;

(3) if $s_i \geq s_j$ (s_i is worse than s_j), $\max(s_i, s_j) = s_i$

(4) if $s_i \leq s_j$ (s_i is not better than s_j), $\min(s_i, s_j) = s_i$

In the practical application, L is 1,2,3,4 and so on commonly. It can be shown as follows:

$S = (s_{-1}, s_0, s_1)$ = (bad, middling, good).

$S = (s_{-2}, s_{-1}, s_0, s_1, s_2)$ = (worse, bad, middling, good, better).

In order to avoid the lose of the lingustic decision information, the disperse linguistic scale $S=(s_{-L},s_{-L+1},\cdots,s_0,\cdots,s_{L-1},s_L)$ is extended to continue linguistic scale $\overline{S}=\{s_\alpha \mid \alpha\in[-q,q]\}$, where, q is a number big enough ,and if $s_\alpha\in S$, then s_α is called original term, else s_α is called extended term. In a general way, the original terms are used to evaluate the risk investment objects, and the extended terms are used to operation and sort[18].

Definition1[19]: suppose $\tilde{s}=[s_a,s_b],s_a,s_b\in\overline{S}$ and $a\le b$, s_a and s_b are the lower bound and the upper bound, $\tilde{s}$ is called uncertain linguistic variable.

Suppose: $\tilde{S}$ is a set of uncertain lingustic variables, any two uncertain variable: $\tilde{s}_1=[s_{a1},s_{b1}]$, $\tilde{s}_2=[s_{a2},s_{b2}]$, the operation rules are as follows:[18][19]:

$$(1)\ \tilde{s}_1\oplus\tilde{s}_2=[s_{a1},s_{b1}]\oplus[s_{a2},s_{b2}]=[s_{a1+a2},s_{b1+b2}] \quad (1)$$

$$(2)\ \lambda\tilde{s}_1=\lambda[s_{a1},s_{b1}]=[s_{\lambda*a1},s_{\lambda*b1}] \quad (2)$$

$$(3)\ \tilde{s}_1\oplus\tilde{s}_2=\tilde{s}_2\oplus\tilde{s}_1 \quad (3)$$

$$(4)\ \lambda(\tilde{s}_1\oplus\tilde{s}_2)=\lambda s_1\oplus\lambda s_2 \quad (4)$$

$$(5)\ (\lambda_1+\lambda_2)\tilde{s}_1=\lambda_1 s_1\oplus\lambda_2 s_1 \quad (5)$$

Definition2[20]: Suppose $\tilde{s}_1=[s_{a1},s_{b1}]$ and $\tilde{s}_2=[s_{a2},s_{b2}]$ are two uncertain linguistic variable, then the distance between $\tilde{s}_1$ and $\tilde{s}_2$ is defined as:

$$d(\tilde{s}_1,\tilde{s}_2)=\tfrac{1}{2}(|a2-a1|+|b2-b1|) \quad (6)$$

B. The desription of the problem

Suppose there are the evaluation m evaluation projects $A=(a_1,a_2,\cdots,a_m)$ and n evaluation indicators $C=(c_1,c_2,\cdots,c_n)$, the evaluation indicator's evaluation values is the matrix $X=[\tilde{x}_{ij}]_{m\times n}$, $\tilde{x}_{ij}$ denotes the evaluation value of the jth indicator of the ith evaluation project. Suppose $\tilde{x}_{ij}$ is shown by uncertain linguistic : $\tilde{x}_{ij}=[x_{a_{ij}},x_{b_{ij}}]$, $x_{a_{ij}},x_{b_{ij}}\in S$, S is the given lingustic scale, $x_{a_{ij}}$ and $x_{b_{ij}}$ are respectively the lower bound and the upper bound of $\tilde{x}_{ij}$. a_{ij} and b_{ij} are nature number level, and $a_{ij}\le b_{ij}$. The weight of the indicators are unknown. Through the analysis of the matrix $X=[\tilde{x}_{ij}]_{m\times n}$, the rank of the projects is confirmed finally.

