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Comparison among three analytical methods for knowledge communities group-decision analysis

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Abstract

Knowledge management can greatly facilitate an organization's learning via strategic insight. Assessing the achievements of knowledge communities (KC) includes both a theoretical basis and practical aspect; however, a cautionary word is in order, because using improper measurements will increase complexity and reduce applicability. Group decision-making, the essence of knowledge communities, lets one considers multi-dimensional problems for the decision-maker, sets priorities for each decision factor, and assesses rankings for all alternatives. The purpose of this study is to establish the objective and measurable patterns to obtain anticipated achievements of KC through conducting a group-decision comparison. The three multiple-criteria decision-making methods we used, simple average weight (SAW), "Technique for Order Preference by Similarity to an Ideal Solution" (TOPSIS) and "VlseKriterijumska Optimizacija I Kompromisno Resenje" (VIKOR), are based on an aggregating function representing "closeness to the ideal point". The TOPSIS and VIKOR methods were used to highlight our innovative idea, academic analysis, and practical appliance value. Simple average weight (SAW) is known to be a common method to get the preliminary outcome. Our study provides a comparison analysis of the above-three methods. An empirical case is illustrated to demonstrate the overall KC achievements, showing their similarities and differences to achieve group decisions. Our results showed that TOPSIS and simple average weight (SAW) had identical rankings overall, but TOPSIS had better distinguishing capability. TOPSIS and VIKOR had almost the same success setting priorities by weight. However, VIKOR produced different rankings than those from TOPSIS and SAW, and VIKOR also made it easy to choose appropriate strategies. Both the TOPSIS and VIKOR methods are suitable for assessing similar problems, provide excellent results close to reality, and grant superior analysis.

Keywords: Knowledge Communities (KC); Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS); VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR); Multiple Criteria Decision Making (MCDM)

1. Introduction

Appraisal of KC in achievements will influence an organization's strategic focus, knowledge transfer, resource allocation, and management performance. Meanwhile, proper measurement and decision-making processes are critical for knowledge management success. We try to analyze group decision of knowledge communities (KC) in achievements through three methods to meet organizational demands. Sixteen criteria and four options were built on the basis of four dimensions – *leadership locus*, *incentive mechanism*, *member interaction*, and *complementary assets* – so as to establish multi-level and multi-criteria frameworks. The results revealed that when KC takes different approaches, their implementation orientations and major impacts differ. In the context of strategic goals and transformation, using different KC will influence resource allocation and overall achievement of success.

Multiple attribute decision making (MADM) and group decision-making are widely used, and there are many such modes proposed in the literature. The chief advantage of

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MADM is that it can give managers many dimensions to consider related elements, and evaluate all possible options under variable degrees. Group decision-making is a process where experts make decisions and consolidate an optimal strategy. Our study constructed a comparison analysis based on AHP (Analytical Hierarchy Process), TOPSIS, and VIKOR. First, we used AHP to establish hierarchy architecture and then expressed individual opinions by comparing pairs. After collecting KC experts' opinions, TOPSIS and VIKOR were utilized to make non-linear calculations so as to obtain final appraisal values from which one can choose the best option. Our analysis was applied to the achievements of KC and we sought to prove the methods' reusability. From the KC illustrative example, this analysis can achieve effective group decision-making faster without requiring long meetings. Its non-linear nature provides better results than do mathematical averages, especially when extreme bias or widely differing viewpoints exist among the decision-makers.

The performance alternatives were ranked according to different group decision methods. There are many key success factors for KC one must consider, and to try to find the best option, our study analyzes and discusses the priority settings based on the constructed model which compares the ranking outcomes among TOPSIS, VIKOR, and SAW. The purpose of this study is to highlight both the innovation and application values. Our three major goals were as follows:

1. Use the fuzzy AHP, TOPSIS, and VIKOR methods to establish an objective appraisal of the KC.
2. Take the case of an R&D organization to illustrate the values and empirical analysis, and to compare with results from the traditional SAW method.
3. Verify the theory, literature review, and applications.

TOPSIS was chosen as an alternative that should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative-ideal solution (NIS) for solving a multiple-criteria decision-making problem. The basic concept of VIKOR lies in first defining the positive and negative ideal solutions. The positive ideal solution is the alternative with the highest value while the negative ideal solution is the one with the least test value. The goal of this study was to use the above two methods to assess the KC value. Our questionnaire was composed of a wide literature review, experts' opinions, and included the 16 criteria and four performance alternatives on the basis of four dimensions (Fig. 2). This study analyzed compromise solutions under well-defined conditions, quantitative goals, and objectively hierarchy system of KC achievement options. The characteristics of our construction (Fig. 2) are considering multiple and trade-off practical problems, adopting multi-criteria solution to discuss the subjective cognition. Before distributing the questionnaires, we conducted a pre-run of this study with experts and then modified the inadequate parts to ensure all the questions could clearly express and measure the criteria. Four dimensions were utilized to construct the analysis: *leadership locus*, *incentive mechanism*, *member interaction*, and *complementary assets*. This let us establish a multi-level and multi-criteria framework. Proper ranking and priorities of KC performance were then assessed using the experts' questionnaires. The results could provide references for choosing the best KC solutions. After studying all related publications, this study applied a quantitative model to compensate for the deficiencies of existing KC analyses, such as subjective or qualitative viewpoints.

There are many dimensions to consider when assessing KC achievements with multiplicative hierarchy criteria (Kerzner, 1989). Many scholars have adopted AHP (Analytic Hierarchy Process) (Saaty, 1977, 1980) to obtain decision-making alternatives. Hwang and Yoon (1981) discuss the method and application of multi-attribute decision-making. It is easy for participants to complete questionnaires based on comparative importance, which parallels human logic, instead of using actual scores. In recent years, scholars have begun to apply Fuzzy AHP (Fuzzy Analytic Hierarchy Process) (Buckley, 1985) to resolve such fuzzy Linguistic Scale problems to facilitate expressions by study participants, such as Cheng and Mon (1994) in the selection of weapons systems.

