Chapter 2
A Fuzzy Multi-Attribute Decision-Making Method for Partner Selection of Cooperation Innovation Alliance

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Abstract The technological cooperation activities among enterprises, universities and research institutes are considered be necessary for accessing complementary technological resources and improving the technology innovation capability. One of the important approaches to cooperation is constructing cooperation innovation alliance. But cooperation innovation alliances are risky. How to choose the right partners and improve the efficiency of cooperation innovation is the question many enterprises concerned with. So the decision-making model of partner selection in cooperation innovation alliance is proposed in this paper, and an index system is set up. It is a fuzzy multiple attribute decision-making problems. And then a fuzzy multiple index decision-making method basing on TOPSIS is proposed. Finally, an example is shown in detail.

Keywords Cooperation innovation · Multi-attribute decision making · Partners selection · TOPSIS · Triangular fuzzy number

2.1 Introduction

With the rapid development of information technology, enterprises need to improve the technology innovation capability and sustain knowledge competitive advantage. But it is difficult for an enterprise to master all of the knowledge required and to realize technological innovation independently because there is a lack of resources, technology, skills or finances. It leads enterprises to search

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beyond their own boundaries for valuable resource (Becker and Dietz 2004). So many enterprises cooperate with each other, and the cooperation activities with other organizations and share knowledge are considered be an opportunity to access technological resources required. It can contribute to faster development of innovations, improved market access, economies of scale and scope, cost sharing and risk spreading (Pedro de Faria 2010).

One of the important approaches to cooperation is constructing cooperation innovation alliance. As the knowledge alliance, strategic cooperation innovation alliance refers to that an enterprise selects external cooperative partners to construct a cooperation alliance to learn each other, and share and acquire knowledge resource and advanced technology in order to create knowledge and technological products, enhance knowledge innovation capability and sustain the knowledge competitive advantage. But cooperation innovation alliances are risky. They are dangerous ventures that can harm unwary participants (Brouthers et al. 1995). And the ratio of failure for technological innovation alliance gets to 50–60 % (Rackham and Rackham 1995). Lots of alliance failures attribute to lacking of professional ability of partners selection including index system and methods methods (Lorange and Roos 1992).

In the process of cooperation innovation, enterprises are the main body of knowledge and technological innovation. The core enterprise need select the most correct cooperative partners, including kinds of enterprises, universities, research institutes and so on. So from the view of enterprises, this paper tries to propose a method to select partners of strategic cooperation innovation alliance that can be used to help enterprises conduct such assessment and make the right choice. In this paper, a framework of decision-making model is proposed and an index system of partner selection for cooperation innovation alliance is set up, and then a fuzzy decision-making method basing on TOPSIS is proposed considering the subjectivity and fuzziness of the indexes.

2.2 The Fuzzy Multi-Attribute Decision-Making Model and the Criteria of Partners Selection

2.2.1 The Framework of Decision-Making Model

In this paper, a framework model of decision-making is proposed (shown in Fig. 2.1). The implement steps and the model for partner selection of cooperation innovation alliance are described in the framework. First, we need find out the influencing factors for the implement of knowledge cooperation strategy and set up the criteria system of partner selection. Then the fuzzy weight and fuzzy assessed value is obtained according to the linguistic variable and triangular fuzzy number. At last, we adopt the TOPSIS method to obtain the ranking order of partners.

