A Research on Supplier Selection Method for CALS

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Abstract. Based on the characteristics of supplier selection for CALS(Continuous Acquisition and Life-cycle Support), that companies with CALS have many suppliers and suppliers are always strategic suppliers, supplier selection process is divided into two phases: pre-selection and making decision. At supplier pre-selection stage, polychromatic sets theory from Russia is introduced as the solution scheme. According to the properties of suppliers themselves and pre-selection evaluating indicators, pre-selection contour Boolean matrix is created automatically. Based on it, supplier pre-selection model is set up. At decision-making stage, popular fuzzy analytic hierarchy process is adopted to set up supplier selection model. On the basis of evaluating indicators of the decision-making stage, the best supplier can be chosen quickly. In the end, an application example of motor company is given to testify the feasibility and effectiveness of the proposed method.

Keywords: *CALS, Supplier selection, Pre-selection, Polychromatic sets, Fuzzy analytic hierarchy process*

1. INTRODUCTION

Since CALS was proposed in 1985 by the American Department of Defense, its application has been common day by day, and it has become the strategy of the enterprise's full-scale information development. Now many countries and organizations, such as America, Japan, English, Singapore and Taiwan area, are studying and popularizing CALS actively. But in our country, CALS is only on theoretic discussion stage, and concrete research job just begins.

As an important step for CALS purchasing, supplier selection is also one of important decision-making questions for enterprise. Supplier influences the product quality, delivery date and competition of enterprise. Especially when the enterprise places its main energy more and more on its core business, contracting non-core business with the supplier, supplier selection appears more importantly.

2. CHARACTERS OF SUPPLIER SELECTION FOR CALS

Selection of contractors, sub-contractors and suppliers can all be considered as supplier selection. Characters of supplier selection for CALS are as follows:

(1) Meeting product lifecycle support

Since CALS is defined as continuous acquisition and lifecycle support, supplier selection for CALS must meet the demand of product lifecycle support. That is to say product information from birth to death must be followed and queried, for example, we can inquire the part's supplier even at its maintenance stage. To achieve the purpose, the information between company and supplier, supplier and supplier must be integrated. Only in this way, information sharing is reached in deed and the demand of lifecycle support is met.

(2) Supplier is strategic cooperative comate

Companies in CALS generally purchase material and machine parts in other companies, suppliers are very important for this kind of company, and belong to strategic suppliers. So supplier selection method and assessment index must accord with strategic supplier selection.

(3) Supplier pre-selection occupies an important position

In order to cooperate with best supplier, company searches suppliers in the whole world; therefore, many suppliers can be chosen. If not pre-selecting but making decision directly on suppliers, decision-making will face many difficulties. Now, companies always pre-select suppliers artificially by some assessment indexes. But it is inefficient and inaccurate by this artificial way.

Up to now, research on supplier pre-selection is little. Literature [1] adopts fuzzy cluster analysis as pre-selection method, and uses analytic hierarchy process to count the weights of evaluating indicators. The defect of this method is complicated model and huge computational complexity, especially when there are many pre-selection evaluating indicators in company. Literature [2] pre-selects suppliers by fuzzy search method, namely uses information retrieval method to pre-select potential suppliers. This method maybe lead too many suppliers satisfied the conditions, thereby gives many jobs to decision-making stage. Literature [3] considers the main jobs of supplier pre-selection are the definition of need, review purchase requisition and setup of evaluating indicators which is subjective; therefore the pre-selection stage should be left to humans rather than machines. Although the definition of need, review purchase requisition and setup of evaluating indicators must be considered in pre-selection stage, if company has many suppliers, a good pre-selection method is also required. So in this paper, supplier selection process is divided into two phases: Pre-selection and making decision. At supplier pre-selection stage, polychromatic sets theory from Russia good at simulation on hierarchical structure is introduced as the solution scheme. At decision-making stage, popular fuzzy analytic hierarchy process is adopted to set up supplier selection model.

