

Study on Performance Appraisal Index for R & D Staff Performance Based on PC-FA

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Abstract Performance appraisal index for R & D staff is a system which can fully reflect and reveal the laws between the behavior and results of the work of R & D staff in the course of their work, and it can reflect and ensure their long-term development goals to achieve the index. In this paper, according to the performance characteristics of R & D staff, an initial index content system is established; then in the light of the actual situation of the surveyed enterprises and job characteristics of R & D staff, factor analysis method is used to make a comprehensive adjustment of the index content; finally, a highly indexed performance appraisal index system of R & D staff is determined.

Key words R & D staff; Performance characteristics; Factor analysis; Performance appraisal index system

1 Introduction

Research and development (R & D) staff, as typical knowledge workers, who have higher stock of human capital, are the core unit to promote the development of knowledge-based economy. How to develop each R & D staff's creativity and enthusiasm is the key factor to enhance the core competitiveness and achieve sustainable development of enterprises. Therefore, a fair, reasonable and scientific assessment has become a key point of efficient work. However, compared with the general staff's work, since the work of R & D staff is creative and cooperative, the nature of the work process is difficult to grasp. Thus, there is a certain difficulty in the process of assessment, which has become a difficult problem for human resource department in the aspect of evaluating performance of R & D staff. At present, there are a lot of researches for the assessment of R & D staff, but these researches have only stayed in the evaluation of the current status and the level of difficulty of the R & D staff. Or some people put forward some assessment principle for R & D staff, but they did not make in-depth study on R & D staff's evaluation system^[1]. Schneider et al. scholars pointed out that the key of performance evaluation for knowledge workers was to grasp the characteristics and the nature of performance, when they discussed "how to build a successful assessment system for performance"^[2]. Chinese scholars Liao Jianqiao et al^[3]. performed a practical analysis of characteristics of performance of knowledge workers. The results show that knowledge workers have the characteristics such as profession, creativity, complexity, duality and team-cooperation and so on. Based on the performance-oriented characteristics, they did a research about the assessment method about the knowledge workers^[4]. Even though there is no research based on the performance characteristics about R & D staff, yet R & D staff, as typical knowledge workers apparently have the performance characteristics of knowledge workers. According to the performance characteristics of R & D staff, the author tries to initially establish an index system about R & D staff's performance characteristics. Then, in view of practical work condition and characteristics of the investigated R & D staff, applying the factor analysis method to perform the general adjustment of the index contents. And finally, the author fixes on the performance evaluation index system in order to provide reference to the business management practice.

2 Performance Characteristics of R & D Staff

2.1 Creativity

The realization of R & D staff's performance is a creative process. Creativity is another distinctive feature of R & D staff; the main reasons are the following aspects:

Firstly, R & D staff have to keep learning and accumulate knowledge to be competent at their work, and to meet the requirements of the developing world and organizations^[5]. Secondly, knowledge includes two types: explicit knowledge and tacit knowledge. Explicit knowledge can be obtained directly from the official exchange, but it is not enough to depend only on explicit knowledge. To make up the deficiency of explicit knowledge, it needs our understanding and creativity. Thirdly, R & D staff's knowledge contains application, creativity, accumulation, and transmission four processes^[6]. Among them, knowledge creativity and application are the aims of knowledge work. However, through working

to create new knowledge or applying knowledge to creatively solve problems is the significant symbol to achieve the performance of R & D staff. While the main proof to measure the performance of knowledge workers is whether it is creative or how much of creativity is included in the performance^[7].

2.2 Difficult monitoring for the performance behavior

General staff's performance evaluation is normally established on the basis of working normalization and standardization, and then monitoring the process of standard working content is to make the evaluation of working process scientific and evident. But the creative characteristic of R & D staff normally determines the low repetition degree of their tasks, and there are no defined processes, procedures and no fixed work rules. Moreover, the working manner changes completely, and the course of the work is usually invisible, this kind of non-standard working content and non-programmed process behavior is difficult to perform process monitoring and evaluation.

2.3 Difficult measurement of the performance

Due to the special nature of R & D staff's work, their work is mainly thinking activities. Labor process is often invisible, the achievement of performance results often needs long time, and experiences a certain period of time. While some work is not great certainty, which will not produce profits immediately. Therefore, the results of work are difficult to be reflected in the short term, and more difficult to quantify.

