Module partitioning study of specialized engineering services based on modular theory

——case on coal production firms

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Abstract—Outsourcing of specialized engineering services has become one of the routes to the innovation and high-quality development of the commercial model of coal production enterprises in China. Currently, although there is practice, no scale-up development has been achieved. In this paper, based on modular theory, under the condition of unknown expert weights, triangular fuzzy number method is used to construct a service unit association relationship evaluation model, and the correlation matrix is calculated. Then, a genetic algorithm is used to cluster the association matrix and obtain the results of the division of the outsourced module of engineering services. Finally, the proposed method is validated using the coal mine development process of coal producers as an example.

1 Introduction

In 2016, the tenth five coal industry development program encouraged coal enterprises to establish specialized service companies [1]. This program provides specialized engineering services to coal production firms and provides policy support for conducting business model innovations.

Coal specialized engineering services are available at home and abroad [2]. Cum according to the service demand party needs, improve mine design, resource distribution, business management and other engineering service activities. However, in practice, specialized engineering services for coal production fail to achieve scale effects because service content is formed based on negotiation between the supply and demand parties, and as a result, there is a lack of standardized service products.

Hongling Xu (2007) argues that modularity in service product design is the basis of industrialization [3]. Modular theory was proposed by Baldwin and Clark at Harvard Business School in 1997 [4]. Xia Hui (2010) considers service modularity as the modularity of service processes, thus forming a series of activities to meet the demands of different markets [5]. Gomes (2008) and Zhang Qianjun (2015) argue that appropriate task modularity has a positive effect on firm performance [6] [7]. Based on the above studies, this paper argues that the service modularity theory can guide the coal production specialty to provide services for industrialization and scale development.

The basis of service module design is module partitioning. References [8-14] have studied the problem

of task module partitioning from different perspectives and methods. However, there is a lack of multi-dimensional analysis of association relationships, in terms of quantitative research, neglecting the effect of expert opinion on evaluation results, and often using fuzzy clustering, the accuracy of its calculation results is affected by artificially set thresholds and is not objective enough. Therefore, this paper proposes a service modularity design method based on multidimensional fuzzy association relationship analysis and solving the optimal module partition scheme.

2 MODELING THE RELATIONSHIP BETWEEN SERVICE UNITS

The smallest unit studied in this paper is the service unit. It has independently complete functions, including the operation of accomplishing active tasks. Basis of module division.

2.1 Linguistic Scale of Association Mode and Relationship Strength

Set up service unit collection $S = \{s_1, s_2, s_3 \dots s_n\}$,

s_i and s_j are two elements in the S . According to reference [15], the relationship between s_i and s_j can be divided into: independent, coupled and dependent, as shown in Tab.1.

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Table1. ASSOCIATION MEEHOD OF SERVICE UNIT

Relation mode	Relation intensity	Illustration
Parallel dependency	S_i is the running condition of S_j , which can be subdivided into parallel dependency and serial dependency according to the execution state of running time
Serial dependency	S_i is the running condition of S_j , which can be subdivided into parallel dependency and serial dependency according to the execution state of running time
Coupling	S_i and S_j are mutually operating conditions
Independent	S_i and S_j can run without the execution of the other party

In this paper, six different semantic scales are established, as shown in Tab.2.

Table2. LANGUAGE VALUES AND CORRESPONDING TRIGONOMETRIC FUZZY NUMBERS

Relation mode	Language scale of relation mode	Triangular fuzzy number
independent	S_i is not associated with S_j	(0,0,0)
Parallel dependency	Weak correlation between S_i and S_j	(0,0.1,0.3)
coupling	The relationship between S_i and S_j is general	(0.2,0.3,0.4)
independent	The relationship between S_i and S_j is strong	(0.4,0.5,0.6)

2.2 Ruantification of Service Unit Relationship

(1) Representation of service unit association matrix

The relationship between service units is a binary relationship, which can be expressed as:

$$R_b = \{(s_i, s_j) \mid s_i, s_j \in S, s_i R s_j, i, j = 1, 2, 3 \dots n\}$$

The triangular fuzzy language evaluation information given by evaluator p ($p \in [1, k]$) constitutes. The

evaluation matrix: $\tilde{R}_{ij}^p = (\tilde{\gamma}_{ij}^p)_{n \times n}$:

$$\tilde{R}_{ij}^p = \begin{pmatrix} s_1 & \tilde{\gamma}_{11}^p & \dots & \tilde{\gamma}_{1n}^p \\ \vdots & \vdots & \ddots & \vdots \\ s_n & \tilde{\gamma}_{n1}^p & \dots & \tilde{\gamma}_{nn}^p \end{pmatrix} \quad (1)$$

