World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:5, No:6, 2011

Study on Applying Fuzzy AHP and GRA in Selection of Agent Construction Enterprise

Shirong Li，Huan Yan

***Abstract*—**To help the client to select a competent agent construction enterprise (ACE), this study aims to investigate the selection standards by using the Fuzzy Analytic Hierarchy Process (FAHP) and build an evaluation mathematical model with Grey Relational Analysis (GRA). According to the outputs of literature review, four orderly levels are established within the model, taking the consideration of various agent construction models in practice. Then, the process of applying FAHP and GRA is discussed in detailed. Finally, through a case study, this paper illustrates how to apply these methods in getting the weights of each standard and the final assessment result.

***Keywords*—**agent construction enterprise, agent construction model, fuzzy analytic hierarchy process, grey relational analysis

I. Introduction

TO improve the performance of the government investment and to enhance the management of the projects invested by government, Government Document of “Decision about the Reform of Investment System” issued by the China State Council in July 2004 pointed out that China would speed up to apply the agent construction system(ACS)in public project. ACS means that choosing professional project management enterprise by several methods such as bidding to implement construction, and this project management enterprise should control the project investment, the project quality, and the project period strictly, and should transfer the project to the client after the acceptance of completion, see as Fig.1. From then on, the ACS started to be implemented all over the country and it has brought improvements to public projects [1]. However, as the ACS is just in the beginning and improving stage and there is no unified law or regulation in China, some problems have come out about this system，and the selection of agent construction enterprise (ACE) is one of them.The ACE plays the key role in the public project’s success [2], but no unified recognition or law has made definite provisions on how to select the ACE. Researches have been done on this problem, but different researchers put emphasis on different aspect of the selection of ACE. As discussed by Ke [3], the ACE club (directory) can be established based on patterning model from the view of cooperation and trust theory , and the model of selection of ACE by using the external incentive mechanism of the project is introduced by comparative analysis of bidding and trust selection mechanism based on reputation, suggested by Deng [4]. These studies discuss some problems on how to select the ACE to some extend. However, they fail to give the theoretic analysis of the factors influencing the selection of ACE and any

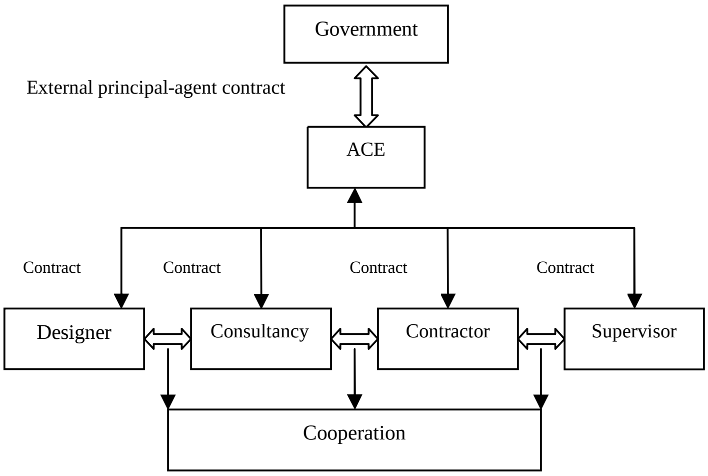

Fig. 1 Relationship of the Contractual Organization of Agent Construction Project

suggestions. On this condition, the selection method of ACE on the basis of project governance theory is given [5] and the bidding is proposed as a good method, but it also fails to give the suggestion on the operational level Studies also have been done from the perspective of performance evaluation of ACE [6]–[8]. This is of usefulness after the completion of the project and the directory establishment of ACE, but not so much useful when selecting ACE for a concrete project. As bidding is the main method, how to select ACE by bidding has also been studied by some researchers with many methods, such as the Analytic Hierarchy Process (AHP) [9]–[10], Fuzzy Mathematics and Layered Grey Relational Analysis [11], Data Envelopment Analysis (DEA) [12], and the combination of AHP, FDF and DEA [13].These give some feasible methods to the selection of ACE. However, these studies do not take the agent construction model into account when selecting ACE, an important consideration for the selection of ACE. As all the agent construction can be divided into three model designed by stage, the different agent construction model has different demands on the ACE. The evaluation system of the previous studies pays less attention to this point. So this paper aims to take the demands of different agent construction model into

Shirong Li, professor, is with the Faculty of Construction Management and Real Estate, Chongqing University, Chongqing, 400045, China (phone: 86-23-65123204; fax: 86-23-65123204; e-mail: lishirong@vip.163.com).

