Adaptability Evaluation of Enterprise Information Systems Based on Object-based Knowledge Mesh

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***Abstract*—To apply enterprise information systems more widely, it is necessary to evaluate their adaptability. In this paper, firstly, an index set of adaptability evaluation system based on object-based knowledge mesh (OKM) is proposed and then, according to goal-question-metrics (GQM) for enterprise information systems, and the quantitative measurement is given. Second, based on similarity to ideal solution (TOPSIS), the evaluation model is built and the adaptability evaluation (AE) algorithm is proposed to evaluate enterprise information systems' adaptability. Finally, the application of the evaluation system and AE algorithm is verified through an example, which provides quantitative references for evaluating and optimizing enterprise information systems' adaptability.**

***Index terms*—adaptability evaluation, enterprise information systems, object-based knowledge mesh, similarity to ideal solution**

I. Introduction

With the development of science and technology, especially information technology, the environment of enterprise information systems (EIS) is changing rapidly. As the change is eternal, EIS should have the ability to adapt to various external and internal environments in order to have continuous competitive advantages. In other words, combined with the environment, EIS should have better relevant properties, like time, flexibility, reconfiguration property, *etc*. These properties all reflect the concept of "adaptability", so the evaluation on adaptability is one of the important aspects in EIS optimization, which is also the main objective of this paper.

At present, there is considerable research on the adaptability of software systems, which can be briefly described as follows: 1) study on the self-adaptability of software [1-2]. 2) study on the adaptive mechanism of software systems [3-5]. 3) study on the adaptability evaluation of EIS [6-9]. As an example of 1) above, Ref. [2] studied the generic adaptive software architecture style, and as an example of 2), Ref. [3] studied an architecture-oriented mechanism for self-adaptation of software systems. These studies have laid a steady foundation for improvement on enterprise information systems' adaptability (EISA). In terms of 3), Ref. [6] studied the evaluation index matrix with three dimensions by dividing the evaluation indexes for information system into layers. However, there are differences between the adaptability of software systems and EISA. Firstly, EIS include not only software but also business process. Secondly, the environment of software systems means the operation carrier or the development platform, but the environment of EIS means the market, external policies and the internal operation environment. Thus, the adaptability of software system isn't equal to EISA. However little reference considers the differences between them, and the related quantitative research is even less.

In order to make quantitative evaluation research on EISA, it's necessary to formalize EIS firstly. As is known, EIS is a kind of very complicated knowledge difficult to be represented by symbolic doctrine or connection doctrine. However, it can be represented by a mesh known as the knowledge mesh (KM), which is proposed to represent manufacturing mode in knowledgeable manufacturing system (KMS) [10]. But for large scaled systems, the KM will be too huge to make further research (such as reconfiguration, etc.), thus object-based knowledge mesh (OKM) [11-13] was brought forward. OKM combines object-oriented technologies and knowledge mesh theory, realizes formal representation of information systems, software systems and manufacturing modes, and solves information explosion in the KM.

Based on OKM, EIS can be formalized. Thereafter the quantitative adaptability evaluation and further optimization of EIS can be studied. In this paper, a set of adaptability evaluation system based on OKM is proposed and the corresponding evaluation model and algorithm are given, which can help enterprises make reasonable decisions.

II. Adaptability Evaluation System

A. Enterprise Information System and its Formal Representation

System performance is determined by its structure. To make quantitative evaluation research on EISA, EIS

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formal representation method is used to formalize its indexes relative with its structure. In the formal representation of EIS by OKM, the mapping relationships are as follows:

(1) Sub-modules of EIS including business process and software can be mapped into atom knowledge points or comprehensive knowledge points.

(2) The relationships between business process and software can be mapped into the complex or information relationships in OKM.

(3) Comprehensive knowledge points can be decomposed into atomic knowledge points.

(4) Each sub-module has specific functions.

Hence, two types of knowledge points are discussed in this paper according to OKM.

According to the representation of EIS by OKM, the following items used in the evaluation of EISA are defined.

(1) BSP^q : the comprehensive knowledge points expressing business process information. Assuming there are n basic business process, m sub-links, i.e. $BP_i = \{BP_{i1}, BP_{i2}, \cdots, BP_{im}\}$.

(2) SSP^q : the comprehensive knowledge points expressing software information. Assuming there are r software sub-modules, i.e. $S = \{S(1), S(2), \cdots, S(r)\}$.