2.4 Duality

The performance of R & D staff not only has objectivity but also has subjectivity. The objectivity on the one hand refers to the laboring results of R & D staff that do not have clear assessment criteria, but the peers are able to make the overall judgment of merits and demerits. On the other hand, it refers to the performance of R & D staff with visual and objective form of expression. Even personal thoughts, ideas, or creativity can also be expressed in an objective and clear form. The subjectivity refers to the performance evaluation about R & D staff. Even the evaluation from the peers is just qualitative and subjective, because the focus is the evaluation of the quality evaluation, thus the evaluation is not possible to be as accurate and quantitative as the measurement of labor working. The duality of R & D staff's performance characteristics demonstrates that, in evaluating the performance of R & D staff, only objective index is not feasible. However, without objectivity is also unfeasible^{[7][8]}.

2.5 Team-cooperation

The specialization of knowledge makes the value creativity of R & D staff perform in the form of division and cooperation. So, many jobs of R & D staff are finished in the form of cooperation. The labor results are the crystallization of the wisdom and the team, and the achievements of performance mostly depend on the cooperation rather than the individual strength. In the team work of R & D staff, although the achievements of team can not be separated from individual, still the team-cooperative results can barely separated to each person^[9]. Therefore, it is difficult to quantitatively define the contribution of certain person, and regard it as a basis for the evaluation of personal performance.

3 Preliminary Establishment of the Performance Evaluation Content System about R & D Staff

Aiming at the performance characteristics for R & D staff, the performance evaluation is identified, including the following aspects:

3.1 Capability

Capability reflects the possibility for individual to complete various tasks^[10].

Firstly, it includes the abilities that they have already possessed, such as professional skills, knowledge and physical ability and other static abilities.

Secondly, it refers to the capability that displays and determines the working efficiency, including innovation ability, the method to solve problems and communication capability and other apparent abilities. The evaluation of capacity not only reflects the enhancement of static ability, but also reflects the apparent ability to play the situation.

Capability means the matching between individual and job position. The right people into the right positions is critical to the capability to play, so we should pay attention to the degree of employee job competency evaluation, comparing employee's knowledge, technology and other practical working behaviors with the expected working aims and job position responsibilities. Labor productivity (input / output), professional skills, learning ability, and creativity, etc. not only reflect the capacity criteria, but also reflect the performance characteristics of R & D staff.

3.2 Attitude

Attitude refers to a more persistent and consistent internal psychological and behavioral tendencies on the outside^[11], mainly including the positivity and negativity, approval and disapproval of behaviors and responses. It embodies in the three aspects of job satisfactory, job involvement, organizational commitment. Employees with high satisfaction are positive towards their work. Job involving means the importance of performance level towards self-worth. Employees with high degree involve in a strong sense of identity and higher efficiency. Organizational commitment refers to the recognition of the individual towards organization and objectives. Only high job satisfactory and high job involvement can have higher organizational commitment. Based on the qualitative analysis of work behavior, work attitude, team spirit, and service attitude etc. can reflect the criteria of attitude. The use of performance assessment can change the job motivation of employees, thus the work attitude can be changed.

3.3 Achievements

Achievements means that organization presents the effective output in the organizational, departmental and individual level in order to achieve its goal, which is the result of organizational expectation and employee's commitment to the organization^[12]. Achievements reflects the work quality, profit level, index completion rate and so on, and embodies what we have done, how much we have done and how much contribution we have done for employees.

The specific details of performance evaluation index system for R & D staff are shown in table 1.

Table 1 Index Content of R & D Staff^[13]

Index Grade O)	R & D staff
Capability	1.The level of expertise
	2.Communication skills
	3.The training level
	4.The new project ROI
	5.Cost control
	6.Input-output ratio
	7.The ratio of views to be adopted
	8.The number of intellectual property owners
	9.Learning motivation
	10.The speed of skills to be improved
	11.The number of participating exchanges
Attitude	12.Teamwork attitude
	13.Knowledge-sharing participation
	14.Responsibility
	15.The standard degree of implementing process
	16.Absenteeism rate
	17.The degree of compliance with rules and regulations
	18.The number of customer complaints
	19.The speed and effectiveness of service
	20.The success rate of project development
Achievements	21.Technical assessment pass rate
	22.The ratio between research expense and revenue
	23.Project size
	24.Project income
	25.Project profit
	26.Project compliance rate
	27.The rate of progress of the project on time
	28.Project quality

4 Comprehensive Adjustment of Index Content Based on Applying Factor Analysis

In the previous section, we initially gained the index content system for R & D staff, but considering the index large scope, it is possible for cross and overlap between indexes. We further carry out the questionnaire and make use of factor analysis to comprehensively adjust the index system.

