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Shi-jing Wang

Hua-an Hu

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Shi-jing Wang[1], Hua-an Hu[2]
Procurement Department, Wuhan Institute of Economics, Luojiadun 122,
Wuhan, 430035, China
[1]E-Mail: wsj_1979@yahoo.com.cn; Tel. 86-013971071036
[2]E-Mail: huhuaan@hotmail.com; Tel. 86-02783447650

Abstract: The data mining approach of rough set theory is being adopted to study the multi-index question of supplier's evaluation and determination in order to reveal the determining rules hidden in the historical evaluative data. After introducing some basic notions of rough set theory, this paper uses a sample to tell the steps of the deducing process in detail, and figures out some satisfying rules of supplier's determination and weights of various attribute's indexes which have been compared to other methods after the calculation. All of these illustrate the method of rough set theory can be used in the area of supplier's selection and solve them with great efficiency.

Keywords: Decision Support, Group Systems

I. Introduction

The supplier's determination is the core of the whole acquisition system , and it can be considered as the most important step in the acquisition process. It has been a time-consuming question for each administrative sector to determine an appropriate supplier. Nowadays, various approaches are adopted to solve the problem of suppliers determination and decide on the quantity of the stocking goods from a selected supplier. The common methods include description、experience and optimization method etc. The descriptive and experimental methods describe the feature of the supplier or set up the weights of determination indexes to undertake the evaluation, the typical methodologies are the plus-weight element analysis method, layer-analysis method and so on[1][2]. As the weights of the determination indexes are set up on the basis of the determiner's experience, the evaluative result is somewhat subjective unavoidably. The optimization method is used to determine who is the supplier of paying the less, and suiting to the special requirement on the basis of the product quality and the consignment of time. Eventually, the factors such as linear, non-linear design, dynamic planning and objective planning are often involved, so the evaluative process is much more complicated. Further more, the determinative process may not be continuous and complete because the historical evaluative data of suppliers are not covered in the method. Rough set theory is a mathematic tool to deal with the incomplete and uncertain problems, to analyze and dispose efficiently the imperfect information, to uncover the hidden knowledge and reveal its potential rule based on the people's cognition of acquired data[3].

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The rest of this paper is organized as follows. Section 2 briefly describes the basic notions of rough set theory. Section 3 provides a case on suppliers' determination and tells the applications that rough set theory can be used in such problems. Concluding remarks and directions for further research are given in section 4.

II. Basic Notions Of Rough Set

II.1. Positive、Negative And Boundary Region

Let U be a non-empty finite set, called universe, and R be an equivalence relation. The pair K= (U, R) is referred to as knowledge base and conceptually, represents our knowledge about the universe. The equivalence relation represents a classification of the domain objects into disjoint classes of objects, which are indistinguishable in terms of available information about them. In other words, these classes represent the basic properties of the universe that can be expressed by the knowledge represented by the relation R, and so they are referred to as elementary categories.

Any subset $X \subseteq U$ of the universe will be called a concept in U. Some concepts can be exactly defined in the approximation space K, whereas other ones cannot be defined. A subset X is an exact set or definable in K, if X is the union of some elementary categories, otherwise, X is a rough set or un-definable. A rough set can be defined approximately by the employment of two exact sets, called lower and upper approximations. The lower approximation, denoted as R_(X), is the set of all elements of domain objects U, which can be certainty classified as elements of a concept X in the knowledge R. The upper approximation, denoted as R(X), is the set of elements of U that can be possibly classified as elements of X using knowledge R. According to these basic concepts, universe can be divided into three disjoints regions, called positive, negative and boundary regions and defined as follows:

$POS_R(X)=R\_(X)$ (1)

$NEG_R(X)= U-R(X)$ (2)

$BND_R (X)= R (X)- R\_(X)$ (3)

The positive region $POS_R(X)$ has the same interpretation as lower approximation. The negative region $NEG_R(X)$ is the collection of objects that can be determined without ambiguity, employing knowledge R, that they do not belong to the set X, that is, they belong to the complement of X. The boundary region $BND_R(X)$ is the un-decidable area of universe, i.e. none of the objects belonging to the borderline area can be classified with certainty into a set X or its complement (-X), at least using knowledge R.

