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Fuzzy integral evaluation on team innovation capability based on team interactive process - Take enterprise's new product R&D team as case study

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ABSTRACT

Studies on team innovation has been the focus of scholars'attention. But Most studies usually starting from the perspective of the whole organization, concern team Innovation as a part of organization innovation system as a whole. This article starts from the analysis of team interactive process behavior, inquires into the dynamic process of team innovation based on mechanism analysis of cognitions and behaviors within team, excavates team interactive process variables which have a major impact on team innovation, then introduces fuzzy integral theory into the analysis and evaluation of team innovation, builds the evaluation index system of team innovation capability, proposes out a modified fuzzy integral evaluation method according to uncompletely independent characteristics between evaluation indicators, establishes evaluation model of team innovation capability, finally carrys out an empirical analysis taking enterprise's new product R&D team as case, thus draws some useful conclusions.

KEYWORDS

Team interactive process;
Team innovation;
Fuzzy measure;
Fuzzy integral evaluation,
R&D Team.

INTRODUCTION

Most scholars research team innovation from organizational innovation perspective before. Scholars such as Marschark, Francis, Young, Johnson, Adair, Kur and Smith et al discussed the influencing factors of team innovation from team organizational structure, information communication and personnel arrangement etc. Some scholars, such as Anderson, Damanpour, de Dreu and Nijstad et al researches team innovation from the different dimensions of organizational innovation[1] While Chinese scholars generally learn from the research experience of foreign scholars, focus on the empirical, few further expand research on the essence of team innovation process.

In essence, no matter from what level and angle research team innovation problem, all relevant factors that affect team innovation must be achieved through team interaction process ultimatel. Therefore, this article tries to analyze team interactive process variables which have a major impact on team innovation, then introduces fuzzy integral theory into the evaluation of

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team innovation, builds the evaluation index system of team innovation capability, proposes out a modified fuzzy integral evaluation method according to uncompletely independent characteristics between evaluation indicators, establishes evaluation model of team innovation capability, finally carrys out an empirical analysis taking enterprise's new product R&D team as case so as to provide a new thinking and new methods for enterprises to how to improve and enhance team innovation capability from the monitoring of team interactive process.

TEAM INTERACTIVE PROCESS VARIABLES INFLUENCING ON TEAM INNOVATION

As a team, the basic attributes of their work is existing cognitive or behavioral process of interaction that promotes each other such as communication, collaboration, motivate, inspiration,etc. Team interactive process variables influencing on team innovation can be explored from four aspects including team conflict, team reflection, team innovation atmosphere and team leadership, and every aspect can be analyzed respectively from interpersonal dimension and task dimension.

Team conflict

Team conflict generally is divided into interpersonal conflict and task conflict by scholars. Interpersonal conflict's affection on team innovation is mainly based on distrust and discord between team members. Task conflict generally refers to inconsistent of views or opinions towards tasks between team members, which influence is more complex on team innovation. de Dreu's two studies on task conflict and team innovation have shown that too high or too low conflict level was not conducive to team innovation, only modest task conflict was able to promote it.[2] When task conflict happens without team, team members will put forward different views in whith constructive comments can improve the quality of decision-making and creativity[3]. Moreover, during the period of solving task conflict, cooperation between the members can prompt them to learn and rain each other, in which applicable ways and means are devised by mutual perspective colliding to ultimately promote team innovation as a whole. Therefore, the impact of team conflict is measured with level of communication between members in terms of interpersonal dimension, and with constructive comments and level of cooperation in terms of task dimension.

Team reflection

Concept of team reflection posed firstly by West in 1996, which is defined as the degree of team members reflecting on team's goals, strategy and process in public, and making adjustments by expecting internal and external situation[4].Scholars carried out many relevant researches from different angles about the impact of team reflection on team innovation. Hoegl and Parboteeah thought that team adept in reflection paid more attention to environment changes, continued to evaluate the environment, that is undoubtedly conducive to propose new team targets, adjust team's behavior, and then promote team innovation[5]. Team reflection is particularly suitable for teams that undertake innovative projects that generally confront much uncertainty that changing internal and external environment brings, thus precisely reflects the ability to cope with the uncertainty[6]. The impact of team reflection on team innovation can be measured from interpersonal dimension and task dimension. Most scholars more concern about reflection activities associated with task called task reflection, and interpersonal reflection is another aspect of team reflection corresponding to task. [9task reflection involves target reflection and behavior adjustment[7], and interpersonal reflection is able to be evaluated with interpersonal adjustment capability.

