An evaluation model of teaching quality of universities based on multi-index fuzzy decision analysis method

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Abstract

Teaching quality of universities is affected and restricted by many types of factors, thus evaluation of teaching quality of universities is of great importance to enhance teaching quality and ability. For this reason, this paper studies teaching quality of universities and proposes an evaluation model based on multi-index fuzzy decision analysis method. By analysing many factors that can affect the improvement of teaching quality of universities, an evaluation model of teaching quality with hierarchical structure is established and different types of evaluation indexes in this evaluation index system are normalized. On the basis of the Fuzzy system theory, Fuzzy memberships of relevant evaluation indexes are constructed, after which weights of these indexes are gained based on the entropy weight. And then a multi-index Fuzzy decision analysis matrix and related Fuzzy correlation degrees of universities' teaching quality are generated. Therefore the level of teaching quality of universities is obtained. The paper also attempts to test the effectiveness of the proposed model and algorithm via specific case studies.

Keywords: teaching quality; higher school; multi-index decision analysis; fuzzy system theory; evaluation model

1 Introduction

With socioeconomic level of modern society continues improving and evolving, universities' talents cultivation tends to be more and more socialized and generalized, focusing more on quality education. Enhancing teaching quality of universities to cultivate qualified, sociable and all-round talents is a complicated and systematic project. Thus it is of great theoretical significance and application value to launch the discussion about the methods of evaluating teaching quality and deepening educational reform within universities [1-3]. So far, some researches and investtigations have been conducted to address the questions about how to enhance teaching quality and how to evaluate teaching quality [4-8]. There are some valuable investigation results; however, it is still hard to formalize the evaluation model due to the fact that teaching quality is affected by many factors. Some evaluation indexes are recessive, fuzzy, complicated and it is not easy to obtain accurate results. Meanwhile, due to the different perspectives and starting points of the researchers while they were dealing with the issues, the various evaluation models focus on different things. Therefore, the models have limitations and fail to evaluate and analyse teaching quality integrally, comprehensively and consistently. This thesis, on the basis of other research papers, attempts to analyse the evaluation of teaching quality of universities from the perspective of multi-index Fuzzy decision analysis [9-12] and constructs a scientific, reasonable and objective evaluation model of teaching quality of universities. The purpose is to establish an evaluation model based on Fuzzy theory, offering new insights and methodologies to evaluate teaching quality of universities.

2 An evaluation model of teaching quality of universities

The selection of the evaluating indexes of universities' teaching quality needs to follow some basic principles so that the construction of the model is scientific, objective and comprehensive.

(1) Principle of science: the selection of teaching quality evaluation indexes should be suitable for the current quality education in universities. The indexes must be selected from scientific and reasonable perspectives.

(2) Principle of integrity: while choosing the evaluation indexes, it is important to not only consider about the internal factors of education implementation, but also to analyse integrally the influential factors in the external environment.

(3) Principle of comprehensiveness: the selection must give considerations to both the existing effects and restrictions of universities and teachers as well as the students.

(4) Principle of objectivity: the selection needs to accord with the practical situation of education implementation in universities. It is not proper to set the indexes according to subjective wishes instead of objective facts.

(5) Principle of convertibility: the different types of indexes chosen should be able to be converted and measured after conversion, thus implementation of the evaluation model would be effective and operable.

Based on the principles above, this thesis proposes a new type of evaluation model of teaching quality of universities as is demonstrated in Table 1.

