University Teachers' Performance Comprehensive Evaluation Based on Principal Component Analysis

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Abstract

The performance of college teachers may affect the development of the university and individual progress at the aspect of teaching and research, so the effective evaluation should consider all the above factors and achieve a satisfied result. In the paper, an evaluation system is, firstly, designed according to three aspects including teaching, research and the development of the subject or major to improve the scientific nature and feasibility of the evaluation of the performance of college teachers. Secondly, the multiple indexes may affect the final evaluation results, then it is necessary to select some of the indexes to make evaluation easily. The principal component analysis is adopted for data dimensionality reduction. Thirdly, the paper proposes seven methods to make a comprehensive evaluation, and the he final sorting result is also given by comparing different methods' outputs and integrating them. Finally, an example illustrates the feasibility and availability of the proposed methods.

Key words: College teachers; Performance evaluation; Principal component analysis; Ideal point method

INTRODUCTION

With constant and deep development of the reform of the personnel system in universities, an increasing number of universities are considering reforming their personnel system. Through scientific, fair and rigorous assessment, the enthusiasm of college teachers is stimulated, the plan for their career is easy to conduct and the job performance of them is prompted to improve (Wu, 2010).

Currently, teachers' performance appraisal is becoming a hot issue about personnel system reform. Liu and Chen (2007). aimed at the problems within performance appraisal system illustrated the principles, index system and the weights of science and technology performance appraisal. Fang et al. (2006) reformed the traditional evaluation methods based on principles of university performance appraisal, and constructed an index system. Lin (2011) analyzed university and college performance appraisal current conditions, and presented an approach to build an evaluation index system in response to the existing problems. Li. (2010) considered the characteristics of teaching-oriented universities, and discovered the system which is more operational in teaching-oriented universities' performance appraisal, then the article used the index system to build detailed measurement methods of performance appraisal. Yu (2008) tried to introduce the company performance appraisal management to university teachers' performance appraisal management, especially introduced Key Performance Indicator (KPI) and Balanced Score Card (BSC), based on the characteristics of universities, the article constructed a teachers' performance appraisal management system which fits the development of University of Dalian better, expecting to provide some reference and example for teachers' performance appraisal management. Zhou (2009) builted a university teachers' performance appraisal index system in complex visual threshold.

The references mentioned above are of high value as example to university teachers' performance appraisal

system. However, these articles didn't conduct enough detailed research on screening the indexes, and the indexed are always too many to evaluate effectively. This article first review the existing references and then build the university teachers' performance appraisal system, and use the PCA method to screen the indexes and comprehensively evaluate the teachers using the ideal point method.

1. CONSTRUCTION OF EVALUATION INDEX SYSTEM

The design of performance appraisal evaluation index system is actually a construction of a measure of value, and the measure of value is then compared to the teachers' performance, the evaluation results based on the measure of value could be obtained. Three aspects will be included in the evaluation index system based on the understanding of university functions, they are teaching, scientific research and development of professional subjects. Teaching provide the students with high level education service, while the science research is an approach to improve the education level and is one of the developing direction of the teachers. The development of professional subjects is what the teachers contribute to the future of their university. Only when these three aspects developed together, can be the evaluation of the teachers be more objective and can the teachers improve with the university better.

Referring to the existing articles, the teaching performance is usually divided into these aspects: teaching routine, students' evaluation of teaching, recognition of supervisor and teachers' mutual evaluation. The classroom teaching, preparation notes for class and the evaluation for homework and examinations are always included in the teaching routine. Students' evaluation of teaching is a marking process for teachers' education attitude, approaches and results; recognition of supervisor is always conducted by the supervisor of the teacher's staff room and usually include the similar education aspects as is in the students' evaluation process. Teachers' mutual evaluation is always processed by other teachers in the same staff room by attending to the teacher's class.

The evaluation index of scientific research is mainly:
a) In the aspect of academic journals, the number of science papers published annually, and the number is calculated by equivalent.
b) In the aspect of scientific research project, the quantity and quality of the scientific research project the teacher took charge or participated in.
c) In the aspect of academic conference, the times the teacher attended to the international or domestic academic conferences and the number of the subject speech the teacher made in those conferences.

d) In the aspect of advanced and visiting studies, the advanced and visiting studies of the teacher in the home and foreign universities.

