Evaluation of Construction Scheme of Comprehensive Technical Support Center of Strategic Backside Warehouse

Qun Deng[1,a,*], Feng Wang[2,b], Ming Gan[3,c]

[1,2,3]Logistic Engineering University, Chongqing. P.R. China

[a]dq_surprise@sina.com, [b]wangfeng2100-2@163.com, [c]gm_225@163.com

*Corresponding author

Keywords: GAHP, Changeable weight, Fuzzy method, Synthetic evaluation.

Abstract. The quantified description obtained by evaluating construction scheme of Comprehensive Technical Support Center (CTSC) of strategic backside warehouse synthetically, which can be regarded as reference for decision, is directively meaningful in reality. Combining the group analytic hierarchy process (GAHP) with fuzzy theory, the subjective weights are obtained firstly, then the changeable synthetic weights are formed by means of modifying the obtained subjective weights, and thus the comprehensive weights can be computed. Finally, according to the results of synthetic evaluation obtained by applying fuzzy synthetic evaluation method to each construction scheme, the optimum scheme can be selected. Case results demonstrate that the proposed method is beneficial to evaluate the construction scheme of CTSC.

Introduction

Comprehensive Technical Support Center (CTSC) of strategic backside warehouse actually consists of Technical Support Center (TSC) and Sorting Distribution Center (SDC). TSC provides a capability to test, maintain and repair equipment as well as dispose rejected material, which plays a major role in undertaking maintenance and repair services for part of war reserve materiel in Zone. Depending on information systems, SDC conducts a series of operations by using automated equipment, including disassembling, picking, recognizing, labeling, assembling and packaging and so on.

After site selection at the early stage of construction, it does not cost too much for the design and evaluation of the construction scheme of CTSC, but greatly influences the rationality of the whole project in all probability. With the gradual development of technology scheme and the follow-up construction, expenses that the project needs will increase sharply, while influences on the rationality of the project decrease similarly in this stage. If inconsiderate at the early stage of construction, it is certain to pay a heavy price in remedy later. Therefore, it is essential for the qualitative and quantitative evaluation of CTSC construction scheme to propose an objective and comprehensive method, which also provides a scientific reference to assist in assessing different construction schemes as well as choosing the only one.

Group analytic hierarchy process (GAHP) is an effective method based on analytic hierarchy process (AHP), which is suitable for solving multi-criteria problems by analyzing the opinions of experts synthetically [1]. Combining GAHP, this paper presents a fuzzy synthetic evaluation method based on changeable weight. First of all, it is necessary to establish an index system for evaluation according to actual requirements. Secondly, the subjective weights can be obtained using GAHP. And then the changeable synthetic weights are formed by means of modifying the obtained subjective weights, and thus the final index weights can be computed. Finally, the optimum scheme can be decided on the basis of the results of synthetic evaluation obtained by applying fuzzy synthetic evaluation method to each construction scheme.

Evaluation Index System

Hierarchical Structure Model

Before using GAHP to solve the problem, an multi-level hierarchical structure model on the evaluation should be established [2]. The hierarchical structure model, according to the relationship, logical relegation and importance of different elements of evaluation object, can be designed in a top-down way.

Generally, the hierarchical structure model can be divided into three layers: target layer, criterion layer and solution layer. Target layer denotes the goal of solving the problem, that is, the expected general goal of hierarchy analysis; criterion layer, which also can be divided concretely into strategic layer, restraint layer and index layer, denotes the intermediate links involved in achieving the expectations by taking certain measures or policies needed; solution layer denotes kinds of alternative schemes including measures, policies and solutions and so on [3].

The hierarchical structure model for CTSC construction scheme evaluation is shown in Fig. 1.

