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BUILDING EVALUATION SYSTEM OF ENTERPRISE NETWORK CAPABILITY BY FUZZY COMPREHENSIVE EVALUATION METHOD

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ПОБУДОВА СИСТЕМИ ОЦІНЮВАННЯ МЕРЕЖЕВИХ МОЖЛИВОСТЕЙ ПІДПРИЄМСТВА МЕТОДОМ НЕЧІТКОГО КОМПЛЕКСНОГО ОЦІНЮВАННЯ

Purpose. This paper uses the fuzzy comprehensive evaluation method to construct the evaluation system of enterprise network capability and realized quantitative evaluation. We want to find the evidence to adjust the building strategy of the enterprise network capacity.

Methodology. We have made many types of research on the enterprise network capability, including the concept, structure, dimensions, factors and their role in the process of innovation performance. The method of experts and the fuzzy comprehensive evaluation method were used for empirical research. The status of enterprise network capacity was analysed clearly.

Findings. Empirical analysis showed that the network capability evaluation is beneficial to measure the size of the enterprise network capability and to compare differences between enterprises network abilities. The enterprises should build the network capacity overall. At the same time, they should pay attention to the structure of network capability.

Originality. The enterprise network capability was evaluated quantitatively by the fuzzy comprehensive evaluation method.

Practical value. The recommendations on the network capacity building strategy for the enterprises were formulated. The enterprises can find the deficiency of network capability building, adjust the development strategy of enterprise network capability, find the problems in the recognition, positioning, planning, integration and optimization, obtain network resources, and improve the competitive advantage.

Keywords: *network capability, fuzzy comprehensive evaluation method, evaluation system*

Introduction. In the network economy era, innovation model is an evolution process, from linear model to the technology and market coupling model, and then to link model, and then to system integration and network mode. The enterprise has always been in an interaction and mutual influence of enterprise network. The enterprise innovation is inseparable from the network environment. The change of external environment contributed to the relationship between the enterprise and government, suppliers, customers, competitors, affected the choice of the ways of enterprise competition and the formulation competition strategy. By the actors, actions and resources enterprises, a network environment has become an important factor affecting enterprise innovation. The formation, internal structure and evolution of direction of network environment will affect the innovation performance of enterprises and competition [1]. In order to gain advantages from network resources, the enterprises embedded in network relationships should be active. In other words, they should participate in the network activities, establish different properties and network in the form of partnership along with other enterprises. They should give the full play to the complementary advantages of the network heterogeneous resources in order to establish and maintain an effective network. Enterprises in the identification, establishment,

management and upgrading the network relationship, should not only focus on the concrete measures of constructing network and the direction of dynamic evolution but also should pay close attention to the real role of network capability [2]. Through the network connection, enterprises identify advantageous resources and opportunities, actively promote the position in the network, and maintain good cooperation and trust relationship with the other enterprises in a high position of enterprise network, establish a long-term mechanism to obtain high quality information, lower the price of network resources to withstand market risks, promote enterprise's growth [3]. The network situation assessment results would be different due to the difference in perception and participation of enterprises. The capability and the actual effect in dealing with network relationships will be of a big difference. Therefore, the network capacity is different. The power to control the network resources also is different. Poor network capacity cannot be directly involved in the innovation network of an enterprise to compensate for obstacles in its own resources. Only a strong network capability allows the enterprise to develop and manage network activities, stimulate the network resources, gain network revenues. Enterprises should identify their problems in the development of the network capability, use external network relationship to improve innovation ability.

In 1987, Hakansson first proposed the concept of network capabilities to define the difference between the enter-

prises dealing with a particular network relationship. The enterprise takes its own internal resources as a part of its basic conditions to build a network. From the point of network resources based view, the network capability is not only intangible resources, but also network resources to break the boundaries of internal resources, and to build competitive advantage [4]. The concept of network capabilities deepens the study on the innovative network from the network level to the micro level of individual enterprises. Network capability is the expansion of core ability in the level of strategy and management [5]. Enterprise network capability has a positive effect on using external scarce resources from social networks [5]. In addition, it can be used to explore the root causes to gain competitive advantage.

