International Journal of u- and e- Service, Science and Technology
Vol.8, No.4 (2015), pp.383-394
http://dx.doi.org/10.14257/ijunesst.2015.8.4.35

Research on the Schedule Optimization Decision of Construction Project Based on Dominance-Based Rough Set

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Abstract

The schedule plan is the important basis of construction project. Because of the uncertain of the construction project environment, the existing schedule plan is very hard to meet the demand of the actual progress, and it is schedule plan optimization decision that is an important progress in the schedule management. The schedule plan optimization decision is a decision-making progress, in which the collaboration among the multi objectives, the constraint conditions, and the collaboration among the multi stakeholders should be considered. In this paper, the dominance-based rough set will be used to make decisions based on characteristics of the schedule plan optimization decision. Through the case study, the decision made by the dominance-based rough set can be understood easily, and improve the Scientific nature in the uncertain construction environment.

Keywords: *schedule, optimization decision, dominance-based rough set, construction project*

1. Introduction

The schedule plan is the important basis of construction project, and a good plan not only can improve the management level and the economic benefit, but also can reduce the risk and the economic loss. At present, with the increase of project uncertainty, the existing plans are very hard to meet the demand of actual progress, and it is a common phenomenon that management targets are out of control, for example, the project investment cost overruns, the schedule delays and so on [1]. It is schedule optimization decision that is an important progress in the schedule management. According to the collaboration among the multi objectives, the constraint conditions, the collaboration among the multi stakeholders, lots of scholars made an extensive research. Yuan and Cao established a schedule optimization model which included the time, the cost, the resource, and the optimization results could be achieved through the Genetic algorithm (GA) [2]. Geem researched the time-cost trade-off with the harmony search algorithm, and it can solve this combinatorial optimization problem [3]. Jun and El-Rayes established a new model and researched the trade-off between maximizing resource utilization efficiency and minimizing the duration of construction projects [4]. Cheng, Tran and Wu studied the optimization between the duration and the resource. They proposed a new FCDE (the Fuzzy Clustering Chaotic-based Differential Evolution) algorithm to solve complex optimization problems [5]. Ashuri and Tavakolan studied the time-cost-resource optimization (TCRO) problems based on the shuffled frog-leaping model. Through the model, the simultaneous optimization of the three important objective could be achieved in the plan [6]. Jaśkowski and Sobotka researched the duration optimization with evolutionary algorithms under deterministic conditions. In the optimized process, authors considered the actual condition (the renewable resources, the different technological and organizational variants) which could affect the results [7]. Ma *et al.* studied the impact of the uncertainty for the schedule plan. Based on the uncertainty, a robust optimization

ISSN: 2005-4246 IJUNESST

model was established, and the optimization results could be achieved through the GA [8]. Ma and Xu proposed a new multiple decision-maker model using bi-level programming, and the model was established in a fuzzy random environment. In order to obtain the optimized results, the global-local-neighbor particle swarm is proposed [9]. Liu and Wang researched the relationship between the multi-skilling and the duration, and they though that multi-skilled crews can be used to optimize project duration and improve work continuity/efficiency in a construction context [10]. Li and Yang studied the relationship between the human's behavior and adjust of schedule plan, and they established an optimization mathematical model for multi projects [11].

Researches about the schedule optimization decision in construction project were made from different perspectives, such as, the multi-objective, uncertainty, human and so on. But there is no research on the three perspectives simultaneously. In this paper, a decision-making method will be studied for the schedule optimization based on the dominance-based rough set.

2. Analysis of Characteristics and the Complex Process of the Schedule Optimization Decision

The decision-making process is complex, in which different phases can be divided, for example, the preparation phase, the making phase and the implementation phase; analyzing the decision environment, decomposing the decision problem, drafting the decision schemes, selecting the decision scheme, and evaluating the decision results. Through the analysis of the process, the decision-making can be summarized as decision-making information, decision making, decision schemes, as showed in the Figure 1. The information is the basis of the decision-making, and lots of elements should be considered.

