Research on the Emergence Evaluation Model of Enterprise Open Value Co-creation Systems

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***Abstract*—In order to effectively evaluate the emergence of enterprise open-value co-creation systems, the concept and characteristics of the emergence of enterprise open-value co-creation systems are explained, and the judgment principle of systems emergent is given. On the basis of the value creation ability index at sub-systems level and systems level, the systems' value creation ability index is fully considered, and the value creation ability index at the systems level is pointed out. As a basis for the emergence of the evaluation systems, the mathematical models of various emergence evaluation indexes are given respectively. This provides a way of thinking for the quantitative evaluation of the emergence of enterprise open value co-creation systems.**

***Index Terms*—enterprise open, value co-creation systems, emergence, value creation ability, evaluation model**

I. PREFACE

Emergence is an important concept of modern frontier complexity science [1], and its quantitative evaluation is particularly difficult. The enterprise open value co-creation systems is a complex big systems composed of multiple subsystems. Because the various subsystems that constitute the systems are both independent and cross-linked, in the process of the evolution of the systems, it is inevitable to present high-intensity emergence features. Reasonable analysis and quantitative evaluation of these emerging characteristics can describe the relationship between the emergence of the open value co-creation systems and the systems value creation ability. And these analyses can provide the necessary guiding principles and decision-making basis to optimize the production resources of the systems to effectively improve the value creation of the systems. Therefore, this paper starts from the analysis of the emergence of complex systems, discusses the concept and characteristics of the emergence of enterprise open value co-creation systems and points out the judgment principle of the emergence of the systems based on the rational analysis of the composition of the emergence evaluation index. The mathematical model of the emergence evaluation index provides a research idea for the quantitative description of the emergence of the enterprise open value co-creation systems.

II. ANALYSIS OF THE CONCEPT OF THE EMERGENCE OF AN OPEN VALUE CO-CREATION SYSTEMS

A. Interpretation of the Emergence of an Open Value Co-Creation Systems

1. The emergence mechanism of complex systems

Since the 1950s, many famous scholars, such as W. Kǒhler, P. Checkland, Bertalanffy and SFI, have been researching on the Emergence. Through in-depth researches, efforts have been made to establish an emerging theoretical framework that conforms to modern scientific norms. American scholars J. Holland and J. Casti explored the emerging conceptual framework [2, 3] through the study of a large number of complex adaptive systems.

Scholars generally believe that the characteristics of complex systems cannot be derived from the characteristics of their components, and the mechanism of high-level organization cannot be completely explained by the mechanism of low-level organization [3, 4]. The systems has attributes that cannot be reduced to its components, so the components of a complex systems are not available. The attributes, features, behaviors, together with the functions as a whole are called Emergent Property. The emergence theory holds that the emergence is both a phenomenon (a behavioral process), and a unique characteristic to a complex systems. Emerging and related theories provide a unique and new perspective and new method for us to explore the complex phenomena, evolutionary laws, structural effects and exogenous effects of complex systems. The evaluation of the systems-level ability of the enterprise value co-creation systems in the complex environment is obvious applicable and superior.

2. The emergence characteristics of the enterprise value co-creation systems

The enterprise value co-creation systems takes the individualized needs of customers as the starting point, meets the needs of customers as the end point, takes the enterprise information systems as a basis, the service as the guide, and creates the whole social domain value as the organizational form (the main co-creation body includes inner value inventors, and the outer cooperative partners which includes value creation subjects, relevant stakeholders, customers, competitors, partners, governments, intermediaries, all units of social participation in value creation, etc.).