Domestic and foreign scholars have made a lot of research on enterprise network capability, including the concept, structure, dimensions, factors and their role in the process of innovation performance [6]. Studies have shown that the capability in different dimensions has different influence path and mechanism in obtaining resources. However, previously made researches on the evaluation of network capabilities focused on the evaluation of the specific enterprises in a particular industry, which did not allow measuring the network capacity fully and quantitatively. This affects the promotion of the range and value of enterprise network theory. Based on existing research results and empirical analysis, this study answers several questions. How to design evaluation system? How to evaluate the status of the enterprise network capability? What is the evidence to adjust the building strategy of the enterprise network capacity? How to adjust?

Creation of the evaluation system of enterprise network capability. *Connotation and elements of network capabilities.* Networks and networking have complex features. Network capability comprises a plurality of elements. Therefore, it is necessary not only to define the research network capabilities connotation but also to analyse the dimensions of the network capacity. The inherent structure and form of the enterprise network capabilities vary. The evolution direction of a network is dynamic. The researches on the concept of network capacity and structure gave different results. Because network capabilities composition looks different in the view of different research perspectives, there is no unified understanding. However, research results are complementary. Möller and Halinen's works appeared the most valuable (1999).

Many scholars accept the division of the network capacity posed by Möller and Halinen. They continue to deepen the research in this direction because it is clear, reasonable and easy to operate. Therefore, we unwound the evaluation index system mainly from the representation theory.

Network visioning capability. Network visioning capability refers to management's skills and competencies in creating valid views of networks and their potential evolution. In order to obtain useful network resources for their own development, the enterprises need to identify the formation process and the result of network with strategic vision, to predict and to grasp the direction of network evolution. This can help enterprises to find opportunities for development from the network environment. Enterprises can develop network management strategies to meet the network competition. Network visioning capability includes

network awareness capability, network identification capability and network positioning capability.

Net management capability. Net management capability refers to a firm's capability to mobilize and coordinate the resources and activities of other actors in the network. This capability requires managing network location, performing network tasks, and promotes network innovation. Net management capability includes network planning capability, network organization capability, network coordination capability and network control capability.

Portfolio management capability. Portfolio management capability refers to a firm's competence in managing supplier and customer portfolios. Enterprises have the ability to assess network partners, establish, maintain and use the network partner's database, maintain customer relationships effectively, increase sales, profits and knowledge input, identify potential customers, assess their lifetime value, and tap their real value, identify the strategic business. To do this, the enterprise needs to collaborate with partners, encourage the member enterprises to interact, build cooperation norms in order to avoid conflicts of interest and to achieve mutual benefit. Network partner shares network resources to play network synergies, achieve the process reengineering and process innovation. Portfolio management capability includes relationship organization capability, relationship integration capability and relations reconfiguration capability.

Relationship management capability. Relationship management capability refers to a firm's competence in handling individual exchange relationships. In order to maintain long-term cooperation relationship, enterprises need to invest in to a cooperation partner, explore new forms of cooperation, break the existing partnership, or terminate a single relationship. Relationship management capability includes relationship communication capability, optimizing relationship capability and relationship coordination capability.

In summary, the network capability is a dynamic capability that is driven by the network-oriented. An enterprise recognizes, locates, integrates and optimizes the network activity.

Enterprise network capability evaluation. In order to understand the status of the network capacity and find the problems, enterprises need to have a scientific and reasonable evaluation system [7]. This research employs the fuzzy comprehensive evaluation because the connotation of network capabilities and the relationship between dimensions have the typical characteristics of the ambiguity and complexity; the evaluation process itself is a kind of mental activity; there are many subjective components. Implementation environment and evaluators, i. e. their knowledge structure, experience, qualifications, affect the results. The fuzzy concept processing by classic mathematics does not give the ideal result. The fuzzy comprehensive evaluation method is a very effective multifactor decision-making method. It can achieve quantitative evaluation through the membership degree theory of fuzzy mathematics, and solve the evaluation problem characterized by complexity, fuzziness and uncertainty. The internal components of these problems have a hierarchical nature.