An empirical case is illustrated to show the results of group decision-making. By adopting TOPSIS (Hwang & Yoon, 1981) and VIKOR (Opricovic, 1998) compared with SAW, this study explored both independent and interrelated criteria. We analyzed 57 questionnaires with software such EcPro (AHP) and Excel and the resulting analysis and explanations are as follows:

For TOPSIS and SAW, the results showed that the utility value of *increased core competency* was highest, followed in order by that of *enhanced work efficiency*, *induced innovative learning*, and *promoted responsiveness*.

For VIKOR, the results showed that the utility value of *increased core competency* was highest, followed by that of *enhanced work efficiency*, *promoted responsiveness*, and *induced innovative learning*.

From the above three methods, the ranking and priorities of TOPSIS and SAW were found to be the same, but TOPSIS and VIKOR had better distinguishing abilities.

The remainder of this paper is organized as follow. Basic concepts and comparisons of KCs are introduced in Section 2. In Section 3 methods of TOPSIS and VIKOR are reviewed. In Section 4 illustrates an empirical case for assessing the architectures of KC in achievements is illustrated to demonstrate the proposed methods. Discussion are presented in Section 5. Finally, we provide conclusions and remarks in last section.

2. Basic concepts and comparisons of KCs in achievement

Most Knowledge Management (KM) projects stress explicit knowledge. However, being able to exchange tacit knowledge is more important today than ever. Current

KMs' central themes emphasize people issue, especially how to cross-organizational boundaries in achievement. As the KM era is coming, KC seems the best way to acquire tacit knowledge nowadays. Therefore, in this subsection the basic concepts of KC implications, KC benchmarking, KC value and comparisons of four KC in achievement.

2.1. KC implications

There are different positions and goals in various KC. Although the names differ, the different terms describe similar content and ideas. In 2000, Verna Allee thought knowledge should include and utilize KC to create organizational knowledge. In 1998, Etienne Wenger first proposed KC in the *Harvard business review.* He believes that KC is informal groups sharing knowledge and passion and pointed out that KC are composed of the three critical elements shown in Table 1.

2.2. KC benchmarking

There is additional team formation in the organization besides KC; examples include formal divisions, project teams, informal networks, and so on. This study compared the four kinds of benchmarking for pursuing targets/goal that will help one understand a KCs characteristics and their appearances (Cohendet & Meyer-Krahmer, 2001; Verna, 2000; Wenger, McDermott, & Snyder, 2002) (Table 2 and 3).

2.3. KC value

KC not only helps organizations, but they help individuals to create the value also. KC is an effective way to share knowledge, and the studies below state their many strengths and values (Wenger, 1998).

2.4. Four KC in achievements

Wenger and Etienne (1998) points out that the intellectual assets residing in KC can lead to positive behavioral changes, which in turn lead to positive influences on the organization. When KC prefers explicit knowledge content, the operation focus tends to reuse intellectual property, emphasizing the storage, access, and reuse of knowledge. In contrast, when KC focuses on promoting working efficiency, they primarily send warnings through analysis and classification of knowledge and also speed up responsiveness. When KC prefers tacit knowledge, however, the operation's key goal is to create collective learning fields, letting experts' exchange, interact with, and shift best practices. This kind of KC raises the capability and facilitates innovation through cross-domain exchanges.

When KC emphasizes competency and efficiency, their organizational performance will stress keeping costs down; on the other hand, KC that focus on innovation and responsiveness will stress keeping revenues up. Our study differentiates among these four KC in achievement as alternatives by examining their different operation modes and performance (Fig. 1).

The first alternative is to *induced innovative learning.* Characteristics include cross-domain studies and sharing to facilitate the innovation, creation, and generation of common interests. These KC also establish safe infrastructures by trial and error.

The second alternative is to *promoted responsiveness.* By collecting and classifying knowledge, KC can directly solve problems because colleagues with similar experience are easy to find. They can help other members who are facing questions because they have a common dictionary and familiarity with the language.

The third alternative is to *increased core competency.* Colleagues promote skills by shifting knowledge practices, providing experts, increasing communication between senior and junior members, and teaching the organization's agreements and customs to its newer members.

The fourth alternative is to *enhanced working efficiency.* KC can reuse already-existing intellectual property, share related documents and information, and enhance productivity with easy-to- study practical knowledge.

The differences between the above-mentioned alternatives lie in the organizational performance and operation modes. Some greatly reduce costs while others increase earnings. Some focus primarily on group learning while some reuse intellectual assets (IA) as a favorable base.

Recognizing that KC affect performance is important because of KC' potential to overcome the inherent problems of a slow-moving, traditional hierarchy in a fast-moving knowledge economy. Associated with the KC, four specific alternatives were identified to link these outcomes toward the multi-dimension criteria. Our study used four

Table 1
Analysis of KC critical elements

Critical elements	Mutual engagement	Joint enterprise	Shared repository
Description	Refers to the actual participation and commitment of people. KC does not only gather people and give the names. The important key is peoples' common interest	At the beginning, the KC forms and members pursue the direction as KC, simultaneously creating the common responsibility relations within the group, usually by affiliates, visions, or goals	In the process of pursuing the common vision, members create resources, namely knowledge banks, containing know-how, methodology, and methods in community

Source: Wenger (1998, Cambridge University Press).

Table 2
Comparison of KC and other groups

Item/group category	Knowledge communities	Formal division	Project team	Informal network
Purpose	1. Share knowledge 2. Promote problem solving skill 3. Accumulate organization knowledge	1. Responsible for divisional function 2. Specialized task assignment	1. Complete project target 2. Cooperation cross divisions	Integrate and exchange valuable information
Teaming	Participate by free will	Lead by division manager	Choose by project leader	Common interest or mutual trust
Characters of members	Similar	Similar	Different	Different
Boundary	Vague	Clear	Clear	Undecided
Driving force	Passion, trust, sense of Identity, commitment	Goal of division	Goal of project	Meet needs each other
Duration	As long as common interest exists	Until reorganization	Until end of project	Lack of definite starting & ending

Source: Verna (2000); Wenger and Snyder (2000); Cohendet and Meyer-Krahmer (2001); Wenger et al. (2002).