According to the knowledge points above, the relationships and functions can be embodied by the knowledge points themselves or between them.

B. EISA Evaluation System based on GQM

To study EIS adaptability optimization, it is necessary to know the influencing factors of EIS adaptability as well as the corresponding index system. Fortunately, Goals-Questions-Metrics (GQM) gives a solution to this problem. GQM is a goal-oriented modeling method for measurement, and it has been successfully used in various fields.

According to GQM [9], the goals can be ensured, which include general goal and sub goals.

(1) General goal: Ensure the evaluation of EIS adaptability for enterprises is correct.

(2) Sub goals: According to the general goal, sub goals and the description are shown in Tab. 1.

The sub-goal A is taken as an example to show the process of the GQM method as shown in Tab. 2, and in the same way other sub goals are analyzed as follows.

TABLE1
SUB GOALS OF THE GENERAL GOAL

Sub Goals	Descriptions
Sub-GoalA : Time as short as possible	Time spent by the system to adopt to the change
Sub-GoalB: Cost as little as possible	Cost spent by the system to adopt to the change
Sub-GoalC: Complexity as low as possible	Complexity of the system to adopt to the change
Sub-GoalD: Risk as low as possible	System risk after adjustment
Sub-GoalE: Robust as well as possible	System stability and reliability after adjustment

TABLE2
MATRIC OF SUB-GOAL A (TIME)

Goals	label	Question and metrics
Q1		Does the time spent in the adjustment influence EISA?
M1		Number of the business process in the adjustment
M1.1	n	Number of the basic business process in the adjustment
M1.2	m	Number of sub-process j in the basic business process i in the adjustment
M2	r	Number of the software module k in the adjustment
Q2		Does the time spent in adjusting elements influence EISA?
M3	$t(BP_{ij})$	Time spent in adjusting business process BP_{ij}
M4	$t(S(k))$	Time spent in adjusting software k

(1) Measurement of sub-goal A (Time)

Q_1 : Does the time spent in the adjustment influence EISA?

$M1$: Number of the business process in the adjustment

$M1.1$: Number of the basic business process in the adjustment

$M1.2$: Number of sub-process j in the basic business process i in the adjustment

$M2$: Number of the software module k in the adjustment

Q_2: Does the time spent in adjusting elements influence EISA?

$M3$: Time spent in adjusting business process BP_{ij}

$M4$: Time spent in adjusting software k

(2) Measurement of sub-goal B (Cost)

Q_1: Does the cost spent in the adjustment influence EISA?

$M1$: Cost of the material u

$M2$: Cost of the resource u'

$M3$: Number of the staff in the adjustment BP_{ij}

$M4$: Number of the staff in the adjustment k

Q_2: Does the time of the element spent in the adjustment influence EISA?

$M5$: Time of the element in the business adjustment BP_{ij}

$M6$: Time of the element in the software module adjustment k

(3) Measurement of sub-goal C (Complexity)

Q_1: Does the module layered in the adjustment influence the EISA?

$M1$: Module layer influence

$M2$: Number of the comprehensive knowledge points in the i_1 th layer in OKM

$M3$: Number of the atom knowledge points in the i_1 th layer in OKM

$M4$: Number of the comprehensive knowledge points in the i_1 th layer in OKM

Q_2: Does the interaction between modules in the adjustment influence the EISA?

$M5$: Relationship between module KP^g and KP^h.

$M6$: Relationship between module KP^g and B^g.

$M7$: Relationship between module KP^h and B^h.

(4) Measurement of sub-goal D (Risk)

Q_1: Does the risk of adjustment influence the EISA?

$M1$: Value of satisfying degree

Q_2: Does the difficulty of adjustment influence the EISA?

$M2$: Difficulty of adjustment in the transformation

Q_3: Does the chaos after the adjustment influence the EISA?

$M3$: Orderly degree before the adjustment

$M4$: Orderly degree after the adjustment

(5) Measurement of sub-goal E (Robust)

Q_1: Does the robust of EIS after adjustment influence the EISA?

$M1$: Number of the indirect layer between basic business process BP_i and BP_j

$M2$: Number of the indirect layer between software $S(k_1)$ and $S(k_2)$

$M3$: Number of the adjustment elements in indirect trigger

$M3.1$: Number of business process with BP_i

$M3.2$: Number of software module with $S(k)$

$M4$: Number of the adjustment elements in direct trigger

$M4.1$: Number of business process with BP_i

$M4.2$: Number of software module with $S(k)$

Q_2: Does the range of the adjustment influence the EISA?