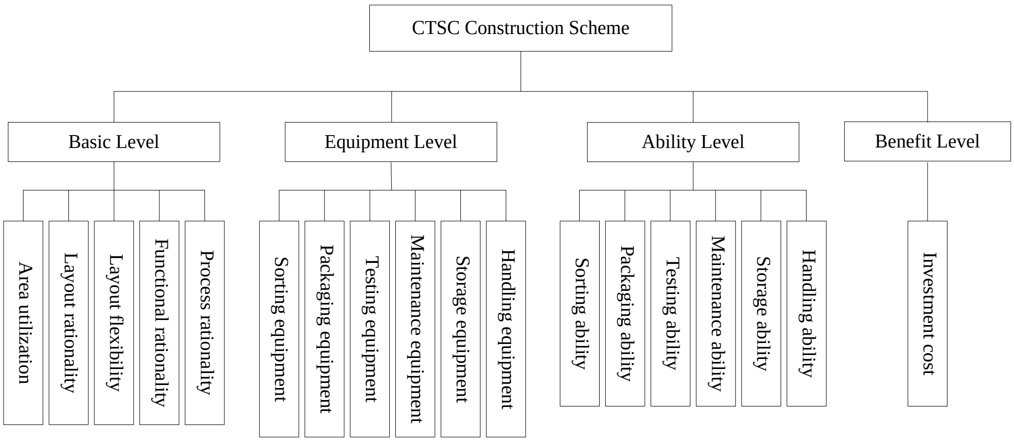

Fig.1 The hierarchical structure model for construction scheme evaluation

Considering actual requirements, the hierarchical structure model for CTSC construction scheme evaluation shown in Fig. 1 selected a critical and representative part of many factors which might influence the evaluation. As a matter of fact, limited to the quantification as well as the evaluation method, there are still certain factors that cannot be included in the model above. It is certainly that, with the further research, indexes may be updated or increased if necessary.

In this paper, the construction scheme of CTSC is evaluated mainly from four levels (that is, the first class indexes): basic, equipment, ability and benefit.

Basic level. The basic level evaluates the reasonable degree of a construction scheme from a layout perspective, which includes five second class indexes: area utilization, layout rationality, layout flexibility, functional rationality and process rationality.

The formula of area utilization rate index under basic level is

$$\alpha = \frac{S^*}{S} \tag{1}$$

Where S^* is the effectively utilizing area, S is the total area, and α is the area utilization rate.

Equipment level. The equipment level mainly evaluates species number, matching state, the degree of adaptation to task demands and so on, which can be involved in supporting operations. There are six second class indexes under this level: sorting equipment, packaging equipment, testing equipment, maintenance equipment, storage equipment, and handling equipment.

Ability level. The ability level mainly evaluates the satisfaction degree of the demands of construction scheme for the operation tasks of CTSC, which consists of six second class indexes: the operation ability of sorting, packaging, maintenance, storage, and handling.

Before evaluation of each work capacity index under ability level, it is obliged to figure out the ratio of maximum work amount to actual requirement first, that is

$$\beta = \frac{Q_{max}}{Q} \tag{2}$$

Where Q_{max} is the maximum work amount, and Q is the actual requirement.

Considering the possibility of excess work capacity (that is, $\beta > 1$), in order to describe the satisfaction degree of a scheme to actual requirement more reasonably, it is necessary to process β further to restrict the value of work capacity index to be between 0 to 1, that is

$$\theta = \begin{cases} \beta & , 0 \le \beta < 1 \\ e^{1-\beta} & , \beta \ge 1 \end{cases} \tag{3}$$

Benefit level. The benefit level mainly focuses on the economy of the construction scheme, including only one second class index, that is, investment cost.

In addition, for all the other second class indexes, centesimal evaluation method can be used by relevant experts, and then scores of these indexes also have to be processed by normalization.

Rules of Thinking Quantization

GAHP usually adopts nine importance levels to express the results given by experts, which are described as an integer from 1 to 9, that is, nine scales method. The rules as well as their meanings are shown in Table 1[4].

