World Transactions on Engineering and Technology Education
Vol.12, No.3, 2014

Analysis based on AHP of factors influencing co-operation between higher vocational colleges and enterprises

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ABSTRACT: Co-operation between schools and enterprises is necessary so as to produce highly skilled students in Chinese higher vocational education and, hence, will feature in the reform and development of such education. In higher vocational and technical colleges, many complex factors affect school-enterprise co-operation, which relate not only to the schools and enterprises, but are also influenced by Government policies. Because of the effectiveness in handling complex decision problems, AHP (analytic hierarchy process) has advantages in analysis of school-enterprise co-operation factors. This study is an investigation into school-enterprise co-operation and its relative importance in vocational and technical colleges. A stratified random sampling method and questionnaires fed into the AHP analysis. The main factors of school-enterprise co-operation were identified and the AHP hierarchical model of factors of school-enterprise co-operation developed. The factors were sorted by importance. This work provides new information and a new tool for assessing the effectiveness of school-enterprise co-operation in higher vocational and technical colleges.

INTRODUCTION

Co-operation between schools and enterprises is necessary so as to produce highly skilled students in Chinese higher vocational education and, hence, will feature in the reform and development of higher vocational education. Vocational and technical colleges aim to cultivate talent possessing both college-level knowledge and technical skills. Hence the teaching should be practice-oriented [1]. School-enterprise co-operation in vocational and technical colleges focuses on technical communication. Vocational and technical colleges regard the technology in enterprises as the basis for the education of their students [2][3].

With rapid economic development and an increasingly competitive job market, vocational colleges came to realise that theoretical knowledge alone is not enough to satisfy the needs of society; practical experience is also essential for students. Meanwhile, enterprises also realise that the lack of professional technical personnel makes long-term development difficult. Therefore, co-operation between higher vocational and technical colleges and enterprises has aroused considerable interest.

Currently, school-enterprise co-operation in higher vocational and technical colleges is not widespread, because there is no effective communication with the enterprises. The low level of co-operation results from an inadequate mechanism for co-operation, including training personnel [4-6]. In higher vocational and technical colleges, there are many complex factors that affect school-enterprise co-operation that relate not only to the schools and enterprises, but are also influenced by Government policies.

In this work, the factors of school-enterprise co-operation were analysed using AHP (analytic hierarchy process), to determine the situation of higher vocational and technical colleges. The authors built a suitable hierarchical model of school-enterprise co-operation and determined the important indicators and parameters at each level. This provided an assessment of the effectiveness of school-enterprise co-operation in higher vocational and technical colleges.

SCHOOL-ENTERPRISE CO-OPERATION FACTORS

Many scholars in China and elsewhere have evaluated school-enterprise co-operation. New evaluation techniques have been proposed and are widely used in various fields. There have been various analysis and evaluation methods for multi-factor evaluations similar to school-enterprise co-operation, e.g. Analytic hierarchy process (AHP), 360-degree feedback, data envelopment analysis (DEA), fuzzy comprehensive evaluation, grey system method, artificial neural networks and fishbone diagram. Each analysis and evaluation method has its advantages, limitations and scope of applicability. In practice, either an appropriate method or combination of methods needs to be selected. The AHP is the most widely used method [7-9].

In this work, 500 educators, career guidance specialists, graduates, representatives of students and business representatives were selected randomly for a survey using the stratified random sampling method. They came from the provincial department of education, city board of education, a career centre, a vocational technical college, a large state-owned enterprise, a foreign-funded enterprise and a private company. They were in various locations.

Questionnaires were used to collect data on the factors of school-enterprise co-operation and determine their relative importance. A total of 500 questionnaires were given out, with 461 valid questionnaires returned. Therefore, this survey can objectively reflect the main factors of school-enterprise co-operation and their relative importance.

The returned 461 valid questionnaires were gathered and analysed to summarise the main factors. These factors refer to national policy support; enterprise social responsibility; relevant systems of enterprise cultural differences between schools and enterprise; capacity for school-enterprise co-operation; school-enterprise co-operation benefits; location of enterprises; enterprise size; school-enterprise communication channels and capacity of enterprise mentor.

BUILDING AN HIERARCHICAL MODEL OF SCHOOL-ENTERPRISE CO-OPERATION

The AHP, a hierarchical decision analysis method, was proposed in the 1970s by Thomas L. Saaty, an American operations researcher and Professor at the University of Pittsburgh. The AHP breaks down the elements into different levels (such as objectives, guidelines and programmes), for qualitative and quantitative analysis [10].

Due to its practicality and effectiveness in dealing with complex decision problems, the AHP has advantages in conducting system analysis and strategic research. It is widely used in politics, the military, education, economics, engineering and other fields [11][12].