Determining evaluation factors. The collection of fuzzy comprehensive evaluation method is the evaluation

index system of enterprise network capability. Möller and Halinen qualitatively explained the relationship between these four interrelated dimensions. Moreover, they said that enterprises must pay attention to the four levels of the enterprises network capabilities. However, when performing, because of their resource constraints, enterprises can only focus on one or several indicators of network capabilities to solve urgent problems. Therefore, the evaluation of network capabilities can be able to provide support for enterprise network management strategy.

$U = \{u_1, u_2, \ldots, u_n\}$, n indicators. This article identifies four evaluation factors, each of the evaluation factors can be divided into sub-factors. In this paper, the index system consists of 4 primary indicators and 13 secondary indicators. U_i is primary indicators, and U_{ik} is secondary indicators. i is the number of primary indicators. U_k denotes the k-th secondary indicators under i-th level indicators (Table 1).

Determining the comment set. The evaluation of expert is not like "yes" or "no". The evaluation set is a fuzzy evaluation vector to evaluation objects, is a fuzzy subset of V.

$\mathbf{V} = \{V_1, V_2, \cdots, V_m\}$, there are m kinds of evaluation.

How much the number of comment set has a greater influence on the result of the evaluation? Let us take 5 as the number of grade. The comment set is

$$V_m = \{V_1, V_2, \ldots, V_5\} = \{Great, Good, Normal, Poor, Very\ poor\}$$
$$B = (b_1, b_2, \ldots, b_m) \in \Phi(V);$$
$$b_j (j = 1, 2, \ldots, m)$$

reflects the status of the evaluation of V_j in the comprehensive evaluation.

Table 1

Enterprise network capability evaluation index system

Target layer U	Primary indicators U_i	Secondary indicators U_{ik}
Enterprise network capability	U_1: Network visioning capability	U_{11}: Network awareness capability
		U_{12}: Network identification capability
		U_{13}: Network positioning capability
	U_2: Net management capability	U_{21}: Network planning capability
		U_{22}: Network organization capability
		U_{23}: Network coordination capability
		U_{24}: Network control capability
	U_3: Portfolio Management Capability	U_{31}: Relationship organization capability
		U_{32}: Relationship integration capability
		U_{33}: Relations reconfiguration capability
	U_4: Relationship management capability	U_{41}: Relationship communication capability
		U_{42}: Optimizing relationship capability
		U_{43}: relationship coordination capability

Determining weight set. Weight calculation is an important step of fuzzy comprehensive evaluation methods. The common methods of calculation are expert opinion method, AHP, pair-wise comparison method. The research employs the expert opinion method.

The contribution of sub-factors of set U to the evaluation results is different, so are weights. The weight is denoted by a_{ij}. Weight set can be expressed as

$$A = (a_1, a_2, \ldots, n).$$

Element $a_i (i = 1, 2, \ldots, n)$ is the weight of factor μ_i to U.

Satisfy the conditions: The total of the primary level weights of evaluation factors is equal to l. The total of weights of each secondary evaluation factors is equal to l. It can be expressed as follows

$$\sum_{i=1}^{n} a_i = 1, 0 \le a_i \le 1).$$

Single factor evaluation. Evaluation scoring of Experts is the single factor evaluation value, which consists of a single factor fuzzy evaluation matrix.

The single factor evaluation of the i-th factor is

$$R_i = (r_{i1}, r_{i2}, \ldots, r_{ij}), (i = 1, 2, \ldots, n; j = 1, 2, \ldots, m).$$

Thus, the single factor fuzzy evaluation matrix is

$$R = R_{ik} = \begin{bmatrix} R_{11} & R_{12} \ldots R_{1m} \\ R_{21} & R_{22} \ldots R_{2m} \\ \vdots & \vdots \quad \vdots \\ R_{n1} & R_{n2} \ldots R_{nm} \end{bmatrix},$$
$$(i = 1, 2, \ldots, n; j = 1, 2, \ldots, m).$$

Then $B_i = A_i \cdot R_i = (b_{i1}, b_{i2}, \ldots, b_{im})$.