Tab.1 Rules for constructing judgment matrix

Scale value	Meanings
1	The two elements are equally important.
3	One element is little more important than the other.
5	One element is more important than the other.
7	One element is much more important than the other.
9	One element is extremely more important than the other.
2,4,6,8	If the difference of two elements is in between, The median of adjacent scale values can be used.
Reciprocal	If the ratio of the importance of element i to j is a_{ij}, The ratio of the importance of element j to i (that is, a_{ji}) satisfies the equation $a_{ji} = \frac{1}{a_{ij}}$.

Judgment Matrix

There are two methods to denote elements of the judgment matrix. One uses real values [5-7], while the other uses symbols of natural languages [8, 9]. According to the rules of thinking quantization explained in Section 2.2, judgment matrixes can be constructed by the experts invited [10]. Assume that, after experts' analysis, a certain judgment matrix is

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{4}$$

Where a_{ij} is the scale value.

Hierarchical Single Arrangement

What hierarchical single arrangement means, is the calculation of the importance weight of the indexes under the current level to a certain index under the higher level. According to the judgment matrix A constructed in Section 2.3, the maximum eigenvalue $\lambda_{\max}$ of A as well as its corresponding eigenvector τ can be calculated.

And then, weight vector can be obtained after normalization of the corresponding eigenvector τ, that is,

$$W = (\omega_1, \omega_2, \omega_3, \cdots, \omega_n) \tag{5}$$

Where ω_i is the weight of the ith index.

Consistency Check

When constructing judgment matrixes and comparing with different indexes, we may probably obtain inconsistent judgment matrixes, which are caused by the subjectivity or one-sidedness of the way we judge as well as the complexity of what we evaluate[11]. Therefore, it is extremely essential to have a consistency check after finishing the establishment of a judgment matrix.

The consistency index of a judgment matrix is

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{6}$$

Where n is the order of the judgment matrix A.

And then, the coordination rate, which can be obtained by calculating the ratio of the consistency index of the judgment matrix (that is, CI) to the consistency index of random judgment matrix with the same rank as the former (that is, RI), is

$$CR = \frac{CI}{RI}. \tag{7}$$

The values of RI in the formula above are shown in Table 2.

Tab.2 The consistency index RI of random judgment matrix

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.94	1.12	1.24	1.32	1.41	1.45

If the coordination rate $CR < 0.1$, then the judgment matrix proves to be consistent; or else to adjust the judgment matrix.

Hierarchical Total Arrangement

What hierarchical total arrangement means, is the calculation of the relative importance weight of the indexes under the criterion layer to the target layer, which is restricted to be a process from the top down. And, it is absolutely needed to have a consistency check after the hierarchical total arrangement, which is also a process from the top down.

Similarly, if the coordination rate $CR_{Total} < 0.1$, then the result of the hierarchical total arrangement proves to be consistent; or else to adjust the judgment matrixes.

Subjective Synthetic Weight

According to the weight of indexes calculated in Section 2.4, synthetic weights of the indexes under different level can be obtained if passing the consistency check.

After calculated based on the opinions of experts (assuming that there are l experts invited), synthetic weights of indexes need to be processed by Hadamard product to obtain the geometric mean values, that is

$$W_i = \left(\prod_{j=1}^{l} W_i^j\right)^{\frac{1}{l}} \tag{8}$$

Where W_i^j is the weight of the ith index given by the jth expert. And then, synthetic weights can be calculated by normalization, which are combined with the opinions of experts.

