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# Research on complex system evaluation based on fuzzy theory

**Yongqiang Chen[1,2]**

*[1]College of Economics & Management, Huazhong Agricultural University, Wuhan, China*
*[2]Business School, Jingangshan University, Ji'an, China*

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**ABSTRACT**

*Complex system evaluation lies in the core position of system engineering theory and methodology and is also a research hotspot and difficulty in system engineering theory and practice research. The paper, taking performance evaluation of integrates with agriculture base and supermarket for example, advances an evaluation indicator system and a fuzzy comprehensive evaluation algorithm. Firstly, a performance evaluation indicator system of integrates with agriculture base and supermarket is designed through analyzing the similarities of general performance evaluation and the specialties of the evaluation object; Secondly, the principle of analytic hierarchy process and fuzzy comprehensive evaluation algorithm are analyzed and the two methods are combined to advance a new algorithm to evaluate complex system with dynamics, subjective and transitional evaluation indicators and improve evaluation accuracy; Thirdly, three integrates are taken for experimental examples and the results illustrate that the improved algorithm can be used for evaluating the performance of integrates with agriculture base and supermarket feasibly and effectively and can provide reference for evaluating other complex systems.*

**Keywords:** Complex system evaluation, fuzzy comprehensive evaluation, analytic hierarchy process, integrates with agriculture base and supermarket.

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## INTRODUCTION

With the development of science and technology, the human society has moved into a material and a extremely complex immaterial network society. Under this condition, more and more attentions have been paid on the study of complex systems. System evaluation has been applied to the each layer from the original single engineering system evaluation to various aspects in the natural science and human 1ife. Therefore the evaluation for the complex system seems to have great practical significance[1].

The traditional evaluation methods include fuzzy comprehensive evaluation, analytic hierarchy process technique and the evaluation method based on the neural network ,etc. The widely application of evaluation ideas has been advanced and the traditional and new evaluation methods come to emergence continuously which deeply richens the application of system evaluation. In this point, people can analyze and understand the system by a certain means in a broader range. When it comes to complex systems, their own complexity determines that the evaluation of complex systems can not be a single evaluation method. Therefore, synthetical evaluation method should be established in complex system evaluation.

## EXPERIMENTAL SECTION

### Literature Review

Following methods are wildly used in the complex system evaluation.□ Analytic hierarchy process(AHP) effectively combines qualitative analysis with quantitative analysis, not only able to guarantee the systematicness and rationality of model, but also able to let decision makers make full use of valuable experience and judgment, so as to provide powerful decision-making support for lots of regulatory decision making problems. The method has such strengths as clear structure and simple computation, but due to its strong subjective judgment, the method also has shortcomings like low evaluation accuracy[2]. Multi-hierarchy comprehensive evaluation of fuzzy mathematics, its principle of is to firstly evaluate various kinds of factors of the same thing, dividing into several big factors according to certain attribute; Then carry out initial hierarchical comprehensive evaluation on certain big factor, and carry out high hierarchical comprehensive evaluation on the result of initial hierarchical comprehensive evaluation based on that. The key of successful application lies in correctly specifying the factor set of fuzzy evaluation and reasonably form fuzzy evaluation matrix, obtaining evaluation result according to matrix calculation result. Make use of fuzzy comprehensive evaluation method can obtain the value grade of evaluated object or mutual precedence relationship; however, the method requires to establish appropriate evaluation matrix of evaluation object, which will obtain different evaluation matrixes due to the inconformity of different experts, leading to the inconformity of final evaluation results[3]. Data envelopment analysis (DEA), starting from the perspective of relative efficiency, evaluates each decision-making unit, and the indicators selected are only relied on input and output. As it doesn't rely on specific production function, it is effective for dealing with the evaluation with various kinds of input and output indicators, suitable for the analysis of benefit, scale economy and industry dynamics. But it is complicated in computational method, subject to certain limitations in application[4].BP neural network method; BP neural network learning algorithm adopts gradient search technology so as to minimize the error mean square value between actual output value and desired output value; the method is adept in the processing of uncertain information. If the input mode is close to training sample, the evaluation system is able to provide correct reasoning conclusion. The method has such advantages as wide applicability and high evaluation accuracy, but it also has some disadvantages like easy to fall into local minimum in the computation, low rate of convergence, and etc[5].

AHP and fuzzy evaluation algorithm are wildly used in complex system evaluation for their own advantages, but they also have their own disadvantages in practice. The paper takes some measures and integrates AHP and fuzzy evaluation algorithm to overcome their own questions and bring their superiorities into full play. In doing so a new algorithm for evaluating complex system is advanced.