Huan Yan, postgraduate, is with the Faculty of Construction Management and Real Estate, Chongqing University, Chongqing, 400045, China (phone: 86-23-65123204; fax: 86-23-65123204; e-mail: yanfoon@163.com).

consideration when choosing ACE by bidding. Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA) are used in this research, making the qualitative index quantitative and combining the qualitative analysis and quantitative analysis together. This model not only reflects the demands of the clients of different agent models objectively, but also experts' advices.

II. Research Methodology

This research framework could be generalized as four parts. To begin with, a comprehensive literature review which helps to develop a framework for this study was given. It reviewed the previous studies on the selection of ACE, reviewing the achievements have been obtained by researchers in China and making them as the theoretic base of this study. Then the agent construction model was analyzed and the emphasis was put on the agent construction model designed by stage, which was of great importance for the establishment of the indexes system of ACE selection. Based on the agent construction model, the indexes system of ACE selection was established by Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA) was used to build the mathematical model for evaluating the ACE. The FAHP was used to make sure of weight of each standard while (GRA) was employed to choose the best competent ACE. Finally, the finding was given and discussed.

III. Agent Construction Model and Agent Construction Enterprise Duties

Currently, the model of agent construction project management can be generalized from two aspects: the source of the project capital and the construction stage [14].

Life cycle of a construction project can be divided into the preliminary stage, the design stage, the construction stage and the operational stage. Therefore, the agent construction project management can be designed according to the stage: the non-overall process agent construction and the overall process agent construction. The preliminary agent construction and the implementation stage agent construction are included in the non-overall process agent construction. The non-overall process agent construction is suitable for the project that has high demands on the professional knowledge so as to use the professional advantages of ACE, while the overall agent construction model is suitable for the project that has not so much high demands on the professional knowledge[15]–[16], see Fig. 2.

A. The preliminary stage agent construction

In the preliminary stage, the client entrust the work of project planning, feasibility study, project financing, preliminary design and a part of bidding ＆ contract-award to the ACE who is responsible for the authenticity of the feasibility study report and the project establishment report (see Fig. 2. A). On this condition, the ACE should be very familiar with the capital construction procedure and the preliminary work of the project.

Stage	Preliminary Stage			Design Stage			Construction stage		
Agent Mode	Feasibility study	Project Financing	Preliminary design	Bidding & Contract-award	Detailed Design	Bidding & Contract-award	Preparation	Construction	Transfer
The Preliminary stage		A							
The Implement stage					B				
The overall process				C					

Fig. 2 Agent Construction Model Divided by Stage

B. The implementation stage agent construction

After the feasibility-study report has been approved by authority or the preliminary design has been completed, the project establishes. Then the project enters the implementation stage. The design stage and the construction stage are included in this stage. The project becomes entity from blueprint. In this stage, the client relegates the management of design and construction of the project to the ACE who manages all-round the project according to the approved project establishment report or the preliminary design. The construction standards, the control of project investment, project quality, project period are the core responsibilities of the ACE (see Fig. 2. B).

C. The overall process agent construction

The overall process agent construction (see Fig. 2. C). is that the owner entrusts the management work of the preliminary stage, the design stage and the construction stage to the ACE. A general idea on the construction function, scale, standards and period are given to the ACE and then the ACE is in charge of the feasibility study and manage all-round the project, from the beginning of the project to the transfer of project. As all the works are implemented by one ACE, unnecessary interface management can be reduced to increase the management efficiency. When it comes to this point, this model is suitable for the project that has not so much high demands on the professional knowledge.

IV. Establishment of the ACE Selection Model Based on FAHP and GRA

A. Establishment of the Bidding Evaluation Indexes System

The bidding evaluation indexes system is the key issue. The scientificity and moderation of the target system establishment influence the objectivity and authenticity to the evaluation result of ACE. So, a set of comprehensive and scientific bidding evaluation indexes system is the key.

To achieve this goal, Fuzzy Analytic Hierarchy Process (FAHP) is used to establish the bidding evaluation indexes system. FAHP is the improved Analytic Hierarchy Process (AHP). AHP is a systematic analysis method to analyze the complicated problem and it is widely used in practice. However, there are some problems about AHP: the consistency checkout of the judgment matrix is difficult, the standards for consistency checkout of the judgment matrix are unscientific [17].So FAHP is put forward to resolve the problem.

Based on the agent model analyze, the bidding evaluation indexes system is established. The demand to the ACE of different agent construction model designed by stage is taken into account so that this model can be appropriate for all the agent construction models.

