



Research Article

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Professional evaluation model of fuzzy mathematics and vocational schools based on factor analysis

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ABSTRACT

The motive power of vocational school development first roots from development direction and needs of society, and second from the institutions' self audit and professional assessment by the state. The two aspects of its development momentum play a vital role. The purpose of professional assessment is both to ensure the healthy development of dominant professions but also improve the insufficient of inferior professions, which has promotion action on the overall training level of institutions and social impact. This paper studies the professional assessment of vocational school, by describing the meaning and importance of evaluation index system, uses the fuzzy mathematics theory to quantify the various indicators, establishes the comprehensive evaluation model, and analyzes the quantization factor of each index. The results show that professional setup has comparative advantages in all the factors, the second is quality and efficiency, and the third is teaching reform situation.

Key words: Index factors, comprehensive evaluation, fuzzy mathematics, vocational colleges

INTRODUCTION

Professional assessment is an important part of education quality assurance system that can objectively reflect the status of the institutions, thereby strengthen the whole construction of the institution, and promote the healthy development of vocational education business. The establishment of evaluation system goal, indicator setup, elements chosen, the contents' description, methods formulation and evaluation conclusion and other aspects are an important part of vocational schools' professional judgment. Although the selection of evaluation index cannot cover everything, as long as the index selection can reflect the school's running level and give the development direction of the school by concise indicator elements [1]. Currently the assessment indicator of vocational school is difficult to use the expression of exact number in the evaluation, commonly use words such as good or average for description, the general evaluation method is difficult to reflect the objective reality, while the use of fuzzy comprehensive evaluation can effectively overcome these shortcomings [2].

International research on disciplines assessment on the one hand focuses on self-assessment, on the other hand extensively uses various assessment systems. The key is the research of its basic structure and basic elements, especially the research on the weight of each element. In recent years as the Chinese government increases emphasis on vocational institutions' education quality, assessment tools on institutions continues standardization and reutilization. But because China's vocational assessment started late, professional assessment techniques by discipline and by profession are still in the exploration and testing stage [3, 4].

This paper, on the basis of previous research, studies the professional assessment index system of vocational institutions, uses the fuzzy mathematics theory to establish fuzzy comprehensive evaluation model, clear the standard requirements of the assessment results, and provides corrective advice for the assessment results under this assessment program.

THE ESTABLISHMENT OF ASSESSMENT INDEX SYSTEM

Evaluation does not seek exhaustive, but it must be able to accurately reflect the school's level of, give the school's development-oriented purpose, constituted by the evaluation objectives -> first level indicator -> second level indicator -> third level indicator [5].

Index system establishment

This paper takes the demonstrated professional evaluation system of secondary vocational schools in Beijing as the template, abandons cumbersome items and takes the essential section in its index system. The professional evaluation index system of general vocational schools is divided into four first level indicators, sixteen second level indicators and forty-three third level indicators. The four first level indicators respectively are professional setup, professional school conditions, teaching reform and quality monitoring, quality and efficiency [6, 7]. The scores of four first level indicators are represented by $\alpha, \beta, \gamma, \chi$. The second level indicators respectively are the professional orientation and planning, construction mechanisms, professional scale, teaching faculty, training base, related resources, training mode, curriculum system, teaching methods and means, evaluation, teaching management and quality control, professional ethics education and vocational guidance, international exchanges and cooperation, student quality and social assessment, social service benefits and demonstration effect total sixteen items. Its scoring

condition is presented by $\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3, \gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6, \gamma_7, \chi_1, \chi_2, \chi_3$. The third level indicators respectively are professional orientation, professional planning, institutions and system, professional dynamic adjustment, academic education, social training, teacher structure, double teaching quality, part-time teachers, teacher teams, practical ability and teaching and research level, the school base equipment and environmental construction, operation and management of the school practical training base, function exertion of the school practical training base, off-campus base training base construction, digital teaching resources, professional books and other text resources, personnel training mode reform by combining learning with working and school-enterprise cooperation, learning and working alternate or order training, internships, public foundation courses, professional core courses, course content, teaching materials construction, teaching methods reform, teaching methods application, assessment content and standards, evaluation methods and the main body of evaluation, institutions and systems, general management, quality control, professional ethics education, vocational guidance, cooperation in running schools, the introduction of the vocational qualification certificate, communication between teachers and students, the quality of employment, vocational qualifications certificates, social assessment, the number of graduates, community service, professional demonstrations and gain honors total forty-three items. Its scoring condition is presented by:

$$\alpha_{11}, \alpha_{12}, \alpha_{21}, \alpha_{22}, \alpha_{31}, \alpha_{32}, \beta_{11}, \beta_{12}, \beta_{13}, \beta_{14}, \beta_{15}, \beta_{21}, \beta_{22}, \beta_{23}, \beta_{24}, \beta_{31}, \beta_{32}, \gamma_{11}, \gamma_{12}, \gamma_{13}, \gamma_{21}, \gamma_{22}, \gamma_{23}, \gamma_{24}, \gamma_{31}, \gamma_{32}, \gamma_{41}, \gamma_{42}, \gamma_{51}, \gamma_{52}, \gamma_{53}, \gamma_{61}, \gamma_{62}, \gamma_{71}, \gamma_{72}, \gamma_{73}, \chi_{11}, \chi_{12}, \chi_{13}, \chi_{21}, \chi_{22}, \chi_{31} \text{ and } \chi_{32}.$$

Quantitative indicators fractional value determination and standardization process

Provision 1: four first level indexes' score is 100 points as shown in formula (1):

$$\alpha_{\max} + \beta_{\max} + \gamma_{\max} + \chi_{\max} = 100 \quad (1)$$

Provision 2: there are total sixteen second level indicators under four first level indexes, and its score is shown in formula (2):

$$\begin{cases} \alpha = \alpha_1 + \alpha_2 + \alpha_3 \\ \beta = \beta_1 + \beta_2 + \beta_3 \\ \gamma = \gamma_1 + \gamma_2 + \gamma_3 + \gamma_4 + \gamma_5 + \gamma_6 + \gamma_7 \\ \chi = \chi_1 + \chi_2 + \chi_3 \end{cases} \quad (2)$$

Provision 3: there are total forty-three third level indicators under sixteen second level indexes, and its score is shown in formula (3):

$$\left\{ \begin{array}{l} \alpha_i = \alpha_{i1} + \alpha_{i2}, (i = 1,2,3) \\ \beta_1 = \sum_{i=1}^5 \beta_{1i}, \beta_2 = \sum_{i=1}^4 \beta_{1i}, \beta_3 = \sum_{i=1}^2 \beta_{1i} \\ \gamma_1 = \sum_{i=1}^3 \gamma_{1i}, \gamma_2 = \sum_{i=1}^4 \gamma_{1i}, \gamma_3 = \sum_{i=1}^2 \beta_{1i} \\ \chi_1 = \sum_{i=1}^3 \chi_{1i}, \chi_2 = \sum_{i=1}^2 \chi_{1i}, \chi_3 = \sum_{i=1}^2 \chi_{1i} \end{array} \right. \quad (3)$$

Provision 4: standardize four first level indicators and we have the expression form of formula (4):

$$\left\{ \begin{array}{l} \hat{\alpha} = \frac{\alpha \times 100}{\alpha_{\max}} \\ \hat{\beta} = \frac{\beta \times 100}{\beta_{\max}} \\ \hat{\gamma} = \frac{\gamma \times 100}{\gamma_{\max}} \\ \hat{\chi} = \frac{\chi \times 100}{\chi_{\max}} \end{array} \right. \quad (4)$$

The determination of the qualitative indicators membership function

The meaning and scoring of the third level indicators is vague and uncertain. The third level indicators have two qualitative scoring items, the first qualitative evaluation done by an expert, and then try to quantify; suppose the reviews of expert on qualitative indicator $f_i(x)$ are very good, good, less good, average, less poor, poor and very poor. We can also use quantitative data to conduct reverse review on remark level, the corresponding quantization scores of the specified comment is shown in Table 1.