Figure 1. The Process of the Decision-Making

2.1 Analysis of Characteristics

According to the decision-making process, the schedule optimization decision has its own characteristics in each phase, and the content is as follows:

(1) The decision information is incomplete.

When making decisions, decision-makers should obtain the relevant information as much as possible. Because of the information cannot be obtain, the information is omitted, the information attributes are unavailability, the cost of the information acquisition is too expensive, as well as the requirement of the important and real-time information, the scarcity of information is widespread. For example, the information mainly comes from the schedule plan, the record of the actual progress, and the deviation analysis in the decision-making process for schedule optimization or control. Because of the recording process description for the actual progress is not clear, the information acquisition is difficult, the information is not accurate and so on, the actual schedule information is incomplete. On the other hand, some information is confidential among the multi stakeholders, and it cannot be share. Therefore, the schedule optimization decision system is an incomplete information system.

(2) Multi-stakeholder participates in the decision-making process.

Multi-stakeholders (owners, suppliers, contractors, supervision unit, design unit, etc.) participate in the construction project, and they also participate in the schedule optimization decision. In the decision-making process, they share information and make decision together. In addition, because of the different roles, and the relationship between multi-stakeholders, the contractors take an important role in the process. Firstly, contractors meet the requirements of the owner; secondly, they consider the supplier's ability which meets the requirements of the construction schedule; thirdly, they should pay attention to advises of the supervision unit and design unit.

(3) The decision-making preference

The decision-making preference is that when facing multiple alternatives, decision makers have the preference for one scheme [12]. There are many factors which can influence the decision-making preference, including the decision characteristics (the decision content, the decision information, the way described for the decision, etc.), the decision-making scenarios (with time pressure or not, the background of the decision-making scenarios, the vagueness of the decision-making scenarios, etc.), decision makers own factors (age, risk preference, motivation, emotion, etc.) [13]. For the schedule optimization decision, such as the cost, the quality and the risk are involved in the process, and different decision makers will focus on the different key problems. In order to achieve the schedule decision more scientific, the preference has to be considered in the decision-making process.

(4) Multi-objective is contained.

In the schedule optimization process, the decision problem is complex, which involves multiple objective demands. In order to achieve the schedule optimization, the decision should not only consider the schedule itself, but also have to consider the cost, the quality, the risk. So the schedule optimization decision is the collaboration among the multi-objective, namely, coordinating the schedule, the cost, the quality, the risk to fulfill the schedule optimization decision-making collaboration.

The schedule optimization decision is a collaborative process for the multi-objective, so there are some problems should be considered, for example, the Non-commensurable(the multi-objective units are inconsistent, and they cannot be directly compared); the possible contradiction between objectives; and each objective function or constraint conditions is difficult to describe by the accurate mathematical formulas.

(5) The decision schemes should be real-time.

The construction project has a strict time constraints. According to the time constraints, the schedule can be made to arrange the implementation of construction process. Therefore, the schedule optimization decision should be made as soon as possible to meet the actual requirement.

According to the analysis of characteristics, the schedule optimization decision is a complex process, as showed in the Figure 2.

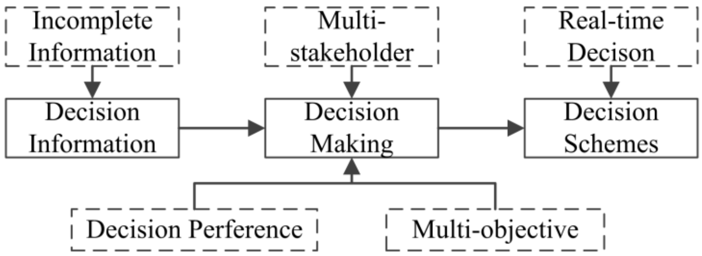

Figure 2. Characteristics of the Schedule Optimization Decision

4.2 Analysis of the Complex Process

With the advancement of the decision-making process, the complexity of the decision-making process is constantly changing, which is showed on the time dimension and in the spatial dimension.

On the time dimension, the evolution of the complexity happens among the knowledge building, the scheme selection and the decision consensus. When the information is shared and integrated by multi-stakeholder, the decision-making knowledge achieves a stable state, then the complexity is the scheme selection. After selecting a scheme, the complexity will be the decision consensus.

