Research on Comprehensive Evaluation of Enterprise's Technological Innovation Talent Team by Using Analytic Network Process (ANP) and Grey Related Analysis

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***Abstract*- The source of innovation is the technological talent .This paper established the indicator system of evaluation of enterprise's technological innovation talent team . It used ANP to determine the weight of indicators and grey related analysis to determine the rank ordering of enterprises. It provides the theoretic and decision foundation for the technological innovation talent environment construction and technological innovation talent cultivation model optimization.**

Kewords- Technological innovation talent; Evaluation indicator system; ANP; Grey related analysis

I. INTRODUCTION

In modern times,the technological innovation talent and the innovation capability are the valuable resources.Building a strong technological innovation talent team is key to sustaining development of enterprises.Without the effective technological innovation talent team,enterprises can not be successful.By reading materials,we can find a lot of papers are related to the technological innovation talent education and cultivation.But the research on the construction of the indicator system of evaluation of enterprise's technological innovation talent team,comprehensive evaluation of technological innovation talent team are limited.In fact,there are some problems in construction of enterprise's technological innovation talent team in China.

Therefore,it is necessary to evaluate the technological innovation talent team and analyse the influential factors.The paper will make enterprises know the key factors of influence and it is useful for reference in the construction of technological innovation talent team.

II. ANP AND GREY RELATED ANALYSIS IN COMPREHENSIVE EVALUATION OF ENTERPRISE'S TECHNOLOGICAL INNOVATION TALENT TEAM

A. Analytic Network Process

The initial study identified the multi-criteria decision technique known as the Analytic Hierarchy Process(AHP) to be the most appropriate for solving complicated problems.AHP was proposed by Saaty in 1980 as a method of solving socio-economic decision making problems and has been used to solve a wide range of problems[1]

Generally,we solve complex problems by discussing them with team members.However,when we do not know the exact relationship in the network structure or the degree of interdependence among considering criteria,it is dangerous to determine by one or two decision makers.ANP is the most important function to determine the relationship of a network structure or the degree of interdependence.The steps are as follows[2]:

Step1:in this step the interactions between and within clusters and elements are determined.

Step2:in this step supermatrix is constructed according to the network built in step1.The priority vectors derived from pairwise comparison matrices are each entered as a part of some column of a supermatrix. The supermatrix represents the influence priority of an element on the left of the matrix on an element at the top of the matrix.

Step3: the supermatrix needs to be stochastic to derive meaningful limiting priorities. So for this reason to get the weighted supermatrix, firstly the influence of the clusters on each cluster with respect to the control criterion is determined. This yields an eigenvector of influence of the clusters on each cluster. Then the unweighted supermatrix is multiplied by the priority weights from the clusters, which yields the weighted supermatrix.

Step4: finally the supermatrix will be steady state by multiplying the weighted supermatrix by itself until the supermatrix's row values converge to the same value for each column of the matrix.

B. Grey Related Analysis

The grey relational analysis method, which is a basic method of grey system theory for systems analysis, is based on qualitative analysis and quantitative analysis.The steps are as follows[3]:

Step1:determine reference number Sequence X_0 and alternative number sequence X_i

$$X_0=(X_{01},X_{02},\cdots,X_{0n})\ ;X_i=(X_{i1},X_{i2},\cdots,X_{in})(i=1,2,\cdots,m)$$

Step2:determine connection coefficient ξ_{ik}

$$\xi_{ik}=\frac{\min\limits_i\min\limits_k|X_{0k}-X_{ik}|+\rho\max\limits_i\max\limits_k|X_{0k}-X_{ik}|}{|X_{0k}-X_{ik}|+\rho\max\limits_i\max\limits_k|X_{0k}-X_{ik}|}$$
$$(i=1,2,\cdots,m;k=1,2,\cdots,n) \quad (1)$$

Step3:determine connection degree

After calculating ξ_{ik} ,the connection between alternative and reference number sequence will be calculated according to the following formula

$$r_i=\frac{1}{n}\sum_k^n\xi_{ik}\ ,\quad \text{i=1,2,...,m} \quad (2)$$

Step4:determine optimal alternative

The feasible alternative X_t is optimal by grey related analysis if $r_t = \max_{1 \le i \le m} r_i$

C. Establishment of Indicator System of Enterprise's Technological Innovation Talent Team

According to theoretical analysis method, through the analysis of characteristics of enterprise's technological innovation talent, we choose indicators from the perspective of strategic management of technological innovation talent team.This paper gives six criteria,nineteen sub-criteria and forty-eight alternatives.The structure of the model is described by its clusters and elements, and by the connection between them.These connections indicate the influence between the elements.