Fuzzy Synthetic Evaluation Based on Changeable Weight

Fuzzy Evaluation Model

Fuzzy assessment theory is an efficient multi-factor decision-making method for evaluating multi-criteria problems [12]. First of all, define the evaluation factor set as U (assuming that there are n indexes in U), which consists of all the indexes of the evaluation index system established in Section 1.1, that is

$$U = \{u_1, u_2, \cdots, u_n\}. \tag{9}$$

Then, define the evaluation judgment set as V, which refines the judgment results of indexes into m levels, that is

$$V = \{v_1, v_2, \cdots, v_m\}. \tag{10}$$

Thirdly, we have to define the membership function of the index in U to the judgment degree in V, that is, fuzzification of the index. The membership function of CTSC construction scheme evaluation is

$$\mu_j(x_i) = e^{-\frac{(x_i - s_j)^2}{2\sigma_j^2}}, \begin{cases} i = 1,2,\cdots,n \\ j = 1,2,\cdots,m \\ x_i \in [0,1] \end{cases} \tag{11}$$

Where x_i is the score of the ith index given by experts, $\mu_j(x_i)$ is the membership function of the index u_i to the judgment degree v_j, and s_j as well as σ_j is the digital feature of different membership functions.

And after processed by normalization, the final membership of the index u_i to the judgment degree v_j is

$$r_{ij} = \frac{\mu_j(x_i)}{\sum_{k=1}^{j} \mu_k(x_i)}. \tag{12}$$

Finally, fuzzy assessment matrix is

$$R = \begin{bmatrix} R_1 \\ \vdots \\ R_n \end{bmatrix} = (r_{ij})_{n\times m}. \tag{13}$$

Objective Index Weight

Assuming that the J_0th judgment degree is defined as reference degree, the membership degree of ith index u_i to the reference degree or above according to the principle of maximum membership degree is

$$\lambda_i = \max(r_{ij}, j \le J_0) = \vee_{j \le J_0} r_{ij}. \tag{14}$$

As can be seen from the formula above, the evaluation result of the ith index u_i becomes worse if the decrease of the value of λ_i, which weight needs to be increased in order to be more objective, that is what we call "stimulation"; or else we have to decrease the weight (that is, w_i) of the relevant index as a "punishment".

From all above mentioned, objective index weight is

$$z_i = \frac{\frac{1}{\lambda_i}}{\sum_{k=1}^{n} \frac{1}{\lambda_k}}, i = 1,2,\cdots,n. \tag{15}$$

According to the definition of objective index weight above, we know that if there is such an index, of which the membership degree to the reference equals 1, then the objective weights of other indexes all become 0s. Therefore, it can be seen that the definition of objective index weight above fits the requirement of CTSC construction scheme evaluation well.

Final Index Weight

The final index weight of CTSC construction scheme evaluation is

$$a_i = \frac{w_i z_i}{\sum_{k=1}^{n} w_k z_k} \tag{16}$$

Where w_i is the subjective index weight obtained by GAHP in Section 2.7, and z_i is the objective index weight. Then, based on w_i and z_i, the weight vector of CTSC construction scheme evaluation is

$$A = (a_1, a_2, \cdots, a_n). \tag{17}$$

Fuzzy Synthetic Evaluation

In order to assess the membership degrees of CTSC construction scheme to different evaluation degrees, we define the fuzzy synthetic evaluation result vector as B, that is

$$B = A_{1\times n} \circ R_{n\times m} = (b_j)_{1\times m}. \tag{18}$$

$$\mathrm{b_j} = \bigvee_{\mathrm{k=1}}^{\mathrm{n}} (\mathrm{a_j} \wedge \mathrm{r_{kj}}), \mathrm{j} = 1,2,\cdots, \mathrm{m}. \tag{19}$$

And the final evaluation result can be calculated according to the principle of maximum membership degree.

Calculation Example Analysis

In order to test the evaluation method mentioned above, this paper took a select from three CTSC construction schemes for example using GAHP as well as fuzzy synthetic evaluation based on changeable weight. Because of the limited space, this paper only concretely analyzed the second class indexes under basic level, of which scores given by experts is shown in Table 3.