The FAHP model can be divided into four basic levels: the target level (TL), the standard level (SL), the index level (IL) and the object level (OL), based on the characters of bidding of ACS.

1． Target Level (TL)

The goal of the evaluation is to determine which ACE is competent, so the target should be to choose a competent ACE for the project invested by the government.

2． Standard level (SL) and Index level (IL)

Standard level (SL) and Index level (IL) are the standards used to measure whether the target could be realized. When it comes to the selection of ACE, it means to investigate all the ACEs with the standards comprehensively. As the selection of ACE differs from the selection of contractors, much more emphasis should be paid not only on the tender price but the comprehensive management ability of the ACE. The ACE must be rich of project management experience and ability, especially a good control of investment, quality and schedule. What is most important is that the standards should reflect the demands of the three agent models designed by stage. The demands to the ACE differs [18].When the client chooses any of the three models, the standards should be applicable. For the preliminary agent model A, the ACE is asked to have a good ability in feasibility study, project financing (if the client can not solve the finance problem), bidding& contract-award, and should be familiar with the capital construction procedure; for the implement agent model B, the ACE must be good at design management ,bidding & contract-award, on-site management and comprehensive management; and for the overall process agent model C, here is a high requirement on the ACE that the ACE is demanded to have high ability in the management from the very beginning to the end of the project.

3． Object level (OL)

Object level represents the agent program of each ACE candidate (indicated by ACE).

Based on the analysis , the bidding evaluation indexes system is built (see Fig. 3).

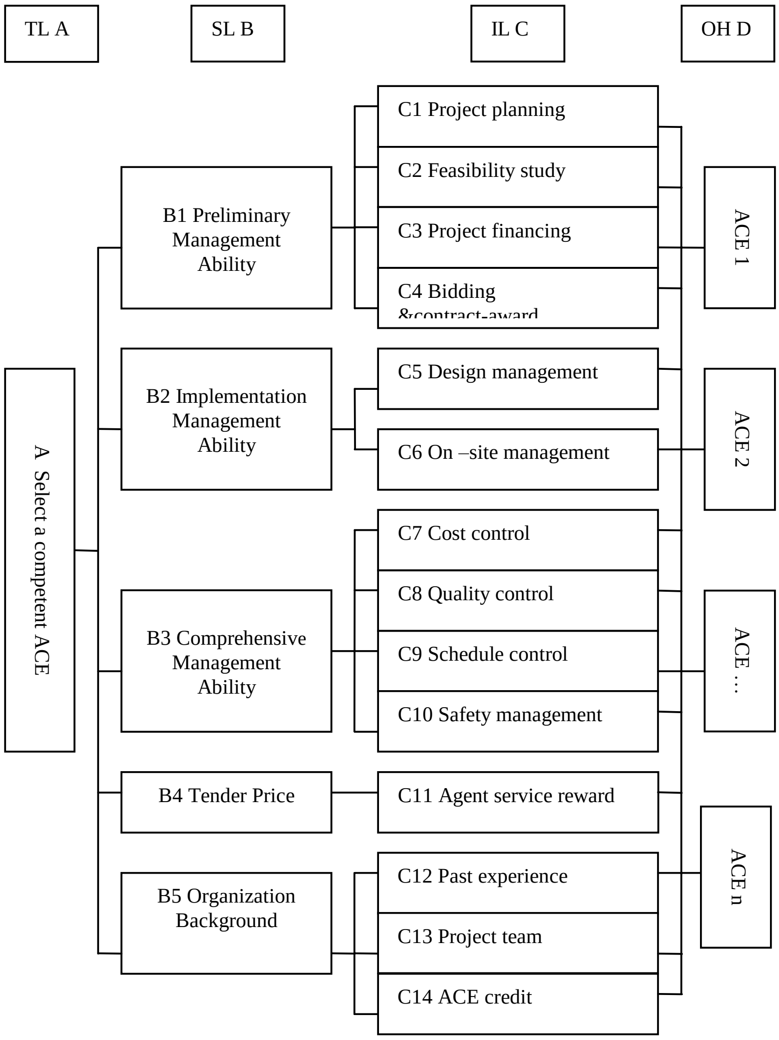

Fig. 3 Bidding evaluation indexes system for the ACE selection

B. Establishment of the Fuzzy Consistent Judgment Matrix

The fuzzy consistent judgment matrix R represents the relative importance of the various factors of one level to the father level. Supposing that standard B has a relationship with the index $c_1, c_2, \dots, c_n$ in the son-level, the fuzzy consistent judgment matrix can be expressed as

$$\begin{array}{c|cccc} B & c_1 & c_2 & \cdots & c_n \\ \hline c_1 & r_{11} & r_{12} & \cdots & r_{1n} \\ c_2 & r_{21} & r_{22} & \cdots & r_{1n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_n & r_{n1} & r_{n2} & \cdots & r_{nn} \end{array} \quad (1)$$

where r_{ij} represents the relative importance the index c_i has over c_j when compared with the standard B .The relative importance can be got by adopting the following 0.1—0.9 Quantity Sale.

