Construction of Engineering Project Risk Intelligent Decision System

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Abstract. Effective risk management is the key to the success of a engineering project. This study first analyzes various potential risk factors in the process of project implementation due to the impact of uncertain events, then the rough set method is introduced and applied to the risk decision of engineering project, and the project risk intelligent decision system based on rough set is constructed. Finally, the feasibility and effectiveness of the system are verified through an example analysis.

1. Introduction
In the process of engineering project implementation, there will usually be various uncertainties, which will cause various potential risks to the realization of the project objective. Effective risk analysis and effective control of the main risk factors are key to the success of the engineering project, the selection process of the main risk factors is actually a process of risk decision-making[1-3]. This study attempts to introduce rough set theory in the process of engineering project risk decision, and to establish an intelligent decision system for engineering project risk based on rough set, which provides a new way for the engineering project risk management.

2. Rough set introduction

2.1. Rough set knowledge reduction
Rough set (RS) theory is a theoretical method to study uncertain knowledge and data, is also a more effective way to deal with complex systems, and currently it is widely used in data mining, decision analysis, etc. The main idea of rough set theory is to derive the decision or classification rules of the problem through knowledge reduction without changing the ability of classification. Knowledge reduction is one of the core contents of the rough set theory. The so-called knowledge reduction is to delete the unrelated or unimportant knowledge under the condition of keeping the knowledge base classification ability unchanged. The basic idea is as follows[4-5]:

Definition1: Let $K = (U, A)$ be the information system, where $U$ is the domain. $A$ is an equivalent family of relations on $U$, $a \in A$, if $U/\text{ind} (A) = U/\text{ind} (A-a)$, then $a$ is the redundant information in $A$.

Definition2: If $P \subseteq A$, given an arbitrary $r \in P$, which cannot be reduced, then the equivalent relation family $P$ is independent, otherwise it is related to $P$. 
Definition 3: \( S = (U, A) \) is an information system, \( P \subseteq A \) is the sub-family of \( A \), if \( \text{ind}(P) = \text{ind}(A) \) and \( P \) is independent, \( P \) is called a reduction of \( A \).

Definition 4: \( S = (U, A) \) is an information system, \( A \) is the equivalence relation of \( U \), the relation(attribute or knowledge) which cannot be reduced called the core attribute of \( A \), the integration made-up by all the core attributes of \( A \) is the core of \( A(\text{core}(A)) \). The detailed knowledge reduction algorithm refer to reference[1-2].

2.2. Decision table reduction
Given the decision system \( T = (U, A = C \cup D, V, f) \), Where \( U \) is the domain, \( C \) is the conditional attribute set, and \( D \) is the decision attribute set. \( V = \bigcup_{a \in A} Va \) is the range of property \( a \in A \), \( f = U \times A \rightarrow V \) is an information function, It assigns an information value to each attribute of each object. That is to take \( a \in A \), \( X \subseteq U \), \( f(X,a) \epsilon Va \). The intersection of all the equivalent relationships in \( C \) is \( \text{ind}(C) \), the intersection of all equivalent relationships in \( D \) is \( \text{ind}(D) \).

If \( P \subseteq C \), \( \text{POS}_{C-P}(D) = \text{POS}_{C}(D) \), it is called \( P \) can be reduced, otherwise, it is said that \( P \) is irreducible, if every equivalence relation \( r \) on \( P \) is irreducible, then \( P \) is independent of \( D \).

The equivalence relation \( P \subseteq C \) is the \( D \) reduction of \( C \), if and only if: ① \( P \) is the \( D \) independent subfamily of \( C \); ② \( \text{POS}_{r}(D) = \text{POS}_{C}(D) \). All the intersection of the equivalence relations is called the \( D \) core of \( C \), recorded as:
\[
\text{Core}_{D}(C) = \bigcap \text{REDD}(P)
\]

3. Construction of project risk decision system based on the rough set

3.1. Extraction of risk factors for engineering projects
Through the actual engineering project survey, and refer to the literatures[6-8], it is found that the potential risk factors affecting the realization of the project target are mainly include technical risk and non-technical risk. Technical risk is mainly design risk, construction risk and other risks. The non-technical risk is mainly natural and environmental risk, policy and economic risk, organization and coordination risk, contract risk, personnel risk, material risk, equipment risk, capital risk, etc. In order to facilitate the research, this study unified the risk of personnel, material and machine as management risk. Finally, the evaluation index system of engineering project risk factors is shown in Figure1.