$\tilde{\gamma}_{ij}^p$ is the evaluation value of evaluator P for the correlation between service units S_i and S_j . It is represented by trigonometric fuzzy language $\tilde{\gamma}_{ij}^p = (\tilde{\gamma}_{ij}^{lp}, \tilde{\gamma}_{ij}^{mp}, \tilde{\gamma}_{ij}^{up})$, $\gamma_{ij}^{lp}, \gamma_{ij}^{mp}, \gamma_{ij}^{up}$ represents the lower limit, the most likely value and the upper limit of the value of the degree of the binary. Association of the service unit given by the evaluator. The algorithm of triangular fuzzy number is:

$$\tilde{a} \pm \tilde{b} = (\tilde{a}^l, \tilde{a}^m, \tilde{a}^u) \pm (\tilde{b}^l, \tilde{b}^m, \tilde{b}^u) = (\tilde{a}^l \pm \tilde{b}^l, \tilde{a}^m \pm \tilde{b}^m, \tilde{a}^u \pm \tilde{b}^u) \quad (2)$$

$$\lambda \tilde{a} = (\lambda a^l, \lambda a^m, \lambda a^u) \quad (3)$$

(2) Consistency of expert opinions and weight of experts

Based on the evaluation information of each expert, the mean value of triangular fuzzy number of the strength of the relationship between service units is obtained

$$\bar{\gamma}_{ij} = \frac{1}{k} \sum_{p=1}^k \tilde{\gamma}_{ij}^p \quad (4)$$

$1 - d(\tilde{a}_1, \tilde{a}_2)$ represents the similarity between two triangular fuzzy numbers. The larger the value is, the more consistent the two triangular fuzzy numbers are. The distance between two triangular fuzzy numbers can be measured by Euclidean distance:

$$d(\tilde{a}_1, \tilde{a}_2) = \sqrt{\left[(\tilde{a}_1^l - \tilde{a}_2^l)^2 + (\tilde{a}_1^m - \tilde{a}_2^m)^2 + (\tilde{a}_1^u - \tilde{a}_2^u)^2 \right]} / 3 \quad (5)$$

Average consistency of evaluation opinions of an expert D_{ij}^p :

$$D_{ij}^p = 1 - d(\tilde{\gamma}_{ij}^p, \bar{\gamma}_{ij}) \quad (6)$$

The individual weight of expert P can be normalized by (7):

$$\omega_{ij}^p = \frac{D_{ij}^p}{\sum_{p=1}^k D_{ij}^p} \quad (7)$$

(3) Service unit Association calculation

The triangular fuzzy number of the association relationship is calculated according to the expert weight.

$$\tilde{\gamma}_{ij} = \sum_{p=1}^k \tilde{\gamma}_{ij}^p \times \omega_{ij}^p \quad (8)$$

The average area method was used to make the image clear.

$$\gamma_{ij} = \frac{\gamma_{ij}^l + 2\gamma_{ij}^m + \gamma_{ij}^u}{4} \quad (9)$$

3 DIVISION OF SERVICE MODULES

3.1 Construction of Objective Function

According to the literature [15] [16] in this paper, modularity degree is used to evaluate the module division results.

$$Q = \sum_{i=1}^n (e_{ii} - a_i^2) \quad (10)$$

Row (or column) $a_i = \sum_{j=1}^m e_{ij}$ Denotes the

number of edges connected to the vertex [15]. Edges are between vertices, expressed as $e_{ij} = a_i \cdot a_j$. The

optimal module partition scheme should have the maximum value of modularity [15].

Suppose there are n attributes. Firstly, the modularity of each attribute is calculated Q_m ($m=1, \dots, n$),

weight μ_m , and $\sum_{m=1}^n \mu_m = 1$. Calculation of integrated modularity Q_{total} .

$$Q_{total} = \sum_{m=1}^n \mu_m Q_m \quad (11)$$

Targeting comprehensive modularity.

$$F(Q) = \max(Q_{total}) \quad (12)$$

3.2 Others

This paper uses integer coding, and gene values for each individual in the initial population are generated by uniformly distributed random numbers. Chromosomes were selected by the disk selection method using single point crossover with pc set to [0.25, 0.75], pm was set at [0.01, 0.2]. The number of iterations was set to 100-5000 times.

