Grey and Fuzzy Evaluation of Information System Disaster Recovery Capability

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Abstract—**Disaster recovery is the key approach to ensure the security of information system and business continuity. Nowadays, it's very urgent to explore a way to evaluate the disaster recovery ability objectively, comprehensively and scientifically before disaster occurs. Initially, our proposal constructs an evaluation system for disaster recovery ability based on the extensive work abroad and domestic in this field. Then, we decide the weight of the evaluation in each level using the hierarchical method. In addition, I make use of expert scoring method to grade different norm set. Finally I employ the fuzzy and gray comprehensive evaluation system to evaluate the recovery ability. According to the result of my research, it's feasible to apply the fuzzy gray comprehensive evaluation method to evaluate disaster recovery ability.**

Keywords- information system;disaster recovery;fuzzy and grey comprehensive evaluation;indicator system;evaluation model

I. INTRODUCTION

With the development of information society, the damage caused by disaster information system will cause inestimable losses to enterprise, because enterprise's dependence on information systems increases. How to prepare for construction of disaster recovery has attracted great attention from all walks of life. Companies are in urgent need of a set of scientific methods, experience in judging disaster recovery capability of the enterprise. In the case of not experiencing a disaster. In this area, the domestic research has just started, and lack of a mature information system disaster recovery capability assessment method.

Literature [1-2] using the analytic hierarchy process (ahp) and fuzzy theory to model and evaluate the information system disaster recovery capability. But simply using fuzzy method will result in the loss of information, which is not conducive to the results of the evaluation. While the grey system theory is focus on to solve the "small sample", "poor information" uncertain problems[3] that the fuzzy mathematics is difficult to solve. This article builds a set of comprehensive information system disaster recovery capability evaluation index system through the study of domestic and foreign disaster recovery plan, and using fuzzy grey comprehensive evaluation method to evaluate a Beijing bank's information system disaster recovery capability, finally put forward some suggestions to improve their disaster recovery capability.

II. THE CONSTRUCTION OF INFORMATION SYSTEM EVALUATION INDEX SYSTEM OF DISASTER RECOVERY CAPABILITY

A. Principles of information system disaster recovery capability evaluation index system

1) Comprehensiveness principle

Comprehensiveness principle requires the evaluation index system of information system disaster recovery should reflect the general characteristics of the disaster recovery capability from different levels, so the design of evaluation index includes disaster recovery planning and implementation, daily operation of disaster backup center, emergency response after the disaster, critical business functions' restoration and operation renewal, as well as the post-disaster reconstruction and back to work of production system.

2) Consistency principle

Consistency means that the consistency between disaster recovery evaluation index system and disaster recovery capacity evaluation's objectives. Therefore, in the design and selection of the disaster recovery capability evaluation, we should start from the general objective of disaster recovery capability evaluation, and set and select index based on it.

3) The principle of hierarchy

The principle of system hierarchy requires that each index should not only to reflect the ability to work in various fields of information systems disaster recovery, but be coordinated to facilitate a comprehensive evaluation of the object of study. Individual evaluation of the evaluation index

system should join with each other, in terms of their meaning, calculation methods, the computation time and scope and so on.

4) Principles of operability

Operability includes information systems disaster recovery evaluation index's own operability as well as its practical feasibility in the evaluation process.

B. Evaluation index system of information systems disaster recovery capability

This paper establish the corresponding index system based on the study of the domestic and international disaster recovery efforts, according to the comprehensiveness, consistency , level and operational principles, and divided them from the disaster organization planning and management, disaster recovery, risk assessment, disaster recovery, backup center construction, disaster recovery technology, disaster recovery routine maintenance work and disaster recovery capabilities.

1) Planning and management of disaster recovery organization

Planning and management of disaster recovery organization is the premise of disaster recovery's successful implementation. It includes disaster recovery strategy management, disaster recovery planners' management and institutional asset management.

2) Assessment of disaster recovery

Risk is an important aspect of disaster recovery planning assessment, which identify and analysis all possible harm for enterprise. Disaster recovery risk assessment includes personnel asset risk assessment, the risk assessment of the management system, the engine room risk assessment, sharing information carrier risk assessment, specific information and its carrier risk assessment.

3) Construction of disaster recovery backup center

The backup center is the work platform of disaster recovery. It includes the implementation of backup center and the data transfer.

4) Disaster recovery technology

Disaster recovery technology supplies the technical support to disaster recovery and restricts the efficiency and flexibility of disaster recovery. It includes the implementation of the high availability technology, storage and backup technology, copy technology and fault detection technology.

5) Routine maintenance work of disaster recovery

Routine maintenance work of disaster recovery guarantees successful implementation. It includes disaster recovery routine maintenance, routine operation and maintenance, and the training plan and exercise.