Tab.3 Experts' data related to the second class indexes under the basic level of each scheme

Basic level	Scheme 1				Scheme 2				Scheme 3			
	Expert 1	Expert 2	Expert 3	Mean value	Expert 1	Expert 2	Expert 3	Mean value	Expert 1	Expert 2	Expert 3	Mean value
Area utilization	0.65	0.57	0.62	0.61	0.85	0.77	0.82	0.81	0.82	0.87	0.85	0.85
Layout rationality	0.89	0.85	0.95	0.90	0.79	0.75	0.85	0.80	0.39	0.35	0.4	0.38
Layout flexibility	0.72	0.79	0.84	0.78	0.62	0.69	0.74	0.68	0.72	0.79	0.84	0.78
Functional rationality	0.44	0.51	0.57	0.51	0.94	0.91	0.87	0.91	0.74	0.71	0.67	0.71
Process rationality	0.82	0.85	0.77	0.81	0.62	0.75	0.77	0.71	0.82	0.85	0.77	0.81

Determination of Subjective Index Weight

The hierarchical structure model of CTSC construction scheme evaluation is as shown in Fig. 1 in Section 2.1. According to the opinions of the three experts invited, judgment matrixes were constructed as the following.

(1) The judgment matrix given by expert 1 is

$$\mathrm{J_1} = \begin{bmatrix} 1 & 1/5 & 1/3 & 1/5 & 1/5 \\ 5 & 1 & 3 & 2 & 2 \\ 3 & 1/3 & 1 & 2 & 2 \\ 5 & 1/2 & 1/2 & 1 & 1 \\ 5 & 1/2 & 1/2 & 1 & 1 \end{bmatrix}. \tag{20}$$

(2) The judgment matrix given by expert 2 is

$$\mathrm{J_2} = \begin{bmatrix} 1 & 1/4 & 1/5 & 1/2 & 1/3 \\ 4 & 1 & 3 & 2 & 1 \\ 5 & 1/3 & 1 & 2 & 2 \\ 2 & 1/2 & 1/2 & 1 & 1/2 \\ 3 & 1 & 1/2 & 2 & 1 \end{bmatrix}. \tag{21}$$

(3) The judgment matrix given by expert 3 is

$$\mathrm{J_3} = \begin{bmatrix} 1 & 1/5 & 1/3 & 1/3 & 1/3 \\ 5 & 1 & 3 & 3 & 3 \\ 3 & 1/3 & 1 & 1 & 1 \\ 3 & 1/3 & 1 & 1 & 1 \\ 3 & 1/3 & 1 & 1 & 1 \end{bmatrix}. \tag{22}$$

After hierarchical single arrangements of the judgment matrixes above, the results of consistent tests we obtained are shown in Table 4.

Tab.4 Results of consistent tests of judgment matrixes

Judgment matrix	J_1	J_2	J_3
CR	0.060307	0.065193	0.009372
Result of consistent test	Pass	Pass	Pass

Calculate the corresponding eigenvector of the maximum eigenvalue for each judgment matrix, process each eigenvector by normalization, and combine the eigenvectors by Hadamard product. Then, the subjective synthetic weight vector of the second class indexes under basic level is

$$W = (0.0600, 0.3821, 0.2157, 0.1553, 0.1869). \tag{23}$$

Establishment of Fuzzy Evaluation Model

(1) Evaluation factor set

$$U = \{u_1, u_2, u_3, u_4, u_5\} \tag{24}$$

where u_1 denotes "area utilization", u_2 denotes "layout rationality", u_3 denotes "layout flexibility", u_4 denotes "functional rationality", and u_5 denotes "process rationality".

(2) Evaluation judgment set

$$V = \{v_1, v_2, v_3, v_4\} \tag{25}$$

where v_1 denotes "excellent", v_2 denotes "good", v_3 denotes "fair", and v_4 denotes "bad".

(3) Membership function

Using the membership function constructed in Section 3.1, in which the values of the digital feature s_j as well as σ_j are shown in Table 5.