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TABLE 1 an evaluation model of teaching quality of universities

System	First class criterion	Second class criterion	Type of Criterion
An evaluation model of teaching quality of universities P	Basic teaching capacity P_1	Basic teaching ability p_{11}	Fuzzy
		Advanced teaching methods p_{12}	Fuzzy
		Flexible teaching approach p_{13}	Fuzzy
		Rational basic course design p_{14}	Fuzzy
		Complete teaching content p_{15}	Fuzzy
	Professional teaching capacity P_2	Rational professional course design p_{21}	Fuzzy
		Curriculum design of professional courses p_{22}	Fuzzy
		Training of professional knowledge p_{23}	Fuzzy
		Integration of professional knowledge p_{24}	Fuzzy
		Development of professional courses p_{25}	Fuzzy
	Input in teaching P_3	Financial investment p_{31}	Fuzzy
		Number of educational reform projects p_{32}	Accurate
		Number of quality courses p_{33}	Accurate
		Level of teaching hardware facilities p_{34}	Fuzzy
		Proportion of teachers with high-grade professional titles in all teaching staff p_{35}	Accurate
		Number of scientific contests p_{36}	Accurate
	Ability training capacity P_4	Innovation ability p_{41}	Fuzzy
		Practical ability p_{42}	Fuzzy
		Self-studying ability p_{43}	Fuzzy
		Scientific research ability p_{44}	Fuzzy
		Number of scientific awards p_{45}	Accurate
		Number of papers and patents p_{46}	Accurate
	Teaching output P_5	Capability of transferring S&T into productivity p_{51}	Accurate
		Social satisfaction p_{52}	Fuzzy
		training ability of talents programs p_{53}	Fuzzy
		Number of educational reform awards p_{54}	Accurate
		Number of papers and monographs on educational reform p_{55}	Accurate

3 Multi-index Fuzzy decision analysis and evaluation of teaching quality of universities

3.1 UNIFORM SCALE PROCESS OF EVALUATION INDEXES OF TEACHING QUALITY

Evaluation of teaching quality of universities is affected by various types of evaluation indexes, among which some have accurate parameter values while others are fuzzy and can only be described qualitatively. Some indexes are of benefit-type, which means that the bigger they are the better; while some are of cost-type, so the smaller the better. To make the evaluations of teaching quality more practical, it is necessary to generate a uniform scale. It can be achieved by the uniform scale process of different evaluation indexes of teaching quality.

The membership value of evaluation index i to the membership level j of teaching quality is c_{ij} . If the index is of benefit-type, then the standardized parameter value v_i is:

$$v_i = \frac{u_i - \min\limits_{1\le j\le n}\left(c_{ij}\right)}{\max\limits_{1\le j\le n}\left(c_{ij}\right) - \min\limits_{1\le j\le n}\left(c_{ij}\right)} \tag{1}$$

And if the index is of cost-type, then the standardized parameter value v_i is:

$$v_i = \frac{\max\limits_{1\le j\le n}\left(c_{ij}\right) - u_i}{\max\limits_{1\le j\le n}\left(c_{ij}\right) - \min\limits_{1\le j\le n}\left(c_{ij}\right)} \tag{2}$$

3.2 WEIGHT ALLOCATION OF EVALUATION INDEXES OF TEACHING QUALITY

Different evaluation indexes of teaching quality often have different weights. Traditional methods of allocating weight are too subjective. Correlated characteristics of the indexes are often ignored by traditional methods. To solve this problem, this paper chooses to distribute the indexes in

forms of information entropy. If there are m evaluation indexes and n objects to be evaluated, the evaluation data matrix $\boldsymbol{A}$ is:

$$\boldsymbol{A}=\begin{vmatrix} a_{11} & \cdots & a_{1i} & \cdots & a_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ a_{i1} & \cdots & a_{ii} & \cdots & a_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ a_{m1} & \cdots & a_{mi} & \cdots & a_{mn} \end{vmatrix} \tag{3}$$

If the parameter value a_{ij} in the matrix is of benefit-type, then the standardized value x_{ij} of it is:

$$x_{ij}=\frac{a_{ij}-\min\limits_{1\le j\le n}\left(a_{ij}\right)}{\max\limits_{1\le j\le n}\left(a_{ij}\right)-\min\limits_{1\le j\le n}\left(a_{ij}\right)} \tag{4}$$