The development of professional subjects includes the number of the course construction the teacher involved in (course construction), the quantity of the multi-level-course construction the teacher involved in (subject construction), and the basic condition of the profession construction the teacher participated in (profession construction).

Although the performance appraisal of the teachers is divided in to three parts, different universities do not emphasis on same points, especially when there's a high quantity of data, for an instance, some teacher may not participate in completion instructions. As a result, the evaluation should base on the data, screen the indexes and set the number of the indexes as small as possible, then the evaluation process can be processed more effectively.

2. THE INDEX-DIMENSION-DESCEND BASED ON PCA

Principal Component Analysis (PCA) is a commonly used multivariate statistical method, it is widely used in the evaluation of related problems in sociology, economy and management, and it gradually becomes a multi-index evaluation technique of actual value (Zhang, 2010).

PCA studies the way to illustrate the structure of multivariate variance-covariance through some minority principal components. In detail: export the minority principal components and try to keep their source information, and make them irrelevant to each other. The main steps are:

a) Collecting the samples when the index is selected. n schemes and p indexes composite the sample original matrix:

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{pmatrix}_{n \times p} .$$

In which, x_{ij} is the jth index of the ith scheme (i=1,2,$\cdots$, n; j=1, 2,$\cdots$, p).

b) Standardizing the indexes to make the dimensions conistent. The standardization equation is as follows:

$$y_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j} .$$

In which

$$\bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}, \quad s_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2} \ (i=1,2,\cdots,n;$$

j=1,2,$\cdots$, p) .

The new matrix after transform is $Y=(y_{ij})$ and the sum of its columns is 0, and the column standard deviation is 1.

c) Calculating the covariance matrix S of Y.

$$s_{ij} = \frac{1}{n}\sum_{k=1}^{n} y_{ki}y_{kj} \ (k=1,2,\cdots,n) \ .$$

d) Calculate root λ of S and the related characteristic vector u.

Set $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_p \geq 0$, then the ith principal component is $z_i = u'_i X$

e) Choosing the first m principal components to construct comprehensive evaluation functions.

The principle is $\beta_m = \sum_{i=1}^{m}\lambda_i \bigg/ \sum_{i=1}^{p}\lambda_i \geq 85\%$ $(1 \leq m < p)$.

Then the first m principal components are $z_1, z_2, \cdots, z_m$, and 85% or more information is kept of p original indexes.

3. COMPREHENSIVE EVALUATION AFTER INDEX DIMENSION-DESCEND

Form the one-way principal component decision matrix

$$\hat{U} = \left[\overset{\wedge}{u_{ij}}\right]_{n \times m}, \overset{\wedge}{u_{ij}} = u_{ij} - \min_i\{u_{ij}\}.$$

Totally, it can be divided into 7 patterns:

a) The value function depending on the first principal component

$$s_{1i} = \overset{\wedge}{u_{i1}} \ ;$$

b) Weighted maximum principal component value function

$$s_{2i} = \max_j(\overset{\wedge}{u_{ij}});$$

c) Weighted principal component and value function model

$$s_{3i} = \sum_{j=1}^{m} w_j \overset{\wedge}{u_{ij}};$$

d) Weighted principal component Euclidean distance value function model

$$s_{4i} = (\sum_{j=1}^{m} w_j \overset{\wedge}{u_{ij}^2})^{0.5} \ ;$$

e) Weighted principal component S space distance value function model

$$s_{5i} = \sum_{j=1}^{m} w_j \frac{1}{2^j} \times \frac{\overset{\wedge}{u_{ij}}}{1+\overset{\wedge}{u_{ij}}} \ ;$$

f) Weighted principal component inner product value function

$$v_{ij} = w_j \overset{\wedge}{u_{ij}}, v^+ = (v_1^+, \ldots, v_m^+)$$

$$v_j^+ = \max_i(v_{ij});$$

$$v^- = (v_1^-, \ldots, v_m^-), v_j^- = 0$$

$$s_{6i} = \sum_{j=1}^{m} v_{ij}v_j^+ \ ;$$

g) Weighted principal component ideal point model

$$s_{7i}^+ = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^+)^2},$$

$$s_{7i}^- = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^-)^2}, s_{7i} = \frac{s_{7i}^-}{s_{7i}^- + s_{7i}^+}.$$

