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Research Article

A Method of Construction Partner Selection for Hybrid Preference Information

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Abstract: In this study, a relevant evaluation index system was established based on the level of information, the sense of social responsibility, as well as factors such as management capacity. The partial order preference has also been determined under the premises that the evaluation index are stochastic, intuitionistic fuzzy and ordinal and the pre-order preference structure is extended to partial order preferences. The combined multi-attribute decision-making model is developed with the uncertain weight of evaluation index, followed by the decision-making process and decision-making method. The feasibility and effectiveness of the approach proposed in this study are illustrated by case study.

Keywords: Combined decision-making model, multiple criteria analysis, partial order, partner selection, preference relation

INTRODUCTION

Partner selection plays an essential role in construction project management (Rackham *et al*., 1995), the high quality partner can insure a healthy and long-term relationship, followed by a win-win situation. Xun-Ming (2009) mentioned that an increasing number of companies aware that their business growth cannot be separated from the cooperation with the main interest party when they facing the intense market competition. Accompanied by the application of cooperative game and partnering model in the construction project management, the partnering selection problems become even more important. Many enterprises have already paid attention to the partnering selection and tried to reduce the risk of cooperation, in order to insure the success of their projects. Besides, partner selection is an essential issue of improving the market competitiveness and international influence of the enterprises. With the rapid development of economic globalization and growing popularity of project management, the project have and significant impact on the entire construction project and the operational performance. In the meantime, the complexity and scale of partnering selection are increasing. Thus, establishing appropriate evaluation system and using scientific evaluation methods play an essential role in selecting the right partners.

From the literature review on China and abroad, many researchers (Bovine and Wang, 2008; Yan *et al*., 2011) have committed in this field and obtained fruitful results. However, after a detailed analysis, there are still some shortages in three aspects: in the establishment of index system, current research only focus on some traditional issues and ignore the impacts of new issues on the entire construction projects, such as: IT investment levels, the attention to social responsibility, management capability and other issues which attract public attention nowadays (Sun, 2007). In terms of methods, current researches mainly adopt the quality method; feature of selection index. Property value may exist in partnering selecting in various forms and they constitute the hybrid preference information of decision-making problems in partnering selection. In the scope of evaluation, the selection method mentioned in current literature mainly suit for single selection problems, the using scope is narrow. To compensate for those shortcomings, a hybrid decision-making model is established in this study. This model is on the basis of current literature review and is aim to make the selection method more reasonable and satisfy the new needs and new changes in construction project management nowadays. It considers the specific situation of incomplete information and building a comprehensive evaluation system with the IT level, the social responsibility and management capacity of the partners. It also considers the form of evidence theory, the randomness, possibility and intuitionistic fuzzy numbers in hybrid preference information. The decision process is also given followed by the decision model.

ESTABLISHMENT OF INDEX SYSTEM

Partner selection is multi-attribute decision-making problem. Based on the literature review and the different evaluation issues in partner selection for

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construction project management nowadays, the index system is established as follows:

- The quality of completed projects C1.
- It depends on the partner's ability of quality control.
- Price level C2. This index embodied by the market price of the projects and the partners' own cost control ability.
- Manufacture capabilities C3. This index reflects the partners' ability and skill.
- Innovation and development potential C4. This index reflects the partners' innovation and potential.
- Partners' reputation C5.
- Financial situation C6. This index reflects the partners' recent financial position and whether can complete the project.
- The level of information technology C7. This index reflects the partners' software and hardware in information system and their application ability.
- Management capability C8. Management capability influences the management of partners directly and influences the cost as well.
- Social responsibility C9. Assess a company from labor rights, human rights protection, social responsibility, environmental standards, fair trade, ethics, social contribution and so on.