And if it is of cost-type, then the standardized value x_{ij} is:

$$x_{ij}=\frac{\max\limits_{1\le j\le n}\left(a_{ij}\right)-a_{ij}}{\max\limits_{1\le j\le n}\left(a_{ij}\right)-\min\limits_{1\le j\le n}\left(a_{ij}\right)} \tag{5}$$

The corresponding information entropy H_i of evaluation index i is:

$$H_i=-\frac{1}{\ln n}\sum_{j=1}^{n}\left(\frac{x_{ij}}{\sum\limits_{j=1}^{n}x_{ij}}*\ln\left(\sum_{j=1}^{n}\left(\frac{x_{ij}}{\sum\limits_{j=1}^{n}x_{ij}}*\ln\left(\frac{x_{ij}}{\sum\limits_{j=1}^{n}x_{ij}}\right)\right)\right)\right) \tag{6}$$

The Weight w_i of evaluation index i is obtained as follow:

$$w_i=\left(1-H_i\right)/\left(m-\sum_{i=1}^{m}H_i\right) \tag{7}$$

3.3 MULTI-INDEX FUZZY MEMBERSHIP OF TEACHING QUALITY OF UNIVERSITIES

The range of quantitative evaluation indexes can be transformed in 0-1 after the standardization of evaluation index in chapter 3.1. And the range of qualitative evaluation indexes can also be transformed in 0-1 if similar quantification method is used to manage the qualitative evaluation indexes. Thus considering the practical situation of teaching quality evaluation in universities, the levels of teaching quality can be classified as excellent (A), good (B), medium (C) and fail (D) with corresponding parameter values as 0.9, 0.7, 0.4 and 0.2 respectively. Then the Fuzzy membership function of evaluation levels of universities' teaching quality can be established based on the trapezoid shaped membership function [13] as follow:

$$f_A\left(v_i\right)=\begin{cases}0 & v_i\le 0.8\\ 10*\left(v_i-0.8\right) & 0.8<v_i\le 0.9\\ 1 & v_i>0.9\end{cases} \tag{8}$$

$$f_B\left(v_i\right)=\begin{cases}0 & v_i\le 0.5\\ 10*\left(v_i-0.5\right) & 0.5<v_i\le 0.6\\ 1 & 0.6<v_i\le 0.8\\ 10*\left(0.9-v_i\right) & 0.8<v_i\le 0.9\\ 0 & v_i>0.9\end{cases} \tag{9}$$

$$f_C\left(v_i\right)=\begin{cases}0 & v_i\le 0.2\\ 10*\left(v_i-0.2\right) & 0.2<v_i\le 0.3\\ 1 & 0.3<v_i\le 0.5\\ 10*\left(0.6-v_i\right) & 0.5<v_i\le 0.6\\ 0 & v_i>0.6\end{cases} \tag{10}$$

$$f_D\left(v_i\right)=\begin{cases}1 & v_i\le 0.2\\ 10*\left(0.3-v_i\right) & 0.2<v_i\le 0.3\\ 0 & v_i>0.3\end{cases} \tag{11}$$

3.4 THE MULTI-INDEX FUZZY EVALUATION MODEL AND ALGORITHM IMPLEMENTATION OF TEACHING QUALITY OF UNIVERSITIES

Through the above discussion, weights of different evaluation indexes of teaching quality and corresponding Fuzzy memberships are obtained and then a multi-index Fuzzy evaluation model with hierarchical structure of teaching quality of universities is constructed. If the second class criterion Weight is w_i^{II} and the Fuzzy membership of the second class criterion is $f_j^{\mathrm{II}}\left(v_i\right)$, then the evaluation outcome of the first class criterion is $G_{\mathrm{ij}}^{\mathrm{I}}$ as follow:

$$G_{ij}^{I} = W_{i}^{II} \otimes F_{j}^{II}(v_i) = \left[w_1^{II}, \cdots, w_{m_I}^{II} \right] \otimes \begin{bmatrix} f_1^{II}(v_1) & \cdots & f_j^{II}(v_1) & \cdots & f_{n_{II}}^{II}(v_1) \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ f_1^{II}(v_i) & \cdots & f_j^{II}(v_i) & \cdots & f_{n_{II}}^{II}(v_i) \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ f_1^{II}(v_{m_{II}}) & \cdots & f_j^{II}(v_{m_{II}}) & \cdots & f_{n_{II}}^{II}(v_{m_{II}}) \end{bmatrix} \tag{12}$$

