System Business Affecting Impact Analysis Method with Crossover Probability Theory

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Abstract. In view of the lack of scale calibration and the influence of expert evaluation preference on the analysis results of information system business impact analysis, an analysis method of system business affecting impact based on crossover probability theory is proposed. Firstly, the experts evaluate the relevance and influence of the business functions of the information system. Then quantify the correlation between system business functions, and generate a comprehensive cross impact matrix. Finally, the preference chain generation algorithm is used to generate the business preference chain of information system, and the interaction relationship of each business of the system is associated. The experiment shows that this method can accurately measure the extent and trend of business interruption affecting other information system businesses.

Keywords: Information system · Business affecting impact · Crossover probability theory · Preference chain

1 Introduction

Business Impact Analysis (BIA) is used to analyze the system loss caused by business interruption, which is an important link of business continuity management [1]. Cai M [2] analyzed the influence of faults through network structure entropy reflecting the characteristics of network structure. Yin R [3] evaluated node importance through node structure hole importance index and adjacent node k-core importance index. Xie L [4] proposed a business affecting impact analysis method for information system. The limitation of the above research lies in that the analysis of the business impact of information system is insufficient, and the impact and intensity of other business after the interruption of a business function of the system are not considered.

In order to solve the shortcomings of the above research, this paper proposes a method of business impact analysis based on crossover probability theory. The association between business function nodes is represented by cross impact matrix. The subjective influence of expert scoring on cross impact matrix is reduced [5], and the

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business functions of information system are abstracted as nodes [6], the preference chain is generated by optimizing preference chain generation algorithm [7], the system is associated with the business function process and business function impact.

2 Analysis Method Architecture Design

The system business affecting impact analysis method based on crossover probability theory is composed of the cross impact matrix processing module and the preference chain generation and business impact analysis module.

Cross impact matrix treatment module: Firstly, the experts evaluate the relevance and influence degree between business functions. Then, the optimal weighting coefficient is obtained by subjective and objective combination weighting method to generate comprehensive weights. Finally, generate the comprehensive cross impact matrix to express the relevance and influence degree between business functions.

Preferential chain generation and business impact analysis module: Firstly, the overall impact of a business function on other business functions (Activity Sum, AS) in the cross impact matrix is used to characterize the impact of business function interruption on the information system. Then, the cross impact matrix and the *AS* are input to the algorithm of preference chain used to generate the system business function preference chain. Finally, according to the *AS* and the preference chain, the influence degree of a business function interruption and the influence trend of other business functions of the system are obtained.

3 Cross Impact Matrix

3.1 Quantification of Business Association Influence Relationship

The crossover probability theory uses the cross impact matrix to store the degree of direct influence between business functions. Business function interruption in information system will have an impact on subsequent business functions. Referring to the asset importance grade evaluation and risk grade division evaluation [8], the business importance evaluation value is 0–100, represents the business importance from low to high, and the inter business impact value is 0–5, represents the impact between businesses ranges from low to high. According to the business importance evaluation value and the inter business impact value, the business importance evaluation matrix and inter business cross impact matrix are generated by expert scoring.

3.2 Generation of Comprehensive Cross Impact Matrix

In order to reduce the subjectivity brought by experts' evaluation as much as possible, it is necessary to give reasonable weights to the inter business cross impact matrix generated by experts' evaluation. The generation process of the comprehensive cross impact matrix $\boldsymbol{R}$ is designed as follows.

Normalized the Business Importance Evaluation Matrix. M experts score the business importance according to the business importance evaluation value, and generate the business importance evaluation matrix. The *ith* expert denotes the importance value of the *jth* business as a_{ij} ($i = 1, 2,\ldots, m; j = 1, 2,\ldots, n$), Normalize the business importance evaluation matrix according to formula (1).

$$b_{ij} = (a_{ij} - a_c^{min})/(a_c^{max} - a_c^{min}) \tag{1}$$

Where $a_c^{\max}$ is the maximum value of importance of *jth* business function and $a_c^{\min}$ is the minimum value of importance of *jth* business function. The normalized decision matrix $\boldsymbol{B}$ is

$$B = \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{m1} & \cdots & b_{mn} \end{pmatrix}$$

Extract Subjective and Objective Weights. The harmonic average value of the business importance evaluation matrix is calculated to obtain the subjective weight of the business function is $W_{1j} = (W_{11}, W_{12},\ldots, W_{1n})^T$. The entropy weight method [9] is used to calculate the objective weight of experts to business is $W_{2j} = (W_{21}, W_{22}, \ldots, W_{2n})^T$.