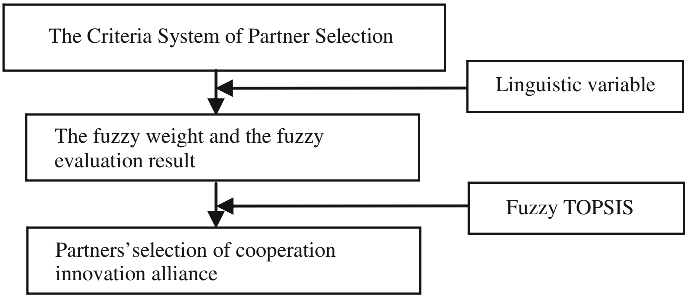

Fig. 2.1 The model framework of partner selection

2.2.2 Establishment of the Multilayer Hierarchical Structure for Decision-Makings

The four key characteristic of strategic alliances are point out by Brouthersas, including complementary skills, cooperative cultures, the compatible goals, and the commensurate levels of risk (Brouthers et al. 1995). It is necessary for enterprises to select partners according to the technology level, the state of the knowledge innovation activities and the running environment which have the potential to impact strategic cooperation innovation process and the technology cooperation goal. So it can be considered that the partner selection of cooperation innovation should adopt a comprehensive index in this paper. We adopt five indices, including the measurement from the aspect of compatibility as well the aspect of the property rights and reputation, technology resource capacity, R&D capacity and management capacity (Wang and Zhou 2008; Yang et al. 2009; Li 2008).

The hierarchical structure for partner selection of cooperation innovation alliance is shown as Table 2.1.

2.3 The Decision-Making Method Basing on the Topsis

During the process of partners' selection, we assume that $A = \{A_1, A_2, \ldots, A_n\}$ is a set of all alternatives. And form a committee of assessment experts and identify the decision-making criteria. $I = \{I_1, I_2, \ldots, I_n\}$ is a set of given evaluation index. The adopted evaluation information includes index weight vector $\tilde{w} = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n)^T$ and fuzzy evaluation matrixes $\tilde{X} = [\tilde{x}_{ij}]_{m \times n}$. The importance weights of each criteria and the linguistic rating can be considered as linguistic variables.

Triangular fuzzy numbers can be used to represent these linguistic variables as Table 2.2.

Table 2.1 A criteria system for partner selection of cooperation innovation alliance

Evaluating index	Concrete evaluating index
Compatibility (I_1)	Organization culture (I_{11})
	Cooperative target (I_{12})
Property rights and reputation (I_2)	The degrees of reputation (I_{21})
	Cooperation experience (I_{22})
	Intellectual property standards (I_{23})
Technology resource capacity (I_3)	The level of knowledge resource and knowledge workers (I_{31})
	The intelligence and standardization of information management system (I_{32})
R&D capacity (I_4)	Technology innovation capacity (I_{41})
	The advancement building of Technology (I_{42})
	Complementarities of technology (I_{43})
Management capacity (I_5)	Risk management capacity (I_{51})
	Communication and coordination capacity (I_{52})

Assume $\tilde{x}_{ij} = (\rho_{ij}, \pi_{ij,}\sigma_{ij})$ is the targeted value of criterion I_j for alternative A_i in triangular fuzzy numbers. Assume that a decision-making group has K persons, $\tilde{w}_j^{\mu}$ is the fuzzy weight for I_j given by evaluators M_{μ} $(\mu = 1, 2, \ldots K)$. $\tilde{x}_{ij}^{\mu}$ is the fuzzy assessed value for I_j of A_i. Calculate the importance of the criteria and the rating of alternatives by formula (2.1) and (2.2):

$$\tilde{w}_j = \frac{1}{K}(\tilde{w}_j^1 + \tilde{w}_j^2 + \cdots + \tilde{w}_j^K) \tag{2.1}$$

$$\tilde{x}_{ij} = \frac{1}{K}(\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \cdots + \tilde{x}_{ij}^K) \tag{2.2}$$

The multi-person multi-criteria decision-making method basing on TOPSIS can be express in the following (Chen 2000; Tang et al. 2008).