If weight of the first class criterion is w_i^I, then the correlation degree sequence of comprehensive Fuzzy evaluation of universities' teaching quality is G_j as follow:

$$G_j = W_i^I \otimes G_{ij}^I = \left[w_1^I, \cdots, w_{m_I}^I \right] \otimes \begin{bmatrix} g_{11}^I & \cdots & g_{1i}^I & \cdots & g_{1n_I}^I \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ g_{21}^I & \cdots & g_{2i}^I & \cdots & g_{2n_I}^I \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ g_{m_I 1}^I & \cdots & g_{m_I i}^I & \cdots & g_{m_I n_I}^I \end{bmatrix} \tag{13}$$

According to the size of the Fuzzy membership in the correlation degree sequence of comprehensive Fuzzy evaluation of teaching quality, the current levels of teaching quality can be obtained, they are:

$$g_k = \max_{1 \le j \le n} \left(G_j \right) = max\left(g_1, \cdots, g_j, \cdots, g_n \right) \tag{14}$$

It indicates that the current level of teaching quality of universities is k. Universities can conduct targeted reforms of its weaknesses with the purpose to develop and improve the teaching quality by fully considering the current levels of their teaching quality.

4 Case studies and model testing

In order to prepare for a coming periodical evaluation within the system, a university under Ministry of Education would like to conduct a self-evaluation prior to the official one, hoping to improve their teaching quality beforehand. This paper attempts to take this periodical evaluation analysis of teaching quality as an example to analyse and explain the multi-index Fuzzy evaluation model of teaching quality of universities and the related algorithm. Like stated above, there are 4 levels of teaching quality: excellent (A), good (B), medium (C) and fail (D). In the meantime, relevant evaluation parameter values of evaluation indexes are collected through research analysis. Corresponding weights of indexes are also calculated via the algorithm mentioned above. All specific data are shown in Table 2.

TABLE 2 Parameter values of evaluation indexes of universities' teaching quality

First class criterion	Weight	Second class criterion	Weight	Parameter value
Basic teaching capacity P_1	0.206	Basic teaching ability p_{11}	0.256	0.962
		Advanced teaching methods p_{12}	0.150	0.881
		Flexible teaching approach p_{13}	0.150	0.805
		Rational basic course design p_{14}	0.231	0.855
		Complete teaching content p_{15}	0.213	0.906
Professional teaching capacity P_2	0.202	Rational professional course design p_{21}	0.201	0.942
		Curriculum design of professional courses p_{22}	0.237	0.935
		Training of professional knowledge p_{23}	0.215	0.862
		Integration of professional knowledge p_{24}	0.171	0.904
		Development of professional courses p_{25}	0.176	0.456
Input in teaching P_3	0.181	Financial investment p_{31}	0.196	0.727
		Number of educational reform projects p_{32}	0.153	18
		Number of quality courses p_{33}	0.197	32
		Level of teaching hardware facilities p_{34}	0.158	0.825
		Proportion of teachers with high-grade professional titles in all teaching staff p_{35}	0.204	0.758
		Number of scientific contests p_{36}	0.092	15

Ability training capacity P_4	0.248	Innovation ability p_{41}	0.190	0.605
		Practical ability p_{42}	0.190	0.916
		Self-studying ability p_{43}	0.190	0.950
		Scientific research ability p_{44}	0.190	0.835
		Number of scientific awards p_{45}	0.110	6
		Number of papers and patents p_{46}	0.110	1.65
Teaching output P_5	0.163	Capability of transferring S&T into productivity p_{51}	0.296	0.876
		Social satisfaction p_{52}	0.235	0.950
		training ability of talents programs p_{53}	0.223	0.920
		Number of educational reform awards p_{54}	0.100	5
		Number of papers and monographs on educational reform p_{55}	0.146	2.65

Based on the algorithm introduced in the thesis, the current Fuzzy membership of first class criterion and second class criterion of teaching quality can be generated by using corresponding computational formulas. Data are in Table 3.