Table 1: The quantify comparison table of qualitative indicators

Expert evaluation	Very good	good	Less good	Average	Less poor	poor	Very poor
Grades	100	90	80	70	60	50	40

Membership function is shown in formula (5)

$$U(x) = \begin{cases} 100 & 100 \geq f_i(x) > 95 \\ 90 & 95 \geq f_i(x) > 85 \\ 80 & 85 \geq f_i(x) > 75 \\ 70 & 75 \geq f_i(x) > 65 \\ 60 & 65 \geq f_i(x) > 55 \\ 50 & 55 \geq f_i(x) > 45 \\ 40 & f_i(x) \leq 45 \end{cases} \quad (5)$$

In Formula (5) $U(x)$ indicates the score of qualitative indicators. In order to facilitate comprehensive evaluation $U(x)$ will be standardized. Suppose $U_{ij}(x)$ is the component evaluation score value of the third level indicator under certain second level indicator, $U_{ij}^*(x)$ represents the normalized scores, N_{ij} means the third level indicator's score under certain second level indicator, then the calculation of $U_{ij}^*(x)$ is in the formula (6):

$$U_{ij}^*(x) = \frac{U_{ij}(x)}{100} \times N_{ij} \times \frac{1}{2} \quad (6)$$

Single factor indicator characteristic analysis

In professional indicator evaluation system of vocational school, the final assessment results are the interaction of all levels of indicators. Each evaluation index represents different meanings, and it can be divided into positive indicators, negative indicators and appropriate indicators according to the contribution of the indicator to the assessment total objective. Since correlation between various indicators is low, this paper selects nonlinear dimensionless fuzzy algorithm for index quantification, and analyzes the influence of a single factor. The positive indicator quantified formula is as shown in formula (7):

$$R_j(x) = \begin{cases} \frac{1 + \sin \left[\frac{\pi \left(x_j - \frac{x_{j\max}}{x_{j\min}} \right)}{x_{j\max} - x_{j\min}} \right]}{2} & x_{j\min} < x_j < x_{j\max} \\ 0 & x_j \leq x_{j\min} \text{ or } x_j \geq x_{j\max} \end{cases} \quad (7)$$

Negative correlation index refers to the indicators that are negative relevant to the overall contribution of the goal, and the quantitative formula is shown in formula (8) below:

$$R_j(x) = \begin{cases} \frac{1 - \sin \left[\frac{\pi \left(x_j - \frac{x_{j\max}}{x_{j\min}} \right)}{x_{j\max} - x_{j\min}} \right]}{2} & x_{j\min} < x_j < x_{j\max} \\ 0 & x_j \leq x_{j\min} \text{ or } x_j \geq x_{j\max} \end{cases} \quad (8)$$

Moderate correlation indicators refer to the indicators that are moderate relevant to the overall contribution of the goal, and the quantitative formula is shown in formula (9) below:

$$R_j(x) = \begin{cases} \frac{1 + \sin \left[\frac{\pi}{x_{j\max} - x_{j\min}} \left(x_j - \frac{x_{j\max} + x_{j\text{mod}}}{x_{j\min}} \right) \right]}{2} & x_{j\min} < x_j < x_{j\text{mod}} \\ \frac{1 - \sin \left[\frac{\pi}{x_{j\max} - x_{j\min}} \left(x_j - \frac{x_{j\max} + x_{j\text{mod}}}{x_{j\min}} \right) \right]}{2} & x_{j\text{mod}} < x_j < x_{j\max} \\ 0 & x_j \leq x_{j\min} \text{ or } x_j \geq x_{j\max} \end{cases} \quad (9)$$

In Formula (7), (8), (9) $R_j(x)$ represents the evaluation value of the J -th evaluation indicator after dimensionless process, x_j represents the original score of the J -th evaluation indicator, $x_{j\max}, x_{j\min}$ represents the minimum and maximum evaluation value of the J -th evaluation indicator, $x_{j\text{mod}}$ represents the most moderate evaluation values of the J -th evaluation indicator. By $R_j(x)$ in equation (7), (8), (9) the contribution of the J -th evaluation indicator on the evaluation results and propose improvement program to the professional building of the institutions.

