# Entropy Evaluation Model of Fractal Integration of the Knowledge of Supply Chain

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***Abstract*—Fractal property of the knowledge of supply chain is confirmed, and the concept of fractal integration is presented. And the knowledge of supply chain is fractal integrated by building modularization fractal knowledge integration network independent of the organization structure. The process of fractal integration of the knowledge is divided into five stages: acquisition, transition, application, innovation and conversion, and the knowledge entropy model of the various stages is built to quantify and evaluate its integration effect. Finally, the knowledge transition of GE supply chain shows that the fractal knowledge integration can drop entropy significantly, and has higher structure order degree.**

***Index Terms*—fractal, knowledge, entropy, supply chain, evaluation**

## I. INTRODUCTION

In supply chain management, it's important that information and knowledge effectively flow. A large number of scholars have separately proposed concept information integration and knowledge integration. In information integration, there are mainly some outcomes. Barlow et al.[1] pointed out that the using information technology for information integration can increase the level of information sharing and significantly improve the links of supply chain organization; Evgeniou [2] pointed out that using rationally information technology and information strategy to integrate enterprise information can improve adaptability and visibility of enterprise. Tang et al.[3] analyzed disadvantages of the traditional supply chain only transfering information among adjacent nodes, and put forward the idea of building information networks; Xie Bin et al.[4] proposed the idea of building an information network integration mode. In knowledge integration, Gran et al.[5]-[6] pointed out that the integration of knowledge rather than knowledge itself form a core competence; Iansiti et al.[7] further extended the concept of integration of knowledge that the knowledge integration of organization including integration of customer knowledge, technical knowledge, enterprise external integration and internal integration. Inkpen [8]-[9] called transition and integration between personal knowledge and organizational knowledge as the process resulting spiral; Volberda, et al.[10] divided the knowledge integration mechanism into three respective integration including the system, coordination skills and social capabilities; Wu, et al.[11] discussed dissipation mechanism of knowledge transfer in organization structure, and establisehed entropy model of knowledge structure and knowledge transfer; Liu [12] researched evolution path model dissipative structureof the enterprise knowledge system. Feng Sibo, et al.[13] argued fractal characteristics and function of knowledge spread, and the approximate fractal dimension in the diffusion of knowledge.

But the relationship between information and knowledge in supply chain system has the homology and derivative. If the integration of information and knowledge is implemented respectively, that is not only a heavy workload, but also the relation and the concept of information and knowledge are difficult to distinguish.

## II. INFORMATION AND KNOWLEDGE OF SUPPLY CHAIN

### *A. The Relationship of Information and Knowledge*

Wu Jiapei [14] according to the British science philosopher Popper (K. Popper) "three worlds" theory, proposed information can be divided into three categories that the first kind is information on ontology about objective information about the physical world, the second kind is hidden information on epistemology about

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subjective spiritual world of human, and the third kind is dominant information on the epistemology about the concept world on objective sense. Three kinds of information must go through processing of different levels to become knowledge, but sometimes the second and the third one can also be directly show knowledge.

Knowledge is processing result of human information, knowledge derives from information dissemination, knowledge and information are indispensable. Based on previous research, the relationship between information and knowledge will be summarized including derived relationship, inclusion relationship, parallel relationship, transforming relationship and complementary relationship.

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From the five relationships, we know that knowledge is information processed by people. Therefore, supply chain can create a knowledge integration mechanism to find an intrinsic link between knowledge and information. Thus, information management can been gone beyond to achieve knowledge integration and management.

### *B. Fractal Information Flow*

Information flow in supply chain has a very important feature —the fractal self-similarity. With information technology advances, modern communication network is used, including communication satellites and ground stations in order to effectively achieve the user reliable communication and huge system including users and computer communications networks for information exchange and dissemination. So, the number of elements contained in the network system (network nodes) is soared to a large amount of countless information flow in the statistical information management system, will show their inherent randomness, and thus constitute the fractal structure of the network with self-similarity. In the early 90s, researchers from Bell Labs of the United States and Boston University collected a large number business data of Ethernet [15] and variable bit rate video services [16], and use fractal method to carried out analysis. The results show that in the actual network traffic statistics prevalence, it exists self-similar feature that transaction occurs independent of time, place and code manner. Therefore, the fractal self-similarity of content, structure or function is a very important nature of the information flow.