Nowadays, majority of evaluation method in partnering selection consider the information asymmetry. However, in the same decision-making process, they always treat only one type of imperfection at the time. Let us note that most of these procedures are based on a probabilistic or a fuzzy modelization. However, many multiple criteria modelizations imply often the presence of different forms of imperfection at the same time. From the current literature, there is seldom research considering decision-making method on hybrid evaluation of information (random, fuzzy and others). Giuseppe (2009) mentioned NAIADE method, Khaled *et al*. (2012) mentioned PAMSSEM method. Sarah *et al*. (2007) proposed a decision-making process with mixed preference information in multi-attribute and he mentioned the decision-makers always have partial order preference.

For the lack in theoretical and methodological in current partner selection, this study propose that the decision-makers' preference information is random, possibility and fuzzy in the condition of incomplete information.

METHODS FOR PARTNER SELECTION

Description of the problem: Suppose A = {a_1, a_2 …, …, a_m} is the model to be evaluated, X = {X_1, X_2 …, X_j …, X_n} is the evaluation set, E is the evaluation

Table 1: Performance matrix of indicators j

Partner	Ω^j	w^j_1	…	w^j_h	…	w^j_H
a_1				⋮		
a_i		…		x^h_{ij}		…
a_m				⋮		

Table 2: Performance matrix for the attribute j integrating the priori information

a_1	C^1_{1j}	…	$C^{h'}_{1j}$	…	$B^{2^H}_{1j}$
⋮	⋮	⋮	⋮		
a_i	C^1_{ij}	…	$C^{h'}_{ij}$	…	$B^{2^H}_{ij}$
⋮	⋮	⋮	⋮		
a_m	C^1_{mj}	…	$C^{h'}_{mj}$	…	$B^{2^H}_{mj}$
A priori belief masses	$m(B^j_1)$	…	$m(B^j_{h'})$	…	$m(B^j_{2^H})$

matrix, this decision model is denoted by(A, X, E). W = (w_1, w_2, … , w_n) is the collection of index weight vector and $\sum_{j=1}^{n} wj = 1$.

E is the evaluation matrix, E = $(e_{ij})_{m\times n}$.

Easy to know e_{ij} may be different types of incomplete preference information. Suppose partner a_i is randomness of attribute data for the evaluation of the value of indicator x_j {j = 1, 2, …, k_1}, for the index x_j {j = k_2 + 1, k_2 +2, …, k_3}, is interval intuitionistic fuzzy numbers; and for the index x_j{j = k_3 + 1, k_3 + 2, …, n} is possible data.

In an uncertain circumstance, we often use random, the likelihood or "evidence" type data to evaluate the program, of course, includes the evaluation of fuzzy or ordinal. Among all uncertain model theory (evidence theory, possibility theory and probability theory), the evidence theory propose a more general framework, while the possibility and probability theory is more for the special case.

For the indicator index x_j {j = k_1 + 1, k_1 +2, …, k_2}, the evaluation matrix is shown in Table 1. The evaluation value for partner a_i to the index x_j is e_{ij}, the evaluation e_{ij} according to the attribute j will depend on the set of the nature states Ω^j = {ω^j_1, … , ω^j_h, … , ω^j_H}. The matrix is represented by the values x^h_{ij} of the set {x^1_{ij}, … , x^h_{ij}, … , x^H_{ij}}. When the nature state ω^j_h(h = 1, 2, … , H) happened, the result of decision scheme a_i is x^h_{ij}. A priori information about the state of nature is listed in Table 2.

Table 2 is based on the model in evidence theory (Ronald, 2011), among them, the prior information expressed by the focal element reliability. Focal element $B_{\acute{h}}^j \subset \Omega^j$ ($\acute{h}$ = 1, 2, … , H), Ω^j = {ω^j_1, … , ω^j_h, … , ω^j_H} is a collection of the state of nature, natural state influence the evaluation value of the index j by partners. According to the theory of evidence, the evaluation value from partners a_i to index j is $C_{ij}^{h'} \subset X_{ij}$, the focal element which relies on the natural state of a subset is $B_{\acute{h}}^j$ ($\acute{h}$ = 1, … , 2^H).

When the priori information of indicators has the possibility of characteristics (Greco *et al*., 2008), we suppose the probability distribution of the evaluation value e_{ij} is π. In such a context, the corresponding belief masses are associated with focal elements that are embedded $B_1^j \subseteq \cdots B_{h'}^j \subseteq \cdots \subseteq B_{H'}^j$.