The 7 different methods may get different sorting results. Let the sorting result from k^{th} comprehensive evaluation method be S_{ki}, $k \in (1, 2, 3, 4, 5, 6, 7)$ then the sorting difference between two arbitrary methods is:

$$D_{kl} = (s_{ki} - s_{li})^2, l \in (1, 2, 3, 4, 5, 6, 7) \ .$$

After having calculated the difference between each method and the other methods individually, we could calculate the two-two difference between the methods, and choose the smallest difference between one or more comprehensive evaluation methods and other methods as the best result.

4. DEMONSTRATION STUDIES

After having conducted performance evaluation within 30 teachers in the education faculty of one university, the unity matrix is shown in Table 1:

Table 1
Unity Values of Performance Evaluation Index

	Index1	Index2	Index3	Index4	Index5	Index6	Index7	Index8	Index9	Index10	Index11	Index12
1	0.014	0.048	0.000	0.071	0.005	0.029	0.051	0.094	0.052	0.029	0.000	0.014
2	0.036	0.035	0.026	0.010	0.046	0.000	0.031	0.013	0.011	0.035	0.065	0.036
3	0.037	0.032	0.000	0.022	0.006	0.257	0.020	0.038	0.023	0.033	0.043	0.037
4	0.046	0.026	0.026	0.014	0.025	0.029	0.033	0.006	0.023	0.034	0.067	0.046
5	0.014	0.014	0.000	0.036	0.015	0.000	0.004	0.078	0.072	0.030	0.001	0.014
6	0.009	0.008	0.026	0.071	0.034	0.000	0.032	0.031	0.023	0.032	0.016	0.009
7	0.011	0.011	0.079	0.142	0.064	0.086	0.031	0.047	0.043	0.031	0.101	0.011

Continued

	Index1	Index2	Index3	Index4	Index5	Index6	Index7	Index8	Index9	Index10	Index11	Index12
8	0.017	0.046	0.079	0.024	0.061	0.086	0.012	0.016	0.043	0.033	0.010	0.017
9	0.006	0.041	0.026	0.000	0.005	0.000	0.055	0.016	0.011	0.030	0.027	0.006
10	0.041	0.053	0.053	0.007	0.046	0.029	0.020	0.013	0.032	0.031	0.032	0.041
11	0.025	0.046	0.026	0.040	0.067	0.000	0.052	0.038	0.034	0.034	0.083	0.025
12	0.130	0.005	0.000	0.000	0.000	0.029	0.000	0.003	0.009	0.041	0.000	0.130
13	0.017	0.027	0.053	0.100	0.051	0.057	0.061	0.063	0.032	0.033	0.083	0.017
14	0.055	0.018	0.079	0.000	0.046	0.000	0.016	0.056	0.043	0.037	0.033	0.055
15	0.107	0.035	0.026	0.014	0.041	0.029	0.037	0.019	0.055	0.033	0.034	0.107
16	0.018	0.047	0.026	0.000	0.006	0.000	0.055	0.047	0.034	0.033	0.000	0.018
17	0.044	0.045	0.000	0.071	0.003	0.000	0.008	0.016	0.009	0.034	0.000	0.044
18	0.019	0.005	0.026	0.003	0.015	0.000	0.017	0.050	0.052	0.031	0.000	0.019
19	0.028	0.026	0.026	0.014	0.052	0.057	0.050	0.038	0.023	0.028	0.073	0.028
20	0.049	0.060	0.000	0.000	0.018	0.029	0.028	0.009	0.017	0.033	0.000	0.049
21	0.024	0.043	0.053	0.036	0.038	0.029	0.025	0.016	0.043	0.032	0.083	0.024
22	0.028	0.040	0.105	0.006	0.041	0.000	0.025	0.088	0.052	0.031	0.015	0.028
23	0.000	0.000	0.026	0.000	0.015	0.029	0.009	0.034	0.049	0.039	0.002	0.000
24	0.038	0.011	0.026	0.000	0.005	0.057	0.012	0.016	0.011	0.033	0.060	0.038
25	0.058	0.004	0.026	0.024	0.071	0.057	0.027	0.034	0.032	0.032	0.029	0.058
26	0.024	0.144	0.026	0.119	0.040	0.029	0.012	0.016	0.052	0.041	0.069	0.024
27	0.015	0.026	0.026	0.083	0.038	0.000	0.023	0.038	0.037	0.034	0.000	0.015
28	0.031	0.030	0.053	0.043	0.044	0.000	0.021	0.025	0.020	0.033	0.004	0.031
29	0.037	0.049	0.079	0.006	0.038	0.000	0.189	0.016	0.034	0.032	0.014	0.037
30	0.024	0.024	0.000	0.044	0.061	0.086	0.042	0.031	0.029	0.037	0.055	0.024