Table 2.2 Linguistic variables for the importance weight of each criterion and the ratings

Linguistic variables of weight	Linguistic variables of index	Corresponding triangle fuzzy numbers
Very low (VL)	Very bad (VB)	(0,0,0.1)
Low (L)	Bad (B)	(0,0.1,0.3)
Medium low (ML)	Worse than middling (WM)	(0.1,0.3,0.5)
Middling (M)	Middling (M)	(0.3,0.5,0.7)
Medium high (MH)	Better than middling (BM)	(0.5,0.7,0.9)
High (H)	Good (G)	(0.7,0.9,1.0)
Very high (VH)	Very good (VG)	(0.9,1.0,1.0)

1. *Construct the normalized fuzzy decision matrix*

According to the fuzzy TOPSIS method, it is necessary to use the linear scale transformation to transform the various criteria scales into a comparable scale. B is the set of benefit criteria, and D is the set of cost criteria, that is

$$\bar{x}_{ij} = (\frac{\rho_{ij}}{\sigma_j^*}, \frac{\pi_{ij}}{\sigma_j^*}, \frac{\sigma_{ij}}{\sigma_j^*}),\ j \in B \tag{2.3}$$

$$\bar{x}_{ij} = (\frac{\rho_j^-}{\rho_{ij}}, \frac{\rho_j^-}{\pi_{ij}}, \frac{\rho_j^-}{\sigma_{ij}}),\ j \in D \tag{2.4}$$

$$\sigma_j^* = \max_i\{\sigma_{ij}\},\ \rho_{\overline{ij}} = \min_i\{\rho_{ij}\} \tag{2.5}$$

Then the ranges of normalized triangular fuzzy numbers belong to $[0, 1]$ can be guaranteed by using this method.

2. *Construct the weighted normalized fuzzy decision matrix*

The weighted normalized fuzzy decision matrix can be constructed as:

$$V = (v_{ij})_{m\times n} = \left(\tilde{w}_j \bar{x}_{ij}\right)_{m\times n} \tag{2.6}$$

3. *Determine the positive ideal alternative S^* and the negative ideal alternative S^-*

The fuzzy positive-ideal solution (FPIS, S^*) can be defined as

$$S^* = \left(v_1^*, v_2^*, \ldots v_n^*\right) \tag{2.7}$$

The fuzzy negative-ideal solution (FNIS, S^-) can be defined as

$$S^- = \left(v_1^-, v_2^-, \ldots v_n^-\right) \tag{2.8}$$

Where $v_j^* = (1, 1, 1)$ and $v_j^- = (0, 0, 0)$, $j = 1, 2, \ldots n$.

4. *Calculate the distance of each alternative from S^* and S^-*

Definition 1. Let $\alpha = (\alpha_1, \alpha_2, \alpha_3)$ and $\beta = (\beta_1, \beta_2, \beta_3)$ be two triangular fuzzy numbers, the distance between them can be calculate as

$$d(\alpha, \beta) = \sqrt{\frac{(\alpha_1 - \beta_1) + (\alpha_2 - \beta_2) + (\alpha_3 - \beta_3)}{3}} \tag{2.9}$$

According to the definition 1, calculate the distance of each alternative from S^* and S^- by using formula (2.10) and (2.11):

$$d_i^* = \sum_{j=1}^{n} d\left(v_{ij}, v_j^*\right),\ i = 1, 2, \ldots m \tag{2.10}$$

$$d_i^- = \sum_{j=1}^{n} d\left(v_{ij}, v_j^-\right),\ i = 1, 2, \ldots m \tag{2.11}$$

5. *Calculate the closeness coefficient and Determine the ranking order*

The closeness coefficient of each alternative is calculated as

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \tag{2.12}$$

The ranking order of all alternatives can be determined by calculating the closeness coefficient. The alternative is closer to the FPIS (S^*) and father form FNIS (S^-) as CC_i approaches to 1. Therefore, we can know who the best alternative is.

2.4 Illustrative Example

Suppose there are three enterprises,A_1, A_2 and A_3 need to be selected as one partner of cooperation innovation alliance. Four evaluators M_1, M_2, M_3 and M_4 have been invited.

The importance weight and fuzzy weights of the criteria are assessed by evaluators as following as Table 2.3.