4.1 The design of questionnaire and the selection of sample

First, we designed the initial questionnaire. After consulting the senior human resource experts, we gained valuable advice on the aspects of index description, the additions and deletions. After further amendment, we obtained the final questionnaire of this thesis. There are twelve representative

enterprises in Beijing, Wuhan, Changsha, Liuzhou four places, where the R & D staff are used as samples of this study. I personally gave out questionnaires, sent emails and other forms of questionnaires to the above sample enterprises. There are total 120 questionnaires, of which 100 valid questionnaires are recovered. The recovery rate is 83.3%.

4.2 The method of analysis

In this paper, the author uses factor analysis, through SPSS software to statistically analyze the data in the questionnaires. The so-called factor analysis means that a number of original variables concentrate on a small number of factors with the minimal loss of information, so that factor has become of multivariate statistical analysis of certain explanatory name^[14].

The idea of factor analysis can be expressed with mathematical models. Suppose there are r variables x_1, x_2, \dots, x_r , and the mean of each variable (or after standard treatment) is 0, standard deviation is 1. Now express each original variable with linear of combining number of $p(p \leq r)$ factors f_1, f_2, \dots, f_p , we have:

$$\begin{cases} x_1 = a_{11}f_1 + a_{12}f_2 + \dots + a_{1p}f_p + \varepsilon_1 \\ x_2 = a_{21}f_1 + a_{22}f_2 + \dots + a_{2p}f_p + \varepsilon_2 \\ \vdots \\ x_r = a_{r1}f_1 + a_{r2}f_2 + \dots + a_{rp}f_p + \varepsilon_r \end{cases} \tag{1}$$

In equation (1), order:

$$X = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_r \end{pmatrix}, A = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1p} \\ a_{21} & a_{22} & \dots & a_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ a_{r1} & a_{r2} & \dots & a_{rp} \end{pmatrix}, F = \begin{pmatrix} f_1 \\ f_2 \\ \vdots \\ f_p \end{pmatrix}, \varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_r \end{pmatrix}$$

The equation (1) can be written in the following matrix form:

$$X_{r \times 1} = A_{r \times p} F_{p \times 1} + \varepsilon_{r \times 1} \tag{2}$$

In equation (2), the F is called factor, because it appears in each original variable's linear expression, so it is known as common factor. The A is called factor loading matrix. The $a_{ij} (i = 1, 2, \dots, r; j = 1, 2, \dots, p)$ is called factor loading, which is the i^{th} original variable in the j^{th} factor's loading factor. The ε is called special factor, which indicates the original variable whose part can not be explained by factors, the mean is 0.

Thus, the problem of common factor actually asks to find the matrix $A_{r \times p}$ that satisfies the above conditions.

4.3 Reliability test

Homogeny reliability method is used to test the reliability of questionnaires. This method that is used to test the internal consistency between projects is called internal consistency reliability method. This paper applies SPSS software to test the homogeny^[15]. In general, if the coefficient of Cronbach'a is no less than 0.65, it can be accepted. To the scale variables that have not yet been verified, as long as the coefficient of Cronbach'a is greater than 0.60, it is acceptable.

Table 2 Internal Consistency Reliability of the Scale

The name of scale	The coefficient of internal consistency (α)
The capability index scale of R & D staff	0.873
The capability index scale of R & D staff	0.820
The capability index scale of R & D staff	0.867

Table 2 shows that in questionnaires, the Cronbach'a coefficients of the capacity scale, the attitude scale and the performance scale are above 0.7, so it indicates that the internal consistency of the whole

questionnaire is good, and the reliability of the data from the questionnaire is higher.