In the spatial dimension, the evolution of the complexity happens between the subject and object, and the evolution is interactive which includes the interaction of the decision knowledge, the interaction of the preference and the interaction of the subject and the object. In the interactive process, the shared information converts the decision superiority.

Figure 3 shows the complexity of the decision process.

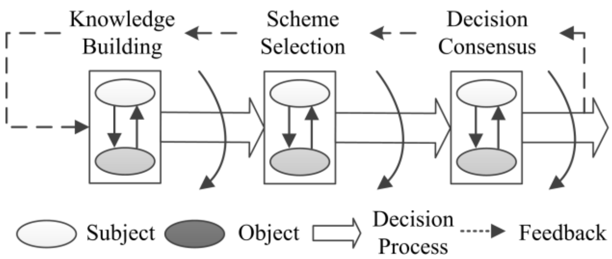

Figure 3. The Evolution of the Complexity

3. Dominance-based Rough Set Theory

Rough set theory was created by Z. Pawlak, and it has been widely applied in many fields for dealing with uncertainty, granularity, and incompleteness of knowledge in information systems [14]. However, the classical rough set method is not able to find the inconsistencies which are related with the preference attributes, such as the price, the speed, etc. These attributes contain preference information, which are not be considered in rough set. In order to process the preference information, Greco et al. proposed the dominance-based rough set [15-17]. In the dominance-based rough set, the rough set model is reestablished by replacing the indiscernibility relation with the dominance relation. The new model not only has the function of the old model, but also can deal with the preference information, and it can generate rules for users to understand easily.

(1) Dominance Relation

Definition 1: $x, y \in U$, if for each $q \in P$, $f(y,q) \geq f(x,q)$, so $yD_p x$. This relation is called the dominance relation.

In the definition 1, there is a preference for the q, and the relation is weak. If for each $q \in P$, $f(y,q) > f(x,q)$, then the relation is strong. If $f(y,q) = f(x,q)$, then the relation is indiscernible.

(2) P-dominating Sets and P-dominated Sets

Definition 2: $P \in C$, and $x \in U$, $y \in U$, P-dominating sets and P-dominated sets can be defined as follow:

$$D_P^+(x) = \{yD_P x\} \quad (1)$$

$$D_P^-(x) = \{xD_P y\} \quad (2)$$

In the dominance-based rough set, the object set U will be divided into a limited decision class by decision-makers. Let be $Cl = \{Cl_t, t \in \{1,2,\cdots,n\}\}$, then $Cl_n \succ \cdots \succ Cl_t \succ \cdots \succ Cl_1$. These classes can be combined from up to down or from down to up, which can be respect $Cl_t^{\geq}$ or $Cl_t^{\leq}$.

$$Cl_t^{\geq} = \bigcup_{s \geq t} Cl_s \quad (3)$$

$$Cl_t^{\leq} = \bigcup_{s \leq t} Cl_s \quad (4)$$

Where $t, s \in \{1,2,\cdots,n\}$. If $x \in Cl_t^{\geq}$, and it means that "x belngs to Cl_t at least"; if $x \in Cl_t^{\leq}$, and it means that "x belngs to Cl_t at most". In the application, the best object is in the Cl_n, and the worst object is in the Cl_1.

(3) Dominance-based Rough Approximation

Definition 3: upper approximation and lower approximation of $Cl_t^{\geq}$ are defined:

$$\underline{P}(Cl_t^{\geq}) = \bigcup\{x \in U : D_P^+(x) \subseteq Cl_t^{\geq}\} \quad (5)$$

$$\overline{P}(Cl_t^{\geq}) = \bigcup\{x \in U : D_P^-(x) \cap Cl_t^{\geq} \neq \phi\} \quad (6)$$

Definition 4: upper approximation and lower approximation of $Cl_t^{\leq}$ are defined:

$$\underline{P}(Cl_t^{\leq}) = \bigcup\{x \in U : D_P^-(x) \subseteq Cl_t^{\leq}\} \quad (7)$$

$$\overline{P}(Cl_t^{\leq}) = \bigcup\{x \in U : D_P^+(x) \cap Cl_t^{\leq} \neq \phi\} \quad (8)$$

4. The Method for the Schedule Optimization Decision

4.1 Decision Hypothesis

Hypothesis 1: Multi-objective is contained in the schedule optimization decision process.