**Evaluation Indicator System Establishment**

Here takes performance evaluation of integrate with agriculture base and supermarket for example to establish an evaluation indicator system. As performance evaluation of integrate with agriculture base and supermarket needs to focus on farmer value which is a special and complicated factors, the similarity of general performance evaluation and the specialty of the topic in this paper shall be combined to establish evaluation indicator system of performance. Integrating the general idea of performance evaluation, and combining existing research literature[7,8], this paper will, from such four aspects as evaluation of internal and external performance, establish the evaluation indicator system of the performance of integrate with agriculture base and supermarket, which includes 3 hierarchies, 4 categories, 15 second-grade indicators; see table 1 for details.

**Table 1 Performance evaluation indicator system of integrates with agriculture base and supermarket**

| Target hierarchy | First -class indicator | Second -class indicator |
|---|---|---|
| Performance of integrates with agriculture base and supermarket | Consumer value performance | Customer satisfaction |
| | | Repeat purchase rate |
| | | Customer complaint rate |
| | | Handling time of the complaint |
| | Supermarket value performance | Return rate of investment |
| | | Supply stability |
| | | Rate of quality monitoring coverage |
| | | Market reaction force |
| | Farmer value performance | Rate of farmer's return |
| | | Improved varieties of agriculture products |
| | | Ability of anti risk ability |
| | | Transportation convenience |
| | Value performance of professional farmers cooperatives | Coordination degree |
| | | Extension rate of agriculture technology |
| | | Own brand promotion |

**Constructing Fuzzy Comprehensive Evaluation Model**

While evaluating complex system, there are lots of problems difficult to be simply described with points; for example, while evaluating a customer, factors influencing evaluation result are mainly educational background of the customer, his income, working experience , and etc. Therefore, different people (including students, peers and experts) may have different evaluations, the evaluation results of whom are also difficult to be quantized. So the evaluation results shall express specific concepts with fuzzy language. Besides, in practical application, the discussed objects are affected by a lot of uncertainty factors, among which fuzziness factor is one of the main influencing factors. Such kind of combination of classical comprehensive evaluation theory with fuzzy theory appears to be logical to evaluate courses. For this reason, the fuzzy comprehensive evaluation method adopted in this thesis has good rationality, scientificity and operability, able to obtain relatively correct, fair and reasonable evaluation results.

The most frequently used in fuzzy decision is fuzzy comprehensive evaluation method, which tries to deduce comprehensive evaluation model of fuzzy mathematics based on fuzzy evaluation theory, and carries out roundly comprehensive evaluation on teachers' course teaching with this, also very effective in specific utilization. To correctly and reasonably stipulate the domain of discourse of fuzzy evaluation and establish fuzzy evaluation matrix is the key to successfully apply fuzzy comprehensive evaluation model.

**Determination method of membership function.** The basic thought of fuzzy theory is the thought of the membership degree attribute towards subject; as previously mentioned, the key to apply fuzzy evaluation model lies in establishing reasonable fuzzy evaluation model, while the key to build fuzzy comprehensive evaluation model is to reasonably build membership function conforming to the facts. The method of determining the membership function of certain fuzzy set remains a difficulty needing to be solved up till now. According to the specific features of comprehensive evaluation of PE course teaching effect, this thesis adopts fuzzy statistical method to determine the membership function of fuzzy evaluation model.

Determining membership function of attribute towards object with fuzzy statistical method is a relatively objective method, which is also widely used. This method, in the specific operation, through fuzzy statistical test, according to the actual existence of membership of attribute, determines specific membership. Fuzzy statistical test generally includes four factors which are domain of discourse $U$, fixed element $x_0$ in $U$, a common set $A^*$ formed by random variables in $U$, a fuzzy set $A$ in $U$ (taking $A^*$ as elastic boundary, and restricting the change of $A^*$). Among the above four elements, $x_0 \in A^*$, thus, the membership function of $x_0$ towards $A$ is unable to be fixed and determined. Now suppose that experimenter does $n$ times of fuzzy statistical test, he/she can carry out calculation according to Formula 1 as follows.

$$A = \frac{Times of x_0 \in A}{n} \quad (1)$$

In specific calculation, with the increase of test times $n$, membership frequency is gradually stable; the stable frequency value is called membership of $x_0$ towards $A$ in fuzzy mathematics, i.e. Formula (2).