Table 3
How KCs help different entities

Entity	Enterprise	Community	Individual
Value	1. Realize organizational strategies 2. Solve cross-field problems quickly 3. Help recruit talent 4. Construct core competency and competitive advantage 5. Reuse best practices 6. Increase innovation	1. Build common language, methods, and models 2. Establish knowledge and expert banks 3. Help knowledge transmission 4. Increase opportunity to find experts 5. Provide power sharing and influence	1. Work efficiency 2. Increase sense of safety for company and colleagues 3. Promote learning 4. Increase skill and competency 5. Offer contribution and face challenges

Source: Verna (2000); Wenger and Snyder (2000); Cohendet and Meyer-Krahmer (2001); Wenger et al. (2002).

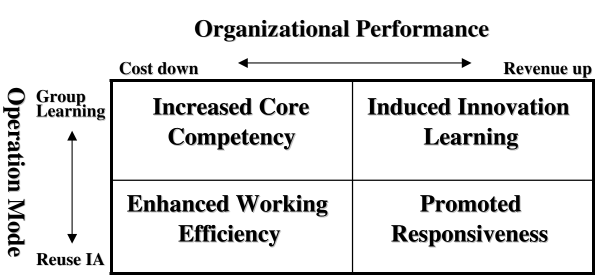

Fig. 1. Four kinds of KC achievements.

alternatives – *induced innovative learning*, *promoted responsiveness*, *increased core competency*, and *enhanced working efficiency* – to discuss the KC performance alternatives. A thorough discussion and analysis of the choices showed that KC alternatives are desirable because they will influence the KM achievements and the community's resource allocation. Table 4 shows that the study follows actual experiences and explains the four KC alternative results.

3. Methods of TOPSIS and VIKOR for KC in achievement

Before building an illustrative example to analyze KC achievements, this section discusses the optimal ranking methods used by multi-criteria decision-making, TOPSIS and VIKOR, as a theoretical basis for the following applications.

3.1. TOPSIS

Multiple-criteria decision-making (MCDM) is used to select a project from several alternatives according to various criteria. Hwang and Yoon (1981) first developed The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The TOPSIS approach is based on the idea that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative-ideal solution (NIS) for solving multiple-criteria decision-making problems. In short, the ideal solution is composed of all the best criteria, whereas the negative ideal solution is made up of all the worst attainable criteria. The calculation processes for this method are as follows:

(1) Normalize the appraisal matrix.
This process transforms different scales and units among various criteria into common measurable units to allow for comparisons of different criteria. Assume x_{ij} is the appraisal matrix R of alternative i under appraisal crite-

Table 4
Comparison of the four KC alternative results

Alternative/dimension	Connection	Interface	Entity	Performance	Key point
Induced innovative learning	Support new ideas and creativity	Establish safe infrastructure for new thinking	Common interest	Revenues up	Group leaning
Promoted responsiveness	Find people with similar experience	Willing to respond to problems	Common language	Revenues up	Reuse IA
Increased core competency	Find experts	Coach of new knowledge	Regulation	Costs down	Group learning
Enhanced working efficiency	Find developed practice	Positive recognition	Know how	Costs down	Reuse IA

rion j; in that case, an element r_{ij} of the normalized appraisal matrix R can be calculated by many normalization methods to achieve this objective.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n. \tag{1}$$

(2) Construct the weighted normalized appraisal matrix. Each appraisal criterion cannot be assumed to be of equal importance because the appraisal criteria have various meanings. There are many methods that can be employed to determine weights, such as the eigenvector method, weighted lease square method, entropy method, AHP, as well as linear programming techniques for multidimensional of analysis preference (LINMAP). The method you choose depends on the nature of the problem. The weighted normalized appraisal matrix can be calculated by multiplying the normalized appraisal matrix r_{ij} with its associated weight w_j to obtain the result v_{ij}:

$$v_{ij} = r_{ij} \times w_j, \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n. \tag{2}$$

(3) Determine the positive and negative ideal solutions. This step can get A^+ and A^- to be the basis to calculate the distances. The positive ideal solution A^+ indicates the most preferable alternative while the negative ideal solution A^- indicates the least preferable alternative. The formulas are as follows:

$$A_j^* = \{(\mathrm{Max}_i v_{ij} | j \in J), (\mathrm{Min}_i v_{ij} | j \in J') | i = 1, 2, \ldots, n\} = \{v_1^*, v_2^*, \ldots, v_j^*, \ldots, v_n^*\}, \tag{3}$$

$$A_j^- = \{(\mathrm{Min}_i v_{ij} | j \in J), (\mathrm{Max}_i v_{ij} | j \in J') | i = 1, 2, \ldots, n\} = \{v_1^-, v_2^-, \ldots, v_j^-, \ldots, v_n^-\}, \tag{4}$$

where A_j^* is the positive ideal solution for the jth criteria, A_j^- is the negative ideal solution for the jth criteria. If associate all A_j^* will have the optimal combinations, which get the highest scores, same as A_j^-.
(4) Calculate the separation measure.
The n-criteria evaluation distance can measure the separation from the positive and negative ideal solution for each alternative.

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \quad i = 1, 2, \ldots, n, \tag{5}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \quad i = 1, 2, \ldots, n. \tag{6}$$

(5) Calculate the relative closeness to the ideal solution. The relative closeness of the ith alternative with respect to the ideal solution A^+ is defined as C_i^*. If alternative i is the positive ideal solution, then $C_i^* = 1$; however, if

alternative i is the negative ideal solution, then $C_i^* = 0$. In other words, if the value of C_i^* is closer to 1, the alternative i will be closer to the positive ideal solution.

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-}, \quad 0 < C_i^* < 1, \; i = 1, 2, \ldots, n. \tag{7}$$

(6) Rank the priority.
A set of alternatives can then be preference ranked according to the descending order of C_i^*.

3.2. VIKOR

Opricovic (1998) and Opricovic and Tzeng (2002) developed VIKOR (the Serbian name, *VlseKriterijumska Optimizacija I Kompromisno Resenje*, means Multi-criteria Optimization and Compromise Solution). This method is based on the compromise programming of multi-criteria decision making (MCDM). Our study used VIKORs ranking method.