The possibility measures coincide with the plausibilities of the embedded focal elements.

When the attribute j is stochastic (Yao, 2007), the focal elements $B_{h'}^j$ are reduced to the singletons $\{\omega^j_h\}$ and the corresponding belief masses correspond to probability measures. In this case, the evaluation value is a random variable X^h_{ij} ,a priori probability distribution is f^h_{ij}. The priori (subjective) probability for each state of the nature $\omega^j_h(h = 1, 2, \dots ,)$ is P^h_j.

Local preference relations: In this study, each of decision makers expresses his preference by giving one of the four following relations:

A_i is preferred to A_k ($A_i \succ A_k$); A_k is preferred to A_i ($A_i \prec A_k$); A_i is indifferent to A_k ($A_k \approx A_k$) ; A_i is incomparable to $A_k(A_i \parallel A_k)$.

Stochastic dominance allows that the policy-makers' risk preference attitude to the program a_i, a_k meet DARA utility function (Yao-Huang, 2003; Kyung and Jeong, 2011). In order to build such a relationship, this study proposes a new method based on the concept of stochastic dominance. It is not easy to decide the decision makers' preferences. If we can get some random advantages, often able to infer a_i is better than a_k. If the evaluation value e_{ij} is a random variable, the stochastic dominance results can be directly applied to determine the preference relation. For example:

$$e_{ij} \approx_j e_{kj} \Leftrightarrow | H_1(x) | = | F_{ij}(x) - F_{kj}(x) | \le s_j, \ \forall x \in [x_{j*}, x_j^*]$$

Among them, $x*_j$ and $x*_j$ are the infimum and supremum of the index evaluation value, $s_j \ge 0$ is the pre-determined threshold, $F_{ij}(x)$ and $F_{kj}(x)$ are the cumulative probability distribution for evaluation value of index j from partners a_i and a_k, x is a feature of this indicator. Besides, when:

$| H_1(x) | > s_j$ （$F_{ij}(x) \ne F_{kj}(x)$）, $e_{ij} \succ_j e_{kj} \Leftrightarrow FSD_j$ or SSD_j or TSD_j e_{kj} $e_{ij} \parallel_j e_{kj} \Leftrightarrow e_{ij}$ non SD_j e_{kj}

Among them, SD* is one of the three types of stochastic dominance (Kyung and Jeong, 2011).

For the indicators of evidence theory, this study use pignistic probability conversion formula proposed by Smets and get the preference programs on the concept of stochastic dominance:

$$BetP(w_h) = \sum_{B_{h'}^j : \omega_h^j \in B_{h'}^j \in P(\Omega)} \frac{1}{|B_{h'}^j|} \frac{m(B_{h'}^j)}{1 - m(\phi)} \tag{1}$$

$\forall B^j\grave{h} \in P(\Omega)$, $m \ne (\emptyset)$among them $|B^j_H|$ is the base in Ω from B^j_H, $BetP(w_h)$ is the pignistic probability of w_h.

For the evaluation for the possibility of partners, we can draw the program's preferences using the relationship proposed by Dubois. This relationship is equivalent to pignistic conversion in the measure theory, the probability p_h of w_h can present like:

$$P_h = \sum_{t=h}^{H} \tfrac{1}{t} \cdot m_t = \sum_{t=h}^{H} \tfrac{1}{t}(\Pi_t - \Pi_{t+1}) \tag{2}$$

Among them, m_t is the trust Mass Function, $m(B_h)$ ($h = 1,2, \dots , H$) $B_1 = \{w_1\}$, $B_2 = \{w_1, w_2\}$,…, $B_h = \{w_1, w_2, \dots , w_h\}$,…, $B_H = \Omega$. So $\forall$ $B \ne B_h$, $m(B) = 0$, for the determined h, there might be $m(B_h) = 0$,$\prod_h = \prod(\{w_h\})$, $\prod$ is the possibility of measure:

$$\Pi(\{w_h\}) = pl(\{w_h\}) = \sum_{t=h}^{H} m_t \tag{3}$$

If the evaluation values of the partners are interval intuitionistic fuzzy numbers, literature (Ze and Chen, 2007) gives the score function and the precise function of interval intuitionistic fuzzy sets:

Suppose $\tilde{\alpha}$ = ([α, b], [c, d]) is an interval - valued intuitionistic fuzzy numbers, then $S(\tilde{\alpha}) = 1/2\ (\alpha - c + b - d)$ is the Score function of $\tilde{\alpha}$, when $S(\tilde{\alpha}) \in$.[-1, 1] Bigger the $S(\tilde{\alpha})$, the bigger the $\tilde{\alpha}$. Besides $h(\tilde{\alpha})= ½(\alpha + b + c + d)$ is the precise function of $\tilde{\alpha}$, when $h(\tilde{\alpha}) \in$ [0, 1].

Intuitionistic fuzzy number of scoring functions and the precise function is similar to the mean and variance statistics. Therefore, they can be considered in the score function value equal to the case of intuitionistic fuzzy number, the greater the value of precise function, the greater the interval intuitionistic fuzzy numbers. Intuitionistic fuzzy numbers of local preference relations construct is given below:

Definition 1: Suppose $\tilde{\alpha}^k_i$ and $\tilde{\alpha}^k_j$ are the evaluation value of index k from partners s_i and s_j, $\tilde{\alpha}^k_i$ and $\tilde{\alpha}^k_j$ are two interval intuitionistic fuzzy numbers. $S(\tilde{\alpha}^k_i)$ and $S(\tilde{\alpha}^k_j)$ are score function of $\tilde{\alpha}^k_i$ and $\tilde{\alpha}^k_j$, h $(\tilde{\alpha}^k_i)$ and h $(\tilde{\alpha}^k_j)$ are precise function:

- If $S(\tilde{\alpha}^k_i) < S(\tilde{\alpha}^k_j)$ and $h(\tilde{\alpha}^k_i) < h(\tilde{\alpha}^k_j) \ge h(\tilde{\alpha}^k_j)$ $h(\tilde{\alpha}^k_j)$ or $> h(\tilde{\alpha}^k_{ij})$but $| h(\tilde{\alpha}^k_i) - h(\tilde{\alpha}^k_j) | - h(\tilde{\alpha}^k_i) \le \delta$, so $\tilde{\alpha}^k_i < \tilde{\alpha}^k_j$
- If $S(\tilde{\alpha}^k_i) < S(\tilde{\alpha}^k_j)$ and $h(\tilde{\alpha}^k_i) < h(\tilde{\alpha}^k_j)$ So $\tilde{\alpha}^k_i \parallel \tilde{\alpha}^k_j$
- if $S(\tilde{\alpha}^k_i) - S(\tilde{\alpha}^k_j)$ and $h(\tilde{\alpha}^k_i) < h(\tilde{\alpha}^k_j)$ so $\tilde{\alpha}^k_i > \tilde{\alpha}^k_j$
- if $S(\tilde{\alpha}^k_i) = S(\tilde{\alpha}^k_j)$ and $| h(\tilde{\alpha}^k_i) < h(\tilde{\alpha}^k_j) \le \sigma$ |, so $\tilde{\alpha}^k_i \approx \tilde{\alpha}^k_j$

While σ can be pre-determined and σ > 0.

The assembly of preference relations: Suppose professionals' preference binary relation of evaluation index X_j to projects A_i and A_k is $R^j(A_i, A_k)$, assembled each evaluation index, expert partners' comprehensive preference of partners (A_i, A_k), is $R(A_i, A_k)$, make w_j the weight of evaluation index C_j, Weight vector = {w_1, w_2, … , w_n} ∈ W meet certain constraints and $w_j \geq 0$ $\sum_{j=1}^{n} w_j = 1$, W is the assemble of the weights of evaluation indexes do not fully determine the collection of information.

