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Fuzzy Hierarchy Synthesis Evaluation of Water Supply & Drainage Talents Based on CDIO

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CDIO engineering education mode is the successful model of the reformation of engineering education. According to the training objectives and curriculum system of water supply & drainage, evaluation index system is proposed based on CDIO standard. The weight of each evaluation factor is calculated by analytic hierarchy process (AHP). The evaluation model is established based on multi-level fuzzy comprehensive evaluation. A university graduate is used for case study. The last score is 82.75. The score is in accordance with the actual situation of the student. The results show that it is feasible to use AHP and fuzzy comprehensive evaluation method for evaluating comprehensive quality of graduates in water supply & drainage practiced the CDIO engineering education.

1. Introduction

CDIO means “Conceive”, “Design”, “Implement” and “Operate”. Based on learning professional basic theory, CDIO engineering education concept is incorporating traditional professional education of school into the actual engineering fields according to the life cycle process method of conception, design, implementation and operation in engineering systems. The life cycle is used as its carrier from the product research to the product operation. Students may study the theory of engineering knowledge, practical experience and all kinds of ability by methods of active, practice and organic connection between courses in the carrier. Then the innovative talents are cultivated with broad knowledge, strong practical ability and good comprehensive qualities conforming to the social demand (Gu, 2012a and 2012b). Therefore, as to the specialty orientation, training direction, course construction, teaching reform, etc, it has very important significance to evaluate the cultivated talents’ knowledge structure, practical ability and comprehensive quality objectively and accurately.
Methods for improving education quality are compared in different countries (Toni, 2014 and 2013). Competencies of different Russian engineering universities’ graduates and the standards of international accreditation agencies and organizations is compared between CDIO, ABET, FENAI, EMF and APEC. The conclusion is to facilitate the invention competency development, Russian universities need to use the practice-based approach to learning together with active employer involvement and active solving of actual production tasks as early as the learning stage (Zamyatina, 2015, 2014a and 2014b). Three questions are brought up: Which are the basic competences that need a contemporary engineer? How can the learning of these basic competences be improved and assessed in engineering students? The implementation of the syllabus and CDIO standards could be seen by the scientific and educational community as a difficult and tedious process, but the results obtained in the projects course-designed by following the guidelines presented in first and second level of CDIO syllabus shows that are worth investing efforts for the implementation of it (Dante, 2014; Pokholkov, 2012; Chuchalin, 2011). The competences codes in the CDIO´s curriculum is compared between the ones defined for the Tunning Project and the International Project Management Association (IPMA). The results show that there is a need to apply holistic models in the definition of an engineering curriculum and the pertinence of these models in the definition of engineering programs in Latin America (Martín, 2011; Barroso, 2009). CDIO concept was regarded as a new model for engineering education whose aims were to develop students’ ability of engineering application to solve their employment problems efficiently. It attempted to change the way of seeking knowledge so as to solve the long-term

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problem across a century about which was more important between knowledge-induction and ability-development in engineering education (Bai, 2013).

The evaluation of students is carried out in many colleges and universities in China. But there is few research and practice in view of CDIO engineering ability evaluation. There are some problems. The first one is the single evaluation way. The results of final exam are mostly considered as the main indicators in evaluating students. To a certain extent, it only reflects to investigate the theoretical knowledge. The second one is the lack of self-assessment. The evaluation results are given by teachers in the traditional teaching evaluation. The students are passive participants. So the evaluation results are one-sided and rigid. The last one is not playing the role of the assessment. Most students only focus on surface evaluation results of pass or good. They paid no attention to the deep impact on learning state of diagnosis, feedback, guidance and encouragement. Also the role is ignored in reflecting teaching process and improving teaching methods. Then according to the present problems existing in the traditional evaluation method, it is proposed to build models of fuzzy hierarchy synthesis evaluation to professional talents of water supply & drainage under the guidance of CDIO concept.