Large amounts of information in supply chain is produced, received, moved, exchanged, updatesd and deleted, however, the information seems messy not simple set, it is a system with inherent link and order. Viewed from the perspective expanding information, capture relevance, similarity of information, as to accurately collect, process and use information. Fractal theory reveals irregular internal law implied from messy, broken, chaotic and complex phenomenon [17]. In information flow of supply chain, the relationship between part and whole, while not identical, is consistent, uniform, and reflect the overall situation in a certain extent [17], and part and the overall in the structure and local function and overall are similar. Therefore, information flow in supply chain has the fractal self-similarity.

### *C. Information Entropy*

Wiener pointed that information is essentially a negative entropy, and information can be converted to a negative entropy, which is the negative entropy of information. Namely that people grasp the greater the amount of information is, the smaller the entropy of the system is, and the smaller the uncertainty of system is. So, it's described the relationship between information and entropy by calculating information entropy.

One source sends information flow including $N$ information to supply chain and constitutes information set $\{ a_i , i =1, \cdots, N \}$.If probability of occurrence of each information is equal, namely probability of occurrence of $a_i$ is $P_i =1/ N$ , then, the amount of information gained is only related to $N$ . When the greater $N$ is, the greater the uncertainty of information un-received is. If the uncertainty after receiving a message is removed, it means that the corresponding information amount is obtained. Shannon defined this information amount by selecting increasing function $\Phi(N)$ of $N$ . Namely

$$\Phi(N) = \ln N \tag{1}$$

If probability of occurrence of each information is equal, then

$$\Phi(a_i) = \ln(1/P_i) \tag{2}$$

Eq.(2) shows that the smaller the probability of occurrence of $a_i$ is, when once it occurs, the greater the amount of information obtained.To calculate the probability distribution of information of a certain source $U$ by (2)

$$H(U) = E(\Phi(a_i)) = \sum_i P_i \ln(1/P_i) = -\sum_i P_i \ln P_i \tag{3}$$

In information theory, $H(U)$ is called as information entropy of $U$ , if probability of occurrence of each information is equal, by (1)

$$H(U) = \Phi = \ln N = \ln(1/P_i) \tag{4}$$

$H(U)$ expresses the average degree of uncertainty of sources, and $\Phi$ is the information to remove the uncertainty degree.

## III. FRACTAL INTEGRATION OF KNOWLEDGE

### *A. Fractal Integration of Knowledge*

Knowledge integration is a new development stage of information integration, and the purpose of knowledge integration is to create value and to improve personal or business ability through the effective use of knowledge. Knowledge integration emphasizes innovation and flow of knowledge, knowledge can be developed only in contact with each other and used to derive new knowledge [18]. Dynamic supply chain need to support collaborative and flexible knowledge system to provide

intelligence and flexibility for supply chain integration and management, and reduce the cost of supply chain members [19], members of the supply chain to fully promote the product or service level, thereby enhancing the competitiveness of the entire supply chain.

Supply chain system is a dissipative structure, and there exists large-scale active source It's shown by (4) that, such information without integration will be generated a lot of positive entropy to undermine the orderliness of supply chain. Therefore, the information integration of supply chain will be another key entropy, but the currently, there are many barriers to information integration, which seriously affected its quality and efficiency.

In this paper, the view is proposed that information integration of supply chain directly exceed to the knowledge integration. On one hand, it's to accumulate knowledge, on the other hand, it can further promote knowledge innovation, and produce mutation fluctuation of knowledge to promote supply chain. However, knowledge integration of supply chain is a systematic project, therefore, it is n ecessary to establish an effective organizational environment—a learning supply chain that is the primary task to promot knowledge integration.

### *B. Learning Supply Chain*

This paper proposes five Strategies to realize creative learning within supply chain, and make it into the reaction function, ultimately any changes in market conditions can be made quickly and effectively response [20] by Senge in "The Fifth Discipline".

(1) To established team learning spirit based on supply chain, and to enhance mental model of supply chain.

(2)To integrate corporate culture of supply chain, to promot knowledge interaction and to create a common vision.

(3)To remove or fuzzy boundaries of organization, to achieve self-transcendence, and to realize system thinking based on supply chain.