TABLE I
THE 0.1—0.9 QUANTITY SALE

Definition	Quality scale
For the comparison of two factors, they are of equal importance	0.5
For the comparison of two factors, factor i is a little more important than j	0.6
For the comparison of two factors, factor i is obviously more important than j	0.7
For the comparison of two factors, factor i is quite more important than j	0.8
For the comparison of two factors, factor i is extremely more important than j	0.9
When the r_{ij} is got by compared α_i with a_j, then r_{ji} = 1- r_{ij} is got by compared a_j with a_i.	0.1, 0.2, 0.3, 0.4

Based on the Quantity Sale, the fuzzy consistent judgment matrix R can be obtained by comparing the index $c_1, c_2, ..., c_n$ with the standard B in the father level.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{1n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \quad (2)$$

Because of the complexity of the problem and the one-sidedness of the cognitive ability, the judgment matrix established may not satisfy the coincidence. In this case, the judgment matrix needs to be adjusted as following steps：

Step 1: choose one judgment matrix of the factor. Without loss of generality, it is thought that it is more certain about the judgment of $r_{11}, r_{12}, ..., r_{1n}$.

Step 2: the elements in the first row of the judgment matrix are subtracted by the corresponding elements in the second row. If the n results are constants, there is no need to adjust the elements in the second row, otherwise they needs until the results are constants.

Step 3: the elements in the first row of the judgment matrix are subtracted by the corresponding elements in the third row. If the n results are constants, there is no need to adjust the elements in the second row, otherwise they needs until the results are constants.

The procedure above does not stop until the results gotten by the elements subtracting in the first row by the corresponding element in the nth row are constants.

C. Weighs of the Elements in the Fuzzy Consistent Judgment Matrix

The fuzzy consistent judgment matrix $R = (r_{ij})_{nxn}$ is gotten by paired comparison of relative importance of $c_1, c_2, ..., c_n$, and the weigh are $w_1, w_2, ..., w_n$ respectively. Then the relational expression is got as

$$r_{ij} = 0.5 + a\left(w_i - w_j\right), i, j = 1, 2, ..., n \quad (3)$$

Where $0 < a \leq 0.5$, a is one measurement of differentiation degree of the people's perception toward the object and it has relationships with the number of the object and the differentiation degree. When the number is big or the differentiation degree is high, the value of a could be a little bigger.

When the judgment matrix R does not satisfy the coincidence, the equality sign in (3) does not establish strictly speaking. Then the weight vector $W = \left[w_1, w_2, ..., w_n\right]^T$ could be obtained with Least Squares, namely by solving the following Constraint Programming problem:

$$\begin{cases} \min z = \sum_{i=1}^{n}\sum_{j=1}^{n}\left[0.5 + a\left(w_i - w_j\right) - r_{ij}\right]^2 \\ s.t. \sum_{i=1}^{n} w_i = 1, w_i \geq 0, (1 \leq i \leq n) \end{cases} \quad (4)$$

From the perspective of Lagrange multiplier method, the Constraint Programming problem (4) is of equal value with the following no Constraint Programming problem (5)：

$$\min L(w, \lambda) = \sum_{i=1}^{n}\sum_{j=1}^{n}\left[0.5 + a\left(w_i - w_j\right) - r_{ij}\right]^2 + 2\lambda\left(\sum_{i=1}^{n} w_i - 1\right) \quad (5)$$

where λ is the Lagrangian Multiplier.