C .The uncertain linguistic evaluation model based on the TOPSIS method

TOPSIS is used to confirm the order of the evaluation objects in virtue of the ideal solution and the negative ideal solution of the multiattribute problems[21]. The ideal solution is a best solution that is assumed(marked as V^+). Each of it's indicator value is the best value of the optional schemes. The negative solution is another worst solution that is assumed(marked as V^-). Each of it's indicator value is the worst value of the optional project. V^+andV^- are compared with each project in the original project set. The distance information of them is used to be the standard to confirm the order of the m projects in X.

The ideal solution of uncertain lingusitic decision matrix $X=[\tilde{x}_{ij}]_{m\times n}$ is

$$V^+=(\tilde{v}_1^+,\tilde{v}_2^+,\cdots,\tilde{v}_n^+) \quad (8)$$

Where, $\tilde{v}_j^+=[v_{a_j}^+,v_{b_j}^+]=[\max_i x_{a_{ij}},\max_i x_{b_{ij}}]$

The negative ideal solution of uncertain lingusitic decision matrix $X=[\tilde{x}_{ij}]_{m\times n}$ is

$$V^-=(\tilde{v}_1^-,\tilde{v}_2^-,\cdots,\tilde{v}_n^-) \quad (9)$$

Where, $\tilde{v}_j^-=[v_{a_j}^-,v_{b_j}^-]=[\min_i x_{a_{ij}},\min_i x_{b_{ij}}]$

The generalized weighted distance between each project a_i and the ideal solution V^+ and negative ideal solution V^- are defined as:

$$d^+(a_i,V^+)=\sum_{j=1}^{n}[w_j d(\tilde{v}_j^+,\tilde{x}_{ij})]^2 \quad (10)$$

$$d^-(a_i,V^-)=\sum_{j=1}^{n}[w_j d(\tilde{v}_j^-,\tilde{x}_{ij})]^2 \quad (11)$$

Where, $d(\tilde{v}_j^+,\tilde{x}_{ij})$ is the distance between the uncertain linguistic variable $\tilde{v}_j^+$ and $\tilde{x}_{ij}$, $d(\tilde{v}_j^-,\tilde{x}_{ij})$ is the distance between $\tilde{v}_j^-$ and $\tilde{x}_{ij}$.

If the distance between each project a_i and ideal project V^+ is smaller, the project is better. The distance between each project a_i and the negative ideal project V^- is bigger, the project is better.

So, the programming model of each project a_i is construted as follows:

$$\min\ d^+(a_i,V^+)=\sum_{j=1}^{n}[w_j d(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})]^2$$
$$s.t\begin{cases}\sum_{j=1}^{n} w_j=1\\ w_j\geq 0\end{cases} \tag{12}$$

$$\max\ d^-(a_i,V^-)=\sum_{j=1}^{n}[w_j d(\boldsymbol{v}_j^-,\boldsymbol{x}_{ij})]^2$$
$$s.t\begin{cases}\sum_{j=1}^{n} w_j=1\\ w_j\geq 0\end{cases} \tag{13}$$

Because the competitory of each project is fair and there is no any preference, a quadratic programming medel can be obtained through the synthesizing the equation(12):

$$\min\ Z(w)=\sum_{i=1}^{m}\sum_{j=1}^{n}[w_j^+ d(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})]^2$$
$$s.t\begin{cases}\sum_{j=1}^{n} w_j^+=1\\ w_j^+\geq 0\end{cases} \tag{14}$$

Construct the Lagrange function:

$$L=\sum_{i=1}^{m}\sum_{j=1}^{n}[w_j^+ d(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})]^2-2\lambda(\sum_{j=1}^{n} w_j^+-1)$$