Generate the Comprehensive Cross Impact Matrix. According to formula (2), the combined weight vector W_j of subjective weight W_{1j} and objective weight W_{2j} is obtained.

$$W_j = \alpha W_{1j} + \beta W_{2j} \tag{2}$$

Where α and β are combined weighting coefficients

$$\alpha = \frac{\frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{n} b_{ij}(W_{1j} - W_{2j}) + \sum_{j=1}^{n} W_{2j}(W_{1j} + W_{2j})}{\sum_{j=1}^{n}(W_{1j} + W_{2j})^2}, \quad \beta = \frac{\sum_{j=1}^{n} W_{1j}(W_{1j} + W_{2j}) - \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{n} b_{ij}(W_{1j} - W_{2j})}{\sum_{j=1}^{n}(W_{1j} + W_{2j})^2} \tag{3}$$

Finally, the linear weighted evaluation model is used to obtain the comprehensive evaluation value vector $\boldsymbol{U}$.

$$\mathrm{U} = \sum_{j=1}^{n} b_{ij} W_j \tag{4}$$

The elements in the comprehensive evaluation value vector $\boldsymbol{U} = (u_1, u_2,\ldots, u_{\mathrm{m}})$ correspond to the weight of each expert. According to the inter business impact value, m experts score the degree of inter business impact, and generate m inter business cross impact matrix $\boldsymbol{Q} = \{\boldsymbol{Q1}, \boldsymbol{Q2},\ldots, \boldsymbol{Qm}\}$. According to the comprehensive evaluation value vector $\boldsymbol{U}$, the corresponding weight of experts is multiplied by the matrix $\boldsymbol{Q1} \sim \boldsymbol{Qm}$,

and then the average value of the weighted m matrices is calculated to generate the comprehensive cross impact matrix $\boldsymbol{R}$, which is the input data of the preference chain generation algorithm.

$$R = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix}$$

4 Business Affecting Impact Analysis

4.1 Active Sum Calculation

In the information system, the overall impact of a business function on all other business functions is called active sum (AS), which is used to measure the impact of business function interruption on information system.

In the comprehensive cross impact matrix $\boldsymbol{R}$, each row of the matrix shows the impact degree of the business function on others. The AS_i of business function i is

$$AS_i = \sum_{j=1}^{n} r_{ij} \tag{5}$$

r_{ij} is an element in the comprehensive cross impact matrix $\boldsymbol{R}$.

4.2 Preference Chain Generation

The preference chain is a chain structure generated by the comprehensive cross impact matrix, which can intuitively express the relevance and priority between business functions. The steps of preference chain generation algorithm are designed as follows:

(1) Calculate the AS of each business in the system.
(2) Select the highest AS of business to insert the head of preference chain.
(3) If multiple businesses have the highest sum of AS, select the first to insert the head of preference chain.
(4) Build preference chain with selected business as root. The entry priority of the remaining business nodes is sorted by AS, the number of affected businesses and the impact value from large to small, and selected the first and the largest nodes.
(5) All nodes enter the chain according to Step (4), until all nodes enter the chain or only the nodes left cannot enter the chain due to insufficient priority.
(6) For the node that is not in the chain, select the node that has been in the chain and has the greatest impact on it as its preorder node, and this node as a branch node to enter the chain according to step (4).

4.3 Business Affecting Impact Analysis

The analysis method of business impact of information system including the measurement of the impact of business function interruption and the trend analysis of the impact of business function interruption on others. In the event of information system business interruption, by analyzing the change of information system business *AS* before and after the business interruption, the influence degree of the interruption on the information system can be understood.

When a business function in an information system is interrupted, the node corresponding to this business function and the edge starting from this node are deleted from the preference chain. Then, the newly added node without indegree in the preference chain is the business function that may be affected by the business function interruption. This method can reflect the influence trend of business function interruption on others of the information system.

5 Experiments and Results

5.1 Business Impact Analysis and Results

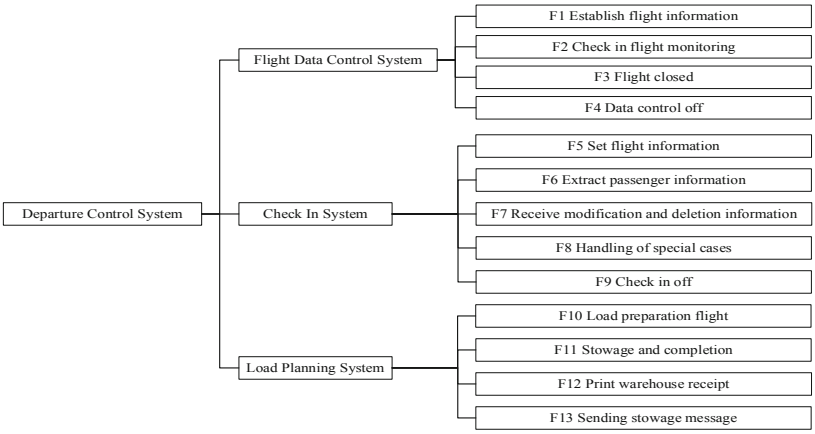

Fig. 1. Functional structure of departure control system.

In order to verify the effectiveness and accuracy of this method, the departure control system of civil aviation airport is selected as the experimental object. The functional structure of the system is shown in Fig. 1.