TABLE 3 Fuzzy membership of the Second class criterion for teaching quality evaluation

Second class criterion	Fuzzy membership			
	A	B	C	D
Basic teaching ability p_{11}	1.000	0	0	0
Advanced teaching methods p_{12}	0.810	0.190	0	0
Flexible teaching approach p_{13}	0.050	0.950	0	0
Rational basic course design p_{14}	0.550	0.450	0	0
Complete teaching content p_{15}	1.000	0	0	0
Rational professional course design p_{21}	1.000	0	0	0
Curriculum design of professional courses p_{22}	1.000	0	0	0
Training of professional knowledge p_{23}	0.620	0.380	0	0
Integration of professional knowledge p_{24}	1.000	0	0	0
Development of professional courses p_{25}	0	0	1.000	0
Financial investment p_{31}	0	1.000	0	0
Number of educational reform projects p_{32}	0.500	0.500	0	0
Number of quality courses p_{33}	0.350	0.650	0	0
Level of teaching hardware facilities p_{34}	0.250	0.750	0	0
Proportion of teachers with high-grade professional titles in all teaching staff p_{35}	0	1.000	0	0
Number of scientific contests p_{36}	0	1.000	0	0
Innovation ability p_{41}	0	1.000	0	0
Practical ability p_{42}	1.000	0	0	0
Self-studying ability p_{43}	1.000	0	0	0
Scientific research ability p_{44}	0.350	0.650	0	0
Number of scientific awards p_{45}	0	1.000	0	0
Number of papers and patents p_{46}	0.250	0.750	0	0
Capability of transferring S&T into productivity p_{51}	0.760	0.240	0	0
Social satisfaction p_{52}	1.000	0	0	0
training ability of talents programs p_{53}	1.000	0	0	0
Number of educational reform awards p_{54}	0	1.000	0	0
Number of papers and monographs on educational reform p_{55}	0	1.000	0	0

TABLE 4 Fuzzy membership of First class criterion for teaching quality evaluation

First class criterion	Fuzzy membership			
	A	B	C	D
Basic teaching capacity P_1	0.725	0.275	0	0
Professional teaching capacity P_2	0.742	0.082	0.176	0
Input in teaching P_3	0.381	0.619	0	0
Ability training capacity P_4	0.474	0.526	0	0
Teaching output P_5	0.683	0.317	0	0

The data above show that the comprehensive Fuzzy membership sequence of the current teaching quality in this university is $g=(0.597,0.367,0.036,0)$. Then according to the principle of optimization, it can be concluded that

$$g_{max}=max(0.597,0.367,0.036,0)=g_A,$$

which means the level of teaching quality of this university is excellent and it is competitive. Nevertheless, its advantages are not strong enough. So the university should take the specific evaluations into consideration and make some changes and improvements in some key and weak links of its teaching process. By doing so, it can enhance effectively its own teaching quality

5 Conclusions

This thesis has analysed and discussed about the issues of evaluation of universities' teaching quality and proposed an evaluation model of teaching quality based on multi-index Fuzzy decision analysis. The paper first proposed a new type of evaluation model of teaching quality of universities taking practical situation of quality evaluation into account. And then it has given a corresponding Fuzzy membership calculation model and index weight allocation model to deal with different types of evaluation indexes in the system. Through these models we can get the Fuzzy memberships and comprehensive memberships of indexes of different levels in the quality evaluation and then we can get the membership levels of current teaching quality of universities. To conclude, this thesis offers a new solution for improvement of teaching quality of universities and also strongly supports computer implementation of intelligent analysis of universities' teaching quality. Case studies have proven the effectiveness and feasibility of the model proposed in the paper

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