The basic concept of VIKOR lies in defining the positive and negative ideal solutions first. The positive ideal solution indicates the alternative with the highest value (score of 100) while the negative ideal solution indicates the alternative with the lowest value (score of 0).

(1) Calculate the normalized value.
For the process of normalized value, when x_{ij} is the original value of the ith option and the jth dimension, the formula is as follows:

$$f_{ij} = X_{ij} \Big/ \sqrt{\sum_{i=1}^{m} X_{ij}^2}, \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n. \tag{8}$$

(2) Determine the best and worst values.
For all the criteria functions the best value was f_j^* and the worst value was f_j^-; that is, for criterion $I = 1, n$, we have formulas (9) and (10)

$$f_j^* = \text{Max}_i f_{ij}, \quad i = 1, 2, \ldots, m, \tag{9}$$

$$f_j^- = \text{Min}_i f_{ij}, \quad i = 1, 2, \ldots, m. \tag{10}$$

When f_j^* is the positive ideal solution for the jth criteria, f_j^- is the negative ideal solution for the jth criteria. If one associates all f_j^*, one will have the optimal combination, which gets the highest scores, the same as f_j^-.
(3) Distance and calculation of final value.
(1) Compute the values s_i and R_i for $i = 1, I$ which is defined as follows:
This step is to calculate the distance from each KC value to the positive ideal solution and then get the sum to obtain the final value. (See formula (11) and (12).)

$$S_i = \sum_{j}^{n} w_i (f_j^* - f_{ij}) / (f_j^* - f_j^-), \tag{11}$$

$$R_i = \text{Max}_j [w_i (f_j^* - f_{ij}) / (f_j^* - f_j^-)], \tag{12}$$

where s_i represents the distance rate of the ith KC achievement to the positive ideal solution (best combination), R_i represents the distance rate of the ith KC achievement to the negative ideal solution (worst combination). The excellence ranking will be based on s_i values and the worst rankings will be based on R_i values. Then, using the following equations, we can calculate the final value.
(2) Compute the values I_i for $i = 1, \ldots, I$, which are defined as

$$I_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1 - v)\left[\frac{R_i - R^*}{R^- - R^*}\right], \tag{13}$$

where $S^* = \text{Min}\, s_i$, $S^- = \text{Max}\, s_i$, $R^* = \text{Min}\, R_i$, $R^- = \text{Max}\, R_i$, and v is a weighting reference. $[(S^- - S^*)/(S - S^*)]$ represents the distance rate from the positive ideal solution of the ith KC achievements In other words, the majority agrees to use the rate of the ith. $[(R^- - R^*)/(R - R^*)]$ represents the distance rate from the negative ideal solution of the ith KC achievements; this means the majority disagree with the rate of the ith KC achievements. Thus, when the v reference is larger (>0.5), the index of I_i will tend to majority rule.

3.3. Discussion and comparisons

The reason for using both TOPSIS and VIKOR is due to the different effects of this study's criteria. For example, when case A gets high grades in most criteria (scores of 80 in 15 criteria), but one criteria grade is very low (score of 50 in 1 criterion), its final value is 1250. In contrast, when case B gets average grades in all criteria (scores of 70 in 16 criteria), its final value is 1120. From the organization's viewpoint, case B is preferable to A. However, one might choose case A over B based on SAW (1250 > 1120). Therefore, this study uses both TOPSIS and VIKOR to set rankings, where S_i is the sum of the distance from PIS and R_i is the sum of the distance from NIS; the rankings will thus provide two reference numbers. Finally, set v to 0.5; we will consider both majority rule and high than the lower value. This proves that TOPSIS and VIKOR together have better distinguishing ability than does traditional SAW for clarifying assessment results.

4. Establishing multi-goal and criteria appraisal models

We constructed a multi-goal and multi-criteria assessment model and established analytical procedures, including a hierarchy structure, questionnaire formats, participants' selections, and performance alternatives for KC based on Fuzzy MCDM theory.

4.1. Forming a study model

The aim of this section is to build a multi-objective and multi-standard evaluation model for KC achievements. The three steps in building the model are:

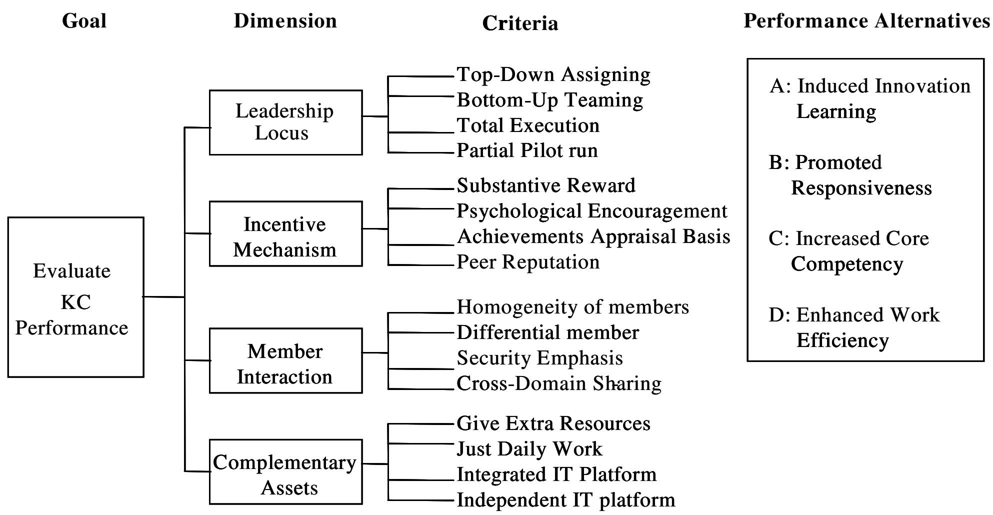

Fig. 2. The hierarchy system of KC achievements options.