II.2. Reduction、Core And Attribute's Significance

The rough set framework is especially suitable to the determination of attribute-value relationships in attribute-value systems. Information systems are formal models of attribute-value systems[4].

Rough set is defined as an information system as a pair S=(U,A), where U is a non-empty, finite set called the universe, and A is a none-empty, finite set of attributes. Also we can describe S in detail that it contains four subsets, S={U, A, V, f}, A contains two subsets C and D, that's mean $A=C\cup D$, where D is a distinguished attribute called the decision attribute, elements of set C, are referred to as condition attributes. V is the set of values of A, called the domain of A, and f is the function that can be defined as: $\forall a \in A, x \in U, f(x,a) \in V$ .We can call such information system a decision table, it represents a classification of the domain of interest. The decision attribute establishes a partition of the universe in disjoint classes. We are interested in identifying every class according to values of condition attributes.

An equivalence relation, called indiscernibility relation, is associated with every subset of attributes $B \subseteq A$. This relation is defined as:

$$IND(B) = \{(x,y) \in U \times U : \forall a \in B, a(x) = a(y)\} \quad (4)$$

During the application of rough set theory, we must emphasize two definitions: Reduction and Core. Reduction means deleting the redundant attributes and values of the decision table. In order to reduce the complexity and gain a better result, a parallel arithmetic should be used. So the definition of core is being put forward. Core consists of indispensability attributes, and it can be deduced by the significance of attributes. Suppose r is a equivalence relation of R,G and R are two sets, if POS(R-{r})(G)=POSR(G),then we say r can be reduced, or can not be reduced. If any element of R can not be reduced, then we call R is independent. Suppose $H \subseteq R$ and H is an independent set, if POSH（G）= POSR（G）,then H is the G reduction of R. The intersection of all relations that can not be eliminated in set R call the core of R, noted Core(R).

Suppose C,D are subsets of A, then the dependency of knowledge D to Knowledge C can be described as: t=γ(C,D)= Card (PosCD)/ Card(U).Card is the radix of set A, and PosCD is the positive region of knowledge D to C. At the foundation of dependence, the significance of an attribute can be described as the changes happening to the classification of the set after the attribute eliminated from the condition attributes. i.e.

$$Sig(C_i) = \frac{\gamma(C,D) - \gamma(C-\{C_i\}D)}{\gamma(C,D)} \quad (5)$$

In formula 5, i is the number of condition attribute, the significance of an attribute describes the effect which takes in the whole decision table and influences to the decision result.

In the rough set framework, the simplifying process of a decision table includes two fundamental tasks. On the one hand, reduction of attributes consists of eliminating redundant or irrelevant attributes, without losing any essential classification information. On the other hand, reduction of attribute values is related to the elimination of the maximum number of condition attribute values, maintaining the classificatory power. Thus, if we obtain a reduced table, it is known as the decision algorithm. Each row of the table represents a decision rule.

Perceived value is a difficult concept in that it is hard to define and measure (Zeithaml, 1988; McDougall and Levesque, 2000). Broadly defined, perceived value is the results or benefits customers receive in relation to the total costs. In other words, it is the difference between perceived benefits and costs (McDougall and Levesque, 2000).

According to Zeithaml (1988), customer-perceived value is the consumer's overall assessment of the utility of a product based on a perception of what is received and what is given. This can vary between people but also from occasion to occasion for the same person (Zeithaml, 1988). Caruana et al. (2000) state; "value is seen to be more individualistic and personal than quality and involves both a give and get component" (p. 1339). Ravald and Grönroos (1996) suggest that customer-perceived value has to be related to different personal values, needs and preferences. In addition, they state, that the financial resources of the consumer must be taken into account.