The systems establishes common values and effective network governance mechanisms, based on the use of knowledge synergies of machine, material, environment, etc., and integrates various value creation resources into resource pools, creates value flows through vertical, horizontal, and cross-interaction, with a certain value transfer mechanism in accordance with the overall value of different subjects. It's a systemsatic systems of connecting, integrating, and interacting with each other to create value for businesses and customers throughout the life cycle of a product or service. It is a dynamic "super systems" consisting of each complex but independent systems that interacts with each other to accomplish the same value creation task. In the enterprise value co-creation systems, each sub-systems within each systems improves the external environment of its own development and benefits from the proximity of its associated sub-systems. In the enterprise value co-creation systems, the interaction between the internal and external systems of the enterprise organization produces cohesion, far exceeding the result of the interaction between the individual systems. The emergence mechanism of enterprise value co-creation systems reflects the trend of value creation integration, modularization, networking, service, scale and collaboration development. Main manifestations are as follows: (1) The emerging characteristics of enterprise value co-creation systems are not the simple sum of the characteristics of each systems. It shows the effect of 1 + 1 > 2; (2) The types of emergent features of the enterprise value co-creation systems are completely different from the types of the characteristics of each systems of the enterprise value co-creation systems; (3) The emergent features cannot be derived or predicted by the ability to separately examine the behavior of a systems of enterprise value co-creation systems. The ability of the enterprise value co-creation systems is not the systems of the single value co-creation systems. Emerging phenomena cannot be predicted, inferred, or reversed from the part itself. (4) Emergence is an objective phenomenon that reflects the overall characteristics of the value co-creation systems, but the overall characteristics are not always emerging. Only those non-additive features that depend on the specific interaction between the parts are emergent.

B. The Judging Principle of the Emergence of Enterprise Open Value Co-Creation Systems

The above characteristics coincide with Muller's three criteria [5] for judging the existence of the emergence, namely the additivity criterion, the novelty criterion and the deductibility criterion [6–8]. Based on Muller's three criteria, combined with the characteristics of the value creation systems and the value creation ability of the composition systems, the following principles for the emergence of the open value co-creation systems of the enterprise are given:

1. The judging principle of inheritance emergence

If a certain value creation ability of the systems originates from the value creation ability of a certain component systems of the whole systems, and the index of the value creation ability is not the algebraic sum of the relevant capability indexes of the systems subsystems, the systems inherits the value creation of the systems. The ability to change and exhibit a non-linear overall value creation is the emergence of the inheritance of the systems.

2. The judging principle of the non-inheritance emergence

If the systems possesses certain of value creation ability, which is not possessed by a single component systems, the emergence of the non-inheritance systems' overall value creation ability is the non-inheritance of the systems.

This paper takes the emergence of the enterprise open value co-creation systems as the enterprise's open value co-creation systems composed of the value intelligence detection and analysis systems, the systems' coordinated control systems, and the systems' collaborative production systems as an exceeding the ability of each component systems. It is demonstrated reflected in the emergence of two levels: The first level is that the systems has the ability to inherit from each component systems, but its capability index is not simply the algebraic summation of the relevant sub-systems capability index within each component systems. And the second level is that the systems has the ability that each component systems did not have, and it is expressed in the overall value creation ability index of the systems.

III. Construction of the Evaluation Index of the Emergence of the Enterprise Open Value Co-Creation Systems

The emergence of the enterprise open-value co-creation systems is mainly reflected in the emergence of the systems' value creation ability. Therefore, the emergence of the systems-level value creation ability can be used to evaluate the emergence of the systems. The so-called value creation ability refers to the ability of enterprises and other units involved in value creation to invest in production factors to complete production or service tasks in the value creation systems. These abilities are determined by members of the value creation systems and various entities participating in the systems and various other quantity and quality of production factors, the network organization governance mechanism, the level of network organization decision management, and the various factors that guarantee the ability of networked production or service comprehensively. These abilities are also related to the external environment of the enterprise and other objective conditions. There are many factors influencing the value creation ability. From the perspective of emergence, analyzing the value creation ability of the enterprise open value co-creation systems mainly considers factors such as production factors, systems governance mechanism, market information, and customer demand forecasting and tracking, command decision, harmonious control, and harmonious production services. It is a series of dynamic process.

Therefore, systems-level value creation capability should mainly include three types of indexes, namely, value intelligence detection and analysis capabilities, systems harmonious control capabilities, and value harmonious production capabilities. Systems-level value creation capability continues to be decomposed at the subsystems level, which can be further described by subsystems-level value creation capability indexes. The systems-level value creation capability is the result of interactions and internal influences among various components within the systems. It mainly includes 2 categories: One is the emergence index of inheritance, including value information collaborative sensing ability and value harmonious production capacity. They inherit from the systems-level value creation ability, but they are the results of the comprehensive effect of two related systems. Although the function is similar to systems-level value creation, it is no longer a simple linear additivity of relevant systems value creation ability indexes; the other one is non-inheritance emergence index, including future competitive situation prediction ability, systems survivability and systems adaptability. They are the results of the comprehensive interaction between the constituent units in the systems. A single systems cannot independently possess these capabilities, so it is a new value creation capability index emerging at the systems level. The inheritance and non-inheritance indexes are the basis for the emergence of the evaluation systems. The better the systems-level value creation ability index emerges, the better the emerging effect of the systems.