By the calculation of product and method, there are

$$b_{ij} = \sum_{j=1}^{m} w_{ij} r_{ij} (i = 1, 2, \ldots, n; j = 1, 2, \ldots, m).$$

Comprehensive evaluation. According to the weight and fuzzy indexes, a comprehensive evaluation can be inferred from bottom to top. Fuzzy comprehensive evaluation sets of a single factor are as the evaluation matrix R of the comprehensive evaluation. The evaluation results vector reflect the membership of each evaluation level. The element of the comment set corresponding to the largest evaluation index can be as the result of a final judgment, which is the evaluation of the enterprise network capability. The comprehensive evaluation set is as follows

$$B = A \cdot R.$$

Then, $B = (b_1, b_2, \ldots, b_m)$ is the overall results.

Case analyses. *Enterprise profile.* A regular undergraduate University "A" hired many well-known professors, scholars, leaders in all fields and talent having an overseas study background or experience, in order to become a leader of applied technology university in business education. It changed knowledge structure, teaching environment, teaching mode, teaching content, assessment methods of the traditional business education. In the process of the implementation of development strategies, university leaders have been insisting critical thinking,

and promote higher education reform, carry out research projects, and have made a number of breakthroughs.

The evaluation team. The evaluation team is made up of 20. They are professional managers, experts, and university administrators with many years of experience in enterprise network capacity management. According to the operation way of expert opinions method, this paper determines indicators layer coefficient and evaluation matrix.

Evaluation.

Single factor evaluation.

1. Determining indicators layer coefficient.

Evaluation group respectively scores for the primary and secondary indexes of network capacity, calculates score and proportion, and takes the proportion as the index weights. The results are as follows

$$A = (0.3, 0.2, 0.2, 0.3) \ A_1 = (0.4, 0.2, 0.4);$$
$$A_2 = (0.3, 0.2, 0.2, 0.3) \ A_3 = (0.2, 0.4, 0.4);$$
$$A_4 = (0.2, 0.5, 0.3).$$

2. Determining evaluation matrix.

After checking the materials of management and teaching activities, the evaluation team determined the evaluation matrix R according to their own experience. Statistical evaluation values are shown in Table 2.

The calculation process.

1. The calculation of fuzzy matrix.

$$R_1 = \begin{bmatrix} 12/20 & 7/20 & 1/20 & 0 & 0 \\ 13/20 & 5/20 & 2/20 & 0 & 0 \\ 10/20 & 7/20 & 3/20 & 0 & 0 \end{bmatrix}.$$

The same available

$$R_2 = \begin{bmatrix} 6/20 & 5/20 & 4/20 & 5/20 & 0 \\ 12/20 & 6/20 & 2/20 & 0 & 0 \\ 11/20 & 4/20 & 3/20 & 2/20 & 0 \\ 6/20 & 7/20 & 5/20 & 2/20 & 0 \end{bmatrix};$$

$$R_3 = \begin{bmatrix} 10/20 & 6/20 & 3/20 & 1/20 & 0 \\ 5/20 & 8/20 & 4/20 & 3/20 & 0 \\ 6/20 & 7/20 & 6/20 & 1/20 & 0 \end{bmatrix};$$

$$R_4 = \begin{bmatrix} 12/20 & 5/20 & 3/20 & 0 & 0 \\ 8/20 & 7/20 & 3/20 & 2/20 & 0 \\ 13/20 & 4/20 & 2/20 & 1/20 & 0 \end{bmatrix}.$$

2. Single factor fuzzy comprehensive evaluation.

Fuzzy comprehensive evaluation factor is the product of the weight value and fuzzy matrix.