3.2. Establishment of decision system
Rough sets are used to make project risk decision. First, a risk decision table is established, and the above nine risk factors are taken as the conditional attributes of the decision table. The attributes of each condition are: \( a(\text{design risk}), b(\text{construction risk}), c(\text{other technical risks}), d(\text{natural and environmental risks}), e(\text{policy and economic risk}), f(\text{organizational coordination risk}), g(\text{contract risk}), h(\text{management risk}), k(\text{capital risk}) \).
The values of each attribute are: 
\[ V_a = \{\text{high, low, no}\} = \{2,1,0\}, \quad V_b = \{\text{high, low, no}\} = \{2,1,0\}, \quad V_c = \{\text{yes, no}\} = \{1,0\}, \quad V_d = \{\text{yes, no}\} = \{1,0\}, \quad V_e = \{\text{stable, unstable}\} = \{1,0\}, \quad V_f = \{\text{good, bad}\} = \{0,1\}, \quad V_g = \{\text{high, low, no}\} = \{2,1,0\}, \quad V_h = \{\text{high, low, no}\} = \{2,1,0\}, \quad V_k = \{\text{yes, no}\} = \{1,0\}. \]

The decision attribute set D consists of risk transfer and risk control, 1 represents risk control and 2 represents risk transfer.

4. Application examples

On the basis of collecting and sorting the risk data of seventeen typical projects built by Nantong general contract company, Jiangsu Jianzhong group, Handan construction industrial group and Beijing construction industrial group, a decision information table of the engineering project risk is obtained in Table1.

| U | a | b | c | d | e | f | g | h | k | D |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 2 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 2 |
| 4 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| 5 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 2 |
| 6 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 2 |
| 7 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 8 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 9 | 1 | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 0 |

Table1 the decision information table

The corresponding minimal decision rules are obtained by using rough sets. The specific steps are as follows:

4.1. Consistency test
After testing, table1 is a consistency decision table, that is, there is no individual with the same decision attribute value but different conditional attribute values (that is, the decision rule).

4.2. Attribute reduction
Using the method of removing the condition attributes one by one, remove the column of a condition attribute from the decision table, and immediately check whether there will be new contradiction rules (condition attribute values are the same but the decision attribute values is different), and then determine whether the condition attribute can be reduced.

After removing a, there is no new inconsistency in the decision table, so a can be cancelled.

After removing b, there are incompatible rules:

Line2: \( a(1)c(0)e(1)d(1)f(1)g(1)h(2)k(0) \rightarrow D(1) \) and Line5: \( a(1)c(0)e(1)d(1)f(1)g(1)h(2)k(0) \rightarrow D(2) \).

The decision table is inconsistent, which means that after removing b, it can't make the correct decision according to a, c, d, e, f, g, h and k, so b cannot be removed.

Similarly, attribute d and f cannot be removed, while a, c, e, g, h, k can be removed, thus getting the core set of table 2 is: \( \text{Core}_D(C) = \{b,d,f\} \)

It is easy to verify that \( R_1 = \{a,b,d,f,h\} \) and \( R_2 = \{b,d,f,g,h\} \) are the reduction of attribute sets A. This paper takes R2 as the attribute reduction.

4.3. Attribute value reduction
4.3.1. A subsubsection. Take one-by-one rule and attribute-by-attribute value analysis, if each attribute value of each rule is removed, there will be no new inconsistencies in the table, then the attribute value can be reduced, the nuclear value table was obtained.