Table 5
Statistical numbers of questionnaires

Groups	Sent	Received	Valid questionnaires	Ratio of effectiveness
Essential technology R&D	18	15	13	72.2%
Advanced technology R&D	18	13	12	66.6%
Key technology reforming	18	14	13	72.2%
Professional task service	21	20	19	90.4%
Total/ratio	75	62	57	76.0%

1. Describe the situation.
2. Establish the multi-goal construction and tree-shape correlation.
3. Evaluate the results.

First, to form a study model, invite experts in the field for brainstorming and discussion. Second, to generate consensus, answer the questions on the basis of the literature review, this study is built on four dimensions – *leadership locus, incentive mechanism, member interaction, and complementary assets*to construct the second-tier criteria.

Table 6
Dimension and criteria weight of each group

Group/weight (rank)/criteria		Essential technology R&D	Advanced technology R&D	Key technology reforming	Professional task service	Rank
Leadership locus	Top-down assigning	0.087 (3)	0.122 (1)	0.037 (12)	0.063 (5)	(4)
	Bottom-up teaming	0.034 (15)	0.036 (14)	0.024 (16)	0.050 (11)	(15)
	Total execution	0.068 (7)	0.054 (10)	0.027 (15)	0.032 (15)	(13)
	Partial pilot run	0.050 (10)	0.062 (6)	0.030 (14)	0.082 (4)	(9)
Incentive mechanism	Substantive reward	0.085 (4)	0.073 (5)	0.081 (5)	0.062 (7)	(5)
	Psychological encouragement	0.044 (11)	0.055 (8)	0.034 (13)	0.037 (14)	(14)
	Achievements appraisal basis	0.088 (2)	0.111 (2)	0.070 (7)	0.107 (2)	(2)
	Peer reputation	0.051 (9)	0.052 (11)	0.052 (11)	0.056 (9)	(11)
Member interaction	Homogeneity of members	0.043 (12)	0.059 (7)	0.076 (6)	0.046 (12)	(10)
	Differential member	0.039 (14)	0.055 (8)	0.061 (8)	0.100 (3)	(6)
	Security emphasis	0.022 (16)	0.093 (3)	0.094 (2)	0.063 (5)	(7)
	Cross-domain sharing	0.085 (4)	0.093 (3)	0.085 (4)	0.118 (1)	(1)
Complementary assets	Give extra resource	0.075 (6)	0.047 (12)	0.093 (3)	0.055 (10)	(7)
	Just daily work	0.057 (8)	0.025 (15)	0.054 (10)	0.042 (13)	(12)
	Integrated IT platform	0.127 (1)	0.042 (13)	0.126 (1)	0.058 (8)	(3)
	Independent IT platform	0.043 (12)	0.021 (16)	0.057 (9)	0.028 (16)	(15)

P.S. All errors are less than 0.002.

The *leadership locus* dimension contains four criteria: top-down assigning, bottom-up teaming, total execution, and partial pilot run.

The *incentive mechanism* dimension contains four criteria: substantive reward, psychological encouragement, achievements appraisal basis, and Peer Reputation.

The *member interaction* dimension contains four criteria: homogeneity of members, differential members, security emphasis, and cross-domain sharing.

The *complementary assets* dimension contains four criteria: Give extra resources, just daily work, integrated IT platform, and Independent IT platform.

The goal is to evaluate KC performance alternatives. Next, four dimensions are created to assess the 16 criteria. Fig. 2 shows the appraisal hierarchy system.

Solving the target of this research, we use the first layer dimensions and the second layer criteria to establish the hierarchy system of KC achievements model as Fig. 2.

4.2. Weight of hierarchy model

The target of this study's questionnaire included 75 experts with KC experience. Seventy-five questionnaires were distributed and divided into four distinct groups:

Essential Technology R&D Groups: 19 questionnaires
Advanced Technology R&D Groups: 20 questionnaires
Key Technology Reforming Groups: 16 questionnaires
Professional Task Service Groups: 20 questionnaires

This study used the average weight of four groups to be the standard of criteria assessment. We received 57 valid questionnaires expressing opinions toward the 16 criteria (Tables 5 and 6).

Table 7
TOPSIS practice designs

Item/criteria			c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
SAW (w_j)			w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}
Criteria value (r_{ij})		1	r_{11}	r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	r_{17}	r_{18}	r_{19}	r_{110}	r_{111}	r_{112}	r_{113}	r_{114}	r_{115}	r_{116}
		2	r_{21}	r_{22}	r_{23}	r_{24}	r_{25}	r_{26}	r_{27}	r_{28}	r_{29}	r_{210}	r_{211}	r_{212}	r_{213}	r_{214}	r_{215}	r_{216}
		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		n	r_{n1}	r_{n2}	r_{n3}	r_{n4}	r_{n5}	r_{n6}	r_{n7}	r_{n8}	r_{n9}	r_{n10}	r_{n11}	r_{n12}	r_{n13}	r_{n14}	r_{n15}	r_{n16}
Weighted value (v_{ij})		1	v_{11}	v_{12}	v_{13}	v_{14}	v_{15}	v_{16}	v_{17}	v_{18}	v_{19}	v_{110}	v_{111}	v_{112}	v_{113}	v_{114}	v_{115}	v_{116}
		2	v_{21}	v_{22}	v_{23}	v_{24}	v_{25}	v_{26}	v_{27}	v_{28}	v_{29}	v_{210}	v_{211}	v_{212}	v_{213}	v_{214}	v_{215}	v_{216}
		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		n	v_{n1}	v_{n2}	v_{n3}	v_{n4}	v_{n5}	v_{n6}	v_{n7}	v_{n8}	v_{n9}	v_{n10}	v_{n11}	v_{n12}	v_{n13}	v_{n14}	v_{n15}	v_{n16}
(PIS) A_j^*			A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*	A_j^*
(NIS) A_j^-			A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-	A_j^-
Options	S_i^-	S_i^-	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
1	S_{1i}^-	S_{1i}^*	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	S_{17}	S_{18}	S_{19}	S_{110}	S_{111}	S_{112}	S_{113}	S_{114}	S_{115}	S_{116}
2	S_{2i}^-	S_{2i}^*	S_{21}	S_{22}	S_{23}	S_{24}	S_{25}	S_{26}	S_{27}	S_{28}	S_{29}	S_{210}	S_{211}	S_{212}	S_{213}	S_{214}	S_{215}	S_{216}
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
m	S_{mi}^-	S_{mi}^*	S_{m1}	S_{m2}	S_{m3}	S_{m4}	S_{m5}	S_{m6}	S_{m7}	S_{m8}	S_{m9}	S_{m10}	S_{m11}	S_{m12}	S_{m13}	S_{m14}	S_{m15}	S_{m16}