In the schedule optimization decision, the schedule, the cost, the resource and the risk are interacted with each other; at the same time, the collaboration among the multi-stakeholder is also an objective which should be considered. The collaboration among the multi-stakeholder, the cost, the resource, the quality and the risk are represented by q_1, q_2, q_3, q_4, q_5 respectively.

Hypothesis 2: the decision-making information is incomplete.

In decision-making process, the information function is defined as $f(x,q)=V$, which means that there is a corresponding value for each object. If the value does not exist, the "*" will be use to represent.

Hypothesis 3: Multi-stakeholder participants in the decision-making process.

According to the system theory, decision-makers, the decision-object, the decision method, and the collaborative rules should be included in a group decision. The Formal formula is $GDM=\{M,O,S,C\}$.

Hypothesis 4: stakeholders are limited rationality.

Due to the decision-makers' limited knowledge, the selection of the decision scheme is between the full rationality and the irrationality.

Hypothesis 5: stakeholders have the preference attributes.

In order to conform to the actual situation, the preference should be considered. In the decision process, there are two rules for the preference: (1) Integrity, for any two schemes A and B, the decision makers have a clear preference ($A\succ B$, or $B\succ A$, or $A\approx B$); (2) Transfer of the preference, for any three schemes A, B, and C,, if $A\succ B$, and $B\succ C$, then $A\succ C$.

4.2 Definition of the Incomplete Schedule Information System

Definition 5: let $S=(U,A,V,f)$ is the schedule information system, where U is the nonempty object set, A is the nonempty attributes sets ($A=C\bigcup D$, in which C is the condition attributes sets, and D is decision attributes sets), and V is attributes values ($V_C=\{V_q:q\in C\}$ is the set for condition attributes values, and $V_D=\{V_d:d\in D\}$ is the set for decision attributes values). For the V_C and V_D, they have the preference attribute. If some V_C are not exist, the "*" will be use to represent.

4.3 Expanded Dominance Relation

Because of the limitation of the actual schedule attributes, the dominance relation should be expanded to meet the attribution contrasting analyses. A constraint condition is added, that is the threshold.

Definition 5: in the $S=(U,A,V,f)$, $P\subseteq A$,the dominance relation SMDOM(P) of P can be defined:

$$\begin{aligned}SMDOM(P)=\Big\{&(x,y)\in U\times U\,\big|\forall q\in P,\left(\left|B_P(x)\cap B_P(y)\right|/\left|C\right|\right)\geq\lambda\wedge\\&\big((f(x,q)=*\wedge f(y,q)=*)\vee(f(x,q)=*\wedge f(y,q)\neq *)\\&\vee(f(y,q)=*\wedge f(x,q)\neq *)\vee(f(x,q)\neq *\wedge f(y,q)\neq *\\&\rightarrow f(y,q)\geq f(x,q))\big)\Big\}\end{aligned} \tag{9}$$

Where $B_P(x)=\{b\,|b\in P\wedge f(x,b)\neq *\}$, that is the number of nonempty condition attributes in each object. λ is the threshold ($0\leq\lambda<1$), and $|C|$ is the cardinal number of the condition attributes sets.

According to the Definition 1 and Definition 2, the dominance relation between x and y can be respect $yD_P^{\lambda}x$, and the P-dominating sets can be respect $yD_P^{+\lambda}x$, and P-dominated sets $yD_P^{-\lambda}x$.

$$D_P^{+\lambda}(x)=\{yD_P^{+\lambda}x\} \tag{10}$$

$$D_P^{-\lambda}(x)=\{yD_P^{-\lambda}x\} \tag{11}$$

The threshold λ can improve the rationality of the decision in the schedule optimization decision, which can be set by decision makers. The value of λ can be decided by $|C|$ and nonempty attributes number of any sample couple N_{ij}.