$M5$: Number of initial software module

$M6$: Number of delete software module

$M7$: Number of revise software module

$M8$: Number of insert software module.

C. Index of EISA Evaluation System

According to GQM [9], the index set can be obtained, as shown in Fig. 1. It includes time, cost, complexity, risk and robust, which are set in terms of system elements.

Combined with OKM, the indices can be quantified, and the results are as follows:

(1) Time

$$T = T_1 + T_2 = \sum_{i=1}^{n}\sum_{j=1}^{m} t\left(BP_{ij}\right) + \sum_{k=1}^{r} t\left(S\left(k\right)\right) \quad (1)$$

Where, $T_1 = \sum_{i=1}^{n}\sum_{j=1}^{m} t\left(BP_{ij}\right)$ and $T_2 = \sum_{k=1}^{r} t\left(S\left(k\right)\right)$ are the time spent on the adjustment with BSP^q and $\left(SSP^q\right)$ respectively.

(2) Cost

$$C = C_s + C_h \quad (2)$$

$$C_s = \sum_i \sum_j \sum_u \left(a_u \times t\left(BP_{ij}\right)\right) + \sum_i \sum_j \sum_{u'} \left(b_{u'} \times PN_{u'}\left(BP_{ij}\right) \times t\left(BP_{ij}\right)\right)$$

$$C_h = \sum_k \sum_u \left(a_u \times t\left(S\left(k\right)\right)\right) + \sum_k \sum_{u'} \left(b_{u'} \times PN_{u'}\left(S\left(k\right)\right) \times t\left(S\left(k\right)\right)\right)$$

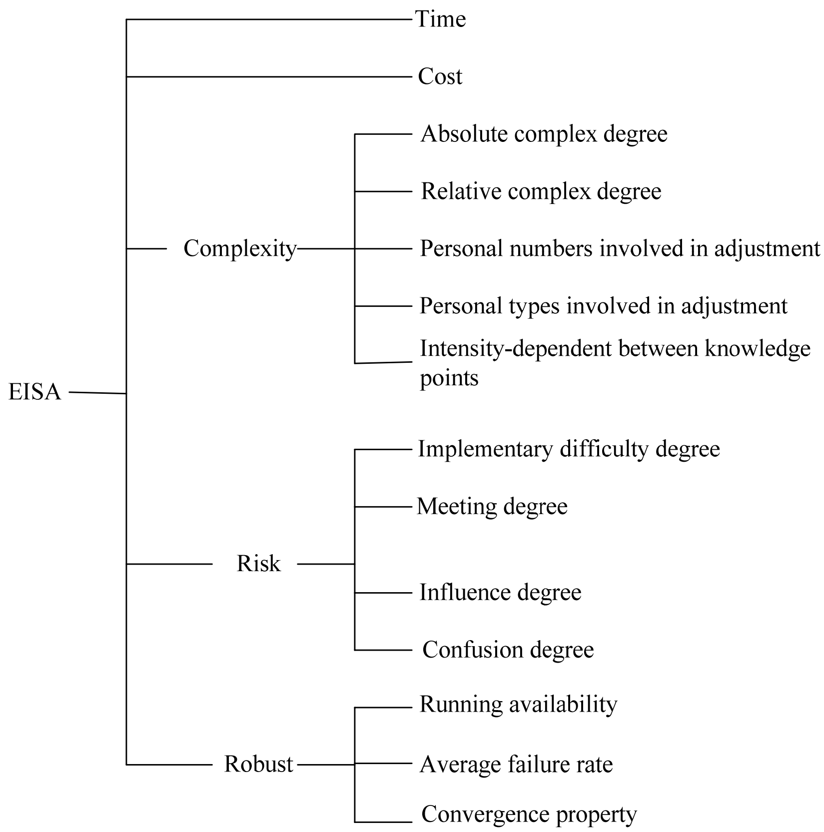

Figure 1. EISA evaluation index system

Where, a_u is the cost of the material u for the adjustment, $b_{u'}$ is the cost of the workforce u' for the adjustment, $PN_{u'}\left(BP_{ij}\right)$ is the number of workforce for the business process adjustment, $PN_{u'}\left(S\left(k\right)\right)$ is the number of workforce for the software adjustment.