Using PCA, the component matrix of 5 principle components is shown in Table 2:

Table 2
Component Matrix

Variable	1	2	3	4	5
VAR00001	-0.834	0.181	0.273	0.284	0.187
VAR00002	0.116	0.366	-0.209	0.183	-0.701
VAR00003	0.452	0.296	0.623	0.156	0.034
VAR00004	0.495	0.388	-0.469	0.206	-0.056
VAR00005	0.402	0.666	0.325	0.152	0.214

To be continued

Continued

Variable	1	2	3	4	5
VAR00006	-0.042	0.273	-0.424	-0.266	0.558
VAR00007	0.234	0.119	0.553	-0.407	-0.328
VAR00008	0.625	-0.453	0.002	0.315	0.309
VAR00009	0.542	-0.197	0.075	0.668	0.092
VAR00010	-0.484	0.326	-0.287	0.434	-0.242
VAR00011	0.254	0.776	-0.106	-0.184	0.234
VAR00012	-0.834	0.181	0.273	0.284	0.187

Then the unity matrix can be converted to Table 3:

Table 3
Converted Table

Teach.	1	2	3	4	5	Teach.	1	2	3	4	5
1	0.3333	0.1602	0.1255	0.0268	0.1235	16	0.2639	0.1115	0.1683	0.0356	0.1572
2	0.2295	0.0749	0.1683	0.0943	0.1207	17	0.1988	0.0757	0.0989	0.0418	0.0557
3	0.2107	0.1681	0.0024	0.1073	0.0944	18	0.2662	0.0882	0.1632	0.0176	0.1364
4	0.2078	0.0762	0.1389	0.0910	0.0961	19	0.2758	0.1258	0.1553	0.1044	0.1347
5	0.3065	0.1008	0.1509	0.0019	0.1209	20	0.1666	0.0774	0.1196	0.0386	0.0979
6	0.3041	0.1222	0.1705	0.0675	0.1043	21	0.2949	0.1036	0.1817	0.1134	0.1100
7	0.4114	0.1894	0.1569	0.1615	0.0681	22	0.3324	0.1237	0.1820	0.0460	0.1690
8	0.2978	0.1423	0.1768	0.0868	0.1195	23	0.2776	0.0933	0.1734	0.0384	0.1495
9	0.2590	0.1013	0.1829	0.0744	0.1610	24	0.1969	0.0672	0.1051	0.0866	0.1146
10	0.2354	0.0932	0.1644	0.0739	0.1095	25	0.2201	0.1091	0.1242	0.0603	0.0808
11	0.3105	0.1195	0.1992	0.1075	0.1255	26	0.3313	0.1333	0.1699	0.1211	0.0548
12	0.0000	0.0000	0.0000	0.0000	0.0000	27	0.3088	0.1269	0.1664	0.0510	0.0883
13	0.3722	0.1787	0.1552	0.1313	0.1073	28	0.2609	0.1040	0.1641	0.0590	0.1029
14	0.2468	0.0801	0.1534	0.0499	0.1235	29	0.2876	0.2027	0.2385	0.0868	0.1557
15	0.1327	0.0687	0.0924	0.0318	0.0267	30	0.2761	0.1410	0.1403	0.1004	0.1049