We select high frequency indicators.Based on this, indicator system can be established. Through the collation of literatures and experts' advice, we can establish a series of indicators from six main categories:Total indicators and relative indicators C_1,Structure indicators C_2,Quality indicators C_3,Turnover indicators C_4,Efficiency indicators C_5,Environmental indicators C_6, as shown in Table I.

Table I Indicator System of Comprehensive Evaluation of Enterprise's Technological Innovation Talent Team

Goal	Criteria	Sub-criteria	Alternatives
Enterprise's technological	Total indicators and relative indicators C_1	Enterprise's total number C_{11}	Number of people who work in the enterprise
		Total number of technological innovation talent C_{12}	Number of engineers and scientists
			Number of senior skilled workers
			Number of potential technological innovation talent
		The rate of technological innovation talent C_{13}	Number of technological innovation talent /enterprise's total number
			the growth rate of technological innovation talent
	Structure indicators C_2	Age structure C_{21}	20-35
			35-55
			55 years old and above
		Rank structure C_{22}	Leader
			Grass-roots
		Education degree structure C_{23}	Junior college education
			Bachelor degree
			Master degree
		Title structure C_{24}	Special senior professional
			Senior professional
			Middle-rank professional
			Primary
	Quality indicators C_3	The basic qualities C_{31}	Moral qualities
			Intelligence qualities
			Physical and mental qualities
		Competencies C_{32}	Foreign language ability
			The computer and Internet skills
	Turnover indicators C_4	Turnover number C_{41}	Number of resigned technological innovation talent
			Number of new technological innovation talent
		Demand rate C_{42}	Demand quantity of technological innovation talent/total number of technological innovation talent
		Turnover rate C_{43}	Turnover number of technological innovation talent/total number of technological innovation talent
			Number of new technological innovation talent/number of resigned technological innovation talent
	Efficiency indicators C_5	Achievement in science and research C_{51}	Number of papers
			Technical patent
			Research projects
		Transformation of achievements in science and research C_{52}	Number of transformation of achievements in science and Research
			Rate of transformation of achievements in science and research
		New-product development C_{53}	Number of new-product
			Profit of new-product
		Contribution rate of technological innovation C_{54}	Profit of technological innovation
			The contribution rate of technological innovation
	Environmental indicators C_6	Supply quantity of technological innovation talent C_{61}	Number of graduation
			Number of overseas returnees
			Number of job seekers
		Enterprise's micro environment C_{62}	Training expenses of technological innovation talent
			Expenses of science and research
			Expenses of technological transformation
			Incentive policy
		Enterprise's macro environment C_{63}	Policy environment
			Economic environment
			Human environment
			Living environment

D. Internal Relationship Structure of Evaluation Indicator System

The six criteria are not independent,there are interaction effects between them.The structure connections of mutual influence and self feedback can be illustrated by the ANP structure principle.The net structure given by Fig.1 is called out dependence.