(3) Complexity

This sub-index set includes the following indexes:

1) Absolute complex degree (ACD for short)

$$ACD = \left(BSP^q\right) + \left(SSP^q\right) \tag{3}$$

Where, $\left(BSP^q\right)$ is the number of BSP^q , and $\left(SSP^q\right)$ is the number of SSP^q .

2) Relative complex degree (RCD for short)

$$RCD = \frac{IN}{N} \tag{4}$$

Where, IN is the number of the knowledge points involved in the adjustment, N is the number of knowledge points.

3) Personal numbers involved in the adjustment (TN for short)

$$TN = \left|\bigcup_{i,j} PT\left(BP_{ij}\right)\right| + \left|\bigcup_{k} PT\left(S\left(k\right)\right)\right| \tag{5}$$

Where, $PT\left(BP_{ij}\right)$ is the workforce types while adjusting BP_{ij} , $PT\left(S\left(k\right)\right)$ is the workforce types while adjusting $S\left(k\right)$.

4) Personal types involved in adjustment (*PN* for short)

$$PN = \sum_i \sum_j \sum_l PN_l\left(BP_{ij}\right) + \sum_k \sum_l PN_l\left(S\left(k\right)\right) \tag{6}$$

Where, $\sum_i \sum_j \sum_l PN_l\left(BP_{ij}\right)$ is the number of workforce while adjusting BP_{ij} , $\sum_k \sum_l PN_l\left(S\left(k\right)\right)$ is the number of workforce while adjusting $S\left(k\right)$.

5) Intensity-dependence between knowledge points (IND for short)

Assuming $BSP_i^q \xrightarrow{d} BP_i$, and $SSP_{jj'}^q \xrightarrow{d} S\left(i'\right)$, thus w_j is the dependence degree between BSP_j^q and BP_i, $w_j^{'}$ is the dependence degree between $SSP_{jj'}^q$ and $S(i')$, w_i is the dependence degree between all BSP^q and BP_i, w_k is the dependence degree between all the SSP^q and BP_i. Then

$$IND = \frac{\sum_j w_j + \sum_{j'} w_j^{'}}{\sum_i w_i + \sum_k w_k} \quad (7)$$

(4) Risk

This index set includes the following sub-indices.

1) Implementation difficulty degree (IDD for short)

Generally speaking, the adjusting operation for business process and software includes increasing operation, modifying operation and deleting operation. The operation object can be the relation between elements (complex relationship or information relationship) or the elements themselves. Assuming that $\lambda_1, \lambda_2, \lambda_3$ represents the difficulty of inserting, revising and deleting operation respectively, $\gamma_1, \gamma_2, \gamma_3$ are the occurrence probability in time T.

$$IDD = \sum_{m=1}^{3}\sum_{n=1}^{3} \lambda_m \gamma_n \quad (8)$$

Where, $\sum_{n=1}^{3} \gamma_n = 1$.

2) Meeting degree (MD for short)

This is a qualitative index and can be classified into four levels: A (completely meet), B (Basically meet), C (Partially meet), D (hardly meet).

3) Influence degree (ID for short)

Assuming there are three influence degree, promoting effect (δ_1), inhibitory effect (δ_2) and no effect (δ_3), the importance of BP_i is $x_i\left(i = 1, 2, \cdots n\right)$, and the importance of $S(j)$ is $y_j\left(j = 1, 2, \cdots r\right)$.

$$\operatorname{sgn}(x_i) = \begin{cases} -1 & \text{inhibitory effect} \\ 0 & \text{no effect} \\ 1 & \text{promoting effect} \end{cases}$$

$$\operatorname{sgn}(y_j) = \begin{cases} -1 & \text{inhibitory effect} \\ 0 & \text{no effect} \\ 1 & \text{promoting effect} \end{cases}$$

Then,

$$ID = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{3} \operatorname{sgn}(x_{ij})\delta_k x_i + \sum_{i=1}^{r}\sum_{j=1}^{r}\sum_{k=1}^{3} \operatorname{sgn}(y_{ij})\delta_k y_j}{\sum_{i=1}^{n} x_i + \sum_{j=1}^{k} y_j} \quad (9)$$

4) Confusion degree (CD for short)

It is a qualitative index, and can be quantified according to the orderly degree before and after the adjustment.

(5) Robust

This index set includes the following sub-indices.