Table2 the nuclear value

| U | b | d | f | g | h | D |
|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 1 | 1 | 2 |
| 2 | 0 | 1 | 1 | 1 | 1 | 2 |
| 3 | 0 | 1 | 1 | 1 | 1 | 2 |
| 4 | 0 | 1 | 1 | 1 | 1 | 2 |
| 5 | 0 | 1 | 1 | 1 | 1 | 2 |
| 6 | 0 | 1 | 1 | 1 | 1 | 2 |
| 7 | 0 | 1 | 1 | 1 | 1 | 2 |
| 8 | 0 | 1 | 1 | 1 | 1 | 2 |

4.3.2. Seeking nuclear reduction. The first category: [1](D1)={1,2,4,7,8,10,11,15,17}

See rule 1: [1]b1={1,3,6,9,10,12,14,15,17} [1]d0={1,2,4,5,7,8,9,10,11,13,14} [1]f0={1,3,8,9,11,12,15,17} [1]g1={1,2,5,6,10,12,14,15,16} [1]h1={1,2,3,4,5,9,11,14} [1]d0∩[1]f0∩[1]g1={1}⊂D(1) [1]f0∩[1]g1∩[1]h1={1}⊂D(1) So d0∩f0∩g1→D(1) and f0∩g1∩h1→D(1).

Similarly, the nuclear reduction of other rules can be obtained, and the nuclear reduction of all the rules is shown in table3 (removing duplicate reduction).

Table3 value reduction table

| U | b | d | f | g | h | D |
|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 1 | 1 | 2 |
| 1' | 0 | 1 | 1 | 1 | 1 | 2 |
| 2 | 0 | 1 | 1 | 1 | 1 | 2 |
| 2' | 0 | 1 | 1 | 1 | 1 | 2 |
| 3 | 0 | 1 | 1 | 1 | 1 | 2 |
| 3' | 0 | 1 | 1 | 1 | 1 | 2 |
| 4 | 0 | 1 | 1 | 1 | 1 | 2 |
| 4' | 0 | 1 | 1 | 1 | 1 | 2 |
| 5 | 0 | 1 | 1 | 1 | 1 | 2 |
| 5' | 0 | 1 | 1 | 1 | 1 | 2 |

4.3.3. Determine the minimum decision algorithm. As can be seen from table4, rule8 has five treaty forms, rule4 and rule10 each has three treaty forms, and rule1, rule2 and rule3 each has two treaty forms. By selecting a reduction form for each rule, the minimum decision algorithm of decision table1 is obtained as follows:
4.3.4 Algorithm synthesis. \( f_0d_0g_1 \lor b_0h_1 \lor d_0g_0 \lor b_0f_0 \lor d_0h_0 \lor f_0h_0 \rightarrow D(1) \) and \( b_1d_1h_1 \lor b_2 \lor d_1f_1 \lor g_2 \lor h_2 \lor b_1f_1h_1 \rightarrow D(2) \).

The algorithm of the above two composite decision rules can be interpreted as:

- Situations where risk control should be considered include: no natural and environmental risks, low contract risk, good organization and coordination ability; no construction risk and low management risk; no natural and environmental risk, no contract risk; no construction risk, good organization and coordination ability; no natural and environmental risk, no management risk; good organization and coordination ability, and no management risk.

- Situations where risk transfer should be considered include: construction risk and management risk are low but exist at the same time, and there are natural and environmental risks; the construction risk is high; the contract risk is high; the management risk is high; have natural and environmental risks, and poor organization and coordination ability; construction risks and management risks are low but exist at the same time, and the organization and coordination ability is poor; the construction risk and management risk is not high but exist at the same time, and the organization and coordination ability is poor.

5. Conclusion

For engineering projects, risks and benefits are often proportional, and whether or not the correct risk decision can be carried out is related to the success or failure of the whole project development. The rough set is applied to the risk decision of engineering project, and the intelligent decision system of project risk is constructed, which can make the decision-making process more objective and reasonable. The analysis of example shows that, due to the error of the survey data, the analysis of result still has some shortcomings, but overall it is feasible and effective, and it can provide reliable decision support for the actual project risk management.

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