The AHP is used to solve complex multi-objective decision-making problems from the perspective of the whole system of school-enterprise co-operation. The AHP hierarchical model is made up of multiple sub-indicators together referring to some criteria; thus, forming a multi-level indicator system, with the overall system goal as a starting point. After fuzzy quantisation, qualitative indicators can be used to calculate single-level weightings to determine the overall importance of objectives at each level. The AHP, thereby, provides a systematic approach to analysing multi-objective optimisation decisions [13].

The AHP has the following advantages for the analysis of school-enterprise co-operation factors: 1) the relative index evaluation system is used to combine qualitative and quantitative indicators; thereby, unifying qualitative judgment with quantitative calculation in a standard index system; 2) the AHP is a systematic way of thinking about decision-making, which is accurate and practical; 3) the most difficult aspects of AHP, such as weight calculations, judgment matrix calculation and consistency checks, have been made straightforward through software systems; and 4) the AHP method has wide application and can be used to build an adaptive evaluation index system by transforming the determination matrix.

For the study here, account was taken of the differences in orientation of higher vocational and technical colleges and the objectives of school-enterprise co-operation. Using the AHP [14], the 10 major factors obtained through the survey were stratified and analysed to build a hierarchical model of school-enterprise co-operation factors (see Figure 1).

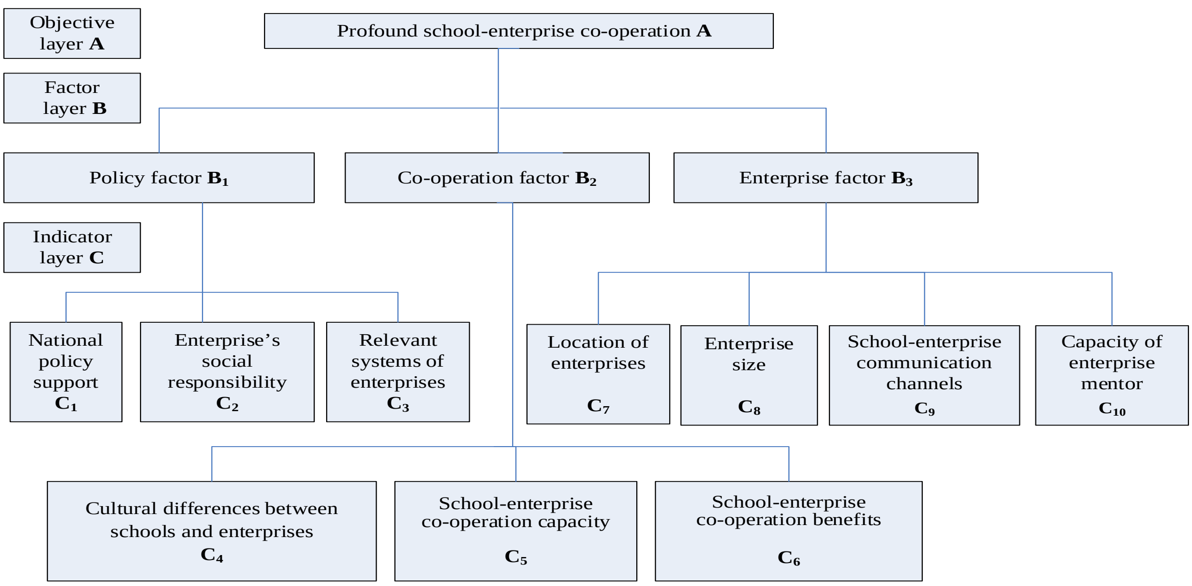

Figure 1: Hierarchical model of school-enterprise co-operation factors.

ANALYSIS ON THE HIERARCHICAL STRUCTURE MODEL

Construction of the Judgment Matrix

The hierarchical structure of the school-enterprise co-operation factors has three layers: the first is *profound co-operation between schools and enterprises* at the objective layer; the second layer is a factor layer having three factors. These are: policy, co-operation and enterprise. The third layer is an indicator layer, with 10 indicators. These are: national policy support, social responsibility, related systems of enterprise, school-enterprise cultural differences, school-enterprise co-operation capacity, school-enterprise co-operation effectiveness, location of enterprises, size of enterprises, school-enterprise communication channels and capacity of enterprise mentors.

In the survey, respondents start from profound co-operation between schools and enterprises at the objective layer, conducting pairwise comparisons between the first layer and policy factor, co-operation factor and business factor at the factor layer. The relative importance of the three factors are expressed in numerical form, and the relative weighting judgment matrix of the objective layer was built. Similarly, the relative weight matrix of the factor layers was built based on the three factors in the factor layer. For example, matrix B_{ij}, with respect to objective layer *A*, indicates the relative importance of B_i to B_j. It is assigned a value from the comparison scale (1-9) [15], thereby, obtaining the relative importance values of B_i to B_j (see Table 1).