III. A Case On Supplier's Determination

III.1. Initial Data of Suppliers

This section demonstrates the application of rough set theory on supplier's determination through a case. The integrated indexes of evaluating suppliers during the actual procurement activities are: Product Quality(PQ)、Purchase Cost(PC) 、 Service Quality(SQ) 、 Fulfillment Of Contract(FOC) etc[5]. Before the step of knowledge discovering through rough set theory from the suppliers' history operation data, we must organize the data in a proper order.

Suppose we have the history data table (Table1) of ten suppliers, in order to reduce the complexity of our exemplification in the case, we classify the four indexes that influence the determination of suppliers into two conditions:

Table1. Suppliers' History Date Table

NO	PQ	PC	SQ	FOC	SL
1	Good	High	Good	Bad	Medium
2	Good	Low	Good	Bad	Important
3	Bad	Low	Bad	Bad	Subordinate
4	Bad	High	Good	Bad	Subordinate
5	Bad	Low	Good	Bad	Medium
6	Good	Low	Good	Good	Important
7	Good	Low	Bad	Good	Important
8	Good	High	Bad	Bad	Subordinate
9	Good	High	Good	Good	Subordinate
10	Bad	Low	Good	Good	Medium

Table2. Suppliers' History Date Table after Dispersing

NO	a	b	c	d	e
1	1	0	1	0	1
2	1	1	1	0	2
3	0	1	0	0	0
4	0	0	1	0	0
5	0	1	1	0	1
6	1	1	1	1	2
7	1	1	0	1	2
8	1	0	0	0	0
9	0	0	1	1	0
10	0	1	1	1	1

Good、Bad or High、Low and Suppliers Level(SL) into: important 、 medium and subordinate. Universe U={1,2,3,4,5,6,7,8,9,10}, Condition attribute set C= ｛Product Quality, Purchase Cost, Service Quality, Fulfillment Of Contract｝=｛PQ, PC，SQ，FOC｝, Decision attribute set D={ Suppliers Level }={SL}.

Here, we use number 1 represents Good condition or low cost, while 0 represents Bad condition or high cost in the value of condition attributes. In decision attributes value, 2 represents the supplier is Important、1 represents Medium and 0 represents Subordinate. After dispersing the data, we use a、b、c and d representing the condition attribute PQ, PC，SQ and FOC, while e representing the decision attribute SL. After these works, we get Table2.

III.2. Application on Rules mining

Form Table1, we know that each row represents a supplier while a column represents an evaluating index to the supplier. These indexes are called attributes in the table and classified into condition attributes and decision attributes. In order to form the simplest decision one, we can reduce the table through the reduction theory of rough set. Then, the decision rules about the selection of suppliers can be deduced from the simplest table. All the rules can guide the decision makers to choose a good supplier from competition ones.

The detailed steps of mining rules are as followings:

(1)Describe the attribute values of history data in a standard mode and reduce the redundant attributes.

(2)Make reduction to the value of decision rule and make out the core of each rule.

(3)Select the effective decision rule to form the reduced decision table.

Now, we use the method of attribute's significance to reduce the redundant attributes of condition table in step(1) above.

U/Ind(a)={(1,2,6,7,8)(3,4,5,9,10)},
U/Ind(b)={(1 ,4,8,9)(2,3,5,6,7,10)},
U/Ind(c)={(1,2,4,5,6,9,10)(3, 7,8)},
U/Ind(d)={(1,2,3,4,5,8)(6,7,9,10)},
U/Ind(a,b,c,d)={(1)(2)(3)(4)(5)(6)(7)(8)(9)(10)},
U/Ind(e)={(1,5,10)(2,6,7)(3,4,8,9)},
PosC(D)={1,2,3,4,5,6,7,8,9,10},
γC(D)=| PosC(D)|/|U|=10/10=1.
After reducing attribute a:
U/Ind(b,c,d)={(1)(2,6)(3)(4,9)(5,10)(7)(8)},
PosC-(a)(D)= ｛3,7,8,9｝,
This time, the dependence of attribute a is:
γC-(a)(D)=4/10=0.4.