If $\frac{Number\ of\ N_{ij}=|C|}{Number\ of\ all\ sample\ couple}>50\%$, then

$$\lambda=\frac{|C|-1}{|C|} \tag{12}$$

If $\frac{Number\ of\ N_{ij}=|C|}{Number\ of\ all\ sample\ couple}<50\%$, and $\frac{Number\ of\ N_{ij}\geq|C|-k}{Number\ of\ all\ sample\ couple}>50\%$, then

$$\lambda=\frac{|C|-k}{|C|} \tag{13}$$

where $k=\{1,2,3,\cdots,|C|\}$.

4.4 Expanded Dominance-based Rough Approximation

For $P\subseteq A$, $x\in U$, $Cl_t^{\geq},Cl_t^{\leq}\subseteq U$, $t=1,2,\cdots,n$, the expanded dominance-based rough approximation of $Cl_t^{\geq}$ is:

$$\underline{P}(Cl_t^{\geq})^{\lambda}=\{x\in U_P^{*}:D_P^{+\lambda}(x)\subseteq Cl_t^{\geq}\} \tag{14}$$

$$\overline{P}(Cl_t^{\geq})^{\lambda}=\bigcup_{x\in Cl_t^{\geq}}D_P^{+\lambda}(x) \tag{15}$$

The boundary region is

$$Bn_P(Cl_t^{\geq})^{\lambda}=\overline{P}(Cl_t^{\geq})^{\lambda}-\underline{P}(Cl_t^{\geq})^{\lambda} \tag{16}$$

The expanded dominance-based rough approximation of $Cl_t^{\leq}$ is

$$\underline{P}(Cl_t^{\leq})^{\lambda}=\{x\in U_P^{*}:D_P^{-\lambda}(x)\subseteq Cl_t^{\leq}\} \tag{17}$$

$$\overline{P}(Cl_t^{\leq})^{\lambda}=\bigcup_{x\in Cl_t^{\leq}}D_P^{-\lambda}(x) \tag{18}$$

The boundary region is

$$Bn_P(Cl_t^{\leq})^{\lambda}=\overline{P}(Cl_t^{\leq})^{\lambda}-\underline{P}(Cl_t^{\leq})^{\lambda} \tag{19}$$

4.5 Classification Accuracy and Classification Quality

(1) Classification accuracy

Classification accuracy of $Cl_t^{\geq}$ is

$$\alpha_{Cl_t^{\geq}}^{\lambda} = \frac{\left|\underline{P}\left(Cl_t^{\geq}\right)^{\lambda}\right|}{\left|\overline{P}\left(Cl_t^{\geq}\right)^{\lambda}\right|} \tag{20}$$

Classification accuracy of $Cl_t^{\leq}$ is

$$\alpha_{Cl_t^{\leq}}^{\lambda} = \frac{\left|\underline{P}\left(Cl_t^{\leq}\right)^{\lambda}\right|}{\left|\overline{P}\left(Cl_t^{\leq}\right)^{\lambda}\right|} \tag{21}$$

(2) Classification quality

Classification quality of Cl is

$$\gamma_P\left(Cl\right)^{\lambda} = \frac{\left|U - \bigcup_{t=1}^{n}\left(Bn_P\left(Cl_t^{\leq}\right)^{\lambda}\right)\right|}{|U|} = \frac{\left|U - \bigcup_{t=1}^{n}\left(Bn_P\left(Cl_t^{\geq}\right)^{\lambda}\right)\right|}{|U|} \tag{22}$$

4.6 Decision Rules for the Schedule Optimization

(1) Deterministic Decision Rules

If $f\left(x,q_1\right) \geq r_{q1}, f\left(x,q_2\right) \geq r_{q2}, \cdots, f\left(x,q_p\right) \geq r_{qp}$, then $x \in Cl_t^{\geq}$, where $P = \left\{q_1, q_2, \cdots, q_p\right\} \subseteq C$, $\left(r_{q1}, r_{q2}, \cdots, r_{qp}\right) \in V_{q1} \times V_{q2} \times \cdots V_{qp}$, $p = 1, 2, 3, 4, 5$, $t = 1, 2, \cdots, n$.