Table 1: Relative importance of B_i and B_j using the AHP comparison scale (1–9).

Relative importance value	Meaning	Description of relative importance
1	Equally important	When compared the two indicators, B_i and B_j are equally important.
3	Slightly stronger	B_i has slightly more importance than B_j.
5	Stronger	B_i is more important than B_j.
7	Especially important	B_i is much more important than B_j.
9	Definitely stronger	B_i is definitely more important than B_j.
2, 4, 6, 8	Between the two adjacent scales	The relative importance of B_i to B_j is between the two adjacent scales.
Reciprocal value	Assigned scale in comparing B_i with B_j is the reciprocal value of that in comparing B_j with B_i.	

After summarising the 461 valid questionnaires from the survey, the statistical average was calculated for the weights of each subordinate indicator to its superior layer. This leads to four judgment matrices of school-enterprise co-operation factors, see Tables 2 to 5. In these tables $\lambda_{\max}$ is the maximum eigenvalue, *CI* is the consistency indicator and *CR* is the consistency ratio. These are defined below in the section *consistency test of judgment matrices*.

Table 2: Judgment matrix *A* - *B*.

A	B_1	B_2	B_3	W_{A-B}	Consistency test indicators
B_1	1	3	4	0.62	$\lambda_{\max} = 3.03$
B_2	1/3	1	2	0.24	$CI = 0.02$
B_3	1/4	1/2	1	0.14	$CR = 0.03 < 0.1$

Table 3: Judgment matrix B_1 - *C*.

B_1	C_1	C_2	C_3	W_{B_1-C}	Consistency test indicators
C_1	1	2	5	0.58	$\lambda_{\max} = 3.006$
C_2	1/2	1	3	0.31	$CI = 0.003$
C_3	1/5	1/3	1	0.11	$CR = 0.01 < 0.1$

Table 4: Judgment matrix B_2 - C.

B_2	C_4	C_5	C_6	W_{B_2-C}	Consistency test indicators
C_4	1	2	4	0.55	$\lambda_{max} = 3.08$
C_5	1/2	1	4	0.34	$CI = 0.04$
C_6	1/4	1/4	1	0.11	$CR = 0.07 < 0.1$

Table 5: Judgment matrix B_3 - C.

B_3	C_7	C_8	C_9	C_{10}	W_{B_3-C}	Consistency test indicators
C_7	1	2	4	5	0.48	$\lambda_{max} = 4.08$
C_8	1/2	1	3	4	0.31	$CI = 0.03$
C_9	1/4	1/3	1	2	0.13	$RI = 0.90$
C_{10}	1/5	1/4	1/2	1	0.08	$CR = 0.03 < 0.1$

WEIGHT CALCULATION

For judgment matrix A - B, the weight values of factors B_1, B_2 and B_3 are calculated to obtain the relative weights of policy factor, co-operation factor and enterprise factor to the objective layer, *school-enterprise profound co-operation*. The steps are as follows [16]:

1. Multiply together the elements of each row of the judgment matrix.

$$w = \prod_{j=1}^{n} a_{ij}, (i = 1,2,3,\cdots,n) = (12, \frac{2}{3}, \frac{1}{8}) ; \tag{1}$$

2. Calculate n-th root of the obtained product where n is the order of the judgment matrix.

$$\overline{w_i} = \sqrt[n]{\prod_{j=1}^{n} a_{ij}}, (i = 1,2,3,\cdots,n) = (2.29, 0.87, 0.5) ; \tag{2}$$

3. Calculate normalised weights of $\overline{w_i}$.

$$w_i = \frac{\overline{w_i}}{\sum_{j=1}^{n} \overline{w_j}}, (i = 1,2,3,\cdots,n) = \begin{cases} w_1 = 0.62 \\ w_2 = 0.24 \\ w_3 = 0.14 \end{cases} ; \tag{3}$$

4. Calculate the weight vector of judgment matrix A - B.

$$W_{A-B} = \begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix} = \begin{pmatrix} 0.62 \\ 0.24 \\ 0.14 \end{pmatrix} ; \tag{4}$$

After filling in the fifth column of Table 2, the relative importance of three factors - policy, co-operation and enterprise - was calculated based on the objective layer. Similarly, the weight vectors of the judgment matrices B_1 - C, B_2 - C and B_3 - C were calculated as W_{B_1-C}, W_{B_2-C} and W_{B_3-C}, which are filled in the fifth column of Table 3 and Table 4, and the sixth column of Table 5, respectively.