$$B_i = A_i \cdot R_i = (b_{i1}, b_{i2}, \ldots, b_{im});$$

$$B_1 = A_1 \cdot R_1 = (0.4, 0.2, 0.4) \begin{bmatrix} 12/20 & 7/20 & 1/20 & 0 & 0 \\ 13/20 & 5/20 & 2/20 & 0 & 0 \\ 10/20 & 7/20 & 3/20 & 0 & 0 \end{bmatrix} =$$

$$= (0.57, 0.33, 0.1, 0, 0).$$

The same available

$$B_2 = (0.41, 0.28, 0.185, 0.125, 0);$$
$$B_3 = (0.32, 0.36, 0.23, 0.09, 0);$$
$$B_4 = (0.515, 0.285, 0.135, 0.065, 0).$$

3. Comprehensive evaluation.

Single factor fuzzy comprehensive evaluation matrix is

$$R = \begin{pmatrix} B_1 & B_2 & B_3 & B_4 & B_5 \end{pmatrix}^T.$$

Then $B = A \cdot R = (0.4715, 0.3125, 0.1535, 0.0625, 0)$.

According to the results of evaluation set above, in accordance with the principle of maximum membership degree, the largest membership is 0.4715. Therefore, it shows that the work in the university network capacity belongs to the medium to high level.

Analysis of the results. From the results, the state of the *A* university network capability is:

1. On the whole, network level is good.

Table 2

Scoring table of network capacity indicators

Target layer U	Primary indicators U_i	Secondary indicators U_{ik}	Great	Good	Normal	Poor	Very poor
Enterprise network capability	U_1: Network visioning capability	U_{11}: Network awareness capability	12	7	1	0	0
		U_{12}: Network identification capability	13	5	2	0	0
		U_{13}: Network positioning capability	10	7	3	0	0
	U_2: Net management capability	U_{21}: Network planning capability	6	5	4	5	0
		U_{22}: Network organization capability	12	6	2	0	0
		U_{23}: Network coordination capability	11	4	3	2	0
		U_{24}: Network control capability	6	7	5	2	0
	U_3: Portfolio Management Capability	U_{31}: Relationship organization capability	10	6	3	1	0
		U_{32}: Relationship integration capability	5	8	4	3	0
		U_{33}: Relations reconfiguration capability	6	7	6	1	0
	U_4: Relationship management capability	U_{41}: Relationship communication capability	12	5	3	0	0
		U_{42}: Optimizing relationship capability	8	7	3	2	0
		U_{43}: relationship coordination capability	13	4	2	1	0

The university senior leaders actively participate in important activities in the field of education, search information and seek opportunities from the government policy, the market, industry and enterprise to promote organizational change, educational reform in order to adapt to changes in the external environment. The university leaders continue to study at first-class universities domestic and foreign and well-known training institutions, expand the university's social networks, introduce the advanced teaching and education management system to improve the level of information and to enhance the work efficiency. The university entrusts or jointly develops outstanding young teachers. The university cooperates with third parties to research and monitor the graduate students, pay close attention to the changes of labour market in order to develop long-term development strategy, revise the talent training scheme and standardize financial management. The university encourages every disciplines and professional in close connection with industry development, invites industry experts to school as a tutor. Teachers lead students to enterprise to visit, internship and complete joint research project. The university encourages teachers to participate in BBS, academic exchange in the field of education. By these means, the University "A" has made some achievements in network capacity building.

2. The structure of network capacity is not reasonable.

It needs to be further optimized. From the scores of expert evaluation, there are some structural problems in the University "A" network capabilities: poor network planning, control, integration and optimization. This is mainly because the key strategic development is inconsistent with the building of enterprise network capabilities. The university recognizes the importance of network capabilities but invests limited resources. It lacks a unified deployment, which results in inconsistent understanding among organizations, departments and schools. This problem is embodied in the reform. Lack of control, different ideas of development at each school, which leads to professional setting cross, grabing resources and wasting resources, inadequate execution, and adjusting the work plan without regard to continuity. The university advocates to carry out research projects, but employees do not have the appropriate skills, such as marketing, managing project and consulting. The development of employees stops because of the growth of the needs of the organization. The organization is not able to optimize and reconstruct network resources timely and effectively. This affects the development process of organizational networking.