3. SUPPLIER PRE-SELECTION BASED ON POLYCHROMATIC SETS CONTOUR BOOLEAN MATRIX

3.1 Advantages of Polychromatic Sets

Polychromatic sets theory, which is a new system theory and tool on dealing with information, is put forward by Russian Professor V. V. Pavlov [4-5]. It uses the formally same mathematics model to emulate different objects, which makes

emulating system more flexible. Moreover, it fits to solve the problems with hierarchical structure, and supplier selection is just this kind of problem. Added to this, polychromatic set has the advantage of algorithmic adaptability, even if supplier amount changes, supplier selection algorithm doesn't need to alter.

3.2 Polychromatic Sets Contour Boolean Matrix

For the conventional set B = $(b_1, b_2, \ldots, b_n)$, an element b_i ($i = 1, 2, \ldots, n$) is distinguished from other elements by its name only, and other properties of the element are not expressed in this expression. From literature [6-7], we can see in the theory of polychromatic sets, suppose $A = (a_1, a_2, \ldots, a_n)$ is an element set, an element a_i ($i = 1, 2, \ldots, n$) in A can be distinguished from other elements by not only its name but also other properties of the element. Suppose $F(A)=(F_1, F_2, \ldots, F_m)$ is the aggregation of properties. Contour Boolean matrix $[A \times F(A)]$ represents the relationship between an element a_i and F_j. In this Boolean expression, if a_i and F_j is related, then $a_{i(j)}=1$, otherwise $a_{i(j)}=0$, and F_j (A) = $(a_{1(j)}, a_{2(j)}, \ldots, a_{n(j)})$. The establishment of this contour Boolean matrix is according to the information or experience of real world. As for supplier pre-selection, contour Boolean matrix is set up based on pre-selection indexes and suppliers' own properties.

$$\left\|C_{i(j)}\right\|_{A,F(A)} = [A \times F(A)] = \begin{bmatrix} a_{1(1)} & \cdots & a_{1(j)} & \cdots & a_{1(m)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{i(1)} & \cdots & a_{i(j)} & \cdots & a_{i(m)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n(1)} & \cdots & a_{n(j)} & \cdots & a_{n(m)} \end{bmatrix} \begin{matrix} a_1 \\ \cdots \\ a_i \\ \cdots \\ a_n \end{matrix} \qquad (1)$$

$$\begin{matrix} F_1 & \cdots & F_j & \cdots & F_m \end{matrix}$$

3.3 Pre-selection Model based on Contour Matrix

As for supplier pre-selection, most companies establish the pre-selection indexes according to their actual situations. We can pre-select suppliers in accordance with pre-selection indexes and suppliers' own properties. The variables and steps of this model are as follows:

(1) Variables of Pre-selection

We suppose $\{ a_1, a_2, \ldots, a_m \}$ is the aggregation of suppliers; $\{ O_1, O_2, \ldots, O_n \}$ is the pre-selection indexes sort and O_{ij} is No. j property of pre-selection index O_i ($i=1,2,\ldots n$, $j=1,2,\ldots m_i$); $\{ S_i \}$ represents the aggregation of pre-selection indexes chosen and $S_i \in \{O_{i1}, O_{i2}, \ldots O_i m_i\}$ ($i=1,2,\ldots n$).

(2) Steps of Pre-selection

1) The aggregation of suppliers is regarded as *A*, and Aggregation of pre-selection indexes *{O_{ij}}* as *F(A)*.

2) Based on suppliers information and formula (1), setting up contour matrix *[A × F(A)]* between suppliers *{ a_1, a_2, ..., a_m }* and pre-selection indexes *{O_{ij}}*.

3) Suppose i equals 1, according to contour matrix *[A ×F(A)]* , we can obtain the value aggregation of $Fs_1(A)$.

4) Repeating step 3) until i=n. Then $Fs_1(A)$, $Fs_2(A)$ ...... $Fs_n(A)$ is obtained.

5) Using *$F_P(A)$* to express the result of $Fs_1(A) \cap Fs_2(A) \cap ... \cap Fs_n(A)$.

6) If the element *$F_P(a_i)$* in *$F_P(A)$* equals 1, supplier a_i is the supplier meets the requirements.

7) End.

4.   SUPPLIER DECISION-MAKING BASED ON FUZZY ANALYTIC HIERARCHY PROCESS

At decision-making stage, analytic hierarchy process is often adopted as evaluating method. But it has some defects, such as difficulty in consistency checkout. So we take fuzzy analytic hierarchy process as supplier decision-making method.