The experimental data comes from the system management files, business function interruption log records and expert scoring data. 20 business cross impact matrices and a business function importance evaluation matrix are generated. According to Sect. 3.2, the subjective and objective comprehensive weight vector $\boldsymbol{U}^T$.

According to $\boldsymbol{U}^T$, the corresponding weight of experts is multiplied by the business cross impact matrices, and then the average value of the weighted matrix is calculated

Table 1. Comprehensive cross impact matrix ***R*** and *AS*.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	AS
F1	0	2.52	2.33	2.68	0.14	2.53	1.95	0.14	0.10	2.90	0.63	0.63	0.63	17.20
F2	0	0	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0	0.29	0.29	0.29	5.30
F3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F4	0	0	2.57	0	0	0	0	0	0	0.08	2.86	2.86	2.86	11.23
F5	0	0	1.30	1.30	0	2.76	2.43	1.80	1.84	1.27	0.63	0.63	0.63	14.59
F6	0	0	1.90	1.90	0	0	3.07	2.47	1.84	0	0.63	0.63	0.63	13.07
F7	0	0	1.93	2.53	0	0	0	1.86	1.86	0	0.63	0.63	0.63	10.08
F8	0	0	0.63	0.63	0.63	0.63	0.63	0	1.93	0	0.63	0.63	0.63	6.99
F9	0	0	2.73	3.11	0	0	0	0	0	0	0.63	0.63	0.63	7.74
F10	0	0.26	0.63	0.88	0	2.43	2.46	0	1.27	0	2.85	2.53	1.90	15.21
F11	0	0	2.53	0	0	0	0	0	0	0	0	2.91	2.53	7.97
F12	0	0	2.53	0	0	0	0	0	0	0	0	0	3.17	5.69
F13	0	0	2.53	0	0	0	0	0	0	0	0	0	0	2.53

to obtain the comprehensive cross impact matrix ***R***. The *AS* of each business function is calculated by formula (5) (see Table 1).

According to Table 1, the preference chain of civil aviation departure control system is generated by Sect. 4.2 preference chain generation algorithm (see Fig. 2).

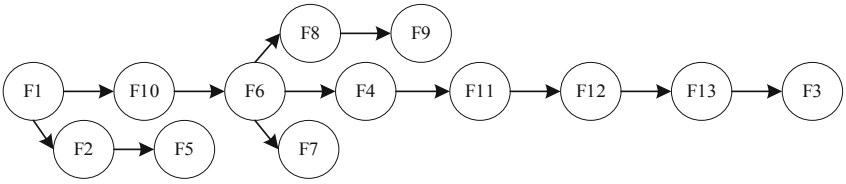

Fig. 2. System business preference chain.

5.2 Accuracy Comparison of System Influence Degree

Taking the comprehensive cross impact matrix ***R*** in Sect. 5.1 as the original data, the business function network structure entropy [2], weighted directed network structure entropy [4], structure hole importance index [3] and the *AS* in this method of business interruption event are calculated respectively, the change of the impact of business interruption on the information system at each time is shown in Fig. 3.

As can be seen from Fig. 3, the change of structure entropy in the event of business function interruption is similar to that of the *AS*. Due to the structure hole importance

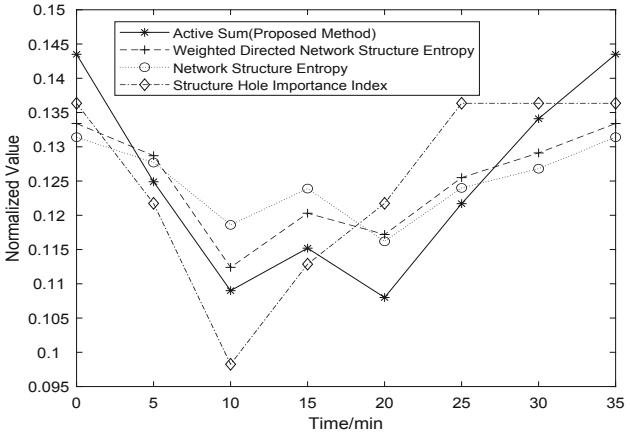

Fig. 3. Normalized data change of each method.

index can not adapt to the chain structure change, it can not accurately express the impact of business function interruption on the system; Compared with the *AS*, the network structure entropy and directed weighted network structure entropy can not accurately reflect the impact on the information system when the business function with high impact is interrupted.

To sum up, the changes of trend of the *AS* obtained by the method in this paper is more consistent with the change of business scope and influence degree in the actual situation.

6 Conclusion

This paper proposes a business impact analysis method based on crossover probability theory. The method oriented to the information system, the correlation between business functions was expressed by cross impact matrix. The preference chain generation algorithm is used to correlate the influence relationship of various business functions in the system. On this basis, the influence trend of business function interruption on other business functions is obtained by analyzing the position of business function interruption in the preference chain. Experimental results show that this method can accurately measure the impact of business function interruption on others of information system.

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