6) Work after the disaster

The work after the disaster is the last part of the disaster recovery, which is directly related to the effects of the disaster recovery. It includes the renewal of the emergency response after the disaster, continued operation of critical business, the reconstruction and rollback of the production system.

C. Fuzzy gray comprehensive evaluation of information systems disaster recovery capabilities

1) Determine the evaluation index set

The information systems disaster recovery capability evaluation index system established by this paper is shown in Figure 1. The second level of evaluation index is $B = (B_1, B_2, B_3, B_4, B_5, B_6)$, on behalf of disaster recovery organization planning and management, disaster recovery, risk assessment, disaster recovery, backup center construction, disaster recovery technology, disaster recovery routine maintenance work and the work of disaster respectively. The third index is $C = (C_{i1}, C_{i2}, C_{i3}, \ldots C_{ij})$, $i = 1,2,3,4,5,6$; C_{ij} means the i-th secondary index j .

2) Determine the weight of each index

Changes in the value of index weight will lead to changes in the final evaluation of the magnitude of the object being evaluated, then directly affect the results of comprehensive evaluation [4]. This paper got the second layer and the third layer corresponding weights through AHP as follows:

$A = (0.1, 0.15, 0.3, 0.15, 0.1, 0.2)$
$a_1 = (0.5, 0.3, 0.2)$
$a_2 = (0.1, 0.1, 0.3, 0.2, 0.3)$
$a_3 = (0.6, 0.4)$
$a_4 = (0.2, 0.3, 0.3, 0.2)$
$a_5 = (0.2, 0.5, 0.3)$
$a_6 = (0.3, 0.4, 0.4)$

1) Determine the remark set

Evaluation of information systems disaster recovery capabilities are unified divided on its own merits rating into ("excellent", "good"," moderate"," poor") four standard, their score is (90,70,50,30), represents by $V = \{V_1, V_2, V_3, V_4\}$. The index level is between adjacent grades. When the capacity values from 10 to 30, it indicates that this aspect of disaster values capability is low; when it values from 30 to 50, indicating this aspect is medium; when it values from 50 to 70, indicating this aspect is higher; when it values from 70 to 90, indicating this aspect is high.

2) Determine the evaluation sample matrix

Using expert scoring method to assess the bank's information systems disaster recovery capabilities, we established 9 disaster recovery evaluation teams, consisting of industry experts in the field. They score every index in the range from 0 to 100. We can get indicators score of the i-th element $(x_1, x_2, x_3 \ldots x_m)$, $M = 9$, and thereby constitute the evaluation sample matrix. (As shown in Table 1)

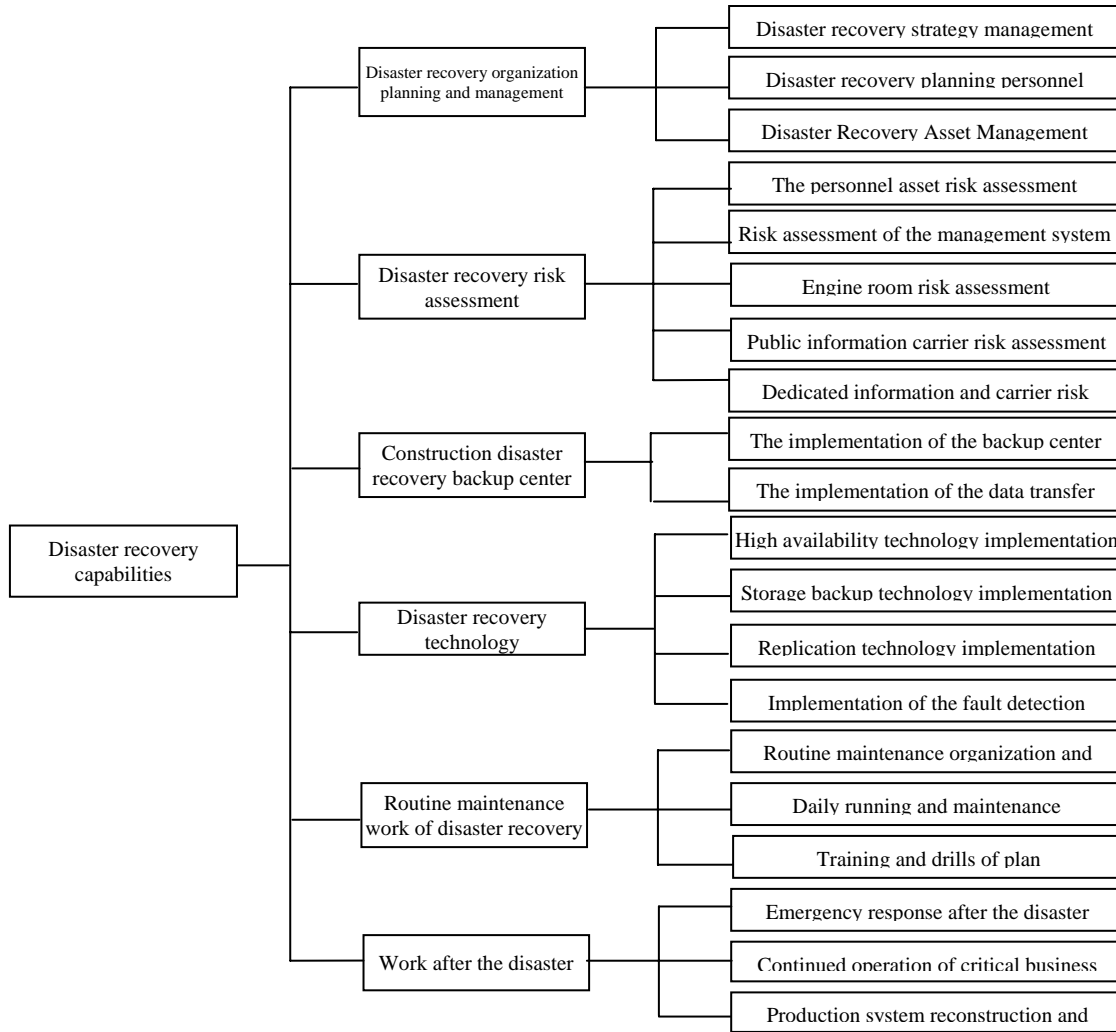#### 3) Established evaluation gray classes and whitening weight function