INDICATORS ANALYSIS AND DATA ACHIEVEMENT

The data achievement of the third level indicators' corresponding items

The third level indicators altogether have forty-three items, and the meaning of each indicator represents the object of expert assessment. Table 2 lists the two experts review projects and original scoring by the expert on each item under each third level indicators. The raw scoring data in the table is the random integer generated by the computer between 80 and 100. Its purpose is data simulation and describing calculation method of the model.

Table 2: Condition list of original experts scoring

Third level indicators	Expert scoring items	Scores
α_{11} (2)	Clear training objectives, accurate and scientific positioning, distinctive vocational teaching	92
	Training program highlights the competency, with strong operation	95
α_{12} (2)	Meet regional economic and social development and industrial restructuring needs, industries and enterprises involved in the formulation of development planning with obvious effect	83
	Planning content is informative, scientific and rational, highlighting the reform and innovation direction of vocational education	85
α_{21} (2)	The establishment of professional Construction Committee that industry enterprises and other employing units involved in	98
	Formed an effective working mechanism of school-enterprise cooperation, with remarkable results	97
α_{22} (2)	Depth research, followed by industrial development and demand changes in employment market, the formation of professional dynamic adjustment mechanism	83
	Dynamically adjust result is remarkable	84
α_{31} (2)	The number of students of the professional academic education is more than 200 people	92
	Quality condition of student	92
α_{32} (2)	Annual train more than 300 people of the social-oriented related vocational training	98
	Training effect is remarkable	98
β_{11} (2)	The number, education, job title and age structure of professional teachers are reasonable	84
	Professional teachers have relevant professional education and work background	87
β_{12} (2)	The number of double teachers can meet the needs of professional teaching reform	80
	Professional teachers have strong practical experience and application skills	77
β_{13} (2)	Employ technical experts from the enterprises and industry to bear the relevant professional courses teaching	99
	Part-time teachers play an active role in the professional development and training of professional teachers	99
β_{14} (2)	With professional creative team identified by City Board of Education, and the city and district-level professional leaders	98
	Professional teachers undertake important work in the provincial level or above industry (professional) Committee	97
β_{15} (3)	Establish and implement a system of professional teachers to business practice, with good results	92
	Carry out in-depth and diversity research work, and achieve remarkable results	85
β_{21} (2)	Training base construction area is standard and the layout is reasonable	95
	Equipment level reaches advanced standards of industries and enterprises	95
β_{22} (3)	With complete equipment employment records and student training manuals	92
	With sound safe operation system and contingency plans	95
β_{23} (3)	Training base construction features match the needs of the curriculum reform	83
	High capacity utilization of training base	85
β_{24} (2)	Establish long-term stable off-campus training base counterparts with profession	98
	Develop and implement management measures of students off-campus training	97
β_{31} (3)	Advanced campus network technology, complete function, valid application	83
	Professional digital teaching resources meet the teaching needs	84
β_{32} (2)	Amount of professional publications and data is sufficient	92
	High utilization rate	92
γ_{11} (2)	Talent training model embodies working and studying combination, school-enterprise cooperation	98
	Enterprises participate in the whole process of teaching	98
γ_{12} (3)	Implement working and studying alternate or order training methods, achieving a certain scale	84
	Schools and enterprises jointly develop personnel training program of working and studying alternate or order training methods	87
γ_{13} (3)	Process management is in place, the organization and implementation are effective	80
	Internship evaluation norm	77
γ_{21} (2)	Public basic course reaches the documentation requirements of administrative departments for education	99
	Implement the ministerial course syllabus, perfect measures, guaranteed quality	99
γ_{22} (3)	Establish professional core courses, and scientific and rational structure	98
	Reflect the vocational core competencies training	97
γ_{23} (2)	Butt professional position work reflects the core skills of positions	92
	Butt vocational qualification is standard	85
γ_{24} (2)	Materials selection is scientific, reflecting the vocational ability training	95
	Reflect the curriculum outcomes, effective application result	95
γ_{31} (2)	Actively explore the teaching method reform under the new concept guidance of "action-oriented" and others	92
	Proper methods using, good teaching effect	95
γ_{41} (2)	Rational use of modern teaching methods	83
	Make full use of information-based teaching resources	85
γ	Establish a academic evaluation system taking student comprehensive vocational ability as the core	98