Get the first order partial derivative of $L(w, \lambda)$ on $w_i \left(i = 1, 2, ..., n\right)$, then let it to be zero, and a simultaneous equation including n algebraic equations (5) is gotten as

$$a\sum_{i=1}^{n}\left[0.5 + a\left(w_i - w_j\right) - r_{ij}\right] - a\sum_{\lambda=1}^{n}\left[0.5 + a\left(w_\lambda - w_i\right) - w_{\lambda i}\right] + 1 = 0$$

$$(i = 1, 2, ..., n) \quad (6)$$

That is $\sum_{j=1}^{n}\left[2a^2\left(w_i - w_j\right) + a\left(r_{ji} - r_{ij}\right)\right] + 1 = 0$

$$(i = 1, 2, ..., n) \quad (7)$$

As $n+1$ unknown numbers $w_1, w_2, ..., w_n, \lambda$ are included while there are only n algebraic equations in (7) above, the only answer can not be gotten. On this situation the algebraic equation $w_1 + w_2 + ... + w_n = 1$ is added to (7) as

$$\begin{cases} 2a^2(n-1)w_1 - 2a^2 w_2 - 2a^2 w_3 - .... - 2a^2 w_n + \lambda = a\sum_{j=1}^{n}\left(r_{1j} - r_{j1}\right) \\ -2a^2 w_1 + 2a^2(n-1)w_2 - 2a^2 w_3 - .... - 2a^2 w_n + \lambda = a\sum_{j=1}^{n}\left(r_{2j} - r_{j2}\right) \\ \cdots\cdots \\ -2a^2 w_1 - 2a^2 w_2 - 2a^2 w_3 - .... - 2a^2(n-1)w_n + \lambda = a\sum_{j=1}^{n}\left(r_{nj} - r_{jn}\right) \\ w_1 + w_2 + ... + w_n = 1 \end{cases} \quad (8)$$

Now the only answer to this problem from the simultaneous equation above can be gotten as

$$W = [w_1, w_2, ..., w_n]^T \quad (9)$$

D. Gain of Characteristic Vector Matrix of the Criterion

Supposing that the alternative set $X_i\,(i = 1,2,...,m)$ is comprised by m participants for the project and the criterion set $x_i\,(i = 1,2,...,n)$ of the alternative's advantage evaluation comprised by n criterions. Then the characteristic vector matrix of the criterion (decision-making matrix) can be gotten as

$$x = \begin{bmatrix} x_1 \\ x_2 \\ ... \\ x_m \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & ... & x_{1n} \\ x_{21} & x_{22} & ... & x_{2n} \\ ... & ... & ... & ... \\ x_{m1} & x_{m2} & ... & x_{mn} \end{bmatrix} \quad (10)$$

1. Ascertainment of the Qualitative and Qualitative Criterion

All the criterions can be divided into either quantitative criterion or qualitative criterion. For the qualitative criterion such as the past experience, the organization team can be evaluated by the linguistic variables and fuzzy number. What linguistic variable differs from numerical variable is that its values are not numbers but words or sentences in a natural or artificial language. Linguistic variables such as "poor management," "good performance," and "moderate risk" describe the vague concept [19]-[21]. Here the Linguistic variables set of the qualitative criterion is established as E = (very good/important, good/important, above average, average, below average, poor/low important, very poor/very low important) in the real-number values ranging in the closed interval between 0 and 1(see Table Ⅱ). Let a trapezoidal fuzzy number be parameterized by x_1, x_2, x_3, x_4 , and then the defuzzification value e is given by the following equation [22]:

$$e = (x_1 + x_2 + x_3 + x_4)/4 \quad (11)$$

The quantitative criterion, such as agent service reward, can be indicated by real mount of money or criterion.

2．The Ascertainment of the Relatively Ideal Alternative

The relative ideal alternative is possible the best competent ACE objectively, getting by selecting the best value of each criterion. In the evaluation criterion, the agent reward is the cost-type criterion which the much smaller the value is the better it is while the organization credit, the ability of management during the preliminary and implementation are benefit-type criterion which the bigger the value is the better it is. It is supposed that the criterion x_{0j} of the relative ideal alternative X^0 satisfies the following conditions：

$x_j^0 = \min\{x_{1j,} x_{2j}, ..., x_{mj}\}$ if the criterion is the cost-type criterion

$x_j^0 = \max\{x_{1j,} x_{2j}, ..., x_{mj}\}$ if the criterion is the benefit-type criterion

TABLE II
FUZZY NUMBER FOR LINGUISTIC VARIABLES

very good/ important (VGV/I)	(0.8, 0.9, 1.0, 1.0)
good /important (G/I)	(0.6, 0.7, 0.8, 0.9)
above average (AA)	(0.5, 0.6, 0.7, 0.8)
Average (A)	(0.4, 0.5, 0.6, 0.7)
below average (BA)	(0.2, 0.3, 0.4, 0.5)
poor/ low important (P/L I)	(0.1, 0.2, 0.3, 0.4)
very poor/ very low important) (VP/VLI)	(0.0, 0.0, 0.1, 0.2)