Let $\partial L/\partial w_j^+=0$, then:

$$2\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})w_j^+-2\lambda=0 \tag{15}$$

viz.: $$w_j^+=\frac{\lambda}{\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})} \tag{16}$$

through $\sum_{j=1}^{n} w_j^+=1$,

then $$\sum_{j=1}^{n}\frac{\lambda}{\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})}=1$$

So: $$\lambda=\frac{1}{\sum_{j=1}^{n}\frac{1}{\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})}} \tag{17}$$

according to equation（17）,

$$w_j^+=\frac{\dfrac{1}{\sum_{j=1}^{n}\frac{1}{\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})}}}{\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^+,\boldsymbol{x}_{ij})} \tag{18}$$

Make the weighted quotiety into equation(10), $d^+(a_i,V^+)$ is obtained.

Synthesize the equation(13), a quadratic programming medel can be obtained:

$$\max\ Z(w)=\sum_{i=1}^{m}\sum_{j=1}^{n}[w_j^- d(\boldsymbol{v}_j^-,\boldsymbol{x}_{ij})]^2$$
$$s.t\begin{cases}\sum_{j=1}^{n} w_j^-=1\\ w_j^-\geq 0\end{cases} \tag{19}$$

Construct the Lagrange function for this problem:

$$L=\sum_{i=1}^{m}\sum_{j=1}^{n}[w_j^- d(\boldsymbol{v}_j^-,\boldsymbol{x}_{ij})]^2-2\lambda(\sum_{j=1}^{n} w_j^--1)$$

We can obtain:

$$w_j^-=\frac{\dfrac{1}{\sum_{j=1}^{n}\frac{1}{\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^-,\boldsymbol{x}_{ij})}}}{\sum_{i=1}^{m} d^2(\boldsymbol{v}_j^-,\boldsymbol{x}_{ij})} \tag{20}$$

Make the weighted quotiety into equation(11), $d^-(a_i,V^-)$ can be obtained.

Finally, calculate the relative adjacent degree:

$$C(a_i)=\frac{d^+(a_i,V^+)}{d^+(a_i,V^+)+d^-(a_i,V^-)} \tag{21}$$

Then, according to $C(a_i)$, confirm the order of the projects. The smaller $C(a_i)$, the better the project.

V. PRACTICAL APPLICATION

A company intends to invest in high-technology project. There are 5 candidate projects to be choosed. Experts evaluate each project using the evaluation indicators proposed in this paper in table 1.In order to simplify the calculation, only 8 indicators are choosed. Thery are: Financing ability（B1）, The supply ability of the production capital（B2）,The standardization degree of the production equipment and process（B6）, The employee's makings（B7）, The capacity of acceptance and time（B10）, The quality and experience of the managers（B14）, The convenience degree of obtaining the related information（B15）,The favorable degree of the policy and legal environment（B18）. Here, the linguistic scale is $S=(s_{-3},s_{-2},s_{-1},s_0,s_1,s_2,s_3)$ =（lowest，lower，low，middling，high，higher，highest）.

The evaluation matrix is:

$$X=[\tilde{x}_{ij}]_{m\times n}=\begin{bmatrix} [s_2,s_3] & [s_1,s_3] & [s_1,s_2] & [s_0,s_2] & [s_2,s_3] & [s_1,s_2] & [s_1,s_2] & [s_0,s_2] \\ [s_1,s_2] & [s_{-1},s_1] & [s_1,s_3] & [s_2,s_3] & [s_1,s_2] & [s_0,s_1] & [s_{-1},s_1] & [s_2,s_3] \\ [s_2,s_3] & [s_1,s_3] & [s_1,s_2] & [s_0,s_1] & [s_2,s_3] & [s_1,s_3] & [s_1,s_2] & [s_2,s_3] \\ [s_2,s_3] & [s_1,s_2] & [s_2,s_3] & [s_2,s_3] & [s_2,s_3] & [s_{-1},s_0] & [s_2,s_3] & [s_2,s_3] \\ [s_0,s_2] & [s_1,s_3] & [s_1,s_2] & [s_2,s_3] & [s_2,s_3] & [s_1,s_3] & [s_2,s_3] & [s_0,s_1] \end{bmatrix}$$