Using this method, there are six steps:

Step 1 Setting up hierarchical structure

We can create evaluating index hierarchical structure by topmost level, some medium levels and lowest level.

Step 2 Constructing fuzzy judgment matrix

Fuzzy judgment matrix *F* expresses the comparison of importance on elements in the same level relative to an element of next higher layer. According to importance metric value comparing a_i to a_j, fuzzy judgment matrix as follows can be obtained:

$$ F = \begin{pmatrix} a_{11} & a_{12} & .... & a_{1n} \\ a_{21} & a_{22} & .... & a_{2n} \\ ...... & ...... & ..... & .... \\ a_{n1} & a_{n2} & .... & a_{nn} \end{pmatrix} \tag{2} $$

Properties of matrix *F* are: (1) *$0<a_{ij}<1$*，and the value must be 0.1, 0.2, …, 0.9; (2) a_{ii}=0.5, i=1,2, …, n; (3) a_{ij}=*1-a_{ji}*, i, j=1, 2, …, n.

Step 3 Checkouting the consistency

Consistency standard is D-value of corresponding elements of rows is constant.

Step 4 Calculating monolayer weight

Monolayer weight is the importance order of elements relative to the element of next higher layer. From literature [8], calculating formula of monolayer weight α_i is as formula (3)：

$$\alpha_i = \frac{1}{n} - \frac{1}{n-1} + \frac{2}{n(n-1)} \sum_{k=1}^{n} a_{ik} \tag{3}$$

Step 5 Calculating composing weight

The weight of the element of lowest level relative to topmost level is the composing weight. Recurrence method uses commonly. Suppose there are n_k elements on kth level, and the weight vector aggregation in relation to topmost level is W_k^1. Based on recursion rule, the composing weight of the element on lowest level is as formula (4):

$$W_n^1 = W_n^{n-1} \cdot W_{n-1}^{n-2} \cdots W_3^2 \cdot W_2^1 = \prod_{i=2}^{n} W_i^{i-1} \tag{4}$$

Step 6 Assessing and computing the score of suppliers

Generally speaking, assessing person marks the indexes of lowest level. If score aggregation of sub indexes is $X = (x_1, x_2, \ldots, x_n)^T$, and their composing weight aggregation is $W = (w_1, w_2, \ldots, w_n)$, the formula of supplier's score is as formula (5). Supplier who gets the topmost score is the best supplier.

$$S = W^T X = \sum_{i=1}^{n} w_i x_i \tag{5}$$

5. EXAMPLES

Now, we take a motor company as our example. It has many suppliers, and supplier pre-selection and decision-making system has set up.

Step 1 Supplier pre-selection

Suppose pre-selection indexes of the company are as follows:

(1) Ownership: state enterprise (We consider it as F_1) and private enterprise (namely F_2)

(2) Company Address: Guangdong province (namely F_3) and other area (namely F_4)

(3) Total Assets: below 5 millions (namely F_5) and above 5 millions (namely F_6)

Suppose the company has four suppliers, and the properties of suppliers are as follows:

Supplier A (We consider it as a_1 of A): state enterprise; Guangdong Province; 3.8 million;

Supplier B (namely a_2): state enterprise; Guangdong Province; 8 million;

Supplier C (namely a_3): private enterprise; Shandong Province; 1 million;

Supplier D (namely a_4): state enterprise; Guangdong Province; 4.5 million;

Now, the pre-selection indexes chosen are: State enterprise, Guangdong province, Total assets below 5 million.

According to step 1) 2) of pre-selection, contour Boolean matrix as Table 1. can be obtained:

Table 1. **A Contour Matrix**

Properties / Supplier	F_1	F_2	F_3	F_4	F_5	F_6
a_1	1	0	1	0	1	0
a_2	1	0	1	0	0	1
a_3	0	1	0	1	1	0
a_4	1	0	1	0	1	0

Now, the pre-selection indexes chosen are State enterprise, Guangdong province and Total assets below 5 million, namely $\{S_i\}=(F_1, F_3, F_5)$. From above contour Boolean matrix, we can see $F_1(A)=(1,1,0,1)$, $F_3(A)=(1,1,0,1)$, $F_5(A)=(1,0,1,1)$, then $F_P(A)= F_1(A) \cap F_3(A) \cap F_5(A)=(1,0,0,1)$. Because $F_P(a_1)=1$ and $F_P(a_4)=1$, supplier A and Supplier D is the suppliers meet pre-selection indexes chosen.