Table 2.3 The importance weight and fuzzy weights of the criteria

Criteria	Evaluators				Fuzzy weights
	M_1	M_2	M_3	M_4	
I_{11}	MH	ML	H	M	(0.4,0.6,0.78)
I_{12}	M	MH	M	H	(0.45,0.65,0.83)
I_{21}	H	VH	MH	H	(0.7,0.88,0.98)
I_{22}	H	MH	VH	M	(0.6,0.78,0.9)
I_{23}	ML	M	M	MH	(0.3,0.5,0.7)
I_{31}	H	M	ML	M	(0.35,0.55,0.73)
I_{32}	M	VH	H	H	(0.65,0.83,0.93)
I_{41}	VH	H	MH	ML	(0.55,0.73,0.85)
I_{42}	H	VH	M	MH	(0.6,0.78,0.9)
I_{43}	H	H	MH	M	(0.55,0.75,0.9)
I_{51}	MH	ML	H	VH	(0.55,0.73,0.85)
I_{52}	M	MH	M	VH	(0.5,0.68,0.83)

The linguistic rating variable (shown in Table 2.2) is used to evaluate the rating of alternatives. The normalized attribute value and the weighted normalized attribute value are constructed as Table 2.4.

Calculate the distance of alternative from the positive ideal alternative and the negative ideal alternative as Table 2.5.

Table 2.4 The weighted normalized attribute value of three alternatives by evaluators under all criteria