Table 8
VIKOR practice designs

Item/criteria			c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
Average weight			w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}
Value		1	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}	f_{16}	F_{17}	f_{18}	f_{19}	f_{110}	f_{111}	f_{112}	f_{113}	f_{114}	f_{115}	f_{116}
		2	f_{21}	f_{22}	f_{23}	f_{24}	f_{25}	f_{26}	F_{27}	f_{28}	f_{29}	f_{210}	f_{211}	f_{212}	f_{213}	f_{214}	f_{215}	f_{216}
		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		n	f_{n1}	f_{n2}	f_{n3}	f_{n4}	f_{n5}	f_{n6}	f_{n7}	f_{n8}	f_{n9}	f_{n10}	f_{n11}	f_{n12}	f_{n13}	f_{n14}	f_{n15}	f_{n16}
	PIS		f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*	f_j^*
	NIS		f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-	f_j^-
KC	Distance of NIS R_i	Distance of PIS S_i	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
1	R_{1j}	S_{1j}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	S_{17}	S_{18}	S_{19}	S_{110}	S_{111}	S_{112}	S_{113}	S_{114}	S_{115}	S_{116}
2	R_{2j}	S_{2j}	S_{21}	S_{22}	S_{23}	S_{24}	S_{25}	S_{26}	S_{27}	S_{28}	S_{29}	S_{210}	S_{211}	S_{212}	S_{213}	S_{214}	S_{215}	S_{216}
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
n	R_{nj}	S_{nj}	S_{n1}	S_{n2}	S_{n3}	S_{n4}	S_{n5}	S_{n6}	S_{n7}	S_{n8}	S_{n9}	S_{n10}	S_{n11}	S_{n12}	S_{n13}	S_{n14}	S_{n15}	S_{n16}

Table 9
KC Final value ranking of n KC

KC achievements/final value (ranking)/v value	0.1	0.2	0.3	0.4	0.5[a]	0.6	0.7	0.8
1	I_1	I_1	I_1	I_1	I_1	I_1	I_1	I_1
2	I_2	I_2	I_2	I_2	I_2	I_2	I_2	I_2
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
n	I_n	I_n	I_n	I_n	I_n	I_n	I_n	I_n

[a] v ordinary value setting.

4.3. Empirical practice model description

(1) TOPSIS practice.
To simplify the following calculation and example, our study used a practice example of TOPSIS where $c_1 \sim c_{16}$ was the criteria and w_j was the simple average weight. According to the weights in Table 6 and formula (1), we established a normalized matrix in the third array; r_{ij} represents the criteria value. The fourth array will get the weighting value matrix v_{ij}, which is w_j multiple r_{ij}. Then, on the basis of formulas (3) and (4), we obtained PIS (A_j^*), NIS (A_j^-), the distance from PIS (S_i^*), the distance from NIS (S_i^-), and the relative approximate value (C_i^*) and ranking (Table 7).
(2) VIKOR practice.
This research assumed there are n KC achievements to assess. We used 16 average-weight ($c_1 \sim c_{16}$) follow Fig. 2 and Table 6, and combined the values acquired by AHP. We derived the PIS and NIS from Table 8 and then put the values into formulas (8)–(10). We computed the distance from each value to PIS based on formulas (11) and (12). Table 5 represents the preferred KC achievements by ranking the results. Wherever v is larger (>0.5), the index of I_i will prefer majority rule, and vice versa. Therefore, decision-makers should adjust the v reference; it is ordinarily 0.5, which means we might use VIKOR when many people are involved in assessment but use TOPSIS when few are involved (Table 9).

5. Empirical analysis and discussion

Some R&D organizations are assessed according to their KC achievements based on the average weight of four groups analyzed and discussed from the standpoint of four values. First, we adopted the weight found in Table 6. Second, we calculated the values, PIS, NIS, and distances. Finally, we obtained the KC final value and ranking.

5.1. Weight of criteria

Among the 16 criteria weights, the *cross-domain sharing* score was the highest (0.098), followed by those of *achieve-*

Table 10
Average weights of 16 criteria

Criteria	Leadership locus				Incentive mechanism			
	Top-down assigning	Bottom-up teaming	Total execution	Partial pilot run	Substantive reward	Psychological encouragement	Achievements appraisal basis	Peer reputation
Weight (ranking)	0.075 (4)	0.037 (15)	0.044 (13)	0.059 (9)	0.074 (5)	0.042 (14)	0.095 (2)	0.053 (11)
Criteria	Member interaction				Complementary assets			
	Homogeneity of members	Differential member	Security emphasis	Cross-domain sharing	Give extra resource	Just daily work	Integrated IT platform	Independent IT platform
Weight (ranking)	0.055 (10)	0.068 (6)	0.067 (7)	0.098 (1)	0.067 (7)	0.045 (12)	0.086 (3)	0.037 (15)

ments appraisal basis (0.095) and *integrated IT platform* (0.086), while *independent IT platform* was the lowest (0.037).

5.2. Effective value of KC

(1) Utilizing the effective values of KC achievements, the criteria data of this study as Table 11.
(2) Distances from PIS and NIS.
(i) TOPSIS.
The best and worst values will be acquired in this step so as to calculate the distances. Table 11 explains the distances from PIS and NIS (Tables 12 and 13).
(ii) VIKOR.
Each KC achievement will be computed in this step by VIKOR. First, add the distances from the ideal solution, then obtain the distances from PIS (S_i) and NIS (R_i) (Table 14).

5.3. Final values and ranking

v value was set from 0.1 to 1.0 to calculate and rank our findings (Table 15). According to VIKOR, when v is larger (>0.5), the I_i index will prefer majority rule. Our study set $v = 0.5$ to get the final value and ranking: 1. *increased core competency*, 2. *promoted responsiveness*, 3. *enhanced working efficiency*, 4. *induced innovative learning* (Table 16).