Team innovation atmosphere

West and Anderson came up with new innovative atmosphere theory on the basis of previous studies on relationship brtween atmosphere and innovation. They believe that team innovation atmosphere is composed of target recognition, participation in security, task orientation and innovation support[8]. Target recognition is to develop a valuable goal to be able to stimulate initiative of team members. Participation in security involves in participation and safety that encourages its members to participate in decision-making and positively solve problems encountered, while harboring a loose environment for cooperation. Task orientation is to attach great importance to performance of tasks related to

team goals, specifically including assessing and correcting control systems and firmly grasping the key link to complete tasks. Innovation support is to provide system, resource and members support for innovation behavior. Therefore, the impact of team innovation atmosphere on team innovation is measured with target recognition and innovation support in terms of interpersonal dimension, and with task orientation and participation in security in terms of task dimension.

Team leadership

To study the impact of team leadership on team innovation through team interactive process, first should understand the role of team leader in team innovation process. Team leaders as an integral part of team leadership, generally play a support and coordination role such as formulating target plan, coordinating and guiding behavior of members etc[9]. They are also the key that links individual and team creativity. Leader 's intervention can improve innovation performance of team, and creative leaders even are able to indicate the direction and pathway for team's novel, creationary programs. The impact of team leadership on team innovation can be achieved through cultivation of team cohesion and team efficacy that is the main source of team initiative that is just key ideological driving force promoting team innovation. The impact of team leadership on team innovation is measured with goal-setting ability, behavior-guiding capacity and resource-allocating capability in terms of task dimension, and with team cohesion and team efficacy in terms of interpersonal dimension.

FUZZY INTEGRAL EVALUATION MODEL FOR TEAM INNOVATION CAPABILITY

Fuzzy integral evaluation method

The article will use Choquet fuzzy integral for a comprehensive evaluation on team innovation capability.

- **Definition 1. Choquet fuzzy integral**

Set a fuzzy measure space (X, F, g), f is a measurable function about x to [0, +•]. Under normal circumstances, if

$f(x_1) \geq \mathrm{K} \geq f(x_i) \geq \mathrm{K} \geq f(x_n)$,

Choquet fuzzy integral for fuzzy measure g is defined as:[10]

$$C = \int f dg = f(x_n)g(x_n) + [f(x_{n-1}) - f(x_n)]g(x_{n-1}) + \cdots + [f(x_1) - f(x_2)]g(x_1) \quad \textbf{(2-1)}$$

Among Equation(2-1), C is comprehensive evaluation value for fuzzy integral. $f(x_i)$ is the indicator of output (performance value) For object pendingly evaluated. $g(x_i)$ takes into account the indicator $x_1, x_2, \ldots, x_i$ important degree (weight):

$$g(X_1) = g(\{x_1\}), g(X_2) = g(\{x_1, x_2\}), \ldots, g(X_n) = g(\{x_1, x_2, \ldots, x_n\})$$

Establishment of evaluation index system

Evaluation index system for team innovation capability as shown in TABLE 1.

Improvement for fuzzy integral evaluation method

To aim at team innovation capability evaluation such that multi-index comprehensive evaluation including quantitative and qualitative indicators, this paper tries to establish an improved fuzzy integral evaluation method relying on semantic variables based on fuzzy integral theory, so as to achieve the purpose of evaluation. Firstly, to determine a new λ-fuzzy measure according to the purpose and characteristics of evaluation for team innovation capability, based on not requiring to meet additive fuzzy measure. Secondly,to quantize the semantic variables using and membership function for trapezoidal fuzzy numbers to represent semantic variables combining the basic principles of Choquet fuzzy integral. lastly, Finally, to build an improved fuzzy integral evaluation method by integrating large amounts of information from multi-experts. This evaluation method sets different λ value according to the actual purpose of evaluation, and obtain preferable evaluation results. Thuswise,we may understand the ranking order of objects evaluated based on the evaluation results, find the shortcomings of objects so as to reach the aim for punishing lagging indicators, rewarding advanced indicators, and develop and implement appropriate improvement strategies to realize balanced development of all indicators.