IV. Modeling of Evaluation Indexes of the Emergence of the Enterprise Open Value Co-Creation Systems

A. Systems Survivability

The survival probability of the systems in the market can reflect the survivability of the systems. Therefore, the systems survivability index Y_1 can be obtained through the network operation success probability P_s, the systems network anti-risk probability P_{rd}, and the systems network connectivity $P_e(G)$ as

$$Y_1 = P_s + (1-P_s)P_{rd} + (1-P_s)(1-P_{rd})P_e(G) \quad (1)$$

The larger the value of Y_1, the stronger the survivability of the systems, and the more obvious the market survival characteristics reflected in the systems' emergence.

Systems network connectivity refers to the probability that a part of the network value creation node is still a connected graph after it is destroyed [9]. For a value network with *n* nodes, we assume that in the network $G(N,d)$ formed by N nodes and d links, the nodes are very reliable while the links fail with the probability P independently. Then, the network connectivity can be expressed as

$$P_e(G) = \sum_{i=n-1}^{d} A_i (1-P)^i P^{d-i} \quad (2)$$

In which A_i is the number of node connected networks (subnets of G) with N nodes and i edges.

Similarly, for an n node value network $G(N,d)$ with N nodes and d links, we assume that the links are very reliable while the nodes fail under the probability Q. Then, network connectivity can be expressed as

$$P_e(G) = 1 - \sum_{i=n}^{d} N_i Q^i (1-Q)^{n-1} \quad (3)$$

where N_i is the number of the disconnected subgraphs after i nodes.

B. Systems Adaptability

The probability that the systems works properly under complex conditions can reflect the systems' adaptability. Therefore, the systems adaptability index Y_2 can be described by the probability of trouble-free operation of the systems under certain production conditions.

Assume that there are S classes of production service styles for N classes of customer value requirements, under M categories of business environments. Furtherly, we assume the probability that the systems works trouble freely is P_{ijk}, when the kth production service style is adopted for the jth customer value requirement under the ith business environment. Therefore, the systems adaptability can be expressed as

$$Y_2 = \sum_{i=1}^{M} \varphi_i \sum_{j=1}^{N} \varphi_{ij} \sum_{k=1}^{S} (\eta_{ijk} P_{ijk}) \quad (4)$$

where φ_i is the probability of the ith kind of commercial competitive environment occurring; φ_{ij} is the probability of the jth customer value under the ith type of commercial competitive environment. While η_{ijk} is the probability of the jth customer value requirements under the ith business competition environment when adopting type k production service pattern.

The larger the value of Y_2, the stronger the adaptability of the systems, and the more obvious the market adaptability characteristics reflected in the systems' emergence.

C. Value Information Collaborative Awareness capability

The probability that the systems successfully acquires, effectively processes, and smoothly transmits customer value propositions and the production or service target information can reflect the capability of the systems' value information collaborative awareness. Therefore, the value information collaborative perception capability index Y_3 can be described by comprehensively integrating the customer value proposition and the probability of production or service target P_t, customer value proposition, production or service target information fusion processing probability P_m and customer value proposition and probability of transmission of production or service target information transmission probability $P_l(i,j)$, i.e.

$$Y_3 = P_t P_m P_l\left(i, j\right) \tag{5}$$

The larger the value of Y_3, the stronger the value information collaborative awareness ability of the systems, and the more obvious the collaborative value characteristics of the systems value information reflected in the systems emergent.

P_m can be expressed as

$$P_m = 1 - \prod_{i=1}^{n}\left(1 - P_{mi}\left(t\right)\right) \tag{6}$$

where $P_{mi}\left(t\right)$ is the probability of the integration of i information sources in n value intelligence collection sources.

$$P_{mi}\left(t\right) = \alpha_i + \beta_i\left(1 - e^{-\omega_i t}\right) \tag{7}$$

In which α_i is the ability of information processing and fusion systems to process data sent by i information sources of information collection; ω_i is the accuracy of information processing and fusion systems dealing with i value intelligence gathering information source information. $0 \le \alpha_i + \beta_i \le 1$ is the maximum value of information processing and fusion systems for the processing capacity of i information source.