Criteria	Candidates	Evaluators				Fuzzy attribute value	Normalized attribute value	Weighted normalized attribute value
		M_1	M_2	M_3	M_4			
I_{11}	A_1	G	M	VG	M	(0.55,0.73,0.85)	(0.59,0.78,0.91)	(0.24,0.47,0.71)
	A_2	VG	BM	G	M	(0.60,0.78,0.90)	(0.65,0.84,0.97)	(0.26,0.50,0.76)
	A_3	M	VG	G	G	(0.65,0.83,0.93)	(0.70,0.89,1)	(0.28,0.53,0.78)
I_{12}	A_1	G	G	VG	BM	(0.70,0.88,0.98)	(0.71,0.90,1)	(0.32,0.59,0.83)
	A_2	M	WM	BM	G	(0.40,0.60,0.78)	(0.41,0.61,0.80)	(0.18,0.40,0.66)
	A_3	BM	M	G	G	(0.55,0.75,0.90)	(0.56,0.77,0.92)	(0.25,0.50,0.76)
I_{21}	A_1	M	G	BM	BM	(0.50,0.70,0.88)	(0.56,0.78,0.98)	(0.39,0.69,0.96)
	A_2	G	BM	M	G	(0.55,0.75,0.90)	(0.61,0.83,1)	(0.43,0.73,0.98)
	A_3	BM	M	WM	M	(0.30,0.50,0.70)	(0.33,0.56,0.78)	(0.23,0.49,0.76)
I_{22}	A_1	G	BM	M	G	(0.55,0.75,0.90)	(0.56,0.77,0.92)	(0.34,0.60,0.83)
	A_2	VG	VG	BM	G	(0.75,0.90,0.98)	(0.77,0.92,1)	(0.46,0.72,0.90)
	A_3	BM	VG	G	M	(0.60,0.78,0.90)	(0.61,0.80,0.92)	(0.37,0.62,0.83)
I_{23}	A_1	G	BM	BM	M	(0.50,0.70,0.88)	(0.54,0.75,0.95)	(0.16,0.38,0.67)
	A_2	M	G	WM	BM	(0.40,0.60,0.78)	(0.43,0.65,0.84)	(0.13,0.33,0.59)
	A_3	M	VG	VG	G	(0.70,0.85,0.93)	(0.75,0.91,1)	(0.23,0.46,0.70)
I_{31}	A_1	VG	WM	G	M	(0.50,0.68,0.80)	(0.56,0.76,0.89)	(0.20,0.42,0.65)
	A_2	BM	G	M	G	(0.55,0.75,0.90)	(0.61,0.83,1)	(0.21,0.46,0.73)
	A_3	G	VG	BM	M	(0.60,0.78,0.90)	(0.67,0.87,1)	(0.23,0.48,0.73)
I_{32}	A_1	BM	G	VG	G	(0.70,0.88,0.98)	(0.71,0.90,1)	(0.46,0.75,0.93)
	A_2	M	BM	G	VG	(0.60,0.78,0.90)	(0.61,0.80,0.92)	(0.40,0.66,0.86)
	A_3	BM	WM	G	VG	(0.55,0.73,0.85)	(0.56,0.74,0.87)	(0.36,0.61,0.81)
I_{41}	A_1	VG	G	G	BM	(0.70,0.88,0.98)	(0.71,0.90,1)	(0.39,0.66,0.85)
	A_2	M	M	BM	G	(0.45,0.65,0.83)	(0.46,0.66,0.85)	(0.25,0.48,0.72)
	A_3	M	G	VG	G	(0.65,0.83,0.93)	(0.66,0.85,0.95)	(0.36,0.62,0.81)
I_{42}	A_1	BM	M	BM	G	(0.50,0.70,0.88)	(0.51,0.71,0.90)	(0.34,0.55,0.81)
	A_2	VG	G	M	WM	(0.50,0.68,0.80)	(0.51,0.69,0.82)	(0.31,0.54,0.74)
	A_3	G	BM	G	VG	(0.70,0.88,0.98)	(0.71,0.90,1)	(0.43,0.70,0.90)
I_{43}	A_1	M	G	G	VG	(0.65,0.83,0.93)	(0.70,0.89,1)	(0.39,0.67,0.90)
	A_2	G	M	G	VG	(0.65,0.83,0.93)	(0.70,0.89,1)	(0.39,0.67,0.90)
	A_3	WM	BM	M	G	(0.40,0.60,0.78)	(0.43,0.65,0.84)	(0.24,0.49,0.76)
I_{51}	A_1	G	G	M	BM	(0.55,0.75,0.90)	(0.56,0.77,0.92)	(0.31,0.56,0.78)
	A_2	M	G	BM	M	(0.45,0.65,0.83)	(0.46,0.66,0.85)	(0.25,0.48,0.72)
	A_3	G	BM	VG	G	(0.70,0.88,0.98)	(0.71,0.90,1)	(0.39,0.66,0.85)
I_{52}	A_1	BM	G	VG	M	(0.60,0.78,0.90)	(0.60,0.78,0.90)	(0.30,0.53,0.75)
	A_2	G	VG	G	G	(0.75,0.93,1)	(0.75,0.93,1)	(0.38,0.63,0.83)
	A_3	M	G	BM	M	(0.45,0.65,0.83)	(0.45,0.65,0.83)	(0.23,0.44,0.69)

Table 2.5 The distance measurement

	s^*	s^-
A_1	5.7527	6.9612
A_2	5.8133	6.97
A_3	5.9693	6.9506

And calculate the closeness coefficient of each organization as $CC_1 = 0.5475$, $CC_2 = 0.5452$, $CC_3 = 0.5380$. The ranking order of organization is A_1, A_2 and A_3. Obviously, A_1 is the most suitable alternative as partner in cooperation innovation alliance.

2.5 Conclusion

Cooperation is considered an important component of innovation process. In this context, cooperation innovation alliance is constructed. Many enterprises, universities and research institutes cooperate in the areas of R&D and innovation. Partners' selection is the important segment of cooperation process. It decides the performance of cooperation innovation alliance. The study is mainly focused on partner selection problem of cooperation innovation alliance. It is a complex and multi-attribute decision-making problem. In this paper an index system of partner selection for cooperation innovation alliance is set up, and a fuzzy decision-making method basing on TOPSIS is proposed. In the future, core enterprise in cooperation innovation alliance should continuously take an in-depth look for the best method for selecting partners and cooperation model that can benefit knowledge cooperation innovation environment as well as knowledge cooperation performance.

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