1)Determination of traditional fuzzy measure

- **Definition 2. λ-fuzzy measure**

If $X = \{x_1, x_2, \cdots, x_n\}$ is finite set, and each vari-

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able x_i correspond to fuzzy density function $g(x_i)$,in which g_λ Can be written as the following formula:[11]

$$g_\lambda(\{x_1, x_2, \ldots, x_n\}) = \sum_{i=1}^{n} g(x_i) + \lambda \sum_{i_1=1}^{n-1} \sum_{i_2=i_1+1}^{n} g(x_{i_1}) g(x_{i_2}) + \cdots + \lambda^{n-1} g(x_1) \cdots g(x_n) = \frac{1}{\lambda}\left| \prod_{i=1}^{n} (1+\lambda g(x_i)) - 1 \right| \quad \lambda \in [-1, \infty), \ \lambda \neq 0 \tag{2-2}$$

$$X = \{x_1, x_2, \cdots, g_\lambda(x_i) x_i\}$$

2)Improvement for λ-fuzzy measure.

There are certain limitations that the traditional λ-fuzzy measure calculation is applied in team innovation capability evaluation, therefore, this paper aims to explore a new method to calculate λ-fuzzy measure. Specifically, first based on the results of analysis for the survey of team innovation capability, use a quantitative method to calculate the weight value(or degree of emphasis) of indicators in different evaluation levels by inducing and integrating views of most experts. Next,

TABLE 1 : Evaluation index system for team innovation

Target layer	First-level indicators	Second-level indicators
Team Innovation capability	Management capacity for team conflict U_1	level of communication U_{11}
		constructive comments U_{12}
		level of cooperation U_{13}
	Capability of team reflection U_2	ability of target reflectionU_{21}
		behavior adjustment capability U_{22}
		interpersonal adjustment capability U_{23}
	Building capacity of team innovation atmosphere U_3	Target identity U_{31}
		innovation support U_{32}
		task orientation U_{33}
		participation in security U_{34}
	Ability of team leadership U_4	goal-setting ability U_{41}
		behavior-guiding capacity U_{42}
		resource-allocating capability U_{43}
		team cohesion U_{44}
		team efficacy U_{45}

TABLE 2 : Degree of emphasis and setting principles of λ-value

Evaluation purposes	Degree of emphasis	λ-value
Emphasis on evaluation objects which indicators perform excellently in terms of a specific or multiple	the indicator's degree of emphasis is improved	λ-value is close to -1
Emphasis on evaluation objects which indicators perform excellently in terms of a single or multiple	all indicators' degree of emphasis is equivalent	
Emphasis on evaluation objects which indicators perform consistently and excellently in terms of a specific or multiple	the indicator's degree of emphasis is improved	λ-value is close to and less than 0
Emphasis on evaluation objects which indicators perform consistently and excellently in terms of a single or multiple	all indicators' degree of emphasis is equivalent	
Emphasis on evaluation objects which indicators perform consistently	all indicators' degree of emphasis is unconstrained	λ-value is greater than 0
mphasis on evaluation objects which indicators perform consistently	all indicators' degree of emphasis is unconstrained	λ-value is greater than or equal to 0

according to the degree of emphasis, setting principles of λ value as shown in TABLE 2 and evaluation objectives, determine parameter λ values. Last, obtain initial λ value according to the Equation(2-1), and perform the normalization processing.

Through the above, the main idea is to improve the method of calculating λ-fuzzy measure. Such new method to determine λ-value not only makes up for the lack of determining traditional λ-fuzzy measure, more importantly,but also satisfies the evaluation target required to achieve by setting different λ values, for example the ranking order of evaluation objects.

Evaluation for team innovation capability

Let Y team innovation capability, first-level indicators $X_1, X_2, \ldots, X_n$, standardized evaluation index value $f(x_i)(i = 1, 2, \ldots n)$, Second-level indicators $X_1^1, X_2^1, \ldots, X_{n_1}^1, X_1^k, X_2^k, \ldots$ÿ $X_{n_k}^k, X_1^n, X_2^n, \ldots, X_{n_n}^n$. The modeling procdure is represented as following steps.

Step 1. Determination of evaluation index value.

give the semantic value for indicators by expert scoring. In the process of scoring the qualitative value of indicators, there is a considerable degree of fuzziness to describe the qualitative indicators, so to use trapezoidal fuzzy number that represents semantic variables to describe the subjective value of assessment. Through questionnaires, we come to the semantic values reflecting qualitative indicators of team innovation ability based on the semantic variable table for evaluation value,[12](shown in TABLE 3)and build the set of indicators' semantic values $\hat{f}1$.