5.4. Discussion

Our Group decision analysis utilizes the same dimensions and criteria to assess KC achievements. Our analysis can meet the appraisal goal based on the same baseline, but the weight importance will differ depending on the nature of each KC. In sum, our study used a real case to prove that the model combines theory and practical experience. Our approach is applicable and feasible, and closes the gap between anticipated results and actual problem solving. We also completed the comparison analysis among TOPSIS, VIKOR, and SAW methods. The findings further demonstrated that *increased core competency* was the highest among the three methods. Even though the ranking outcomes were the same, TOPSIS and VIKOR were both better at clarifying the differences between alternatives than SAW could. Our results prove that traditional methods are not better than TOPSIS or VIKOR for getting clear KC results. TOPSIS is one of the MCDA evaluation methods that used a compromise solution. TOPSIS should satisfy the closest to the positive ideal solution and the farthest from the negative ideal solution. We achieved the final value to implement the multi-goal group decisions by calculating the comparative distance from the ideal solution. TOPSIS set $p = 2$ to express the largest Max-Min variance to find the solution. In contrast, VIKOR set $p = 1$ (each variance had the same weight) and $p = \infty$ (to only express the weight of the largest variance) to find the two distances and to set weight v and $1 - v$ to justify all possible combinations.

Carrying on the priority analysis using VIKOR, the minority bias was avoided and the majority opinions were represented. VIKOR may be used in the multi-goal decision-making for many reasons. First, it helps to find the final decision index as does TOPSIS, but VIKOR also takes the side effects into consideration. Second, VIKOR uses relative distances and different computing modes and weights to formulate an overall target minority injury are smallest when considering the side effect in situation. There

Table 11
Effective values of four KC achievements

Group/weight (rank)/criteria		Induced innovative learning	Promoted responsiveness	Increased core competency	Enhanced working efficiency
Leadership locus	Top-down assigning	66	70	79	77
	Bottom-up teaming	79	72	72	70
	Total execution	63	72	72	74
	Partial pilot run	75	68	75	71
Incentive mechanism	Substantive reward	70	69	75	77
	Psychological encouragement	78	72	72	74
	Achievements appraisal basis	70	74	77	79
	Peer reputation	78	72	73	80
Member interaction	Homogeneity of members	58	67	72	75
	Differential member	82	68	70	67
	Security emphasis	56	57	67	63
	Cross-domain sharing	83	75	75	70
Complementary assets	Give extra resource	74	72	75	74
	Just daily work	59	66	67	70
	Integrated IT platform	76	77	77	80
	Independent IT platform	66	66	69	65

Table 12
PIS and NIS regarding 16 criteria

Criteria	Leadership locus				Incentive mechanism			
	Top-down assigning	Bottom-up teaming	Total execution	Partial pilot run	Substantive reward	Psychological encouragement	Achievements appraisal basis	Peer reputation
PIS	79	79	74	75	77	78	79	80
NIS	70	70	63	68	69	72	70	72
Criteria	Member interaction				Complementary assets			
	Homogeneity member	Differential member	Security emphasis	Cross-domain sharing	Give extra resource	Just daily work	Integrated IT platform	Independent IT platform
PIS	75	82	67	83	75	70	80	69
NIS	58	67	56	70	72	59	76	65

Table 13
Distance from PIS and NIS (by TOPSIS)

Group/weight (rank)/criteria		Induced innovative learning	Promoted responsiveness	Increased core competency	Enhance working efficiency
Distance from NIS		0.000143	0.000045	0.000179	0.000180
Distance from PIS		0.000201	0.000188	0.000077	0.000136
Leadership locus	Top-down assigning	0.075	0.049	0.000	0.011
	Bottom-up teaming	0.000	0.030	0.030	0.037
	Total execution	0.044	0.006	0.006	0.000
	Partial pilot run	0.000	0.059	0.000	0.032
Incentive mechanism	Substantive reward	0.070	0.074	0.024	0.000
	Psychological encouragement	0.000	0.042	0.039	0.028
	Achievements appraisal basis	0.095	0.061	0.023	0.000
	Peer reputation	0.016	0.053	0.044	0.000
Member interaction	Homogeneity member	0.055	0.025	0.009	0.000
	Differential member	0.000	0.060	0.051	0.068
	Security emphasis	0.067	0.062	0.000	0.022
	Cross-domain sharing	0.000	0.063	0.061	0.098
Complementary assets	Give extra resource	0.019	0.067	0.000	0.005
	Just daily work	0.045	0.017	0.011	0.000
	Integrated IT platform	0.086	0.068	0.068	0.000
	Independent IT platform	0.031	0.031	0.000	0.037

Table 14
Distances from PIS and NIS (by VIKOR)

Group/weight (rank)/criteria		Induced innovative learning	Promoted responsiveness	Increased core competency	Enhanced working efficiency
Distance from NIS		0.095	0.074	0.068	0.098
Distance from PIS		0.602	0.764	0.365	0.338
Leadership locus	Top-down assigning	0.075	0.049	0.000	0.011
	Bottom-up teaming	0.000	0.030	0.030	0.037
	Total execution	0.044	0.006	0.006	0.000
	Partial pilot run	0.000	0.059	0.000	0.032
Incentive mechanism	Substantive reward	0.070	0.074	0.024	0.000
	Psychological encouragement	0.000	0.042	0.039	0.028
	Achievements appraisal basis	0.095	0.061	0.023	0.000
	Peer reputation	0.016	0.053	0.044	0.000
Member interaction	Homogeneity of members	0.055	0.025	0.009	0.000
	Differential member	0.000	0.060	0.051	0.068
	Security emphasis	0.067	0.062	0.000	0.022
	Cross-domain sharing	0.000	0.063	0.061	0.098
Complementary assets	Give extra resource	0.019	0.067	0.000	0.005
	Just daily work	0.045	0.017	0.011	0.000
	Integrated IT platform	0.086	0.068	0.068	0.000
	Independent IT platform	0.031	0.031	0.000	0.037

Table 15
Final values and rankings using TOPSIS

Achievements/final values and rankings	Positive ideal solution	Negative ideal solution	Final value	Ranking
Induced innovative learning	0.000201	0.000143	0.415	3
Promoted responsiveness	0.000188	0.000045	0.192	4
Increased core competency	0.000077	0.000179	0.700	1
Enhanced working efficiency	0.000136	0.000180	0.569	2

are PIS but no NIS in VIKOR. When comparing TOPSIS and VIKOR, there are two major differences.