$P_l\left(i, j\right)$ can be characterized by the pair connectivity rate of the terminal, namely, the probability that there is at least one link between two designated nodes after the network is damaged. Assume that in a network with N nodes and d links, each link is independently destroyed with the probability P, while each node is independently destroyed with probability Q. $P_l\left(i, j\right)$ is the probability of any two nodes between i, j in the network.

When $P \ge Q$,

$$P_l\left(i, j\right) = \sum_{k=0}^{d} A_{i-j}^{e}\left(k\right)\left(1-P\right)^k P^{d-k} \tag{8}$$

When $Q \ge P$,

$$P_l\left(i, j\right) = \sum_{k=0}^{n-2} A_{i-j}^{n}\left(k\right)\left(1-Q\right)^k Q^{n-2-k} \tag{9}$$

where $A_{i-j}^{e}\left(k\right)$ stands for, the number of sets of k links that satisfy the following conditions: When k links are normal while $d-k$ links are destroyed in each set, there is still at least 1 link between i and j. Similarly, $A_{i-j}^{n}\left(k\right)$ stands for that the number of sets of k nodes that satisfy the following conditions: When k nodes work while the rest $n-2-k$ nodes are not working in each set, there is still at least 1 link between i, j.

D. Collaborative production capacity

The collaborative production capacity of the systems can be reflected by the probability of smooth transmission about the instructions of customers' needs on products or services, the probability of meeting the feasibility of production conditions and the probability of the production according to the target in the systems. Therefore, the systems collaborative production capacity index Y_4 can be described by the probability of transmission through production or service instructions $P_1'\left(i, j\right)$, target production condition feasibility probability P_f and the probability of meeting the production target and producing the product demanded by the customers P_k.

$$Y_4 = P_1'\left(i, j\right) P_f P_k \tag{10}$$

The larger the value of Y_4, the stronger the collaborative production capacity of the systems, and the more obvious the production collaborative characteristics of the systems reflected in the systems' emergence.

In fact, $P_1'\left(i, j\right)$ reflects the probability that there is at least one link between two designated nodes after the value co-creation network is damaged. Therefore, it can also be characterized by the pair connectivity rate, and the establishment of the evaluation model can refer to the method of establishing $P_1\left(i, j\right)$ evaluation model, the probability of transmitting the target information.

E. Future commercial competitive situation prediction capability

Future commercial competition situation prediction must meet the requirements of accuracy, completeness and timeliness. Therefore, the future commercial competition situation prediction ability index Y_5 can be described by the accuracy of the future commercial competition situation prediction P_a, the completeness rate of future commercial competition situation prediction P_c and the processing efficiency of future commercial competitive situation information P_d, namely

$$Y_5 = \omega_a P_a + \omega_c P_c + \omega_d P_d \tag{11}$$

where ω_a, ω_c, ω_d are respectively the weight of P_a, P_c, P_d. The larger the value of Y_5, the stronger the forecasting ability of the future commercial competitive situation of the systems, and the more obvious the future market competitive situational awareness and prediction characteristics of the systems reflected in the systems emergent.

Accuracy of future commercial competition situation prediction P_a refers to the coincidence degree between the characteristics obtained from the predictions of the value creation systems about the customer value assertion and the product or service demanded by the customers, and the true target characteristics. Assume that $u_j\left(-1\le u_j\le 0\right)$ is the weighting factor of the effect from the wrong target market information, while $s_j\left(0<s_j<1\right)$ is the weighting factor of the effect from the performance characteristics of the target feature. Furtherly, o_{ij} is the jth characteristic value of the ith target, and r_{ij} is the jth perception prediction characteristic value of the ith target. Then, the average deviation degree between the perceptual prediction characteristic value and the objective eigenvalue of the ith target after the future commercial competition situation forecast is

$$V_i=\sum_{j=1}^{m}\frac{\left|r_{ij}-o_{ij}\right|\left(u_j+s_j\right)}{o_{ij}} \tag{12}$$