Conclusions. On the basis of existing literature about enterprise network capacity in the connotation and composition, this paper builds the evaluation index system of the enterprise network capacity, uses the method of experts and the fuzzy comprehensive evaluation method for empirical research, expresses the status of enterprise network capacity clearly.

Research shows that in the previous studies on the enterprise network capacity were mostly qualitative. As seen from the results of the evaluation matrix, the enterprise should not only build the network capacity overall but also pay attention to the structure. The empirical analysis shows that the fuzzy comprehensive evaluation method can get the value of enterprise network capacity. It allows for identification of the problems in the recognition, positioning, planning, integration and optimization. This paper provides a reference for the network capacity building strategy for an enterprise.

In the process of quantitative analysis, there are still some limitations for use of the quantitative method. Different quantitative evaluation methods can be used in further research to improve the validity and reliability of the evaluation results. In management practice, because enterprises differ in nature, the stage of life cycle and industry, the weights may be different.

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Мета. У даній роботі використовується метод нечіткого комплексного оцінювання для побудови системи оцінювання корпоративних мережевих можливостей і проведення кількісної оцінки. Робота спрямована на пошук підстав для коригування стратегії підприємства з побудови мережі зв'язків.

Методика. Проведене дослідження корпоративних мережевих можливостей, включаючи концепцію, структуру, розміри, фактори та їх роль у процесі інноваційної діяльності. Потім використано метод експертів, метод нечіткого комплексного оцінювання для емпіричних досліджень, проаналізовано стан мережі зв'язків підприємства.

Результати. Емпіричний аналіз показав, що запропонована оцінка мережевих можливостей дозволяє

вимірювати мережеві можливості підприємства та виявляти їх відмінності. Підприємства повинні розвивати мережеві можливості в цілому. У той же час, їм слід звертати увагу на структуру мережі зв'язків.

Наукова новизна. Уперше досліджена можливість кількісного оцінювання мережевих можливостей підприємства за допомогою методу нечіткого комплексного оцінювання.

Практична значимість. Надані рекомендації щодо стратегії побудови мережі зв'язків підприємства. Співробітники підприємств зможуть виявити недоліки мережі зв'язків і скоригувати стратегію розвитку мережевих можливостей підприємства, усунути проблеми впізнаваності, позиціонування, планування, інтеграції та оптимізації, отримати мережеві ресурси, а також поліпшити конкурентоспроможність.

Ключові слова: *мережеві можливості, метод нечіткого комплексного оцінювання, система оцінювання*

Цель. В данной работе используется метод нечеткого комплексного оценивания для построения системы оценивания корпоративных сетевых возможностей и проведения количественной оценки. Работа направлена на поиск оснований для корректировки стратегии предприятия по построению сети связей.

Методика. Проведены исследования корпоративных сетевых возможностей, включая концепцию, структуру, размеры, факторы и их роль в процессе инновационной деятельности. Затем использован метод экспертов, метод нечеткого комплексного оценивания для эмпирических исследований, проанализировано состояние сети связей предприятия.

Результаты. Эмпирический анализ показал, что предложенная оценка сетевых возможностей позволяет измерять сетевые возможности предприятия и выявлять их различия. Предприятия должны развивать сетевые возможности в целом. В то же время, им следует обращать внимание на структуру сети связей.

Научная новизна. Впервые исследована возможность количественного оценивания сетевых возможностей предприятия с помощью метода нечеткого комплексного оценивания.

Практическая значимость. Даны рекомендации по стратегии построения сети связей предприятия. Сотрудники предприятий смогут обнаружить недостатки сети связей и скорректировать стратегию развития сетевых возможностей предприятия, устранит проблемы узнаваемости, позиционирования, планирования, интеграции и оптимизации, получит сетевые ресурсы, а также улучшит конкурентоспособность.

Ключевые слова: *сетевые возможности, метод нечеткого комплексного оценивания, система оценивания*