2. Evaluation index system based on CDIO

2.1 Training target of innovative talents in water supply & drainage

It should actively promote the higher education and the economic and social development closely in training innovative talents of water supply & drainage. It may adapt to the transformation of economic development patterns and economic structure adjustment actively. The high quality talents are training to meet the needs of social and economic development by optimizing the structure of talent training and the allocation of resources and deepening reform of the personnel training mode. The main training objective is to cultivate practical engineering and technical talents with innovation ability. Students are required to learn the necessary professional knowledge, basic theory, system knowledge for engineering application and the basic skills of English and computer. Students may have strong hands-on and practical application skills with spirit of innovation and humanity quality. Then students can adapt to the needs of the development of national economy after graduation. Therefore, it may be carried out according to the training objectives and requirements for quality evaluation of innovative talents in water supply & drainage.

2.2 Construction of evaluation index system based on CDIO

The impact factors are various evaluating students. The influence degree of factors is different. It's impossible to take each factors into consideration. So the decomposition coordination principle of large system theory is used to decompose influence factors into several layers. Each layer contains multiple factors. The factors may be streamline and hierarchical. According to the CDIO cultivating concept, engineering graduates should have four sorts of knowledge ability. They are engineering elementary knowledge, personal ability, interpersonal ability to team and engineering system ability respectively (Ge, 2011). The CDIO concept is introduced in the training mode of creative talents in water supply & drainage. The students are required in comprehensive training mode to expected target on the four levels. Not only the engineering elementary knowledge is mastered, and also the corresponding engineering application innovation ability is possessed. Then the training system with professional characteristic is formed. According to the CDIO engineering education mode and the characteristics of strong applicability and practicality, index system is designed to evaluate innovative talents quality in water supply & drainage with established outline and training objectives. The index system includes 4 first-level indicators and 18 secondary indicators. The structure is shown in Figure 1 below.

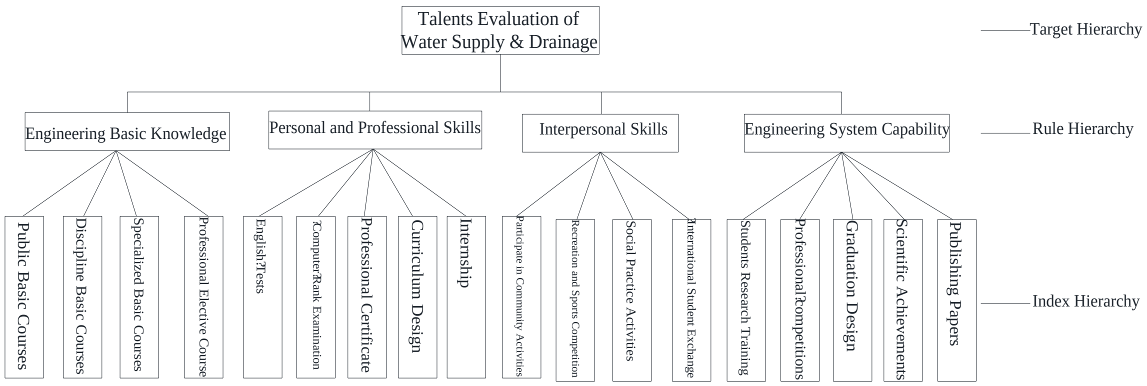

Figure 1: Evaluation index system

3. Hierarchical analysis and fuzzy evaluation model

3.1 Establish Evaluate Factor Weights in fuzzy matrix

It's assumed that the primary evaluation factors set is U={U_1, U_2, U_3, U_4}. The secondary evaluation factors are U_1={u_1, u_2, u_3, u_4}, U_2={u_5, u_6, u_7, u_8} , U_3={u_{10}, u_{11}, u_{12}, u_{13}, u_{14}}, U_4={u_{14}, u_{15}, u_{16}, u_{17}, u_{18}}. The evaluation set is V={v_1, v_2, v_3, v_4, v_5}. Among them, v_1 means excellence, v_2 means good, v_3 means medium, v_4 means qualified and v_5 means qualified. For each index u_i=(i=1,2,…,18) in the evaluation factors set, the membership $r_{ij}(R/u_i)$ is analyzed as to each level evaluation set v_j=(j=1,2,3,4,5). The fuzzy relation matrix is obtained as follows:

$$R=\begin{bmatrix} R/U_1 \\ R/U_2 \\ \vdots \\ R/U_m \end{bmatrix}=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1k} \\ r_{21} & r_{22} & \cdots & r_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mk} \end{bmatrix}_{m\times k} \tag{1}$$