Then the characteristic vector matrix of the criterion including $n+1$ alternatives is obtained as

$$\bar{x} = \begin{bmatrix} x_1 \\ x_2 \\ ... \\ x_m \\ x^0 \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & ... & x_{1n} \\ x_{21} & x_{22} & ... & x_{2n} \\ ... & ... & ... & ... \\ x_{m1} & x_{m2} & ... & x_{mn} \\ x^0_{1j} & x^0_{2j} & ... & x^0_{mj} \end{bmatrix} \quad (12)$$

3．Normalization of the Characteristic Vector Matrix of the Criterion

Because different evaluation criterions have different dimensions and the value differences between them are obvious, the characteristic vector matrix of the criterion needs to be normalized to eliminate the influence on the decision-making.

For the cost-type criterion, let

$$s_{ij} = (x_{imax} - s_{ij})/(x_{imax} - s_{imin}) \quad (13)$$

For the benefit-type criterion, let

$$s_{ij} = (x_{ij} - s_{imin})/(x_{imax} - s_{imin}) \quad (14)$$

After normalization by using (13) and (14), the normalized characteristic vector matrix of the criterion is gotten as

$$S = \begin{bmatrix} s_{11} & s_{12} & ... & s_{1n} \\ s_{21} & s_{22} & ... & s_{2n} \\ ... & ... & ... & ... \\ s_{m1} & s_{m2} & ... & s_{mn} \\ s^0_1 & s^0_2 & ... & s^0_m \end{bmatrix} \quad (15)$$

4．Calculation of the Correlation Degree Index Value

According the GRA, e correlation degree index value r_{ij} between the criterion of the in the decision-making matrix of the alternative i and the criterion j of the relative ideal alternative S^0 is

$$r = \frac{\min_i \min_j |s_{ij} - s_j^0| + r \max_i \max_j |s_{ij} - s_j^0|}{|s_{ij} - s_j^0| + r \max_i \max_j |s_{ij} - s_j^0|} \quad (16)$$

Where ρ is resolution ratio，0< ρ <1 generally ρ .

Based on the equation above the correlation degree index value matrix is gotten as

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \quad (17)$$

5. *Calculation of the Correlation Degree Value*

The correlation degree is the level for measuring the similarity degree of the index sequence and it ranges in the closed interval between 0 and 1.The closer the value is to 1 , the higher the similarity degree of the index sequence has compared to the relative idea alternative. The correlation degree value of each alternative to the relative idea alternative can be gotten as

$$V = R \times W^T = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \times \begin{bmatrix} W_1 \\ W_2 \\ \cdots \\ W_n \end{bmatrix} = \begin{bmatrix} v_1 \\ v_2 \\ \cdots \\ v_n \end{bmatrix} \quad (18)$$

Sequence the correlation degree value v_i , and chose the alternative with the highest correlation degree value as the most competent ACE for the project.

V.CASE STUDY

A case is studied to illustrate the application of the proposed ACE selection method. The ACS is used in is a municipal facility in Chongqing, China, and this project is the overall process agent construction.

Seven experts are invited to evaluate the relative importance of all the standards. After strict calculation on the weight value, the fuzzy consistent judgment matrix R is got. Next, based on the analysis in section Ⅳ, the weights of index can be got by FAHP (see Table Ⅲ).

TABLE III
WEIGHTS OF THE INDEX

B_i	B_i weighting	C_i	c_i weighting
B1	0.21	C1	0.275
		C2	0.234
		C3	0.156
		C4	0.335
B2	0.23	C5	0.432
		C6	0.568
B3	0.27	C7	0.276
		C8	0.306
		C9	0.254
		C10	0.164
B4	0.15	C11	1.000
B5	0.14	C12	0.285
		C13	0.396
		C14	0.319

And then, the experts evaluate each index of four agent programs (see Table Ⅳ).

TABLE IV
LINGUISTIC ASSESSMENT OF EACH AGENT PROGRAM

Prog-ram	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*C11*	*C12*	*C13*	*C14*
Ⅰ	G	VP	G	P	A	AA	P	G	VG	AA	20	G	AA	G
Ⅱ	VG	G	VG	VG	G	G	BA	G	A	A	26	P	G	A
Ⅲ	A	VG	BA	VG	A	VG	A	AA	A	VP	23	P	P	A
Ⅳ	BA	G	A	G	A	VG	VP	G	G	A	18	VG	VG	A

C11 represents the Agent service reward and the unit of it is million CNY.