4 CASE ANALYSIS

4.1 Identification Of Specialized Service Units Of Coal Production Enterprises

Based on the principle of technology behavior, combined with field investigation in coal production enterprises, this paper forms a list of service units as in Tab.3.

Table3. LIST OF SPECIALIZED SERVICE UNITS

NO	Service unit	NO	Service unit
1	Mine design	2	Environmental protection engineering
3	Administrative engineering	4	Hoisting engineering
5	Power-supply engineering	6	Ventilation engineering
7	Auxiliary engineering	8	Mining
9	Drivage	10	Supporting and installation Of equipment
11	Lifting system	12	Ventilation and drainage
13	Power supply	14	Moving upside down
15	Coal Preparation	16	Provisioning
17	Coal transportation	18	Sales
19	Equipment maintenance	20	Equipment leasing
21	Mine constructiontechnical consultation	22	Technical consultation
23	Training		

4.2 Relationship Measurement of Professional Service Unit

Based on [2] and [17-19], this paper reviews the relationship between service units in three dimensions, safety, function and economy. Space is limited, only some

of the results of this review are truncated, as summarized in Table 4.

Table4. SERVICE UNITS SECURITY RELATIONSHIP EVALUATIO

		S_{88}	S_{89}		S_{23}
	P_1	...	(0.8,0.9,1)	...	(0,0,0)
	P_2	...	(0.8,0.9,1)	...	(0,0,0)
	P_3	...	(0.8,0.9,1)	...	(0,0,0)
	P_4	...	(0.8,0.9,1)	...	(0,0,0)
	P_5	...	(0.6,0.7,0.8)	...	(0,0,0)
D_{ij}^p	p_1	...	...	...	1
	p_2	...	...	...	1
	p_3	...	...	...	1
	p_4	...	...	...	1
	p_5	...	...	...	1
ω_{ij}^p	p_1	...	0.2	...	0.2
	p_2	...	0.2	...	0.2
	p_3	...	0.2	...	0.2
	p_4	...	0.2	...	0.2
	p_5	...	0.2	...	0.2
	$\tilde{\gamma}_{ij}$	...	(0.76,0.86,0.96)	...	(0,0,0)
	γ_{ij}	...	0.864	...	0

The security association matrix of service unit is obtained by calculation $R_{ij}^s = \left(\gamma_{ij}^s \right)_{23 \times 23}$

[illegible]

Similarly, we can calculate the economic relation matrix $R_{ij}^e = (\gamma_{ij}^e)_{23 \times 23}$ 、function relation matrix

$$R_{ij}^f = \left(\gamma_{ij}^f \right)_{23 \times 23} \quad (\text{get it from } 463906442@qq.com) .$$

4.3 Division Scheme Solution and Result Analysis of Coal Specialized Service Module

In this paper, the parameters of the GA were set as follows: $n = 60$, $pc = 0.45$, $pm = 0.01$. Calculations were performed using MATLAB 2016a version. The results showed that it could be divided into 14 modules, as shown in Table 5.

Table5. SERVICE UNITS SECURITY RELATIONSHIP EVALUATION

Modules	Service unit	Modules	Service unit
1	Technical consultation	2	Coal Preparation
3	Sales	4	Environmental protection engineering
5	Administrative engineering	6	Equipment leasing
7	Provisioning	8	Mine construction technical consultation
9	Equipment maintenance	10	Auxiliary engineering
11	Training	12	Coal transportation
13	Mining、Drivage、Transportation and hoisting、Ventilation and drainage、Power supply、Supporting and installation of equipment 、moving upside down		
14	Mine design、Ventilation engineering、Power supply engineering、Administrative engineering		

5 CONCLUSION

This paper presents the division method of engineering specialized service module and practices in combination with coal production enterprises. In cases where the expert weights were unknown, a triangular fuzzy number method was adopted to evaluate the association relationship and calculate the expert weights. And genetic algorithm is employed to calculate the optimal service module partitioning scheme. The research results of this paper provide the foundation for the development of the professional division of labour and professional service industrialization of coal enterprises.

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