Tab.5 Values of s_j and σ_j of the membership function

Judgment degree	Excellent	Good	Fair	Bad
j	1	2	3	4
s_j	0.9	0.7	0.5	0.2
σ_j	0.1	0.1	0.1	0.1

The images of the membership functions corresponded to different judgment degrees are shown in Fig. 2.

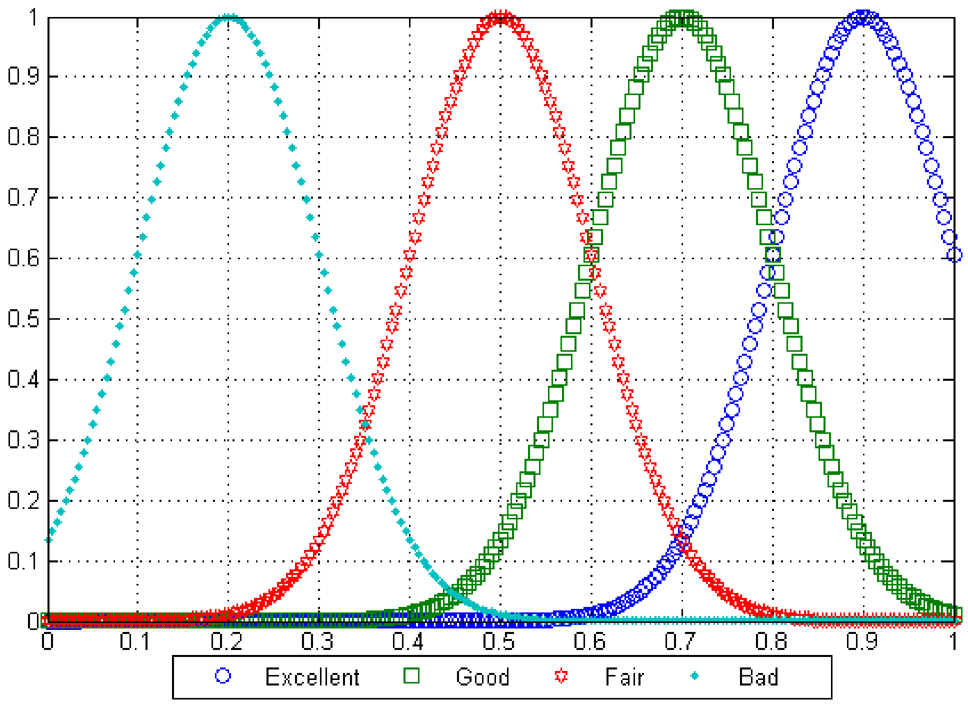

Fig.2 Figures of membership functions correspond to different judgment degrees

(4) Fuzzy assessment matrix

According to the evaluation judgment set and the membership function, fuzzy assessment matrixes can be calculated after fuzzification of the second class indexes under basic level, that is

$$R_I = \begin{bmatrix} 0.0164 & 0.6869 & 0.5261 & 0.0002 \\ 0.9994 & 0.1446 & 0.0004 & 0.0000 \\ 0.5063 & 0.7066 & 0.0181 & 0.0000 \\ 0.0004 & 0.1543 & 0.9978 & 0.0091 \\ 0.6869 & 0.5261 & 0.0074 & 0.0000 \end{bmatrix}. \tag{26}$$

$$R_{II} = \begin{bmatrix} 0.6869 & 0.5261 & 0.0074 & 0.0000 \\ 0.5863 & 0.6267 & 0.0123 & 0.0000 \\ 0.0956 & 0.9862 & 0.1863 & 0.0000 \\ 0.9978 & 0.1182 & 0.0003 & 0.0000 \\ 0.1751 & 0.9912 & 0.1027 & 0.0000 \end{bmatrix}. \tag{27}$$

$$R_{III} = \begin{bmatrix} 0.8674 & 0.3411 & 0.0025 & 0.0000 \\ 0.0000 & 0.0060 & 0.4868 & 0.1979 \\ 0.5063 & 0.7066 & 0.0181 & 0.0000 \\ 0.1543 & 0.9978 & 0.1182 & 0.0000 \\ 0.6869 & 0.5261 & 0.0074 & 0.0000 \end{bmatrix}. \tag{28}$$