Rating proportion is used to determine the membership function of each index in the model. r_{ij} is the element of line i and column j in matrix R. r_{ij} is membership degree of the evaluation index rated as grade v_j=(j=1,2,…,k) from the perspective of factor u_i. That is to say, $r_{ij}=d_j/d$ in the express 1, where d is the number of participate experts in the evaluation, dj is the number of experts of making the first j evaluation scale Vj for the ith evaluation index, m is the number of evaluation index, and k is judging level (k = 5)(Guo, 2012) .

3.2 Determine the weight of each index

The next step is to calculate the weight of each level element after establishing level of the hierarchical structure and determining the membership function between the upper and lower elements. The relative importance of each lower level to the same upper indicators is different. In order to reflect the importance of each index, a corresponding weights W_i should be given to each index. In this paper the analytic hierarchy process (AHP) is used to calculate the weight of each index. From the hierarchical structure model of layer 2, the paired comparison method and the proportion of 1~9 scaling method are used to assign importance degree of the same layer factors which belong to each factor in upper layer. Then judgment matrix is constructed until the bottom(Zhang, 2014). As to each judgment matrix, the eigenvector corresponding to the maximum characteristic root is obtained. The weight of each index may be calculated by normalizing the characteristic vectors. To test the consistency of judgment matrix, the maximum characteristic root λ_{max} is used to check the consistency of judgment matrix.

3.3 Multistage fuzzy comprehensive evaluation

There are only two levels in the index system. So the two stage fuzzy comprehensive evaluation method is used to evaluate in the model. That is to say, evaluation is from the lower to the upper level. The upper fuzzy matrix is the synthesis of the lower comprehensive evaluation. The method of weighted mean is used to evaluate comprehensively. The comprehensive evaluation set of a certain level index is Q=WR.
Where, W is the weights set of each factor,
R is fuzzy matrix.

(1) Level 1 assessment
There're "i" indicators in level 1, where i=1,2,…,m(m=4). As to the ith level 1 indicators, there're "j" indicators in level 2, where i=1,2,…,n(n=4,5,4,5). As to the index U_{ij}, the fuzzy membership degree corresponding to different levels can be determined by the above-mentioned single factor evaluation method. Then the corresponding evaluation matrix is obtained as follows: $R_{ij}=[r_{ij1}, r_{ij2}, r_{ij3}, r_{ij4}, r_{ij5}]$. With all the single factor evaluation matrix, the fuzzy comprehensive evaluation matrix R_i is obtained. Multiply the weight vector of evaluation index by R_i to get evaluation vector of U_{ij}.

$$W_i\times R_i=(W_{i1},W_{i2},W_{i3},W_{i4})\bullet\begin{bmatrix} b_{i11} & b_{i12} & b_{i13} & b_{i14} & b_{i15} \\ b_{i21} & b_{i22} & b_{i23} & b_{i24} & b_{i25} \\ b_{i31} & b_{i32} & b_{i33} & b_{i34} & b_{i35} \\ b_{i41} & b_{i42} & b_{i43} & b_{i44} & b_{i45} \end{bmatrix} \tag{2}$$

Calculated by type (2), the Level 1 vector of normalization processed evaluation index is as follows: B_i=(B_{i1}, B_{i2}, B_{i3}, B_{i4})

(2) Level 2 assessment

According to the 1st level evaluation of U_{ij} and considering its weight distribution, fuzzy evaluation of U_i is given to U_i again. The 2th fuzzy comprehensive evaluation matrix is obtained according to the vector for level 1 assessment. Multiplied by the weight vector, the level 2 evaluation vector is obtained as follows:

$$W \times R = (W_1, W_2, W_3, W_4) \bullet \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \end{bmatrix} \tag{3}$$

Calculated by type (3), the Level 2 vector of normalization processed evaluation index is as follows: $B=(b_1, b_2, b_3, b_4\}$.