Following the same principle above, the dependence of other attributes are:

γC-(b)(D)= 4/10=0.4,

γC-(c)(D)= 6/10=0.6,

γC-(d)(D)= 10/10=1.

From the attributes' dependence we know that the classification ability does not change after deleting attribute d, so attribute d is redundant in this decision table. Then deleting attribute d and unite line 1 and 2、line 3 and 8、7 and 10,we get a new decision table Table3.

Table3. Decision Table after Attribute Redundant

NO	a	b	c	e
1	1	0	1	1
2,6	1	1	1	2
3	0	1	0	0
4,9	0	0	1	0
5,10	0	1	1	1
7	1	1	0	2
8	1	0	0	0

The second step of the deduce process is valve reduction to table 3 and achievement of the cores of all rules. First, let us look at rule 1 of Tab.3:

Set F= {[1]a, [1]b, [1]c}

={(1,2,6,7,8),(1,4,8,9), (1,2,4,5,6,9,10)}.

Decision Category [1]e= {1,5,10} .

Here, a(1)=1,b(1)=0,c(1)=1,e(1)=1.

[1]a∩[1]b= {1,8} , $\{1,8\} \not\subset [1]e$;

[1]a∩[1]c= {1,2,6} ,$\{1,2,6\} \not\subset [1]e$;

[1]b∩[1]c= {1,4,9} ,$\{1,4,9\} \not\subset [1]e$.

So, we make out the core of decision rule 1, the core is: a(1)=1,b(1)=0,c(1)=1.

In the same method, we can get the cores of other decision rules:

Core of rule 2 and 6 is: a(2)=1,b(2)=1 ;

Core of rule 3 is: a(3)=0,c(3)=0;

Core of rule 4 and 9 is: b(4)=0,c(4)=1;

Core of rule 5 and 10 is: a(5)=0,b(5)=1, c(5)=1;

Core of rule 7 is: a(7)=1,b(7)=1;

Core of rule 8 is: b(8)=0,c(8)=0.

At last, we get the decision Table4 after the value reduction.

Table4. Decision Table after Value Reduction

NO	a	b	c	e
1	1	0	1	1
2,6	1	1	－	2
3	0	－	0	0
4,9	－	0	1	0
5,10	0	1	1	1
7	1	1	－	2
8	－	0	0	0

At last, we get the rules about suppliers' determination from Table4, these are:

(1)If supplier's product quality and service quality are good, though the cost of purchase is high, we can consider the supplier as a medium one during selection;

(2)If supplier's product quality is good and the cost is low, even we don't know the other indexes of the supplier, we can consider it as an important one;

(3)If the supplier's quality of product and service are bad, even we don't know the other indexes of the supplier, we can consider it as a subordinate one;

(4)Need not consider supplier's product quality, if the cost is high, though the service quality is good, we also consider it as a subordinate one;

(5)If the supplier's product quality is bad, while the cost and service are satisfying, we can consider it as a medium one during selection;

(6)Need not consider supplier's product quality, if the cost and service are not satisfying, then we can consider it as a subordinate one.

III.3. Application on Weights Ascertaining

Besides the rules we got in section3.2, we can also make out the weights of the evaluating indexes of these suppliers from the following steps.

(1)According to formula (5), make out all the significances Sig(Ci)(i=1,2, …… ,n)of every attributes in set C={C1,C2,……Cn}.

(2)Treat Sig(Ci) we got in step(1) with formula (6) and consider the result Pi as the objective weight of every condition attribute Ci.

$$Pi = Sig(Ci) \,/\, \sum_{i=1}^{n} Sig(Ci) \quad (6)$$

(3)Experts give the subjective weights Qi(i=1,2, …… ,n) of all attributes of set C={C1,C2,……Cn}and the subjective weights must fulfill the condition of $\sum_{i=1}^{n} Qi$ =1。

(4)Decision makers choose the proper experiential factor "a" and make out the integrated weights of attributes Ci based on formula (7).