The results of the 7 comprehensive evaluation methods of PCA, the evaluation results are shown in Table 4:

Table 4
The Evaluation Results 7 Comprehensive Evaluation Methods

Teachers	1	2	3	4	5	6	7
1	0.3065	0.3065	0.162207	0.196419	0.048317	0.013759	0.804705
2	0.1546	0.1546	0.077049	0.099494	0.024844	0.006649	0.64263
3	0.2083	0.2083	0.133778	0.152724	0.038039	0.009924	0.468264
4	0.1316	0.1316	0.059911	0.081323	0.021166	0.005541	0.524917
5	0.3046	0.3046	0.165626	0.198009	0.047555	0.013686	0.713509
6	0.2366	0.2366	0.114107	0.14689	0.037312	0.010279	0.809986
7	0.3433	0.3433	0.170414	0.213727	0.051576	0.015052	0.938719
8	0.211	0.211	0.10287	0.131349	0.03421	0.009209	0.850843
9	0.1846	0.1846	0.098352	0.12127	0.030206	0.008155	0.762796
10	0.1615	0.1615	0.078838	0.10228	0.026465	0.006989	0.645367
11	0.203	0.203	0.08912	0.1243	0.031075	0.008538	0.883415
12	0	0	0	0	0	0	0
13	0.2649	0.2649	0.116474	0.159245	0.040238	0.011258	0.94193
14	0.1969	0.1969	0.100598	0.125993	0.031711	0.008614	0.62961
15	0.106	0.106	0.056533	0.070051	0.01973	0.00479	0.174569
16	0.2283	0.2283	0.132493	0.154533	0.038189	0.010435	0.727819
17	0.157	0.157	0.071885	0.095788	0.025947	0.006731	0.356759

Continued

Teachers	1	2	3	4	5	6	7
18	0.2486	0.2486	0.139998	0.165833	0.040385	0.011244	0.668267
19	0.1714	0.1714	0.075352	0.103063	0.027071	0.007219	0.802611
20	0.128	0.128	0.073345	0.086339	0.023036	0.005829	0.349854
21	0.1913	0.1913	0.08013	0.115959	0.028856	0.007922	0.827694
22	0.2864	0.2864	0.153331	0.185149	0.044568	0.012762	0.867205
23	0.2392	0.2392	0.130636	0.157437	0.038418	0.010692	0.737728
24	0.1297	0.1297	0.059631	0.079442	0.020599	0.005437	0.452491
25	0.1598	0.1598	0.078054	0.099533	0.027186	0.006998	0.529319
26	0.2765	0.2765	0.1391	0.173426	0.043321	0.012141	0.850415
27	0.2578	0.2578	0.127945	0.161794	0.040831	0.011329	0.788173
28	0.2019	0.2019	0.101597	0.127904	0.032946	0.00886	0.694232
29	0.2008	0.2008	0.127531	0.144967	0.036914	0.009604	0.909684
30	0.1757	0.1757	0.075507	0.10532	0.028247	0.007427	0.775678

Depending on the results above, the results from the first and the second method are identical, and the other 5 methods have the smallest difference with other methods, which is 40.14. As a result, the sorting result from the fifth method is the final result.

CONCLUSION

In modern society, the main difficulties exist in many universities in China, which are how to make comprehensive and scientific evaluation for the teachers. Based on their main task, the paper divides the factors into three parts, which are teaching, scientific research and development of professional subjects. Teaching may be the basic job, and research will improve the effect of teaching because some development in the area could modify corresponding theory and practice. The development of professional subjects is the contribution the teacher proposes for the university.

The initial twelve indexes have been modified through the principal component analysis, and seven indexes may be the final evaluation indexes, which have been proved effectively and feasibly.

In the example, twenty-six teachers have been considered as the samples. It is obvious that different methods will develop evaluation results. The best methods have been selected through comparing the differences among different results, which could make sure the scientific processes and put the results accepted by more persons into practices. The procedure will reduce the subjective characteristic and enhance the objectiveness.

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