1) Running availability (A for short)

$$A = \frac{T_v}{T_v + T_d} \quad (10)$$

Where, T_v is the time of EIS in normal operation, while T_d is the opposite.

2) Average failure rate (λ' for short)

$$\lambda' = \frac{dr}{N^{'}dt} = \frac{r(t+\Delta t) - r(t)}{N^{'} \times \Delta t} \quad (11)$$

Where, Δt is the time interval, $\Delta r(t)$ is the failure numbers of tested knowledge points in $(t, t+\Delta t)$, and $N^{'}$ is the total numbers of knowledge points.

3) Convergence property (CP for short)

Definition 1: the maximize trigger layer numbers

Assuming that $LBN(BP_{ij})$ is the layer numbers between BP_{ij} and BP_{ik}, $LSN(S(i))$ is the layer numbers between $S(i)$ and $S(j)$. If $\exists BPS(r)$, which meets $BPS(r_i) \xrightarrow{D} BP_{ij}$, then $LBN(BP_{ij}) = 0$. If $\exists BP_{ik}$, which meets $BP_{ik} \xrightarrow{I} BP_{ij}$ or $BP_{ik} \xrightarrow{M} BP_{ij}$, then $LBN(BP_{ij}) = LBN(BP_{ik}) + 1$, and the trigger layer number CC_1 is $\max(LBN(BP_{ij}))$, i.e., $CC_1 = \max(LBN(BP_{ij}))$. Similarly, as to software, if $\exists BPS(r)$, which meets $BPS(r_i) \xrightarrow{D} S(i)$, then $LSN(S(i)) = 0$. If $\exists S(j)$, which meets

$S(j) \xrightarrow{I} S(i)$ or $S(j) \xrightarrow{M} S(i)$, then $LSN(S(i)) = LSN(S(j)) + 1$ and the corresponding trigger layer number $CC_1^{'}$ is $\max(LSN(S(i)))$, i.e., $CC_1^{'} = \max(LSN(S(i)))$. Then, $C_1 = CC_1 + CC_1^{'}$.

Definition 2: Assuming that the number of basic adjusting units of indirect trigger or mapping trigger is S_{IM}, then the ratio between S_{IM} and the number of basic adjusting units of direct trigger C_2 is

$$C_2 = CC_2 + CC_2^{'} = \frac{IN(BP_{ij}) + MN(BP_{ij})}{DN(BP_{ij})} + \frac{IN(S(i)) + MN(S(i))}{DN(S(i))} \quad (12)$$

Then

$$CP = \frac{1}{C_1 \times C_2} \quad (13)$$

Where, C_1 is the maximize trigger layer numbers, and C_2 is the ratio between indirect and direct trigger numbers.

III. EVALUATION MODEL AND CORRESPONDING ALGORITHM

A. Evaluation Model

Assuming that $OR = \{\theta_1, \theta_2, \cdots, \theta_l\}$ is the set of l evaluation objects, and θ_e is the e^{th} $(1 \le e \le l)$ information system. And the evaluation index set is $TR = \{t_1, t_2, \cdots, t_p\}$, where t_f is the f^{th} $(1 \le f \le p)$ aspect in the evaluation index set. So each EISA can be evaluated via $t_f = \{a_{e1}^f, a_{e2}^f, \cdots, a_{ez}^f\}$, and the evaluation matrix is $A_2 = \left(a_{es}^{(f)}\right)_{l \times z}$, where $a_{es}^{(f)}$ is the s^{th} $(1 \le s \le z)$ index value of the e^{th} information system with the f^{th} aspect. Adaptability evaluation (AE) algorithm is proposed in this paper based on similarity to ideal solution.

B. AE Algorithm

According to the evaluation index system and model, the steps of AE algorithm are shown as follows:

Step 1: obtain the evaluation index matrix $A_2 = \left(a_{es}^{(f)}\right)_{l \times z}$, where $1 \le e \le l$, $1 \le f \le p$, $1 \le s \le z$. And according to the attribute of each index, if all the elements in the i^{th} line are worse than those of the j^{th} line, then the j^{th} information system is better than the i^{th} information system.

$$A_2 = \begin{bmatrix} a_{11}^{(1)} & a_{12}^{(2)} & \cdots & a_{1z}^{(p)} \\ a_{21}^{(1)} & a_{22}^{(2)} & \cdots & a_{2z}^{(p)} \\ \vdots & \vdots & & \vdots \\ a_{l1}^{(1)} & a_{l2}^{(2)} & \cdots & a_{lz}^{(p)} \end{bmatrix}$$

Step 2: conform the ideal solution matrix $A_2^{(*)}$ and the negative ideal solution matrix $A_2^{(-*)}$. $A_2^{(*)}$ and $A_2^{(-*)}$ are selected according to the corresponding index attributes.