Step 2 Choose the best supplier based on fuzzy analytic hierarchy process

In step 1, we have pre-selected supplier A and Supplier D. Suppose evaluating indexes and the hierarchical structure of the motor company are as Figure 1:
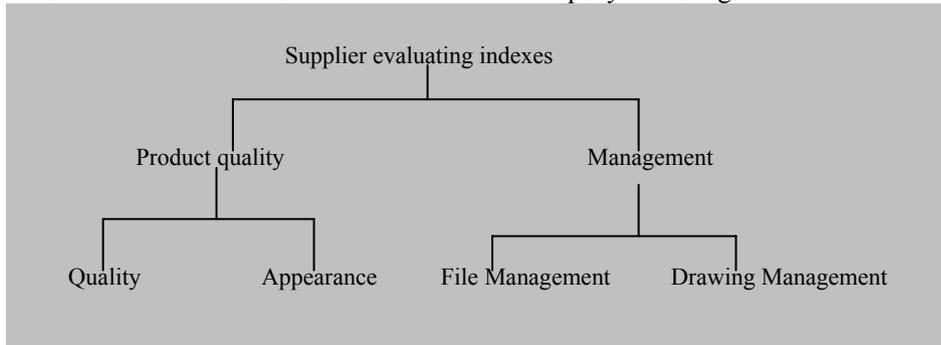

Figure 1. Supplier Evaluating Indexes

According to index importance degree and formula (3), monolayer weight of all indexes can be obtained. Suppose it is as Figure 2. Using formula (4), we can get composing weight of indexes on lowest level as Table 2. From Table 2, we can see composing weight of quality is 0.42(0.6×0.7), composing weight of appearance is 0.28, composing weight of file management is 0.15, composing weight of drawing management is 0.15.
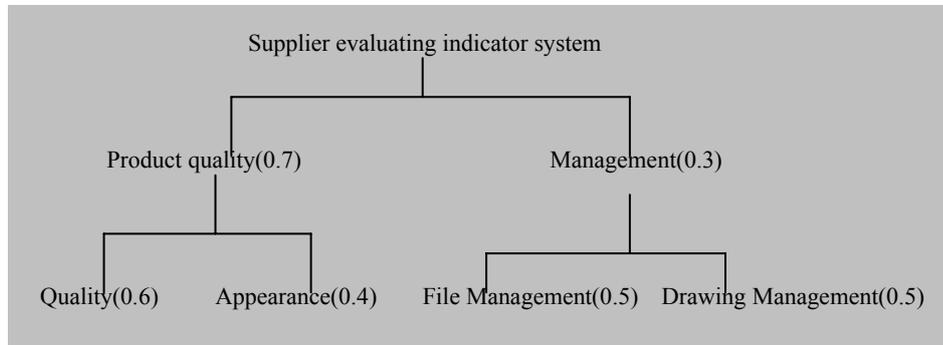
Figure 2. Monolayer Weight of all Indexes

Table 2. Composing Weight of Indexes on Lowest Level

	Quality	Appearance	File Management	Drawing Management
composing weight	0.42	0.28	0.15	0.15

Managers of the company mark the indexes of lowest level according to suppliers' behavior. Now we suppose that the lowest level indexes score are as Table 3.

Table 3. The Score of Lowest Level Indexes of Supplier A and D

	Quality	Appearance	File Management	Drawing Management
Supplier A	90	80	88	86
Supplier D	85	90	89	90

Based on composing weight of Table 2 and the score of Table 3, using formula (5), the score of supplier A and D can be obtained. The total score of supplier A is 86.3 (90×0.42+80×0.28+88×0.15+86×0.15) and the total score of supplier D is 87.75 (85×0.42+90×0.28+89×0.15+90×0.15), so supplier D is the best supplier.

6. CONCLUSIONS

In this paper, we bring forward supplier selection method for CALS, and use polychromatic sets contour Boolean matrix into supplier pre-selection, then use fuzzy analytic hierarchy process at decision-making stage. Using this method can choose suppliers accurately and quickly, thus bring great economic benefit for enterprise.

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