TABLE 3 : Semantic variable table of qualitative indicators

Semantic values	Semantic value
Worse	(0, 0, 0.1, 0.2)
Bad	(0.2, 0.2, 0.3, 0.4)
Average	(0.4, 0.5, 0.5, 0.6)
good	(0.5, 0.6, 0.7, 0.7)
better	(0.8, 0.9, 1, 1)

$$\hat{f}1 = \left\{ \hat{f}_j(X_i^k) \middle| k = 1, 2, \ldots, n; i = 1, 2, \ldots, dn_k; j = 1, 2, \ldots, m \right\}$$

$\hat{f}_j(X_i^k)$ is the semantic value for X_i^k, belongs to trapezoidal fuzzy number, expressed as$(a_i^k, b_i^k, c_i^k, d_i^k)$, $a_i^k \in [0,1], b_i^k \in [0,1], c_i^k \in [0,1], d_i^k \in [0,1]$; n represents amount of evaluation level; dn_k is amount of qualitative indicators under X^k; m is amount of of experts.

Calculating the fuzzy value $\hat{f}1$ of evaluation indicators by integrating multiple experts' opinions.

$$\hat{f}(X_i^k) = \frac{1}{m} \otimes \left\{ \hat{f}_1(X_i^k) \oplus \hat{f}_2(X_i^k) \oplus \ldots \oplus \hat{f}_m(X_i^k) \right\}$$
$$\hat{f} = \left\{ \hat{f}(X_i^k) \middle| k = 1, 2, \ldots n; i = 1, 2, \ldots, dn_k \right\} \quad \textbf{(2-3)}$$

To obtain the value of qualitative indicators by defuzzification computing to convert the fuzzy number of qualitative indicators into a clear value using relative distance formula according to the characteristics of evaluation for team innovation capability. The calculation method is as follows:[12]

$$f(X_i^k) = M(\hat{f}(X_i^k)) = \frac{d_i^{k-}}{d_i^{k-} + d_i^{k*}}$$
$$d_i^{k-} = \sqrt{\frac{1}{4}((a_i^k)^2 + (b_i^k)^2 + (c_i^k)^2 + (d_i^k)^2)}$$
$$d_i^{k*} = \sqrt{\frac{1}{4}((1 - a_i^k)^2 + (1 - b_i^k)^2 + (1 - c_i^k)^2 + (1 - d_i^k)^2)} \quad \textbf{(2-4)}$$
$$(k = 1, 2, \ldots n; i = 1, 2, \ldots, dn_k)$$

Step 2. To calculate evaluation values at all index levels.

Firstly, to calculate semantic value of fuzzy density for all evaluation indicators according to TABLE 3, structure judgment matrix, determine all indicators' fuzzy density using Delphi method. Secondly, to come to λ-value according to TABLE 2, calculate λ-fuzzy measure, and go normalization processing. Finally, to obtain the evaluation value $f(X^k)$ for X^k using equation (2-1), And then to calculate comprehensive evaluation value of team innovation capability.

$$f(X^k) = f(X_{i_{nk}}^k)\, g_\lambda\left(\left\{X_{i_1}^K, X_{i_2}^K, \ldots, X_{i_{nk}}^K\right\}\right) + \cdots$$
$$+ (f(X_{i_2}^k) - f(X_{i_3}^k))\, g_\lambda\left(\left\{X_{i_1}^k, X_{i_2}^k\right\}\right) + (f(X_{i_1}^k) - f(X_{i_2}^k))\, g_\lambda(X_{i_1}^k)$$

EMPIRICAL ANALYSIS

Empirical analysis selected two large home appliance manufacturing enterprises A and B. In order to reflect typical behavioral characteristics as innovative team, the survey samples in the form of the most typical, representative new product development team are respectively selected three groups from A and B so as to make horizontal and vertical comparison for the fol-

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low-up assessment. In order to get a more objective result of assessment, the questionnaires targeted at the corporate R&D team leaders and key team members. We issued 50 questionnaire tables, recovered 48, the valid questionnaires 45, valid questionnaire rate 90%.

TABLE 4 : Evaluation index value list of corporate R&D team innovation capability after pretreatment

	Enterprise A			Enterprise B		
	N_1	N_2	N_3	N_4	N_5	N_6
U_{11}	0.039	0.137	0.477	0.171	0.548	1.000
U_{12}	0.200	0.700	0.800	0.714	0.810	0.917
U_{13}	0.063	0.087	0.125	0.889	0.608	0.508
U_{21}	0.633	0.630	0.901	0.896	0.508	0.628
U_{22}	0.810	0.810	0.905	0.781	0.813	0.567
U_{23}	0.719	0.813	0.906	0.526	0.053	0.524
U_{31}	0.513	0.250	0.750	0.893	0.873	0.507
U_{32}	0.500	0.616	0.504	0.607	0.619	0.524
U_{33}	0.619	0.605	0.609	0.890	0.623	0.517
U_{34}	0.621	0.630	0.617	0.618	0.513	0.867
U_{41}	0.317	0.342	0.640	0.400	0.600	0.630
U_{42}	0.200	0.400	0.500	0.600	0.400	0.508
U_{43}	0.421	0.474	0.621	0.618	0.631	0.519
U_{44}	0.148	0.155	0.376	0.290	0.436	0.967
U_{45}	0.250	0.684	0.719	0.500	0.614	0.503