Step 3: make indices dimensionless as $A_2 = \left(a_{es}^{(f)}\right)_{l \times z}$.

$$A_2^{(e)} = \begin{bmatrix} \frac{a_{11}^{(1)}}{a_{11}^{(1*)}} & \frac{a_{11}^{(2)}}{a_{12}^{(2*)}} & \cdots & \frac{a_{11}^{(p)}}{a_{1z}^{(p*)}} \\ \frac{a_{22}^{(1)}}{a_{21}^{(1*)}} & \frac{a_{22}^{(2)}}{a_{22}^{(2*)}} & \cdots & \frac{a_{22}^{(p)}}{a_{2z}^{(p*)}} \\ \vdots & \vdots & & \vdots \\ \frac{a_{lz}^{(1)}}{a_{l1}^{(1*)}} & \frac{a_{lz}^{(2)}}{a_{l2}^{(2*)}} & \cdots & \frac{a_{lz}^{(p)}}{a_{lz}^{(p*)}} \end{bmatrix}$$

Step 4: make the weighted processing to t_f. Assuming that the weight of P aspects is $w = (w_1, w_2, \cdots, w_p)$, then

$$A_2^{(e)\,'} = \begin{bmatrix} \frac{w_1 a_{11}^{(1)}}{a_{11}^{(1*)}} & \frac{w_2 a_{11}^{(2)}}{a_{12}^{(2*)}} & \cdots & \frac{w_p a_{11}^{(p)}}{a_{1z}^{(p*)}} \\ \frac{w_1 a_{22}^{(1)}}{a_{21}^{(1*)}} & \frac{w_2 a_{22}^{(2)}}{a_{22}^{(2*)}} & \cdots & \frac{w_p a_{22}^{(p)}}{a_{2z}^{(p*)}} \\ \vdots & \vdots & & \vdots \\ \frac{w_1 a_{lz}^{(1)}}{a_{l1}^{(1*)}} & \frac{w_2 a_{lz}^{(2)}}{a_{l2}^{(2*)}} & \cdots & \frac{w_p a_{lz}^{(p)}}{a_{lz}^{(p*)}} \end{bmatrix}$$

Step 5: conform the ideal solution matrix $A_2^{(*)\,'}$ and the negative ideal solution matrix $A_2^{(-*)\,'}$ again.

Step 6: compute the distances between $A_2^{(e)\,'}$ and $A_2^{(*)\,'}$, $A_2^{(e)\,'}$ and $A_2^{(-*)\,'}$ respectively.

TABLE 3
THE INDEX VALUE OF THE EXAMPLE

EIS	Index													
	Time	**Cost**	**Complexity**						**Risk**			**Robust**		
	0.15	0.25	0.2						0.25			0.15		
	T	C	ACD	RCD	TN	PN	IND	IDD	MD	ID	CD	A	λ'	CP
EIS1	30	50	20	0.5	10	50	0.6	1.7	B	0.6	3	0.6	0.05	0.08
EIS2	25	45	18	0.5	10	45	0.4	1.5	B	0.5	3	0.8	0.03	0.1
EIS3	35	40	25	0.6	8	30	0.45	1.2	B	0.5	3	0.85	0.02	0.15

* The value of A, B, C, D are 7, 5, 3, 1 respectively.

Step 7: compute the relative approach degree.

$$d_e = \frac{\left\|d_i^{'}\right\|}{\left\|d_i^{*}\right\| + \left\|d_i^{-*}\right\|}$$

Where, $\left\|d_i^{*}\right\|$ is the distance between $A_2^{(e)}$' and A_2^{*}, $\left\|d_i^{-*}\right\|$ is the distance between $A_2^{(e)}$' and A_2^{-*}, $\left\|d_i^{*}\right\|$ and $\left\|d_i^{-*}\right\|$ can be measured by matrix norm.

Step 8: sort the EISA according to the relative approach degree.