Figure 1 Information System Disaster recovery capability evaluation index system

TABLE 1 EXPERT SCORING TABLE

Index Layer	Expert1	Expert2	Expert3	Expert4	Expert5	Expert6	Expert7	Expert8	Expert9
Disaster recovery strategy management	46	43	51	56	57	61	38	45	45
Disaster recovery planning, personnel management	78	68	59	53	67	65	76	74	59
Institutional Information Asset Management	45	56	48	42	35	39	60	53	56
Risk assessment of the personnel asset	87	89	90	91	80	79	85	87	86
Risk assessment of the management system	76	72	73	82	86	81	85	81	79
Risk assessment of the engine room	85	83	81	84	76	82	79	73	90
Risk assessment of the shared information carrier	46	56	58	57	59	53	54	60	44
Risk assessment of the specific information and its carrier	72	80	63	68	74	76	78	81	86
The implementation of the backup center	78	76	85	84	81	71	69	75	68
The implementation of the data transmission	70	76	56	45	70	68	61	64	62
The implementation of high-availability technologies	93	81	75	69	83	90	73	79	85
The implementation of storage backup technology	45	43	34	36	48	49	38	56	64
The implementation of copy technology	67	63	64	69	70	71	58	63	60
The implementation of fault detection techniques	34	35	39	37	34	39	38	45	41
The organization and management of the daily maintenance	45	42	46	43	51	29	34	29	54

Daily operation and maintenance	67	68	59	49	62	67	62	54	58
The training plan and exercise.	39	35	40	46	49	50	54	56	54
Emergency response after the disaster	89	90	80	85	87	84	91	86	82
Continued operation of critical business	80	84	86	70	78	73	72	74	82
Reconstruction and rollback of the production system.	42	46	48	46	50	39	40	54	52

The whitening weight function based on gray theory evaluation gray class is as follows:

$$f_1(x_{ij}) = \begin{cases} \dfrac{x_{ij}}{90}, & x_{ij} \in [0,90] \\ 1, & x_{ij} \in [90,100] \end{cases}$$

$$f_2(x_{ij}) = \begin{cases} \dfrac{x_{ij}}{70}, & x_{ij} \in [0,70] \\ \dfrac{100 - x_{ij}}{30}, & x_{ij} \in [70,100] \end{cases}$$

$$f_3(x_{ij}) = \begin{cases} \dfrac{x_{ij}}{50}, & x_{ij} \in [0,50] \\ \dfrac{100 - x_{ij}}{50}, & x_{ij} \in [50,100] \end{cases}$$

$$f_4(x_{ij}) = \begin{cases} \dfrac{x_{ij}}{30}, & x_{ij} \in [50,100] \\ 1, & x_{ij} \in [0,30] \end{cases}$$

4) Calculate the number of gray evaluation

Take High availability technology implementation index for instance, its gray evaluation is:

$$C_{411} = \sum_{k=1}^{m} f_1(x_{ijk}) = 8.03$$

$$C_{412} = \sum_{k=1}^{m} f_2(x_{ijk}) = 5.68$$

$$C_{413} = \sum_{k=1}^{m} f_3(x_{ijk}) = 3.44$$

$$C_{414} = \sum_{k=1}^{m} f_4(x_{ijk}) = 24.03$$

For index C_{41}, the total number of gray evaluation belongs to each evaluation gray class is $C_{41} = C_{411} + C_{412} + C_{413} + C_{414}$.