TABLE 5 : Weights of all levels of evaluation indicators on R&D team innovation capability

First-level indicators	Weights	Second-level indicators	Weights
		U_{11}	0.601
U_1	0.719	U_{12}	0.685
		U_{13}	0.614
		U_{21}	0.639
U_2	0.807	U_{22}	0.682
		U_{23}	0.640
		U_{31}	0.665
		U_{32}	0.515
U_3	0.898	U_{33}	0.633
		U_{34}	0.596
		U_{41}	0.631
		U_{42}	0.744
U_4	0.783	U_{43}	0.565
		U_{44}	0.532
		U_{45}	0.527

1)Preprocessing of sample data

semantic value for different experts is determined based on survey data, then calculate the fuzzy values. After defuzzification computing using Equation(2-3), the result of data preprocessing is shown in TABLE 4.

2)Weight determination and comprehensive evaluation.

Through questionnaires, to give out the degree of emphasis on all levels of evaluation indicators according to the experts' expertise, and then structure judgment matrix, weight evaluation indicators of all levels using Delphi. The calculated results shown in TABLE 5

First-level evaluation indicators is calculated as shown in TABLE 6. The comprehensive evaluation value is as shown in TABLE 7.

TABLE 6 : Fuzzy integral values of first-level evaluation indicators

	Enterprise A			Enterprise B		
	N1	N2	N3	N4	N5	N6
U_1	0.581	0.537	0.892	0.745	0.857	0.626
U_2	0.840	0.839	0.900	0.872	0.833	0.867
U_3	0.558	0.599	0.759	0.832	0.642	0.741
U_4	0.202	0.289	0.445	0.414	0.355	0.410

TABLE 7 : Comparison for comprehensive evaluation value of corporate R&D team innovation capability

team	Enterprise A			Enterprise B		
	N_1	N_2	N_3	N_4	N_5	N_6
Comprehensive evaluation value	0.616	0.704	0.898	0.842	0.804	0.788
Ranking	6	5	1	2	3	4

CONCLUSION

As can be seen by the above evaluation results, the comprehensive evaluation value of innovation capability of three groups of new product development team respectively selected from enterprise A and B is greater than 0.6, and the evaluation results are above good, means that overall innovation level of R&D team in enterprise A is greater than B. From the calculation results of first-level indicators for six groups, we find that the best performing indicator is capability of team reflection which evaluation values are greater than 0.8, slightly better performing indicator is management capacity for team conflict and building capacity of team innovation atmosphere which evaluation values are greater than

0.5, poorer performing indicator is ability of team leadership which evaluation values are less than 0.5. Analysis can be drawn further on second-level indicators with better performance corresponding to first-level indicators that both Enterprise A and B attach great importance to team goals and action reflect that means rethinking the tasks and goals to further clarify the directivity of team innovation and stimulate the generation of new ideas, meanwhile they also gave high priority to establishing good communication and cooperation atmosphere, training identity and belonging of members, adopting recommendations views of staff, related supporting for tasks and concern for individual employee etc. On the other hand, both A and B perform pretty bad at"team leadership" evaluation level, the reason may be that there exists conceptual obstacles on team resource allocation in leader level or unclear responsibilities when tasks are assigned.

Although the overall level of innovation of new product development team from A and B is good, there are also differences in terms of the overall performance of innovative capability between A and B, besides, in each enterprise, the innovation capability from different project team also performed unevenly. Therefore, there are still some areas for improvement on team innovation management that can be found from the ranking of evaluation results. From the vertical perspective, the level of innovation performance of different project teams in each enterprise project team is inconsistent, we can judge by evaluation value which aspects of team interaction problems need to be improved, so as to establish the basis. From the lateral perspective, the overall innovation level of R&D team from A is not as good as B, which can be seen all levels of evaluation values from A are lower than B, thus enterprises can summarize by the evaluation activities which interactive factors hinder team innovation, so as to formulate targeted strategic plans.

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