Through Table Ⅳ, the characteristic vector matrix of the criterion can be got as

$$X = \begin{bmatrix} 0.75 & 0.075 & 0.75 & 0.25 & 0.55 & 0.65 & 0.25 & 0.75 & 0.9 & 0.65 & 20 & 0.75 & 0.65 & 0.75 \\ 0.9 & 0.75 & 0.9 & 0.9 & 0.75 & 0.75 & 0.35 & 0.75 & 0.55 & 0.55 & 26 & 0.25 & 0.75 & 0.55 \\ 0.55 & 0.9 & 0.35 & 0.9 & 0.55 & 0.9 & 0.55 & 0.65 & 0.55 & 0.075 & 23 & 0.25 & 0.25 & 0.55 \\ 0.35 & 0.75 & 0.55 & 0.75 & 0.55 & 0.9 & 0.075 & 0.75 & 0.75 & 0.55 & 18 & 0.9 & 0.9 & 0.55 \end{bmatrix}$$

And then through the GRA method introduced before, the correlation degree index value matrix is gotten as

$$R = \begin{bmatrix} 0.63 & 0.33 & 0.63 & 0.33 & 0.33 & 0.33 & 0.36 & 1 & 1 & 0.7 & 0.63 & 0.63 & 0.56 & 1 \\ 1 & 0.63 & 1 & 1 & 1 & 0.45 & 0.42 & 1 & 0.33 & 0.56 & 0.33 & 0.33 & 0.63 & 0.33 \\ 0.42 & 1 & 0.33 & 1 & 0.33 & 1 & 0.56 & 0.33 & 1 & 0.33 & 0.42 & 0.33 & 0.33 & 0.33 \\ 0.33 & 0.63 & 0.42 & 0.63 & 0.33 & 1 & 0.33 & 1 & 0.5 & 0.56 & 1 & 1 & 1 & 0.33 \end{bmatrix}$$

According to (18), the correlation degree value v_i of each agent program can be got as

$$V = \begin{bmatrix} v_1 & v_2 & v_3 & v_4 \end{bmatrix}^T = \begin{bmatrix} 0.576 & 0.637 & 0.579 & 0.698 \end{bmatrix}$$

namely $v_4 > v_2 > v_3 > v_1$, it indicates that the agent program Ⅳ is closest to the relative ideal alternative program, so the ACE Ⅳ is the competent ACE. In practice, the agent construction project was entrusted to the ACE Ⅳ. At present, the project has been completed and the project is well done in the whole process. In this case, the ACE Ⅳ can be said to be a competent ACE.

VI. CONCLUSION

The ACE plays the key role in the public project's success and the selection of the ACE is an important issue of the ACE. But no unified law has been made on how to select the ACE. So there is a need to explore appropriate methods on how to select the most competent ACE for the projects invested by government .Based on the existing researches, this paper established the bidding evaluation indexes system for the ACE selection based on the agent construction model designed by stage with FAHP and the mathematical model with GRA, which would help the government to select the best competent ACE for the public project in China.

1) The established bidding evaluation indexes system for the ACE selection in this paper is applicable for all the agent construction models designed by stage. One hand, as all the agent construction projects always can be divided by stage and

the certain project is ether the non-overall process agent construction model or the overall process agent construction model, this index system is universal to this point. On the other hand, this index system could also reflect the different demands on the ACE obviously.

2) Through the analysis of the index system, the Grey Relational Analysis was employed to build the mathematical model for selecting the best competent agent construction enterprise. This model is a combination of the qualitative analysis and quantitative analysis, not only reflecting many factors for the evaluation of ACE objectively but adopting the experts' opinions.

REFERENCES

[1] L. Sun, "Study on the Performance Assessment of the Agent Construction Enterprise for the Non-profit Project Invested by Government," *Economic Research Guide*, vol. 21, pp. 177–179, 2009.

[2] L. Yan, Y.-L. Yin, and D.-J. Fan, "A Conceptual Model for Public Project Governance" (in Chinese), *China Soft Science Magazine*, vol. 6, pp. 130–135, 2004.

[3] H. Ke, Study on Management Performance Improvement of Public Project Based on Agent Construction Model, *Tianjin Polytechnic University,* 2007.

[4] J.-J. Deng, "Study on Motivation System of Agent Construction Enterprise for Project Invested by government," *Tianjin Polytechnic University*, 2007.

[5] L. Yan, R. Xing, and G.-D. Zhou, "On the Selection Method of Construction Agent Organization on the Basis of Project Governance Theory," *Journal of Beijing Institute of Technology (Social Science Edition)*, vol. 11, pp. 31-37, Dec. 2009.