$$\mu_A(x_0) = \lim_{n\to\infty} \frac{Times of x_0 \in A}{n} \quad (2)$$

**Establishment of fuzzy comprehensive evaluation matrix.** The second key to successfully use fuzzy comprehensive evaluation model is to reasonably build fuzzy comprehensive evaluation matrix. Now use $U = \{u_1, u_2, u_3 ... u_n\}$ to express $n$ kinds of indicators (or influencing factors) of study object, which can be called indicator set (or factor set). Use $V = \{v_1, v_2, v_3 ... v_m\}$ to express evaluation set (also called evaluation set, decision set, etc.), formed by $m$ kinds of evaluation indicators of all the indicators (i.e. factors). Indicators (number and name of indicators) can be generally determined according to decider's specific demand in specific evaluation. As previous said, in the practical practice of evaluation, the evaluation set of indicators (factors) of many problems is not that clear, instead, it is relatively fuzzy. So comprehensive evaluation result is a fuzzy subset on $V$, as shown in formula (3).

$$B = (b_1, b_2, b_3 ... b_k) \in F(V) \quad (3)$$

In Formula (3), membership of evaluation $b_k$ towards fuzzy subset $B$ is obtained through the calculation of $\mu_B(v_k) = b_k (k = 1,2,3,...m)$, which can reflect the role of the $k$ th evaluation $v_k$ played in comprehensive evaluation. Comprehensive evaluation set $B$ relies on the weight values of each indicator, i.e. $B$ shall be the fuzzy subset on indicator set $U$ , $A=(a_1,a_2,a_3...a_n)\in F(U)$ , and meeting that the sum of indicator weight is 1; in which $a_i$ indicates the weight of the $i$ th indicator. Hence, while the weight set $A$ is set, a corresponding comprehensive evaluation set $B$ can be determined. General steps to determine fuzzy comprehensive evaluation mainly include the following ones.

 Determine indicator set $U=\{u_1,u_2,u_3...u_n\}$ ;

 Calculate determination evaluation set $V=\{v_1,v_2,v_3...v_m\}$ ;

 Calculate determination fuzzy evaluation matrix $R=(r_{ij})_{n\times m}$ ;While determining fuzzy evaluation matrix $R=(r_{ij})_{n\times m}$ , first, carry out evaluation of $f(u_i)=(i=1,2,3...n)$ on each indicator $u_i$ , a fuzzy mapping $f$ from indicator set $U$ to evaluation set $V$ can be obtained; the mapping is as shown in formula (4).

$$\begin{aligned} &f:U\rightarrow F(U) \\ &\quad u_i\mapsto f(u_i)=(r_{i1},r_{r2},r_{i3}...r_{im})\in F(V) \end{aligned} \tag{4}$$

Then, deduce fuzzy relation $R_f\in F(U\times V)$ according fuzzy mapping $f$ , as shown in formula 5[3].

$$R_f(u_i,v_j)\in f(u_i)(v_j)=r_{ij}=(i=1,2,3...n;\ j=1,2,3...m) \tag{5}$$

As a result, fuzzy evaluation matrix $R=(r_{ij})_{n\times m}$ can be calculated, $(U,V,R)$ is the model of fuzzy comprehensive evaluation; $U,V,R$ are generally called the necessary elements of the model.

 Comprehensive evaluation: as to a set in which weight $A=(a_1,a_2,a_3...a_n)\in F(U)$ , through model $M(\vee,\wedge)$ , take compositional operation of maximum—minimum, then obtain final comprehensive evaluation matrix, as shown in Formula 6.

$$B=A\circ R(\Leftrightarrow b_j=\bigvee_{i=1}^{n}(a_i\wedge r_{ij}),\ j=1,2,3,...m) \tag{6}$$

According to the above, we can know that the correct determination of weight $A=(a_1,a_2,a_3...a_n)$ in evaluation set $V$ plays a critical role in final comprehensive evaluation. $A=(a_1,a_2,a_3...a_n)$ is generally determined by model designer by virtue of self relevant experience, but this is often subjective. If the weight set is to reflect actual situation, to objectively and faithfully reflect actual situation, weighting statistics, experts evaluation or fuzzy relation can be adopted to determine $A=(a_1,a_2,a_3...a_n)$ ; for practical application, different determination methods can be chosen according to different situations[7,8].

**Specific Evaluation Step**

Fuzzy overall evaluation in this paper is conducted according to the following five steps.

① Establishing valuation element set. Evaluation element set is an ordinary set constituted by all the elements influencing evaluation object; suppose there are n evaluation indicator elements expressed by $u_1,u_2,u_3,...$ , un respectively, then the set constituted by these n evaluation elements is called evaluation element set, i.e. $U=u_1,u_2,u_3,...u_n$ .