(4) To draft incentives to develop and encourage staff to learn, share knowledge or information.

(5) To create advanced personnel training system.

Learning supply chain is the result of innovation and study to form a network of cooperation and collaboration that expands of mutual cooperation and coordination of internal and external environment. And it effectively promots acquisition, movement, transformation, application and innovation of knowledge. Through establishment of the learning organization, supply chain is become a network-based environment, learning organization, and its employees to create, access and transfer of knowledge, and then adjust their own behavior to reflect the new knowledge and insights. Both through their own experience to learn and success stories from other people to learn, they will quickly and efficiently accumulate and transfer knowledge, to develop their own core competencies [21].

### *C. NMFIK*

Fractal integration of knowledge of supply chain is defined that different sources, different carriers, different content, different forms of knowledge is achieved to realize knowledge application and generation of new knowledge, according to its own fractal law through new permutations, combinations, cross and creation. Fractal integration of knowledge of supply chain is achieved by building the network of modular fractal integration of knowledge (NMFIK).

NMFIK is constructed independent of outside organization structure of supply chain, shown by Fig.1. NMFIK achieve a high degree of coordination through building similar fractal structure, function and operation target al. Staff person is the minimum fractal element, and NMFIK is separated into some levels from supply chain to individual knowledge. Design of NMFIK achieve self-knowledge integration and innovation and provide new sources of knowledge for users, from personal knowledge to collective knowledge of nested systematic coupling of organic layers of knowledge of supply chain.

In the process of knowledge integration, NMFIK shows the internal network and external networks, tangible and intangible network. Internal network mainly refers to NMFIK formed of computer and information technology. Tangible network is material and technological foundation integration of knowledge and organizational learning. Intangible mainly refers to the invisible network of mutual collaboration and cooperation of people face to face communication.
Outside organization refers to learning based on invisible web-based. Fractal structure of NMFIK can share resources by making each part of supply chain contain the key knowledge of the overall knowledge in information, models, rules, plans of management.

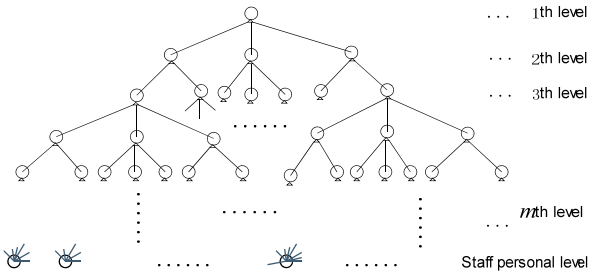


Figure 1. the network of modular fractal integration of knowledge

△——Inclusion relationship；○——Node module

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### *D. The Process of Knowledge Integration*

Knowledge of supply chain system is reflected on personal knowledge, which is essentially a human resources as well as the potential intellectual capital. When personal knowledge of supply chain combinates with the specific functions or tasks, the individual knowledge can create value. This association among personal knowledge in the node module of supply chain will form modular knowledge. And it's fractal modular integration of knowledge from personal knowledge to the knowledge module.

Cooperation of node module in supply chain is often dynamic and multi-objective, that is node module with different partners in different modules, comprehensive knowledge on a number of targets in co-operation.Modular knowledge integration is achieved cross-border knowledge exchange and cooperation to some extent modules, and realize knowledge integration of module - module. However, in order to form the systematization of knowledge of supply chain system, it's necessary to carry out the entire supply chain optimization and knowledge combination. Knowledge should be integrated into the module from the lower level graduated high-level fractal module integration, until to be integrated into the node enterprises knowledge, and then, from further integration of enterprise knowledge, up to knowledge integration of supply chain systematic. Nested hierarchy of knowledge in supply chain is shown by Fig.2.