IV. EXAMPLES

A. Background

The evaluation approach is exemplified through a case study as follows. There are three information systems with similar functions and it's necessary to evaluate their adaptability in order to find a better plan. Firstly, the indexes are quantified according to Eq. (1) ~ (13) as shown in Tab. 3.

Take implementation difficulty degree as an example to show the evaluation method. According to historical data, the probabilities of inserting, revising and deleting operation are $\gamma_1 = \gamma_2 = \gamma_3 = \frac{1}{3}$, and the difficulty degree are 2, 1.6 and 1.5 respectively. Then IDD of the first information system is 1.7.

B. Example Analysis

According to AE algorithm, the data in Table 1 is processed as follows:

(1) According to step 1, evaluation index matrix is obtained.

$$A_2 = \begin{bmatrix} 30 & 50 & 20 & 0.5 & 10 & 50 & 0.6 & 1.7 & 5 & 0.6 & 3 & 0.6 & 0.05 & 0.08 \\ 25 & 45 & 18 & 0.5 & 10 & 45 & 0.4 & 1.5 & 5 & 0.5 & 3 & 0.8 & 0.03 & 0.1 \\ 35 & 40 & 25 & 0.6 & 8 & 30 & 0.45 & 1.2 & 5 & 0.5 & 3 & 0.85 & 0.02 & 0.15 \end{bmatrix}$$

As the index values in the second line are better than those of the first line according to index attributes, so the second information system is better than the first information system.

(2) According to step 2, the ideal solution matrix and the negative ideal solution matrix are obtained.

$$A^{(*)} = \begin{bmatrix} 25 & 40 & 18 & 0.5 & 8 & 30 & 0.4 & 1.2 & 5 & 0.5 & 3 & 0.85 & 0.02 & 0.08 \\ 25 & 40 & 18 & 0.5 & 8 & 30 & 0.4 & 1.2 & 5 & 0.5 & 3 & 0.85 & 0.02 & 0.08 \\ 25 & 40 & 18 & 0.5 & 8 & 30 & 0.4 & 1.2 & 5 & 0.5 & 3 & 0.85 & 0.02 & 0.08 \end{bmatrix}$$

$$A^{(-*)} = \begin{bmatrix} 35 & 50 & 25 & 0.6 & 10 & 50 & 0.6 & 1.7 & 5 & 0.6 & 3 & 0.6 & 0.05 & 0.15 \\ 35 & 50 & 25 & 0.6 & 10 & 50 & 0.6 & 1.7 & 5 & 0.6 & 3 & 0.6 & 0.05 & 0.15 \\ 35 & 50 & 25 & 0.6 & 10 & 50 & 0.6 & 1.7 & 5 & 0.6 & 3 & 0.6 & 0.05 & 0.15 \end{bmatrix}$$

(3) According to step 3, the indices are made dimensionless.

$$A_2^{(e)} = \begin{bmatrix} 1.20 & 1.00 & 1.40 \\ 1.25 & 1.13 & 1.00 \\ 1.11 & 1.00 & 1.39 \\ 1.00 & 1.00 & 1.20 \\ 1.25 & 1.25 & 1.00 \\ 1.67 & 1.50 & 1.00 \\ 1.50 & 1.00 & 1.13 \\ 1.42 & 1.25 & 1.00 \\ 1.00 & 1.00 & 1.00 \\ 1.20 & 1.00 & 1.00 \\ 1.00 & 1.00 & 1.00 \\ 0.71 & 0.94 & 1.00 \\ 2.50 & 1.50 & 1.00 \\ 1.00 & 1.25 & 1.88 \end{bmatrix}^{T}$$

(4) According to step 4, the evaluation sub-index sets are weighted. The weight of the five aspects is $w = (w_1, w_2, \cdots, w_5) = (0.15\ \ 0.25\ \ 0.20\ \ 0.25\ \ 0.15)$ according to Delphi, and the weighted matrix is

$$A_2^{(e)}{}' = \begin{bmatrix} 0.18 & 0.15 & 0.21 \\ 0.31 & 0.28 & 0.25 \\ 0.22 & 0.20 & 0.28 \\ 0.20 & 0.20 & 0.24 \\ 0.25 & 0.25 & 0.20 \\ 0.33 & 0.30 & 0.20 \\ 0.30 & 0.20 & 0.23 \\ 0.36 & 0.31 & 0.25 \\ 0.25 & 0.25 & 0.25 \\ 0.30 & 0.25 & 0.25 \\ 0.25 & 0.25 & 0.25 \\ 0.11 & 0.14 & 0.15 \\ 0.38 & 0.23 & 0.15 \\ 0.15 & 0.19 & 0.28 \end{bmatrix}^T$$

(5) According to step 5, the ideal solution matrix and the negative ideal solution matrix of the present matrix are obtained.