	Examination content reflects knowledge, abilities, emotional attitudes values that is necessary for the completion of professional activities	97
γ_{51} (2)	Combine process evaluation with summative assessment, and the evaluation ways are flexible	83
	The main body of evaluation is diverse, attach importance to student self-assessment and enterprises evaluation	84
γ_{52} (2)	Sound organization, reasonable management team structure, excellent quality	92
	Teaching management system is complete	92
γ_{53} (3)	Management tool is advanced	98
	General Manager is effective	98
γ_{61} (3)	Establish and perfect the quality monitoring system	84
	Quality control is in place, timely feedback and effective guidance	87
γ_{62} (2)	Whole personnel, whole round and whole process carry out moral education work	80
	Emphasis on the students' professional ethics education and career quality development in the professional education, and the effect is significant	77
γ_{71} (1)	Sound institutions	99
	Vocational guidance implements the whole process of personnel training with good effect	99
γ_{72} (2)	Develop cooperative education with various forms	98
	Promote professional development with remarkable results	97
γ_{73} (2)	The introduction of international career (professional) qualifications	92
	A high proportion of students obtaining the vocational qualification certificate	85
χ_{11} (3)	Develop international students exchange with various forms	95
	Overseas teachers' training are targeted with effective result	95
χ_{12} (3)	Employment units have high industry recognition	92
	There are typical examples of employment and entrepreneurship	95
χ_{13} (3)	Effective implementation of vocational qualification certificate training	83
	Certificates obtain is closely associated with the profession and shows an increasing trend	85
χ_{21} (2)	The social evaluation working mechanism is perfect	98
	The work plans of graduates quality tracking are specific, management process are complete	97
χ_{22} (3)	Delivery graduates for the society for many years	83
	Reach a certain amount	84
χ_{31} (3)	Positively provide a variety of relevant social training for the industry and enterprise	92
	Flexible way, significant economic and social benefits	92
χ_{32} (3)	Get all of these provincial teaching achievement awards	98
	The achievements of teacher or student in various professional competitions at or above the provincial level and industry systems are outstanding	98

Comprehensive assessment results

Substituting the raw score data of Table 2 into the formula (5) and (6), we can obtain $U_{ij}^*(x)$ and the score matrix of the third level indicators as shown in formula (10):