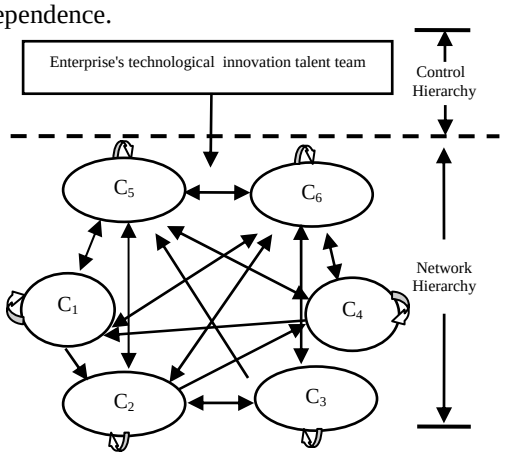

Fig.1. Connections in a Network

E. The Supermatrix and The Weights

A supermatrix is a two-dimensional matrix of elements by elements. The priority vectors from the paired comparisons appear in the appropriate column of the supermatrix. In the supermatrix, the sum of each column corresponds to the number of comparison sets[4]. All the numbers which corresponds to the influence of the C_i cluster on the left on the C_j cluster at the top are multiplied by the weight of the cluster C_i . Applying the cluster matrix numbers to their respective blocks in the unweighted supermatrix yields the weighted matrix that is column stochastic.Finally,we get the weights of criteria and sub-criteria of technological innovation talent team[5],as shown in Table II.

We can conclude according to Table II:

*1)*The weight of environmental indicators is the first, ϖ_6=0.4460;next is efficiency indicators, ϖ_5=0.2732;the third one is quality indicators, ϖ_3=0.1122;the fourth one is turnover indicators, ϖ_4 =0.0782;the fifth one is total indicators and relative indicators, ϖ_1=0.0502;the weight of structure indicators is final, ϖ_2 =0.0402.

*2)*The environmental indicators are most important.It not only includes the incentive policy and the input for the technological innovation,but also includes supply quantity of technological innovation talent and policy support.They have impact on every indicator directly and are critical to the evaluation object.

*3)*The second one is efficiency indicators.For evaluating the strength of technological innovation talent team,efficiency indicators are direct way.No matter horizontal comparison among enterprises or vertical comparison among each enterprise itself,achievement in science and research,new-product development and contribution rate of technological innovation are key indicators in evaluating technological innovation talent team.

*4)*Quality indicators can not be overlooked.To enhance the capability of technological innovation,establishing a efficiency technological innovation talent team is important for enterprises.

Table II Weights of Technological Innovation Talent Team

Goal	Criteria	Weights	Sub-criteria	Weights
Enterprise's technological innovation talent team	C_1	0.0502	C_{11}	0.0059
			C_{12}	0.0154
			C_{13}	0.0289
	C_2	0.0402	C_{21}	0.0004
			C_{22}	0.0083
			C_{23}	0.0069
			C_{24}	0.0246
	C_3	0.1122	C_{31}	0.0320
			C_{32}	00801
	C_4	0.0782	C_{41}	0.0194
			C_{42}	0.0242
			C_{43}	0.0346
	C_5	0.2732	C_{51}	0.0263
			C_{52}	0.0440
			C_{53}	0.0785
			C_{54}	0.1244
	C_6	0.4460	C_{61}	0.0221
			C_{62}	0.2933
			C_{63}	0.1307

*5)*Turnover indicators have influence on the long-term development of enterprise's technological innovation talent team.The turnover of talent reflects enterprise's vitality and human resource policy.A stable technological innovation talent team is critical to enterprise's success.

*6)*Without the support of absolute quantity of employees,enterprises can not establish a high quality,high efficiency and high level technological innovation talent team.Although the total indicators and relative indicators can influence the efficiency of the team,the restraint is very limited.But we can not overlook them.

*7)*Reasonable structure can promote the efficiency of technological innovation talent team on the premise of good and open environment,high quality technological innovation talent and a stable team.So the weight comes bottom.

III. EXAMPLE

Here, we shall analyse the following example with the method of grey related analysis.We regard the optimal value of indicators of investigated enterprises' technological innovation talent team as corresponding elements $v_{0k}(k=0,1,\cdots,n)$ of reference number sequence V_0 ,the indicators of the enterprises which are evaluated as corresponding elements $v_{ik}(i=1,2,\cdots,m;k=1,2,\cdots,n)$ of alternative number sequence V_i .We should determine the connection degree R_i。 The rank ordering of the connection degree R_i is the rank ordering of superior or inferior in strength of enterprise's technological innovation talent team.