Among them R, $R^j \in \{\succ, \prec, \|, \approx\}$, ∈ $\Phi^R(A_i, A_k)$, represents the weighted distance from the partners comprehensive preference of (A_i, A_k), to the partners preference of (A_i, A_k), according to evaluation index X_j:

$$\Phi^R(A_i, A_k) = \sum_{j=1}^{n} w_j d(R, R^j(A_i, A_k))$$

d(R, R^j (A_i, A_k)) is the distance between binary relation R^j(A_i, A_k), and $R \in \{\succ, \prec, \|, \approx\}$. B = {($A_i$, A_k)/ {(A_i, A_k) ∈ X × X}, calculate the deviation d(R, R^j (A_i, A_k)) from $R \in \{\succ, \prec, \|, \approx\}$ of all partners in Band establish the following optimization model:

$$\min_{R \in \{\succ, \approx, \|, \prec\}} \Phi^R(A_i, A_k) = \sum_{j=1}^{n} w_j d(R, R^j(A_i, A_k)) \tag{4}$$

s.t. w ∈ W

The algorithm process is as follows:

Step 1: Construct partners on collection B = {(A_i, A_k)/{(A_i, A_k) ∈ $X \times X$}, calculate the deviation $d(R, R^j(A_i, A_k))$ from $R \in \{\succ, \prec, \|, \approx\}$ of all partners in B.

Step 2: Create optimization model. Solving the optimization model, get the collective preference relation R* from all partners in B. If there is only one issue in R*, which means exist only one collective preference relation that makes the deviation Φ^R (A_i, A_k) the minimum. So the preference relation r* is defined as collective preference relation from decision-maker to suppliers (A_i, A_k), otherwise, go to the next step.

Step 3: Using the priority principle of binary relations $\{\succ, \prec, \|, \approx\}$. Using the priority principle to filter the elements of R*, if R* is only one element, then the preference relation r^* was determined as collective preference relation for the partners to (A_i, A_k). Otherwise go to the next step.

Step 4: Application assembly rules. If R* have two priority preference relations $\succ$ and $\prec$, using the assembly rules of Roy (1993), get the collective preference for (A_i, A_k).

Table 3: Performance matrices for partners and priori information of C1

	Ω^1				
	w^1_1	w^1_2	w^1_3	w^1_4	w^1_5
	0.28	0.23	0.1	0.28	0.11
S_1	3	1	2	6	4
S_2	1	3	4	6	3
S_3	2	1	2	3	5
S_4	6	1	4	4	2
S_5	4	2	4	1	5

Table 4: Performance matrices for partners and priori information of C1 and C2

	Ω^2				Ω^3		
	w^2_1	w^2_2	w^2_3	w^2_4	w^2_1	w^2_2	w^2_3
	0.3	0.3	0.2	0.2	0.1	0.5	0.4
S_1	3	1	2	6	1	1	5
S_2	1	3	4	3	2	2	3
S_3	2	2	3	5	2	4	1
S_4	6	1	4	2	3	3	2
S_5	4	2	4	5	2	6	4

CASE STUDY

Assume that there are five partners S = {S_1, S_2, S_3 , S_4, S_5}, to choose from, intends to select one treat a construction project as the enterprise as the core enterprise partners. The expert panels are composite of the person in charge of the project's technical, project managers, as well as an external group of experts. After the group discussion, they decide choosing the quality of completed projects C1, price level C2, Manufacture capabilities C3, innovation and development potential C4, partners' reputation C5, financial situation C6, the level of information technology C7, management capability C8, social responsibility C9, as the nine index to evaluate the five projects to be selected. After marketing survey, the quality of completed projects C1, price level C2 and Manufacture capabilities C3 are random indexes; innovation and development potential C4 and partners' reputation C5 are type of evidence theory values; financial situation C6 and the level of information technology C7 belong to the possibility indicators; management capability C8 and social responsibility C9 are interval Intuitionistic fuzzy numbers. After a market survey and organizing historical data, the evaluation team collates the available priori information for the evaluation and alternative partners on the evaluation value of each index, as Table 3 to 8 shows; the evaluation of incomplete information is as follows:

$$W = \{(w_1, \cdots, w_9) \mid w_1, \cdots, w_9 \geq 0.06,$$
$$w_1 > w_2 > w_4 > w_9 \succ w_3$$

Try to select a partner which treats itself as core enterprise from these five enterprises.