5) Calculate the assessment weight matrix

We also use C_{41}, and get the assessment weight belongs to each gray class of C_{41}:

$$C_{41}(r_1) = \frac{C_{411}}{\sum_{n=1}^{4} C_{41n}} = 0.5013$$

$$C_{41}(r_2) = \frac{C_{412}}{\sum_{n=1}^{4} C_{41n}} = 0.1742$$

$$C_{41}(r_3) = \frac{C_{413}}{\sum_{n=1}^{4} C_{41n}} = 0.2245$$

$$C_{41}(r_4) = \frac{C_{414}}{\sum_{n=1}^{4} C_{41n}} = 0.0934$$

Similarly:
$$C_{42} = (0.3651, 0.1542, 0.2891, 0.1915)$$
$$C_{43} = (0.4613, 0.1519, 0.1689, 0.2178)$$
$$C_{44} = (0.4357, 0.1956, 0.2319, 0.1367)$$

We can constitute the weight matrix of R_4 secondary evaluation B_4 (Disaster recovery technology) by the weight vector of C_{41}, C_{42}, C_{43}, C_{44}.

6) Fuzzy Comprehensive Evaluation

Through the weight vector and weight matrix of the third –level index, we can obtain fuzzy comprehensive evaluation matrix C of each factor evaluation. Take Disaster recovery technology evaluation index for instance:

$$C_4 = a_4 \times R_4$$

$$= (0.2, 0.3, 0.3, 0.2) \times \begin{bmatrix} 0.5013 & 0.1742 & 0.2245 & 0.0934 \\ 0.3651 & 0.1542 & 0.2891 & 0.1915 \\ 0.4613 & 0.1519 & 0.1689 & 0.2178 \\ 0.4357 & 0.1956 & 0.2319 & 0.1367 \end{bmatrix}$$

$$= (0.4353, 0.1658, 0.2287, 0.1688)$$

Similarly, the other five second level evaluation index's fuzzy comprehensive evaluation matrix can be drawn. The score of each factor in the factors layer is:

$$B = C \times V^T$$

$$= \begin{bmatrix} 0.4078 & 0.2479 & 0.1023 & 0.2411 \\ 0.4215 & 0.3101 & 0.0875 & 0.1801 \\ 0.4511 & 0.1983 & 0.2104 & 0.1397 \\ 0.4353 & 0.1658 & 0.2287 & 0.1688 \\ 0.3976 & 0.2645 & 0.1552 & 0.1826 \\ 0.4022 & 0.1866 & 0.2135 & 0.1971 \end{bmatrix} \times (90, 70, 50, 30)$$

$$= (66.403, 69.42, 69.191, 67.282, 67.537, 65.848)$$

The final score of information systems disaster recovery capability is:

$$A^* = B^T \times A$$
$$= (66.403, 69.42, 69.191, 67.282, 67.537, 65.848)$$
$$\times (0.1, 0.15, 0.3, 0.15, 0.1, 0.2)$$
$$= 67.8262$$

The result of the evaluation is 67.8262, the bank's information systems disaster recovery capability is at a higher level. The risk assessment of disaster recovery, construction of disaster recovery backup center and disaster recovery technology is the point of the entire disaster recovery. And the implementation of fault detection technology and the training and exercises of plan is the weak link. The suggestion is investing in the introduction of advanced fault detection technology, taking the disaster recovery center's personnel systematic training and increase the plan exercise frequency, so that the information systems disaster recovery capabilities of this business can be improved to a higher level.

III. CONCLUSION

The evaluation of information systems disaster recovery capabilities is fuzzy due to the evaluation criterion's lack of standard, is grey due to the differences of evaluators' level and experience [5]. Using a combination of gray theory and fuzzy comprehensive evaluation method to build information systems disaster recovery capability evaluation model, can make a quantitative assessment of the information systems disaster recovery capabilities. This method is better in solving the problem that evaluation index is difficult to accurately quantify and statistics, so that the results of the evaluation is more objective and accurate. Evaluation results show that the fuzzy gray comprehensive evaluation method used in this paper is a scientific, and put forward feasible and effective targeted recommendations for the bank to improve its information systems disaster recovery capabilities.

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