$$\mathbf{R}_3 = \begin{bmatrix} \alpha_{11} & \alpha_{12} & 0 & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 0 & 0 & 0 \\ \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & 0 \\ \beta_{31} & \beta_{32} & 0 & 0 & 0 \\ \gamma_{11} & \gamma_{12} & \gamma_{13} & 0 & 0 \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{24} & 0 \\ \gamma_{31} & 0 & 0 & 0 & 0 \\ \gamma_{41} & \gamma_{42} & 0 & 0 & 0 \\ \gamma_{51} & \gamma_{52} & \gamma_{53} & 0 & 0 \\ \gamma_{61} & \gamma_{62} & 0 & 0 & 0 \\ \gamma_{71} & \gamma_{72} & \gamma_{73} & 0 & 0 \\ \chi_{11} & \chi_{12} & \chi_{13} & 0 & 0 \\ \chi_{21} & \chi_{22} & 0 & 0 & 0 \\ \chi_{31} & \chi_{32} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 1.8 & 1.6 & 0 & 0 & 0 \\ 2 & 1.6 & 0 & 0 & 0 \\ 1.8 & 2 & 0 & 0 & 0 \\ 1.7 & 1.6 & 2 & 2 & 2.55 \\ 1.8 & 2.7 & 2.4 & 2 & 0 \\ 2.4 & 1.8 & 0 & 0 & 0 \\ 2 & 2.55 & 2.4 & 0 & 0 \\ 2 & 3 & 1.7 & 1.8 & 0 \\ 1.8 & 0 & 0 & 0 & 0 \\ 1.6 & 2 & 0 & 0 & 0 \\ 1.6 & 1.8 & 3 & 0 & 0 \\ 2.55 & 1.6 & 0 & 0 & 0 \\ 1 & 2 & 1.7 & 0 & 0 \\ 2.7 & 2.7 & 2.4 & 0 & 0 \\ 2 & 2.4 & 0 & 0 & 0 \\ 2.7 & 3 & 0 & 0 & 0 \end{bmatrix} \tag{10}$$

Substituting the score value in the third level index matrix into the formula (3), we can get the score matrix of the second level indicators as shown in formula (11):

$$\mathbf{R}_2 = \begin{bmatrix} \alpha_1 & \beta_1 & \gamma_1 & \chi_1 \\ \alpha_2 & \beta_2 & \gamma_2 & \chi_2 \\ \alpha_3 & \beta_3 & \gamma_3 & \chi_3 \\ 0 & 0 & \gamma_4 & 0 \\ 0 & 0 & \gamma_5 & 0 \\ 0 & 0 & \gamma_6 & 0 \\ 0 & 0 & \gamma_7 & 0 \end{bmatrix} = \begin{bmatrix} 3.4 & 9.85 & 6.95 & 7.8 \\ 3.6 & 8.9 & 8.5 & 4.4 \\ 3.8 & 4.2 & 1.8 & 5.7 \\ 0 & 0 & 3.6 & 0 \\ 0 & 0 & 6.4 & 0 \\ 0 & 0 & 4.15 & 0 \\ 0 & 0 & 4.7 & 0 \end{bmatrix} \quad (11)$$

Substituting the score value in the second level index matrix into the formula (2), we can get the score matrix of the first level indicators as shown in formula (12):

$$\mathbf{R}_1 = [\alpha \ \beta \ \gamma \ \chi] = [108 \ 2295 \ 361 \ 179] \quad (12)$$

Comprehensive assessment score is shown in formula (13):

$$R = \alpha + \beta + \gamma + \chi = 87.75 \quad (13)$$

Then compare the resulting value of R with the comprehensive evaluation criteria value predetermined by the jury, and check the comprehensive evaluation results. The normalized score vector of the first level index is shown in formula (14):

$$\hat{\mathbf{R}}_1 = [\hat{\alpha} \ \hat{\beta} \ \hat{\gamma} \ \hat{\chi}] = [90 \ 88.27 \ 85.95 \ 89.5] \quad (14)$$

The formula (14) shows that the merits degree sort of first level indicators is $\alpha, \chi, \beta, \gamma$, namely the professional setup has comparative advantages in all the indicators, the second is quality and efficiency, and the third is teaching reform situation.

CONCLUSION

The professional evaluation system of vocational schools that this paper sets well reflects the professional building problem of a school, and the professional assessment comprehensive results of a particular vocational college is decided by the original score from the actual expert jury. Depending on the different institutions different expert may use professional evaluation index system that this paper designs to assess professional construction condition of colleges, and use the fuzzy mathematical models that this paper creates to solve the assessment results. According to the normalized score vectors of the first level index determine the indicators that need improvement, and then bring the original score value into the formula (7) (8) (9), obtain correlation between individual indicators and assessment results and conduct specialized improvements. The fuzzy mathematical model and calculation methods established in this paper have a strong applicability for the professional indicators assessment.

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