CONSISTENCY TEST OF JUDGMENT MATRICES

To ensure the effectiveness of the judgment matrix, a consistency test should be carried out on each weight vector of the judgment matrix layer. For example, the consistency test of judgment matrix A - B is as below [17].

1. Multiply the rank of judgment matrix *A* - *B* with weight vector W_{A-B}, obtaining $A_{A-B} \cdot W_{A-B}$.

$$A_{A-B} \cdot W_{A-B} = \begin{pmatrix} 1 & 3 & 4 \\ \frac{1}{3} & 1 & 2 \\ \frac{1}{4} & \frac{1}{2} & 1 \end{pmatrix}_{3\times 3} \begin{pmatrix} 0.62 \\ 0.24 \\ 0.14 \end{pmatrix}_{3\times 1} = \begin{pmatrix} 1.90 \\ 0.73 \\ 0.42 \end{pmatrix}_{3\times 1} ; \quad (5)$$

2. Calculate the maximum eigenvalue of judgment matrix *A* - *B*:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nw_i}, (i = 1,2,\cdots,n) = \frac{1.90}{3\times 0.62} + \frac{0.73}{3\times 0.24} + \frac{0.42}{3\times 0.14} = 3.03 ; \quad (6)$$

3. Calculate the consistency indicator of judgment matrix *A* - *B*:

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{3.03 - 3}{3-1} = 0.02 ; \quad (7)$$

4. Referring to Table 6, average random consistency index values [18] can be obtained according to the order of the judgment matrix, *n*:

$$RI = 0.58 \quad (8)$$

5. Calculate the consistency ratio:

$$CR = \frac{CI}{RI} = \frac{0.02}{0.58} = 0.03 < 0.1 ; \quad (9)$$

6. If the consistency ratio is less than 0.1, then judgment matrix *A* - *B* passes the consistency test, and the judgment matrix is valid.

7. Consistency test indicators $\lambda_{\max}$, *CI* and *CR* are filled in the sixth column of Table 2.

Table 6: Mean random consistency indicators.

Order of matrix	1	2	3	4	5	6
RI	0.00	0.00	0.58	0.90	0.12	1.24

Similarly, consistency tests are conducted on judgment matrices B_1 - *C*, B_2 - *C* and B_3 - *C*, obtaining the consistency ratios: 0.01, 0.07 and 0.03, respectively. These three values are all less than 0.1, so judgment matrices B_1 - *C*, B_2 - *C* and B_3 - *C*, also pass the consistency test. Consistency test indicators $\lambda_{\max}$, *CI* and *CR* are filled in the sixth column of Tables 3 and 4, and $\lambda_{\max}$, *CI*, *CR* and *RI* are in the seventh column of Table 5.

SORTING BY IMPORTANCE

The overall importance of the factors of the hierarchical model for school-enterprise co-operation were calculated according to the single-level weights at each layer (the sorted weighted elements). The relative weights of three factors and 10 indicators to the overall objective *school-enterprise profound co-operation* are listed in Table 7.

Table 7: Weights of constituent elements.

Objective layer A	Factor layer B	Indicator layer C	Weight of indicators W
Profound school-enterprise co-operation	Policy factor	National policy support C_1	0.36
		Enterprise social responsibility C_2	0.19
		Relevant systems of enterprises C_3	0.07
	Co-operation factor	Cultural differences between schools and enterprises C_4	0.13
		School-enterprise co-operation capacity C_5	0.08
		School-enterprise co-operation benefits C_6	0.03

	Enterprise factor	Location of enterprises C_7	0.07
		Enterprise size C_8	0.04
		School-enterprise communication channels C_9	0.02
		Capacity of enterprise mentor C_{10}	0.01

CONCLUSIONS

The hierarchical model of school-enterprise co-operation factors contains 10 elements involving aspects of policy, co-operation and enterprise. By using the model, the main factors that affect school-enterprise co-operation were determined. The judgment matrices at all layers passed the consistency test; therefore, the hierarchical model of school-enterprise co-operation factors is valid.

The school-enterprise co-operation factors were analysed using the analytic hierarchy process (AHP). Sorting by importance yields the following order of factor, from most important to least: national policy support; enterprise social responsibility; cultural differences between schools and enterprises; school-enterprise co-operation capacity; relevant systems of enterprise; location of enterprises; enterprise size; school-enterprise co-operation benefits; school-enterprise communication channels and capacity of enterprise mentor.

National policy support, enterprise social responsibility and school-enterprise cultural differences are the three main factors for school-enterprise co-operation, with the overall weight close to 70 per cent. These three factors can be used to promote school-enterprise co-operation in higher vocational and technical colleges, and to evaluate the effectiveness of school-enterprise co-operation.

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