(3) Comprehensive assessment

The results of comprehensive evaluation is quantified by the weighted average method. That is X=B*V, where, X is the score of comprehensive evaluation, V is grade evaluation matrix.

4. Case Study

The CDIO ability of students majored in Water Supply & Drainage is evaluated by the above established multistage fuzzy comprehensive evaluation model in a university. The value range of all levels is given by the university as follows: excellence (90~100), good (80~89), medium (70~79), qualified (60 ~ 69), unqualified (≤59). In order to quantitative comprehensive evaluation results, the mid-value is taken to represent the level respectively. Then the grade evaluation matrix is as follows: V'=[95 85 75 65 55]. The experts of professional class teachers in school and engineers in enterprise are invited to guide to a senior graduates. So model is established for evaluating.

4.1 Students background

A student majored in Water Supply & Drainage is selected to test the model. The selected student is graduated from a university in June, 2015. From freshman year to senior year, the student has a broad professional knowledge and is good at design. He get along well with teachers and students. But his English is not good. The scientific research ability is not strong. In general, the student is good.

4.2 To calculate index weight at all levels

(1) Index weight of Level 2

W_i=(0.134, 0.474, 0.32, 0.072)

W_2=(0.289, 0.384, 0.145, 0.125, 0.057)

W_3=(0.098, 0.503, 0.098, 0.301)

W_4=(0.122, 0.272, 0.272, 0.272, 0.061)

(2) Index weight of Level 1

W=(0.537, 0.244, 0.153, 0.066)

4.3 Fuzzy comprehensive evaluation

(1) Single factor evaluation

Analyzing the single factor of the secondary indexes, the single factor evaluation vector matrix are obtained as follows:

$$R_1 = \begin{bmatrix} 0 & 0.8 & 0.2 & 0 & 0 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix}, \quad R_2 = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0 & 0.8 & 0.2 & 0 & 0 \\ 0 & 0 & 0.7 & 0.3 & 0 \end{bmatrix},$$

$$R_3 = \begin{bmatrix} 0 & 0.4 & 0.6 & 0 & 0 \\ 0 & 0.2 & 0.8 & 0 & 0 \\ 0 & 0 & 0.7 & 0.3 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix}, \quad R_4 = \begin{bmatrix} 0 & 0.4 & 0.6 & 0 & 0 \\ 0 & 0.2 & 0.8 & 0 & 0 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 \end{bmatrix}$$

(2) Level 1 assessment:
The 1st level evaluation vector is obtained as the weight of each secondary index multiplied by the single factor evaluation vector matrix.
The evaluation vector of engineering basic knowledge is

B_1=(0.1834, 0.7898, 0.0268, 0, 0)

The evaluation vector of personal and professional skills is

B_2=(0.0145, 0.5195, 0.4489, 0.0171, 0)

The evaluation vector of interpersonal skills is

B_3=(0, 0.1389, 0.5298, 0.3304, 0)

The evaluation vector of engineering system capability is

B_4=(0.100, 0.6083, 0.2908, 0, 0)

(3) Level 2 assessment:

B=(0.1086, 0.6124, 0.2242, 0.0547, 0)

4.4 Comprehensive evaluation results

The comprehensive evaluation results of the student is obtained as the comprehensive evaluation vector multiplied by grade evaluation matrix. It is X=B*V=82.75. That is to say, the comprehensive quality of the graduates is good judged from CDIO. And so on, the same graduates are evaluated respectively in this way. The comprehensive evaluation values are obtained. The results are ranked uniformly. The higher the comprehensive evaluation, the CDIO ability of the student is stronger.

5. Conclusions

The model is based on the idea of CDIO, analytic hierarchy process (AHP) and fuzzy evaluation method. It is used to evaluate the graduates' comprehensive qualities in water supply & drainage after practicing the CDIO engineering education. And it is good for exploring innovative talents cultivation system to meet the needs of social development. For a specific professional or different complex teaching process, the evaluation indexes can be changed. Or more levels of the evaluation index system can be established. The evaluation process can be broken down pointedly. Then the evaluation may reflect the real situation more. It can not only provide theoretical basis for the selection of high-quality talent, but also can promote the development of subject construction by using the model for comprehensive evaluation.

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