According to the conditions and the aforementioned knowledge in this case, the decision-making steps are as follows:

Table 5: Performance matrices for partners of C4, C5, C6 and C7

	Ω^2 (C4)			Ω^2 (C5)			Ω^2 (C6)			Ω^2 (C7)		
Partner	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1	w^2_1
S_1	90	90	100	35	70	45	35	70	45	70	100	120
S_2	120	90	100	45	30	45	45	30	45	60	70	100
S_3	110	130	80	45	60	25	45	60	25	70	80	90
S_4	80	110	120	40	70	30	40	70	30	80	70	110
S_5	100	120	80	50	45	35	45	50	30	100	60	90

Table 6: The priori information for C4 and C5

	$\emptyset$	$\{w^4_1\}$	$\{w^4_2\}$	$\{w^4_3\}$	$\{w^4_1, w^4_2\}$	$\{w^4_1, w^4_3\}$	$\{w^4_2, w^4_3\}$	$\{w^4_1, w^4_2, w^4_3\}$
$m(B^4\grave{h})$			0.1		0.6			0.3
$m(B^4\grave{h})$		0.47				0.2		0.33

Table 7: The priori information for C6 and C7

	$\emptyset$	$\{w^4_1\}$	$\{w^4_2\}$	$\{w^4_3\}$	$\{w^4_1, w^4_2\}$	$\{w^4_1, w^4_3\}$	$\{w^4_2, w^4_3\}$	$\{w^4_1, w^4_2, w^4_3\}$
$m(B^4\grave{h})$				0.2		0.2		0.6
$m(B^4\grave{h})$		0.1			0.3		0.2	0.4
$\prod(B^7\grave{h})$	0.0	0.8	0.6	1.0	0.8	1.0	1.0	1.0
$\prod(B^8\grave{h})$	0.0	0.8	0.9	0.6	1.0	1.0	0.9	1.0

Table 8: Performance matrices for partners of C8 and C9

	Alternative partners				
Evaluation index	S_1	S_2	S_3	S_4	S_5
C8	([0.4165,0.5597], [0.2459,0.3804])	([0.517,0.6574], [0.1739,0.2947])	([0.4703,0.5900], [0.1933,0.3424])	([0.5407,0.6702], [0.1149,0.2400]),	([0.5375,0.6536], [0.1772,0.3557])
C9	([0.4856,0.5838], [0.2115,0.3310])	([0.4267,0.5319], [0.234,0.3807])	([0.2915,0.3598], [0.4729,0.5733])	([0.3486,0.4616], [0.4054,0.5144])	([0.3675,0.4990], [0.2236,0.3663])

Table 9: Local preference relations for the index of C1

	R_1				
Partner	S_1	S_2	S_3	S_4	S_5
S_1	*	$\approx$	$\succ$	$\|$	$\|$
S_2	$\approx$	*	$\|$	$\succ$	$\|$
S_3	$\succ$	$\|$	*	$\prec$	$\prec$
S_4	$\|$	$\succ$	$\succ$	*	$\succ$
S_5	$\|$	$\|$	$\succ$	$\prec$	*

Table 10: Local preference relations for Indicator C2

	R_3				
Partner	S_1	S_2	S_3	S_4	S_5
S_1	*	$\|$	$\prec$	$\prec$	$\prec$
S_2	$\|$	*	$\|$	$\prec$	$\prec$
S_3	$\succ$	$\|$	*	$\prec$	$\prec$
S_4	$\|$	$\succ$	$\succ$	*	$\prec$
S_5	$\succ$	$\succ$	$\succ$	$\succ$	*

Step 1: Construct collection for the partners: $\{(S_1, S_2), \ldots (S_1, S_5), \ldots (S_3, S_5), \ldots (S_4, S_5)\}$

Step 2: Determine the local preference relations:

Due to the quality of completed projects C1, price level C2 and Manufacture capabilities C3 are random indexes, the stochastic dominance relations of suppliers can be obtained directly according to the definition of stochastic dominance. Draw local preference relation of five enterprises $S = \{S_1, S_2, S_3, S_4, S_5\}$ respectively for the quality of completed projects C1, price level C2 and Manufacture capabilities C3, as shown in Table 9 to 11.