I=αQ+(1－α)P (0≤α≤1) (7)

The first step is to make out the significances of all attributes, so the significances of suppliers' evaluating indexes a、b、c and d are:

Sig(a)=(PosC(D)－PosC-(a)(D))/ PosC(D)

=(1-0.4)/1=0.6,

Sig(b)=(PosC(D)－PosC-(b)(D))/ PosC(D)

=(1-0.4)/1=0.6,

Sig(c)=(PosC(D)－PosC-(c)(D))/ PosC(D)

=(1-0.6)/1=0.4,

Sig(d)=(PosC(D)－PosC-(d)(D))/ PosC(D)

=(1-1)/1=0.

According to formula (6), we can get:

Sig(a)'=0.6/(0.6+0.6+0.4+0)=0.375,

Sig(b)'=0.6/(0.6+0.6+0.4+0)=0.375,

Sig(c)'=0.4/(0.6+0.6+0.4+0)=0.25,

Sig(d)'=0/(0.6+0.6+0.4+0)=0.

After getting the objective weights Pi, we should combine them with experiential ones Qi. Here, suppose experts' weights of condition attributes C={a,b,c,d} are 0.3、0.4、0.2 and 0.1, decision makers attach much more importance to experts knowledge, so we choose the experiential factor to 0.8, then, according to formula (7), these integrated weights are:

I(a)=0.8×0.3+ (1-0.8) ×0.375=0.315,

I(b)=0.8×0.4+ (1-0.8) ×0.375=0.395,

I(c)=0.8×0.2+ (1-0.8) ×0.25=0.21,

I(d)=0.8×0.1+ (1-0.8) ×0=0.08.

From the Formulas above we know that the weights of ascertaining indexes a、b、c、d are:0.315、0.395、0.21、0.08. So, decision makers emphasize " Cost" most during their procurement, the followings are " Product Quality" 、"Service Quality" and "Fulfillment Of Contract ".

Table5. Attributes' weights from different methods

Attrib / Meth	a	b	c	d
Delphi	0.300	0.400	0.200	0.100
Statistic	0.375	0.375	0.250	0
Duality comparison	0.333	0.333	0.250	0.084
Rough Set	0.315	0.395	0.210	0.080

Table5 compares weights of attributes deduced from different methods. Comparing with other methods (Delphi or Statistic Method), we can see that the weights deduced from method rough set are much more accorded with the principle of ascertaining weights (the principle of combining subjective attitudes of decision makers with objective condition). This method considers both the suggestions of experts and the influences of objective statistics, avoiding the shortcoming of emphasizing particularly on one side in ancient methods. Decision makers can choose proper experiential factor to modify the proportion of subjective and subjective significances according to the background of application, this way, we can get more rational indexes' weights of evaluating suppliers.

IV. Conclusions

From the case have presented above, we can draw the conclusions about the application of rough set theory on the selection of suppliers as follows:

(1)From the sight of objectivity of supplier's determination, the application of rough set, can make out the weights of decision indexes objectively and reflect the weights of them, avoiding the condition of establishing the weights subjectively in other evaluating approaches. Further more, with the increase of experiment data, the rules we deduce will press close to the real world, so the approach of rough set can increase the objectivity and reality of the determination.

(2)From the sight of continuity of supplier's determination, the application of rough set, can take good advantage of the supplier's history evaluating data and analyze the experimental knowledge of former determination, finding the potential rules in supplier's selection. So, the classification model established through rough set has good continuity.

(3)From the sight of data mining, the decision table in rough set approach is similar with the relation table in relation database, so the application of rough set is good at practicability and reliability[6]. In addition, rough set approach can analyze suppliers' historical data in advance and delete the redundant attributes, so it improves the efficiency of determination and reduces the faulty rate.

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