According to Table II,we can know the weight of indicators.But because of the incomparability of data,the indicators of enterprise's total number $C_{11,}$ total number of technological innovation talent$C_{12,}$turnover number$C_{41,}$supply quantity of technological innovation talentC_{61} are not included for statistical analysis.We should determine the weight of each indicator by using ANP again.

We choose eight enterprises in Jilin Province as data samples.Then we calculate alternative number sequence and reference number sequence.Using(1),the connection coefficient $\xi_{ik}(i=1,2,\cdots,8;\ k=1,2,\cdots,15)$ is then calculated and arranged matrix $E_{8\times15}$,as shown in Table III.

By these results,we know that the connection between every alternative and reference number sequence is,respectively

$R_A=(r_1,r_2,\cdots,r_6)$ =(0.2625,0.2585,0.2753,0.2563,0.2304,0.2508,0.2750,0.2608）

We rank feasible alternatives from largest to smallest.The rank ordering of feasible alternatives is C>G>A>H>B>D>F>E.

Here the rank ordering implies that enterprise C has the

highest connection degree, it is 0.2753,that means enterprise C is the best one among the eight enterprises.

According to Table III,the connection coefficient of some key indicators such as enterprise's micro environment ,macro environment, contribution rate of technological innovation and age structure of enterprise C reach or nearly reach largest value 1.That is to say,enterprise C invests more in technological innovation than other enterprises.Enterprise C has good policy in technological innovation talent team construction.But in terms of enterprise E,the connection coefficient of indicators is lower than other enterprises,that is to say,enterprise E should make more effort in enhancing the quality of technological innovation talent team.

Table III Connection Coefficient($E_{8\times15}$)

indicators / enterprises	C_{13}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{42}	C_{43}	C_{51}	C_{52}	C_{53}	C_{54}	C_{62}	C_{63}
A	0.94	0.89	0.50	0.91	0.86	0.54	0.63	1.00	0.63	0.89	0.96	0.73	0.98	1.00	0.68
B	0.99	0.91	0.99	0.91	0.89	0.68	0.75	1.00	0.77	0.79	0.88	0.65	0.93	1.00	0.66
C	0.90	1.00	0.93	0.94	0.97	0.89	0.85	0.95	0.46	0.80	0.49	0.58	0.99	1.00	0.99
D	0.90	0.87	0.81	0.95	0.88	0.62	0.81	1.00	0.48	0.77	0.45	0.67	0.94	1.00	0.71
E	0.90	0.71	0.40	0.74	0.87	0.33	0.38	0.82	0.61	0.84	0.87	0.57	0.80	1.00	0.40
F	0.94	0.94	0.49	0.95	0.90	0.52	0.61	0.99	0.74	0.72	0.44	0.67	0.94	1.00	0.65
G	0.90	1.00	1.00	0.92	1.00	0.94	0.78	0.72	0.42	0.81	1.00	0.60	0.97	1.00	0.91
H	0.97	0.97	0.66	0.95	0.93	0.70	0.66	0.92	0.50	0.96	0.79	0.57	0.99	1.00	0.72

IV. CONCLUSION

The comprehensive evaluation of enterprise's technological innovation talent team is an important problem to enterprises.We first establish the indicator system,and then determine the weight of every indicator by using ANP approach.Finally,the paper rank the enterprises in the order by using grey related analysis approach.Through the adoption of theoretical research and empirical analysis methods,we can conclude:

1) The evaluation of enterprise's technological innovation talent team is creation of the combining powers.Enterprises have to make effort in various aspects in order to improve their strength in technological innovation talent team.

2) The indicator system of technological innovation talent team is a dynamic system.

3) In the system,environmental indicators are important, next are efficiency indicators, quality indicators,turnover indicators, total indicators and relative indicators and structure indicators.

4) The indicators in the system are not independent. They interacts and are attached to one another.So the application of the ANP is desirable.

5) Enterprises can make horizontal comparison among enterprises and horizontal vertical among each enterprise in the development of technological innovation talent team by using grey related analysis. Enterprises can also improve the indicators which have low correlation degree and then enhance the strength of technological innovation talent team.

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