4.4 The test of the applicability

The correlations between the variables have the ability of analysis and the results have the practical basic premise, or else, common factors can not be extracted. Therefore, the correlation test is necessary for the analysis. At current, tests that use factor analysis test are Bartlett test and KMO test, of which, Bartlett sphericity test is used to judge whether the relative coefficient factor matrix is the unit matrix. If the observation of the statistics is relatively large, and the corresponding possibility P value is less than a given significant level α , then the original variable is suitable for factor analysis. On the contrary, it is not suitable for factor analysis. The test of KMO is used to compare the index between the simple correlation coefficient of variables and partial correlation coefficient of variables. KMO value is closer to 0. The original variable is not suitable for the factor analysis. The value above 0.9 is very suitable; the value of 0.8 is suitable. The value of 0.7 means the general, while the value of 0.6 is not suitable, and the value of no more than 0.5 is not proper.

4.5 Factor analysis

In this thesis, the author adopts the maximum likelihood method to estimate the factor loading matrix, using factor analysis extracts the common factors whose eigenvalue is more than 1 in order to easily name and explain common factors ,and then treat the common factors using the method of orthogonal rotation(maximum variance method).Observe each scale table ,according to the key index principle and each factor loading scale on each dimension ,and then delete the unreasonable factors so as to make sure that the scale tables which are more suitable for the index system in requirements of contents and construct.

4.5.1 The analysis of ability index

We analyzed the main component factor analysis of the 11 indexes of the ability performance scale tables of R & D staff, the results of the analysis are shown in table 3.

The analysis results show that except for the loading scale of the index “number of participating in exchange” in all dimension is less than 0.5, the rest of indexes in each dimension’s loading scale is more than 0.5.Through analysis, the index of “the number of participating in exchanges” and the index of “active learning” are overlapped, so we delete the index of “the number of participating in exchanges”, and keep the rest of indexes.

Table 3 KMO & Bartlett Sphericity Test of Capability Performance Scale about R & D Staff

The capabilities performance about R & D staff	Component			
	1	2	3	4
The level of expertise	.894	.295	.172	.245
The ability to communicate with people	.842	.351	.288	.277
The level of training	.814	.137	.424	.117
ROI	-.146	.960	-.215	-.072
Cost control rate	-.257	.944	-.022	-.039
Input-output ratio	-.133	.831	-.312	-.124
The rate of accepted views	.083	.099	.903	.156
The number of intellectual property rights	.446	.319	.771	.112
Active learning	.116	-.377	.170	.794
The speed of improving skills	.275	.274	.224	.862
The number of participating in exchanges	.260	.297	.341	.154
KMO=0.837, Sig=0.000, Cumulative%=84.313%				

Note: Factor extraction method is principle component analysis. Rotation method is the maximum standard deviation method. The rotation frequency is 6 times.

It can be seen from table 3 that the projects of the first factor are associated with the professional skills of experts, including professional knowledge , the ability of communicating with people and the level of training, their factor loading scales are 0.894, 0.842 and 0.814 respectively, thus it can be named professional skills; The second factor is related to labor productivity, including the return on investment of new projects(ROI),cost control and input-out ratio, their factor loading scales are 0.960, 0.944 and 0.831 respectively, so it can be called labor productivity; The projects of the third factor are related to the innovation capability of R & D staff, including the rate of accepted views and the number of intellectual property, their factor loading scales are 0.903 and 0.771 respectively, therefore, it can be called the innovation capability; The projects of the fourth factor relating to the learning ability of the R

& D staff include the activity of learning and the speed of improving skills, the factor loading scales of them are 0.794 and 0.862 respectively, thus, it can be named learning capability. The value of KMO is 0.837, which is more than 0.6, indicating that the sample rate is high; the associated probability of the spherical test is 0.000, less than the significant level 0.01; the factor cumulative variance contribution rate is 84.313%, which can explain most variances. Ultimately, this scale table is divided into four dimensions, ten indexes, and the construct validity of this scale table is quite good.

4.5.2 The analysis of the attitude index

We analyzed the eight topics of the attitude performance scale table about the R & D staff; the results of the analysis are shown in table 4.