Table 11: Local preference relations for Indicator C3

	R_2				
Partner	S_1	S_2	S_3	S_4	S_5
S_1	*	$\succ$	$\|$	$\prec$	$\prec$
S_2	$\prec$	*	$\prec$	$\|$	$\prec$
S_3	$\|$	$\|$	*	$\|$	$\prec$
S_4	$\succ$	$\|$	$\|$	*	$\prec$
S_5	$\succ$	$\succ$	$\succ$	$\succ$	*

Table 12: Pignistic probability for C4 and C5

	$\{w^4_1\}$	$\{w^4_2\}$	$\{w^4_3\}$
$m(B^4\grave{h})$	0.4	0.5	0.1
$m(B^4\grave{h})$	0.68	0.11	0.21

Table 13: Pignistic probability for C6 and C7

	$\{w^6_1\}$	$\{w^6_2\}$	$\{w^6_3\}$
$P(w^6_h)$	0.3	0.2	0.5
$P(w^7_h)$	0.383	0.383	0.234

Innovation and development potential C4 and partners' reputation C5 are type of evidence theory values, use formula (1) to transfer their prior information (Table 12). Index C4 can be transformed to $BetP(w^4_h)$ with Pignistic transformation.

For example, $BetP(w^4_2) = 0.1 + 0.6/2 + 0.3/3 = 0.5$. We can get the pignistic probability of C5 in the same way.

Financial situation C6 and the level of information technology C7 belong to the possibility indicators. Using the preference relation by Dubois, we can get $P(w^6_h)$ and $P(w^7_h)$.

Table 14: The local preference relations for the indicators C4 and C5

	R_4					R_5				
Partner	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
S_1	*	$\prec$	$\|$	$\|$	$\|$	*	$\|$	$\|$	$\approx$	$\prec$
S_2	$\succ$	*	$\|$	$\succ$	$\prec$	$\|$	*	$\succ$	$\succ$	$\prec$
S_3	$\|$		*	$\succ$	$\succ$	$\|$	$\prec$	*	$\|$	$\prec$
S_4	$\|$	$\prec$	$\prec$	*	$\prec$	$\approx$	$\prec$	$\|$	*	$\prec$
S_5	$\|$	$\succ$	$\prec$	$\succ$	*	$\succ$	$\succ$	$\succ$	$\succ$	*

Table 15: The local preference relations for the indicators C6 and C7

	R_6					R_7				
Partner	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
S_1	*	$\succ$	$\succ$	$\succ$	$\succ$	*	$\succ$	$\succ$	$\succ$	$\succ$
S_2	$\prec$	*	$\succ$	$\succ$	$\approx$	$\prec$	*	$\prec$	$\prec$	$\prec$
S_3	$\prec$	$\prec$	*	$\prec$	$\prec$	$\prec$	$\succ$	*	$\prec$	$\|$
S_4	$\prec$	$\prec$	$\succ$	*	$\prec$	$\prec$	$\succ$	$\succ$	*	$\approx$
S_5	$\prec$	$\approx$	$\succ$	$\succ$	*	$\prec$	$\succ$	$\|$	$\approx$	*