1. TOPSIS considers majority rule while VIKOR considers the smallest injures, and,
2. TOPSIS adds weight in the distance calculation while VIKOR adds weight in the final value.

The rankings will be almost identical if the processes follow the same weight between TOPSIS and VIKOR, but there will be different results when VIKOR is designed to give more choices for decision-makers. In sum, when there are explicit parameters, we should use VIKOR, but when we lack an explicit v value, we should use TOPSIS. The priority settings are the same between TOPSIS and SAW, but SAW values are all extremely close and so it is hard to identify the differences. Our study compared the three methods that we hope will give policy-makers more informed choices (Table 17).

6. Conclusions and suggestions

KC is both an important tool for condensing cross-domain integration energy and a source of core competency. When choosing specific infrastructures to implement KC, firms should first decide which of the four achievements they want their KC to achieve, and let that goal drive the decision. The main goal of this research is to construct a group-decision analysis to enhance knowledge sharing. In order to realize this target, *leadership locus*, *incentive mechanism*, *member interaction*, and *complementary assets* should be taken into consideration. Our study analyzed the weights and values of four dimensions and 16 criteria with an actual case, conducted real diagnostic analysis, and discussed validity and usability. We hope our research can help provide firms with valuable references when implementing KC.

6.1. Conclusions

Anticipated achievements of KC will guide different goals and ways; therefore, establishing objective and measurable patterns is a critical issue for further research.

Table 16
Final values and rankings using VIKOR

Achievements/final values/v values	0.1	0.2	0.3	0.4	0.5[a]	0.6	0.7	0.8	0.9	1.0
Induced innovative learning	0.120 (3)	0.149 (4)	0.177 (4)	0.206 (4)	0.235 (4)	0.264 (4)	0.293 (4)	0.322 (4)	0.351 (4)	0.380 (4)
Promoted responsiveness	0.712 (1)	0.688 (1)	0.665 (1)	0.642 (2)	0.618 (2)	0.595 (3)	0.572 (3)	0.548 (3)	0.525 (3)	0.502 (3)
Increased core competency	0.382 (2)	0.499 (2)	0.616 (2)	0.733 (1)	0.850 (1)	0.967 (1)	1.084 (1)	1.201 (1)	1.319 (1)	1.436 (1)
Enhanced working efficiency	0.100 (4)	0.200 (3)	0.300 (3)	0.400 (3)	0.500 (3)	0.600 (2)	0.700 (2)	0.800 (2)	0.900 (2)	1.000 (2)

[a] v value was set 0.5.

Table 17
Four final values and rankings by three methods

Achievements/final values (ranking)/methods	TOPSIS	VIKOR ($v = 0.5$)	SAW
Induced innovative learning	0.415 (3)	0.235 (4)	71.36 (3)
Promoted responsiveness	0.192 (4)	0.618 (2)	70.16 (4)
Increased core competency	0.700 (1)	0.850 (1)	73.52 (1)
Enhanced working efficiency	0.569 (2)	0.500 (3)	73.38 (2)

From correlated literature, we may use mixed criteria instead of single criteria to evaluate and verify KC achievements. The group-decision analysis adopts the weight (Table 10) as the basis for calculation according to experts in this field. The findings revealed *increased core competency* was first overall. As to the weight of criteria, *cross-domain sharing* was highest, followed by *achievements appraisal basis* and the *integrated IT platform*. The lowest scores were for *bottom-up building* and *independent IT platform*. This study developed a KC achievement matrix (Fig. 1) and used *induced innovative learning*, *promoted responsiveness*, *increased core competency*, and *enhanced working efficiency* as the four kinds of achievement alternatives, enabling one to choose the best method to determine future trends.

Regarding SAW, the scores of four kinds of achievements were larger than 70 and had few differences among them. Our study proves that traditional methods cannot clarify decision-making as well as TOPSIS or VIKOR can.

Regarding VIKOR, our study tried to set v from 0.1 to 1.0. We found that when the v parameter is larger (>0.5), the index of I_i will prefer majority rule; a smaller v however will lead one to accept majority rule. Also, smaller v values will lead to an acceptance of majority opinions. The rankings for VIKOR calculations when v is set to 0.5 are: *increased core competency* $\succ$ *promoted responsiveness* $\succ$ *enhanced working efficiency* $\succ$ *induced innovative learning*.

Regarding TOPSIS, *increased core competency* had the highest ranking. The chief advantages of TOPSIS are deciding criteria and weights by experienced experts in sum; our study combined the TOPSIS, VIKOR and SAW methods to make analysis comparisons so as to respond to the majority opinions.

6.2. Suggestions

When KC was first implemented, firms often opposed it because of different views and preferences of top management. If firms choose different criteria under the four dimensions of *leadership locus*, *incentive mechanism*, *member interaction*, and *complementary assets*, its operating mode and performance will also differ. Our KC construction can provide firms with general references, but the weight-settings depend on the individual situations. Similar questions may use TOPSIS or VIKOR to solve for different appraisal criteria and obtain more realistic results and better analysis quality. Unlike traditional appraisal methods, both TOPSIS and VIKOR can clearly distinguish the KC achievement results. Therefore, we suggest using the above two methods, mutually, to enhance distinction ability and avoid missing fuzzy data.

In today's knowledge economy, a firm's competitive advantage lies in knowledge instead of in land, capital, or technology. Many scholars believe, in certain organizations, KC itself can become the organizations' most valuable property. However, displaying and measuring the value of KC is difficult. Our study suggests building a reliable group-decision analysis to calculate the actual benefits for the organization.

Our study also provides a complete appraisal model to show each layer and its weights. The information interface also plays an important role; for example, we suggest suitable software be designed to combine theory and practice to mass application. Clearly, KC is growing in value as more people recognize their potential; we hope this research has contributed to this movement and we invite further research on this crucial topic.

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