②Confirming valuation set. Evaluation set is also called judgment set, which is comprised of all the evaluation results of evaluator on evaluation object, is an ordinary set formed by all the possible evaluation results of evaluators on evaluation object. Evaluation results can be divided into m hierarchies according to actual demand of specific cases, which can be expressed by $v_1,v_2,v_3,...v_m$ , respectively, then evaluation set can be constituted as $V=v_1,v_2,v_3,...v_m$ ;

③Confirm the weight of evaluation indicator. The reasonable confirmation of indicator weight embodies the different weight relations among all the evaluation indicators in the system, increases the comparability among all the evaluation indicators and the effectiveness of evaluation result. AHP is objective with such merits as practicability, conciseness and systematicness. Thus, this paper adopts AHP to confirm the weights of all the evaluation indicators, obtaining the weight $w_i$ of each evaluation indicator $u_i$. The set constituted by each weight $w_i$ is called weight set $W$, as shown in formula 7[9];

$$CI = (\lambda_{\max} - n)/(n-1) \quad (8)$$

In formula 8, $\lambda_{\max}$ is the maximum eigenvalue of judgment matrix, n is the number of comparison indicator. $\lambda_{\max}$ is calculated as follows: respectively multiply elements in each line of judgment matrix by vector component of weight $W$, then add, obtaining $A_{wi}$; divide $A_{wi}$ respectively by $w_i$, obtaining value $A_{wi}/w_i$. $\lambda_{\max}$ is the average value of $A_{wi}/w_i$. In order to confirm the allowed range of inconsistency degree, the corresponding average random consistency indicator $RI$ of $n$ can be looked for table 2.

At last, judge whether the matrix is consistent through consistency ratio $CR$, $CR = CI/RI$. If $CR \prec 0.1$, the consistency of judgment matrix is acceptable. Whereas, if $CR \geq 0.1$, the consistency of judgment matrix is unacceptable; judgment matrix should be properly amended to keep the consistency of judgment matrix to certain extent.

**Table 2 Average random consistency indicator**

| Order | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $RI$ | 0 | 0 | 0.58 | 0.90 | 1.12 |

④ Single-factor fuzzy evaluation. Suppose that evaluation object carries out evaluation according to the $i_{th}$ factor in factor set $U$, $u_i(i = 1,2,3...n)$, the subordination of which as to the $j_{th}$ factor in evaluation set $V$ $v_j(j = 1,2,3...m)$ is expressed as $r_{ij}$, formula 3 can be used to show the evaluation result of the $i_{th}$ factor $u_i$.

## RESULTS AND DISCUSSION

### Experimental Results and Analysis

Experimental data come from database of three integrates with agriculture base and supermarkets, call A ,B and C respectively. For data of customer part, consumers of integrates are selected as the basis for data training and experimental verification in the paper, totally 1500 consumers' data for study data that come from practical investigation and visit. In order to make the selected consumers' data representatives, 300 farmers (100 farmers from each supermarket) with more than 2 years, 300 farmers with 1 year integrate experience, 300 farmers with less than 1 year integrate experience.

Limited to paper space, the evaluation of intermediate results is omitted here, only providing secondary evaluation results and final comprehensive evaluation results, see table 3.

**Table 3 Part evaluation results of different integrates**

| | Consumer value | Supermarket value | Farmer value | Cooperatives Value | Final evaluation |
|---|---|---|---|---|---|
| A | 4.652 | 4.082 | 4.532 | 4.332 | 4.367 |
| B | 4.376 | 3.881 | 4.386 | 4.201 | 4.176 |
| C | 3.871 | 3.464 | 3.991 | 3.560 | 3.521 |

As for the performance of the presented algorithm, this paper also realizes the application of the DEA[4] and ordinary fuzzy evaluation algorithm[1], evaluation performance of different algorithms is shown in Table 4. In table 4 evaluation results of training effects of different integrates are selected and compared with artificial evaluation to calculate the evaluation accuracy.

**Table 4 Evaluation performance comparison of different algorithms**

| | Algorithm in the paper | Ordinary fuzzy algorithm | DEA algorithm |
|---|---|---|---|
| Evaluation accuracy | 92.66% | 79.54% | 75.86% |

## CONCLUSION

Comprehensive evaluation of complex system is an effective method for analyzing complex system and lies in the core status of the entire evaluation system of system engineering. Thus, there is a favorable application prospect for the analysis and competitiveness evaluation of complex system performance based on the principle of fuzzy analysis. This paper makes use of multi-hierarchy fuzzy evaluation method to establish comprehensive evaluation model for performance evaluation of integrate with agriculture base and supermarket, also carries out case study taking the data of three integrates as an example. Meanwhile, the multi-hierarchy fuzzy evaluation method built in this paper can be reference for the analysis and evaluation of other complex system analysis.

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