Table 4 KMO & Bartlett Sphericity Measure of Attitude Performance Scale about R & D Staff

Attitude performance index about R & D staff	Component		
	1	2	3
The attitude of team-cooperation	-.053	.884	.138
Participating degree in knowledge sharing	.010	.848	.123
Responsibility	-.375	.685	.084
The degree of implementing the standard process	.867	-.151	-.020
Absenteeism rate	-.066	-.026	-.139
The degree of compliance with the rules and regulations	.912	-.090	-.132
The number of customer complaints	-.015	.128	.982
The speed and effectiveness of service	-.135	.211	.964

KMO=0.800, sig=0.000, Cumulative%=73.959%

Note: Factor extraction method is principle component analysis. Rotation method is the maximum standard deviation method, the rotation frequency is 5 times.

The analysis results show that except for the index “absenteeism rate” in all dimension’s loading scale is less than 0.5, the rest of indexes in each dimension’s loading scale is more than 0.5. Through analysis, the index of “absenteeism rate” and the index of “the degree of compliance with the rules and regulations” are overlapped, so we delete the index of “absenteeism rate”, and keep the rest of indexes. It can be seen from table 4 that the projects of the first factor are associated with the attitude of experts, including the degree of compliance with the rules and regulations and the degree of implementing the standard process, their factor loading scales are 0.912 and 0.867 respectively, thus it can be named work attitude; The second factor is related to team spirit, including the attitude of team-cooperation, degree of participating in sharing knowledge, the responsibility, their factor loading scale are 0.884, 0.8448 and 0.685 respectively, so it can be called team spirit; The projects of the third factor are related to the service attitude to customers of R & D staff, including the number of customer complaints, the speed and effectiveness of service, their factor loading scales are 0.982 and 0.964 respectively, therefore it can be called the service attitude; The value of KMO is 0.800, which is more than 0.6, indicating that the sample rate is high; the associated probability of the spherical test is 0.000, less than the significant level 0.01; the factor cumulative variance contribution rate is 73.959%, which can explain most variances. Ultimately, this scale table is divided into three dimensions, seven indexes, and the construct validity of this scale table is quite good.

4.5.3 The analysis of performance index

We analyzed the principal component factor analysis of the 9 indexes of the performance scale tables about R & D staff, the results of the analysis are shown in table 5.

The analysis results show that except for the index “the on time rate of R & D projects” in all dimension’s loading scale is less than 0.5, the rest of indexes in each dimension’s loading scale is more than 0.5. Through the analysis, the index of “the compliance rate of R & D projects” may include “the on time rate of R & D projects”, so we delete this index of “the on time rate of R & D projects”, and keep the rest of indexes.

It can be seen from table 5 that the projects of the first factor are associated with the profit condition of experts, including the profit, the scale and the revenue of the R & D projects, their factor loading scales are 0.942, 0.923 and 0.966 respectively, thus it can be named profit; The second factor is related to the development condition of new projects, including the success rate of R & D projects, expense-revenue ratio and the accreditation pass rate, their factor loading scales are 0.792, 0.857 and 0.963 respectively, so it can be called the new project development; The projects of the third factor are related to the work effect of R & D staff, including the compliance rate of R & D projects and the

quality of R & D projects, their factor loading scales are 0.984 and 0.897 respectively, therefore it can be called work effect; The value of KMO is 0.821, which is more than 0.6, indicating that the sample rate is high; the associated probability of the spherical test is 0.000, less than the significant level 0.01; the factor cumulative variance contribution rate is 72.689%, which can explain most variances. Ultimately, this scale table is divided into three dimensions, eight indexes, and the construct validity of this scale table is quite good.

Table 5 KMO & Bartlett Sphericity Measure of Results Scale about R & D Staff

The performance index about R & D staff	Component		
	1	2	3
The projects development success rate about R & D staff	.454	.792	.167
The accreditation pass rate	.165	.963	.121
The expense-revenue ratio	.165	.857	.121
The scale of R & D projects	.923	.157	.154
The revenue of R & D projects	.966	.201	.035
The profit of R & D projects	.942	.201	.035
The compliance rate of R & D projects	.081	.094	.984
The on time rate of R & D projects	.037	.252	.303
The quality of R & D projects	.081	.094	.897

KMO=0.821, Sig=0.000, Cumulative%=72.689%

Note: Factor extraction method is principle component analysis. Rotation method is the maximum standard deviation method. The rotation frequency is 5 times.