So, for M production or service targets from the customer's requirements, whose weight coefficients are respectively $\omega_1,\omega_2,\cdots,\omega_M$ and $\omega_1+\omega_2+\cdots+\omega_M=1$, the accuracy rate P_a of future commercial competition situation prediction can be expressed as

$$P_a=\sum_{i=1}^{M}\omega_i\left(1-V_i\right) \tag{13}$$

The completeness rate of future commercial competition situation prediction P_c refers to the extent that the types and quantities of future commercial competitive situational awareness and predictions obtained in the customer's production tasks are consistent with the market environment. Assume P_{c1} with P_{c2} are respectively the target species completeness rate and the target number completeness rate, and P_{c3} is the business situation prediction range completeness rate. Then the formula can be rewritten as

$$P_c=P_{c1}P_{c2}\left(1-e^{-P_{c3}}\right) \tag{14}$$

where P_{c1} is the ratio between the correctly discovered number of production target types from the commercial competitive situational awareness and prediction and the actual number of production target types in the market environment; P_{c2} is the ratio between the correctly discovered number of production targets from the commercial competitive situational awareness and prediction and the actual number of production targets in the market environment; Moreover, P_{c3} is the ratio between the forecast range in future business competitive situational awareness and forecasting and actual forecast range in the market environment.

Processing efficiency P_d of future commercial competitive situation information refers to the ratio between the target quantity of the production information that can be correctly predicted within unit time and the total number of targets. P_d can be written as

$$P_d=\frac{N_0\left(T\right)}{TN\left(T\right)} \tag{15}$$

where T is a designated time interval. $N_0\left(T\right)$ is the number of targets that the production information can be correctly predicted within the time interval T; $N\left(T\right)$ is the total number of production targets of the customer within time interval T.

V. Conclusion

According to different task requirements, the organizational structure of open-value co-creation systems of enterprises will continue to be in a complex dynamic evolution. The current emergence process in the evolution process makes the analysis process of the architecture more complicated and confusing. Therefore, reasonable evaluation and quantitatively describe the emergence of systems in the study of enterprise open value co-creation systems are of vital importance. This paper explains the concept of the emergence of enterprise open value co-creation systems, points out the principle of judging the emergence of the systems and preliminary gives the composition and evaluation model of the emerging value evaluation systems of enterprise open value co-creation systems. These evaluation models can provide principles and basis for the evaluation of enterprise open value co-creation systems and provide evaluation criteria. They can also provide optimization ideas for enterprise open value co-creation systems optimization based on value creation ability.

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References

[1] S. Li, and X. Tian, *Nonlinear Science and Complexity Science*. Harbin: Harbin Institute of Technology Press, 2006, ch. 4. (in Chinese)

[2] J. Holland, *Emerging—from chaos to order*. Translated by Y. Chen, H. Ding, and M. Gu. Shanghai: Shanghai Science and Technology Press, 2001, ch. 2–3. (in Chinese)

[3] G. D. M. Serugendo, M. P. Gleizes, and A. Karageor-Gos, “Self-Organisation and Emergence in MAS: An Overview,” *Informatica*, vol. 30, pp. 45–54, 2006.

[4] M. Liu, “Research on the Emerging Mechanism of Complex Group Decision System,” *Journal of System Science*, vol. 17, pp. 67–70, 2009.

[5] S. Jin, C. Ren, and H. Huang. “The emergence of complex system and multi-agent analysis based on holism,” *Computer Engineering and Science*, vol. 32, pp. 1–6, 2010.

[6] S. Y. Auyang, *Foundations of Complex Systems Theories: In Economics, Evolutionary Biology, and Statistical Physics.* Oxford: Oxford University Press, 1998, ch. 1.
[7] K. Ueda. “Synthesis and Emergence: Research Overview”. *Artificial Intelligence in Engineering,* vol. 15, no. 4, 2001, pp. 321–327.
[8] S. Jin, H. Huang, and G. Fan. “Research and Development of Emerging Multi-Agent System,” *Chinese Journal of Computers,* vol. 31, pp. 881–895, 2008.
[9] C. Chang, D. Lin, and Z. Zhai. “Study on the optimal terminal guidance law with falling point and falling angle constraints,” *Journal of Beijing Institute of Technology,* vol. 29, pp. 234–239, 2009.

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