[6] G.-P. Xu, G.-D. Zhou, and Y.-N. Wu, "Study on Agent Construction Organization Performance Evaluation System of the Project Invested by Government," *Construction Economy*, vol. 284, pp. 21-24, Jun. 2006.

[7] Q.-M. Luo, and Y.-H. Liao, "Performance Assessment of Agent Construction Enterprise for Project Invested by Government," *Science and Technology Information*, vol. 4, pp. 242, 2008.

[8] H. Xie, "Post-assessment on the Implementation of Agent Construction System for Project Invested by Government," *China Collective Economic*, pp. 55-56, Jun. 2010.

[9] Y.-T. Zhang, "The Selection of Agent Construction Enterprise Based on AHP," *China Collective Economic*, vol. 3, pp. 80–81, Jan. 2010.

[10] H.-L. Yin, G.-Z. Cao and Q.-S. Liang, "The Selection of Agent Construction Enterprise Based on AHP," The Collected Papers of the Third Yellow River International Forum, pp: 198-202. 2010.

[11] J. Huang, and L. Shen, "Study on the Selection of Agent Construction Enterprise Based on Fussy Mathematics and Layered Grey Relational Analysis," *Mathematic in Practice and Theory*, vol. 38, pp. 28-35, Nov. 2007.

[12] X.-B. Huang, Q. Huang, and Y.-D. Huang, "Evaluation Method of Construction Agent System Based on DEA," *Journal of Chongqing Jiaotong University*, vol. 28, pp. 751-767, Aug. 2009.

[13] B. Zhao, S.-L. Zhang, and Y.-J. Q, "Performance Assessment of Agent Construction Enterprise for Project Invested by Government Based on AFD," *Journal of Chongqing University*, vol. 30, pp. 139–143, Nov. 2007.

[14] L. Yan, L.-X. Jia, and R. Xing, "Study on Reputation Effects of Agent Construction Enterprise in Incomplete Competition." *Research on Financial and Economic Issues*, vol. 9, pp. 58–63, Sep. 2010.

[15] B.-Y. Pan, and Y.-B. Xu, "The Design of the Agent Construction Project Management Mode, " in Conf. Rec. 2009 IEEE Int. Conf. Management and Service Science, pp. 1 – 4.

[16] Y.-L. Yin, and X.-Y. Yan, "Theory and Practice of Agent Construction in Public Project," T*ianjjn University Press*, 2005, pp. 153-162.

[17] J.-J. Zhang, "Fuzzy Analytical Hierarchy Process," F*uzzy System and Mathematics*, vol. 14, pp. 80-88, Jun. 2000.

[18] Y.-L. Yin, and X.-Y. Yan, "Theory and Practice of Agent Construction in Public Project," *Tianjjn University Press*, 2005, pp. 153-162.

[19] L. A. Zadeh, "Fuzzy Sets," Inf. Control., 1965, pp. 338–353.

[20] K. J. Schmucker, "Fuzzy Sets, Natural Language Computation, and Risk Analysis," *Computer Science Press*, New York, 1984.

[21] G. J. Klir, and T. A. Folger, "Fuzzy Sets, Uncertainty and Information," *Prentice-Hall, Englewood Cliffs*, N. J., 1988.

[22] A. Kaufmann, and M. M. Gupta, "Introduction to Fuzzy Arithmetic Theory and Application," *Van Nostrand Reinhold*, New York, 1991.

Shirong Li As the Deputy Director of Chongqing Foreign Trade & Economic Relations Commission in China and CIOB President (2009-2010) in UK, Professor Shirong Li is not only responsible for promotion of foreign investment in Chongqing, but also engaged in promoting the development of the global construction industry. During the period between 2003 and 2006, she worked as vice mayor in local government Shapingba District and is responsible for urban development and construction.She is a part-time professor of construction management in Chongqing University, a visiting professor in Reading University, the reform of China's construction industry, sustainable urbanization, government function in construction, government construction management, private finance in public works and international construction.Professor Li received four British professional qualifications, including the Chartered Environmentalist of the Society for the environment (CEnv), and the Fellows of the Chartered Institute of Building (FCIOB), the Royal Institution of Chartered Survey (FRICS) and the Institution of Civil Engineers (FICE). She has a PhD form University of Reading in UK, a MSc degree in construction management and a Bachelor degree in Civil Engineering from Chongqing Construction University. She is a member of the Industrialized Building Advisory Committee and the Construction Health and Safety Advisory Committee for the ministry of Construction, China.