Calculation of Final Index Weight

As mentioned in Section 3.2, we defined the 3th judgment degree (that is, "Fair") as reference degree, and calculate the membership degree vector λ, which denotes the membership degree of each index to reference or above, as well as the objective index weight vector Z, according to the fuzzy assessment matrix. Then, based on the subjective synthetic weight vector W calculated in Section 4.1, final weight vectors of the indexes under basic level of each construction scheme can be obtained by further calculation, that is

$$A_I = (0.0727\ , 0.3179\ , 0.2538\ , 0.1295\ , 0.2262). \tag{29}$$

$$A_{II} = (0.0694\ , 0.4838\ , 0.1736\ , 0.1236\ , 0.1496). \tag{30}$$

$$A_{III} = (0.0436\ , 0.4946\ , 0.1923\ , 0.0981\ , 0.1714). \tag{31}$$

Fuzzy Synthetic Evaluation

As mentioned in Section 3.4, the fuzzy synthetic evaluation result vectors of indexes under basic level of each construction schemes can be calculated [13], that is

$$B_I = A_I \circ R_I = (0.44757\ , 0.35736\ , 0.18229\ , 0.01278). \tag{32}$$

$$B_{II} = A_{II} \circ R_{II} = (0.42395\ , 0.42395\ , 0.15209\ , 0.00001)\ . \tag{33}$$

$$B_{III} = A_{III} \circ R_{III} = (0.17985\ , 0.17985\ , 0.45522\ , 0.18508). \tag{34}$$

According to the principle of maximum membership degree, the final evaluation results of the second class indexes under basic level of each construction scheme are shown in Table 6.

Tab.6 Final judgment results of the second class indexes under basic level of each scheme

Index	Scheme 1	Scheme 2	Scheme 3
Basic level	Excellent	Excellent	Fair

Similarly, the final evaluation results of the first class indexes of each construction scheme are shown in Table 7.

Tab.7 Final judgment results of the first class indexes of each construction scheme

The first class index	Final Judgment results		
	Scheme 1	Scheme 2	Scheme 3
Basic level	Excellent	Excellent	Fair
Equipment level	Good	Excellent	Excellent
Ability level	Good	Excellent	Excellent
Benefit level	Good	Good	Good

The membership degrees as well as judgment results of each construction scheme are shown in Table 8.

Tab.8 Membership degrees and judgment results of each construction scheme

Evaluation object	Membership degrees				Judgment result
	Excellent	Good	Fair	Bad	
Scheme 1	0.19277	0.39768	0.39768	0.01188	Good
Scheme 2	0.47600	0.37168	0.15226	0.00007	Excellent
Scheme 3	0.37422	0.37422	0.12578	0.12578	Excellent

According to the principle of maximum membership degree, we know that the second construction scheme is optimum.

Result Analysis

Also take the second class indexes under basic level for example. The subjective weights, mean experts' data and final weights of the second class indexes under basic level of each construction scheme are shown in Table 9.

Tab.9 Weights and mean experts' data of the second class indexes under basic level

Basic level	Subjective weight	Mean experts' data			Final weight		
		Scheme 1	Scheme 2	Scheme 3	Scheme 1	Scheme 2	Scheme 3
Area utilization	0.0600	0.6133	0.8133	0.8467	0.0727	0.0694	0.0436
Layout rationality	0.3821	0.8967	0.7967	0.3800	0.3179	0.4838	0.4946
Layout flexibility	0.2157	0.7833	0.6833	0.7833	0.2538	0.1736	0.1923
Functional rationality	0.1553	0.5067	0.9067	0.7067	0.1295	0.1236	0.0981
Process rationality	0.1869	0.8133	0.7133	0.8133	0.2262	0.1496	0.1714