Table16: The local preference relations for the indicators C8 and C9

	R_8					R_9				
Partner	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
S_1	*			$\prec$	$\|$	*	$\succ$	$\succ$	$\succ$	$\|$
S_2	$\succ$	*	$\|$	$\prec$	$\succ$	$\prec$	*	$\succ$	$\succ$	$\succ$
S_3	$\succ$	$\|$	*	$\prec$	$\|$	$\prec$	$\prec$	*	$\prec$	$\prec$
S_4	$\succ$	$\succ$	$\succ$	*	$\succ$	$\prec$	$\prec$	$\succ$	*	$\prec$
S_5	$\|$	$\succ$	$\|$	$\prec$	*	$\|$	$\prec$	$\succ$	$\succ$	*

According to formula (2), since $\prod(B) = \sup^{\pi}_{w\in B}(w)$, $B_1 = \{w^6_3\}$ and $\prod_1 = \prod(\{w^6_3\}) = 1$; $B2 = \{w^6_3, w^6_1\}$and $\prod_2 = \prod(\{w^6_3\})$; $B3 = \{w^6_1, w^6_2, w^6_3\}$and $\prod_3 = \prod(\{w^6_3\}) = 0.6$; $\prod_4 = 0$.

Using the possibility measure and the probability of transition relations to get pignistic probability, for example:

$$p_1 = P(w_3^6) = \sum_{t=1}^{3} \frac{\Pi_t - \Pi_{t+1}}{t}$$
$$= \frac{\Pi_1 - \Pi_2}{1} + \frac{\Pi_2 - \Pi_3}{2} + \frac{\Pi_3 - \Pi_4}{3}$$
$$= \frac{1-0.8}{1} + \frac{0.8-0.6}{2} + \frac{0.6-0}{3} = 0.5$$

This is the way to get the pignistic probability of the C6 and C7, are shown in Table 15. For the evaluation index C_j, we can get the local preference relations R_j (j = 4, 5, 6, 7) by application of stochastic dominance results (Table 14 to 16), the specific steps can be found in the randomized controlled.

For the management capability C8 and social responsibility C9, we can use interval intuitionistic fuzzy numbers theory and definition 1 and get the local preference relations (Table 16).

Step 3: The establishment of the optimization model.

Calculate the deviation $d(R, R^j, (S_i, S_k))$ for the evaluation C_j and $R \in \{\succ, \prec, \|, \approx\}$ from formula (3) and Table 1 and take it into the model (4), Such as partners (S_1, S_2), to solve the following optimization problem (4):

Obtained: $R^*(S_1, S_2) = \{\approx, \|\}$, in the same way

$$R^*(S_1, S_3) = \{\|\},\ R^*(S_1, S_4) = \{\succ\}$$
$$R^*(S_1, S_5) = \{\succ, \|\},\ R^*(S_2, S_3) = \{\|\}$$
$$R^*(S_2, S_4) = \{\succ, \|\},\ R^*(S_2, S_5) = \{\succ, \|\}$$
$$R^*(S_3, S_4) = \{\|\},\ R^*(S_3, S_5) = \{\succ\}$$
$$R^*(S_4, S_5) = \{\|\}$$

Using priority principles and rules of assembly of binary relations $\{\succ, \prec, \|, \approx\}$, get the result ($S_i$, S_k) (i, k = 1, … , 5), their preferences as follows:

$$S_1 \approx S_2, S_1 \| S_3, S_1 \succ S_4, S_1 \succ S_5, S_2 \| S_3,$$
$$S_2 \succ S_4, S_2 \succ S_5, S_3 \| S_4, S_3 \succ S_5, S_4 \| S_5$$

CONCLUSION

Under the assumption that the evaluation index system with hybrid features, this paper studied partner selection under the conditions of information incomplete. Based on the current project management circumstances, the IT skill of project partners, awareness of social responsibility and measures and management capabilities and other factors have become a practical consideration of the important factors in the success of the project. An evaluation index system of these factors is established on the basis of the nine factors which can reflect the overall level of project partners. The partial order preference has also been determined under the premises that the evaluation index are stochastic, intuitionistic fuzzy and ordinal and the pre-order preference structure is extended to partial order preferences. The combined multi-attribute decision-making model is developed with the uncertain weight of evaluation index power in incomplete certain information, followed by the decision-making process and decision-making method. The feasibility and effectiveness of this model are illustrated with case study.

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