If $f\left(x,q_1\right) \leq r_{q1}, f\left(x,q_2\right) \leq r_{q2}, \cdots, f\left(x,q_p\right) \leq r_{qp}$, then $x \in Cl_t^{\leq}$, where $P = \left\{q_1, q_2, \cdots, q_p\right\} \subseteq C$, $\left(r_{q1}, r_{q2}, \cdots, r_{qp}\right) \in V_{q1} \times V_{q2} \times \cdots V_{qp}$, $p = 1, 2, 3, 4, 5$, $t = 1, 2, \cdots, n$.

(2) Possible Decision Rule

If $f\left(x,q_1\right) \geq r_{q1}, f\left(x,q_2\right) \geq r_{q2}, \cdots, f\left(x,q_k\right) \geq r_{qk}$, $f\left(x,q_{k+1}\right) \leq r_{q1}, f\left(x,q_{k+2}\right) \leq r_{q2}, \cdots, f\left(x,q_p\right) \leq r_{qp}$, then $x \in Cl_t \bigcup Cl_{t+1} \bigcup \cdots \bigcup Cl_s$, where $Q' = \left\{q_1, q_2, \cdots, q_k\right\} \subseteq C$, $Q'' = \left\{q_{k+1}, q_{k+2}, \cdots, q_p\right\} \subseteq C$, $P = Q' \bigcup Q''$, $\left(r_{q1}, r_{q2}, \cdots, r_{qp}\right) \in V_{q1} \times V_{q2} \times \cdots \times V_{qp}$, $s, t \in \left\{1, 2, \cdots, n\right\}$, $t < s$.

5. Case Study

Because of the complex environment, the schedule of a construction project should be optimized to meet the actual requirements. Table 1 is the decision table of the construction project, which is made by different project stakeholders. The collaboration among the multi-stakeholder, the cost, the resource, the quality and the risk are represented by q_1, q_2, q_3, q_4, q_5 respectively. In addition, the "*" is use to represent the attributes value which cannot be obtained.

In the Table 1, $U = \left\{1, 2, 3, 4, 5, 6, 7, 8\right\}$, q_1, q_2, q_3, q_4, q_5 are the condition attributes, and d is the decision attribute.

Let $P=\{q_1,q_2,q_3,q_4,q_5\}$, $Cl_1=\{x\in U_P^*,\ f(x,d)=Bad\}=\{1,6,7,8\}$, and $Cl_2=\{x\in U_P^*,\ f(x,d)=Good\}=\{2,3,4,5\}$. $Cl_1^{\leq}=Cl_1$, $Cl_2^{\geq}=Cl_2$, $Cl_1^{\geq}=Cl_2^{\leq}=U$.

According to the Formula (12) or (13), $\lambda=0.8$.

According to the Formula (9),

$Bp(1)=\{q_1,q_2,q_3,q_4,q_5\}$; $Bp(2)=\{q_2,q_3,q_4,q_5\}$; $Bp(3)=\{q_1,q_2,q_3,q_4,q_5\}$;

$Bp(4)=\{q_1,q_2,q_3,q_4,q_5\}$; $Bp(5)=\{q_1,q_2,q_3,q_5\}$; $Bp(6)=\{q_1,q_3,q_4,q_5\}$;

$Bp(7)=\{q_1,q_2,q_3,q_5\}$; $Bp(8)=\{q_1,q_2,q_4,q_5\}$.

$D_p^{+\lambda}(1)=\{1,2,3,5\}$, $D_p^{+\lambda}(2)=\{2,3\}$, $D_p^{+\lambda}(3)=\{3\}$;

$D_p^{+\lambda}(4)=\{2,3,4,5,7\}$, $D_p^{+\lambda}(5)=\{3,5\}$, $D_p^{+\lambda}(6)=\{3,6\}$;

$D_p^{+\lambda}(7)=\{3,5,7\}$, $D_p^{+\lambda}(8)=\{3,8\}$.