According to the data shown in Table 9, using the fuzzy synthetic evaluation method based on changeable weight which is presented in this paper, the subjective weight of an index can be decreased as a "punishment" when its mean score given by experts gets too high (for example, the index "functional rationality" of the second construction scheme); or else its subjective weight can be increased as a "stimulation" (for example, the index "layout rationality" of the third construction scheme). Therefore, by this way, we can obtain more reasonable final index weights.

Summary

Compared with the subjective index weight obtained by using GAHP simply, the index weight, which is determined by fuzzy synthetic evaluation method based on changeable weight, reflects not only the importance of each index but also the merits of different CTSC construction schemes objectively. Using the method presented in this paper, by which the impact of certain worsening index can be magnified, we can evaluate construction schemes more reasonably. The quantified description obtained by the proposed method, which can be regarded as reference for decision, is beneficial to evaluate the optimum construction scheme of CTSC.

References

[1] LAN Ji-bin, XU Yang, HUO Liang-an, LIU Jia-zhong. Research on the Priorities of Fuzzy Analytical Hierarchy Process, Systems Engineering – Theory & Practice, 2006,9: 107-112.

[2] ZHANG Ji-jun. Fuzzy Analytical Hierarchy Process. Fuzzy Systems and Mathematics, 2000, 14(2): 80-88.

[3] ZHAO Xia, ZHAO Cheng-yong, JIA Xiu-fang, LI Geng-yin. Fuzzy Synthetic Evaluation of Power Quality Based on Changeable Weight. Power System Technology, 2005, 29(6): 11-16.

[4] YANG Wei-long, JI Jin-yao, TANG Chun-ye. Application of Fuzzy Comprehensive Evaluation Method Based on GAHP on Submarine Combat Scheme Evaluation. Command Control & Simulation, 2009, 31(4): 68-72.

[5] Orlovsky S A. Decision-making with a Fuzzy Preference Relation. Fuzzy Sets and Systems, 1978, 1: 155-167.

[6] Tanino T. Fuzzy Preference Orderings in Group Decision Making. Fuzzy Sets and Systems, 1984, 12: 117-131.

[7] Chiclana F, Herrera F, Herrera-Viedma E, Poyatos M C. A Classification Method of Alternatives for Multiple Preference Ordering Criteria Based on Fuzzy Majority. Journal of Fuzzy Mathematics, 1996, 4: 128-143.

[8] Herrera F, Herrera-Viedma E, Verdegay J L. A Sequential Selection Process in Group Decision Making with Linguistic Assessment. Information Science, 1995, 85: 233-239.

[9] Marimin M U, Itsuo H, Hiroyuki T. Linguistic Labels for Expressing Fuzzy Preference Relations in Fuzzy Group Decision Making. IEEE Transactions on Systems, Man, and Cybernetics, 1998, 28(2): 205-218.

[10]HAN Li, MEI Qiang, LU Yu-mei, JI Min. Analysis and Study on AHP-Fuzzy Comprehensive Evaluation. China Safety Science Journal, 2004, 14(7): 86-89.

[11]XIAO Si-han, FAN Zhi-ping, WANG Meng-guang. Study on Consistency of Fuzzy Judgment Matrix. Journal of Systems Engineering, 2001, 16(2): 142-145.

[12]JIA Qing-quan, SONG Jia-hua, LAN Hua, YANG Yi-han,YIN Chang-xin. Quality of Electricity Commodity and Its Fuzzy Evalution. Power System Technology, 2000, 24(6): 46-49.

[13]LI Yan-mei, SUN Wei. Application of Multilevel Fuzzy Synthetic Evaluation on Power Plant Election. Modern Electric Power, 2004, 21(2): 27-30.