The evaluation seps using the method this paper proposed are:

(1) Calculate the ideal solution and the negative ideal solution V^+,V^-:

$$V^+=(\tilde{v}_1^+,\tilde{v}_2^+,\tilde{v}_3^+,\tilde{v}_4^+)=([s_2,s_3]\ [s_1,s_3]\ [s_2,s_3]\ [s_2,s_3][s_2,s_3]\ [s_1,s_3]\ [s_2,s_3]\ [s_2,s_3]).$$

$$V^-=(\tilde{v}_1^-,\tilde{v}_2^-,\tilde{v}_3^-,\tilde{v}_4^-)=([s_0,s_2]\ [s_{-1},s_1]\ [s_1,s_2]\ [s_0,s_1][s_1,s_2]\ [s_{-1},s_0]\ [s_{-1},s_1]\ [s_0,s_1]).$$

(2)According to equation(6), calculate the distance $d(\tilde{v}_j^+,\tilde{x}_{ij}),d(\tilde{v}_j^-,\tilde{x}_{ij})$:

$$d(\tilde{v}_j^+,\tilde{x}_{ij})|_{m\times n}=\begin{bmatrix} 0 & 0 & 1 & 1.5 & 0 & 0.5 & 1 & 1.5 \\ 1 & 2 & 0.5 & 0 & 1 & 1.5 & 2.5 & 0 \\ 0 & 0 & 1 & 2 & 0 & 0 & 1 & 0 \\ 0 & 0.5 & 0 & 0 & 0 & 2.5 & 0 & 0 \\ 2 & 0 & 1 & 0 & 0 & 0 & 0 & 2 \end{bmatrix}$$

$$d(\tilde{v}_j^-,\tilde{x}_{ij})|_{m\times n}=\begin{bmatrix} 1.5 & 2 & 0 & 0.5 & 1 & 2 & 1.5 & 0.5 \\ 0.5 & 0 & 0.5 & 2 & 0 & 1 & 0 & 2 \\ 1.5 & 2 & 0 & 0 & 1 & 2.5 & 1.5 & 2 \\ 1.5 & 1.5 & 1 & 2 & 1 & 0 & 2.5 & 2 \\ 0 & 2 & 0 & 2 & 1 & 2.5 & 2.5 & 0 \end{bmatrix}$$

(3)According to equation (18), calculate w_j^+:

$$w^+=\left(0.1098,0.1318\ ,0.0941,0.0941,0.3295,0.0732,0.0732,0.0941\right).$$

(4)According to equation(10), calculate:

$$d^{+}(a_i,V^{+})=\left(0.0554\ ,0.2379,0.0497,0.0379,0.0926\right).$$

(5)According to equation(20), calculate w_j^- :

$$w^{-}=\left(0.0926\ ,0.0455,0.5187\ ,0.0529,0.1621,0.0371,0.0381,0.0529\right).$$

(6) According to equation (11), calculate:

$$d^{-}(a_i,V^{-})=\left(0.0640,0.0932,0.0769,0.3508,0.0634\right).$$

(7)According to equation(21), calculate:

$$C(a_i)=\left(0.4641,0.7185,0.3924,0.0974,0.5934\right)$$

(8) According to the value of $C(a_i)$, confirm the rank of the candidate projects:

$A_2 > A_5 > A_1 > A_3 > A_4$.

So, the best investment project is A_2 , and the worsest one is A_4 .

The method this paper proposed can confirm which high-technology project is worth to invest.

VI. Conclusions

On the foundation of relative literatures, this paper research proposes a evaluation indicator system of the high-technology project investment. Then a evaluation model based on the uncertain linguistic variable and TOPSIS method. The concept of this method is clear and the calculation is simple and convenient. The example of the practical application proves that this method is efficient and feasible. This indicators system and evaluation model can be used widely in the area of risk evaluation of high-technology project investment.

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