$D_p^{-\lambda}(1)=\{1\}$, $D_p^{-\lambda}(2)=\{1,2,4\}$, $D_p^{-\lambda}(3)=U$;

$D_p^{-\lambda}(4)=\{4\}$, $D_p^{-\lambda}(5)=\{1,4,5,7\}$, $D_p^{-\lambda}(6)=\{6\}$;

$D_p^{-\lambda}(7)=\{4,7\}$, $D_p^{-\lambda}(8)=\{8\}$.

Table 1. The Decision Table of the Schedule Optimization

No.	Attributes values					Decision values
	q_1	q_2	q_3	q_4	q_5	d
1	Bad	Average	Bad	Bad	Average	Bad
2	*	Good	Average	Bad	Average	Good
3	Good	Good	Good	Good	Good	Good
4	Bad	Average	Average	Bad	Bad	Good
5	Good	Average	Good	*	Average	Good
6	Bad	*	Bad	Good	Bad	Bad
7	Good	Average	Average	*	Bad	Bad
8	Good	Bad	*	Bad	Average	Bad

According to the Formula (14)-（19）,

$\underline{P}(Cl_1^{\leq})^{\lambda}=\{1,6,8\}$, $\overline{P}(Cl_1^{\leq})^{\lambda}=\{1,6,4,7,8\}$, $Bn_p(Cl_1^{\leq})^{\lambda}=\{4,7\}$.

$\underline{P}(Cl_2^{\geq})^{\lambda}=\{2,3,5\}$, $\overline{P}(Cl_2^{\geq})^{\lambda}=\{2,3,4,5,7\}$, $Bn_p(Cl_2^{\geq})^{\lambda}=\{4,7\}$.

According to the Formula (21) and (22),

$\alpha_{Cl_1^{\leq}}^{\lambda}=\frac{3}{5}$, $\alpha_{Cl_2^{\geq}}^{\lambda}=\frac{3}{5}$, $\gamma_P(Cl)^{\lambda}=\frac{3}{4}$.

The minimum reducing set of condition attribute set is $\{q_1,q_2,q_3,q_4\}$.

Finally, the decision rules is:

(1) if $r_{q_1}\leq Bad$, $r_{q_2}\leq Average$, $r_{q_3}\leq Average$, $r_{q_4}\leq Bad$ then $x\in Cl_1^{\leq}$. that is, if the collaboration among the multi-stakeholder was bad at most, the cost was average at most, the resource was average at most, the quality was bad at most in an optimization scheme, then the schedule optimization scheme is bad, which cannot be adopt.

(2) if $r_{q_1}\geq Good$, $r_{q_2}\geq Average$, $r_{q_3}\geq Good$, $r_{q_4}\geq Bad$ then $x\in Cl_2^{\geq}$. That is, if the collaboration among the multi-stakeholder was good at least, the cost was average at

least, the resource was good at least, the quality was bad at least in an optimization scheme, then the schedule optimization scheme is good, which can be adopt.

6. Conclusion

The schedule optimization is an essential process in the construction project. In this paper, the characteristics of schedule optimization decision are analyzed, which included the incomplete decision information, the multi-object, the multi-stakeholder, the preference and so on. These characteristics improve the complexity of the schedule optimization decision, and some new methods are needed. Dominance-based rough set is a mathematical tool which can deal with the incomplete information and the preference, and it is a good choice for the schedule optimization decision. Based on dominance-based rough set, the schedule decision system is defined, and the decision process is designed. Finally, the decision rules are made. Through a case application, dominance-based rough set can be used in the schedule optimization, and it provides a new decision method for construction project.

This paper is a preliminary research, and the deeper research should be done in the future: (1) the attributes of the decision table should be more specific, and the more specific decision rules can be made; (2) the decision table is small in the case, so the minimum reducing set can be found easily. If the decision table contained more content, it will be a NP problem for finding the minimum reducing set. It is necessary to study the applicability of the minimum reducing set next step.

Acknowledgements

This study is supported by the National Natural Science Foundation of China (NSFC) (Grant No. 51378160).

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