According to index attributes, the ideal solution matrix is:

$$A_2^{(e)}{}' = \begin{bmatrix} 0.18 & 0.15 & 0.21 \\ 0.31 & 0.28 & 0.25 \\ 0.22 & 0.20 & 0.28 \\ 0.20 & 0.20 & 0.24 \\ 0.25 & 0.25 & 0.20 \\ 0.33 & 0.30 & 0.20 \\ 0.30 & 0.20 & 0.23 \\ 0.36 & 0.31 & 0.25 \\ 0.25 & 0.25 & 0.25 \\ 0.30 & 0.25 & 0.25 \\ 0.25 & 0.25 & 0.25 \\ 0.11 & 0.14 & 0.15 \\ 0.38 & 0.23 & 0.15 \\ 0.15 & 0.19 & 0.28 \end{bmatrix}^T$$

and the negative ideal solution matrix is

$$A_2^{(-*)}{}' = \begin{bmatrix} 0.21 & 0.21 & 0.21 \\ 0.31 & 0.31 & 0.31 \\ 0.28 & 0.28 & 0.28 \\ 0.24 & 0.24 & 0.24 \\ 0.25 & 0.25 & 0.25 \\ 0.33 & 0.33 & 0.33 \\ 0.30 & 0.30 & 0.30 \\ 0.36 & 0.36 & 0.36 \\ 0.25 & 0.25 & 0.25 \\ 0.30 & 0.30 & 0.30 \\ 0.25 & 0.25 & 0.25 \\ 0.11 & 0.11 & 0.11 \\ 0.38 & 0.38 & 0.38 \\ 0.28 & 0.28 & 0.28 \end{bmatrix}^T$$

(6) According to step 6, the distance between $A_2^{(e)}{}'$ and $A_2^{(*)}{}'$ is calculated, as well as $A_2^{(e)}{}'$ and $A_2^{(-*)}{}'$. $A^* = A_2^{(e)}{}' - A_2^{(*)}{}'$ and $A^{-*} = A_2^{(e)}{}' - A_2^{(-*)}{}'$ can be obtained.

(7) According to step 7, the relative approach degree between $A_2^{(e)}{}'$ and A_2^* is calculated, as well as $A_2^{(e)}{}'$ and A_2^{-*}.

$$\|d_1^{-*}\| = 0.1517, \|d_2^{-*}\| = 0.2447, \|d_3^{-*}\| = 0.3114$$

$$\|d_1^{*}\| = 0.3216, \|d_2^{*}\| = 0.1584, \|d_3^{*}\| = 0.1715$$

So according to AE algorithm and the data in Tab. 3, the three EIS relative approach degrees are as follows.

$$d_1 = \frac{\|d_1^*\|}{\|d_1^*\| + \|d_1^{-*}\|} = 0.6795$$

$$d_2 = \frac{\|d_2^*\|}{\|d_2^*\| + \|d_2^{-*}\|} = 0.3930$$

$$d_3 = \frac{\|d_3^*\|}{\|d_3^*\| + \|d_3^{-*}\|} = 0.3551$$

As $d_3 < d_2 < d_1$, the third EISA is the best, and the first EISA is the worst. Therefore, the enterprise can adopt the third enterprise information system, or improve its designed system, so that its information system can meet the changing environment better.

V. CONCLUSIONS

The adaptability is an important quality for an enterprise to survive in the dynamic environment. Enterprises with better adaptability can have continuous growth and improvement. With the advent of information age, the adaptability of enterprise information systems becomes an important factor to judge their competitive advantage.

In this paper, a set of adaptability index system is proposed, including five aspects: time, cost, complexity, risk and robust. On the basis of the index system, the evaluation model is built and the corresponding algorithm is given, so the EISA can be evaluated. In practice, enterprises can combine the better information systems with their own conditions to fully understand and design or improve their own information systems with better adaptability. The evaluation model and algorithm are helpful in understanding the adaptability and in laying the foundation for enterprises to make effective decisions.

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