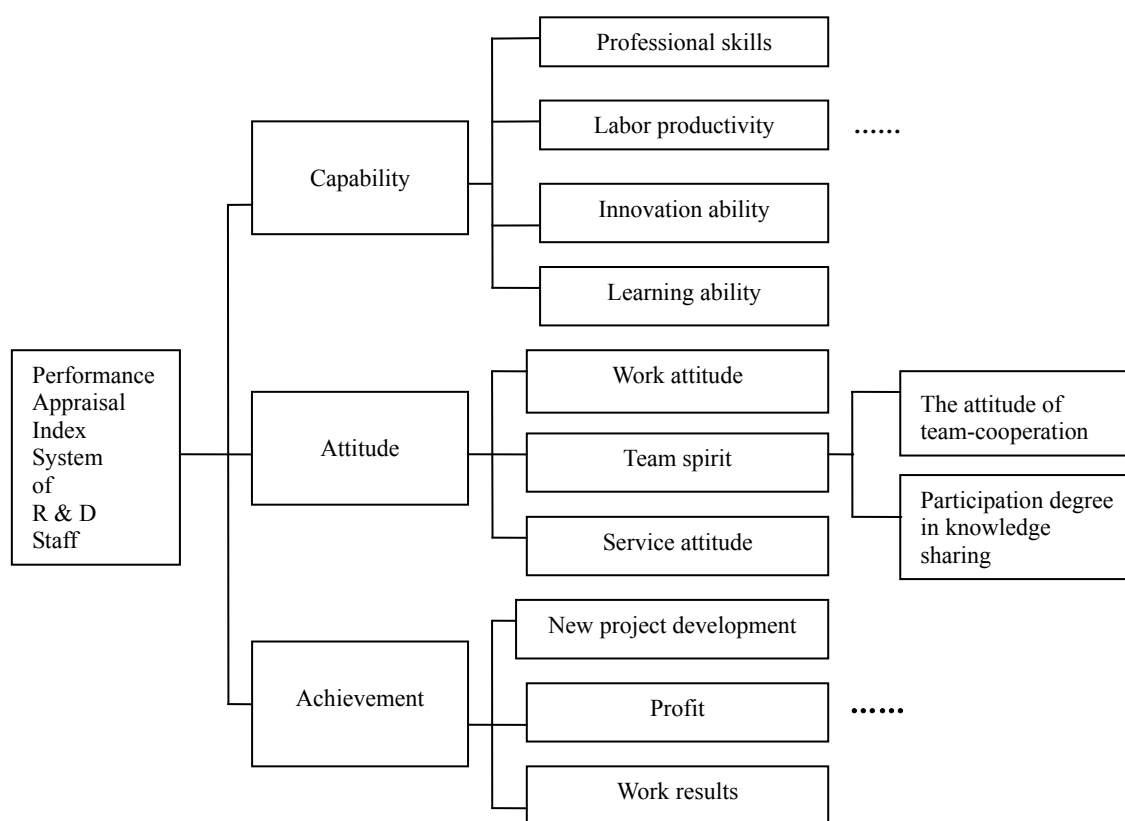


Figure 1 Performance Appraisal Index System of R & D Staff

4.5.4 The performance appraisal index system of R & D staff after adjustment

According to the above analysis of the performance evaluation dimensions for R & D staff,

learning ability, innovation ability, labor productivity and professional skills is the first specific index layer of ability dimension, work attitude, team spirit and service attitude is the first concrete index layer of attitude dimension, and new project development, profitability and work results are the first concrete index layer of performance dimension. Therefore, in the light of the goal of making the ultimate decision (performance evaluation scores of R & D staff), we can establish the following evaluation index system (as shown in Figure 1).

5 Conclusion

R & D staff, as a special group belonging to enterprise employees, is engaged in creative work. They are the source of business innovation and the key for its development. In the era of knowledge economy, how to develop each R & D staff's creativity and enthusiasm is the key factor to enhance the core competitiveness and achieve sustainable development of enterprises. Therefore, it is of a very real sense to establish a reasonable index system for R & D staff. In this paper, we adopted both qualitative and quantitative methods. We established an initial index content system; and then made a comprehensive adjustment of the index content by factor analysis method; in the end we determined a performance appraisal index system of R & D staff. It is operational in the actual performance assessment of enterprises, and has a potential market value.

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