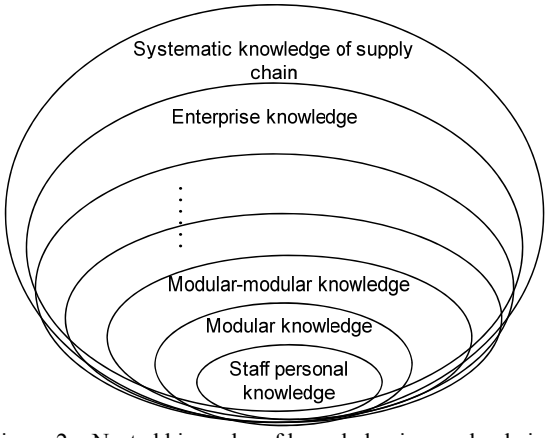


Figure 2. Nested hierarchy of knowledge in supply chain

### *E. The Mechanism of Knowledge Integration*

Knowledge flow inevitably have demonstrated the fractal traits in the fractal integration process. Accordingly, it's proposed fractal is mechanism for knowledge integration mechanism. Modular knowledge integration network regard level of knowledge of fractal supply chain as a modular system, which is shaped by the two sub-subsystem module coupled system of knowledge, not simple addition of per second fractal structure and function of knowledge, but organic coupled with more complex capability of nested layers of knowledge integration and more rapid diffusion of knowledge flow or the fractal hierarchy, by means of Internet and other hardware support activities, as well as corporate culture, system organizational learning and other soft environment knowledge of supply chain integration in both directions. Knowledge transfer from personal to the module, and personal feedback from module to learn, that realize cycle increased of integration in both directions. Knowledge integration is fractal process, fractal function, fractal feedback mechanism and dynamic nature.

## IV. ENTROPY EVALUATION MODEL OF FRACTAL INTEGRATION OF THE KNOWLEDGE

Based on the definition of Shannon entropy, knowledge entropy is proposed in this paper that measure degree knowledge eliminate the uncertainty for people, also belong to the scope of negative entropy. Entropy increasing of knowledge is as a measure of level of uncertainty and confusion and the complexity of existing state of knowledge of supply chain, and belong to the scope of positive entropy.

In Knowledge integration process, it exists the two-way cycle process of tacit knowledge - explicit - implicit or explicit - implicit - explicit integration In this paper, knowledge in the integration process will be divided into five processs including acquisition, transition, conversion, application and innovation, that are five main sources of knowledge entropy production.

### *A. Entropy Evaluation Model of Knowledge Acquisition*

Knowledge acquisition process in supply chain includes two aspects, one is from the node of supply chain, the other is to acquire knowledge from the external environment. Knowledge acquisition is also the recognition process of knowledge. Therefore, the primary task of knowledge integration is on knowledge acquisition and identification including useful knowledge for storage and classification and useless knowledge for removing.

So, Entropy Evaluation Model of knowledge acquisition is

$$H_1 = C_1 \sum P_{1i} \ln P_{1i} \tag{5}$$

$H_1$ ——Entropy of knowledge acquisition

$C_1$ —— Proportion of revenue from knowledge acquisition, revenue from knowledge acquisition $\Delta E_1$ /Total revenue from knowledge integration $\Delta E$ , namely $C_1 = \frac{\Delta E_1}{\Delta E}$ , $C_1$ can be positive, negative or zero.

$P_{1i}$ ——Probability of knowledge acquisition

### *B. Entropy Evaluation Model of Knowledge Conversion*

In knowledge integration mechanism, it is an important part of knowledge to achieve gradual accumulation and growth of knowledge through conversion process between tacit and explicit knowledge.

So, Entropy Evaluation Model of knowledge conversion is

$$H_2 = C_2 \sum P_{2i} \ln P_{2i} \quad (6)$$

$H_2$ ——Entropy of knowledge conversion

$C_2$ — — Proportion of revenue from knowledge conversion, revenue from knowledge conversion $\Delta E_2$ /Total revenue from knowledge integration $\Delta E$ , namely $C_2 = \frac{\Delta E_2}{\Delta E}$ , $C_2$ can be positive, negative or zero.

$P_{2i}$ ——Probability of knowledge conversion

### C. Entropy Evaluation Model of Knowledge Application

The ultimate goal of knowledge integration is to achieve application of knowledge in supply chain. Organization or researchers transfer knowledge explicit knowledge in applications into personal tacit knowledge to accumulate personal special skills, by means of learning by doing, doing by using. In the process of applying knowledge, it's particular emphasis on the coordination of knowledge among its members, including the stock of knowledge among members, knowledge of the absorptive capacity, ability to coordinate the application of knowledge [24]. And the goal of knowledge application is to ensure that knowledge on the final product in all aspects is guaranteed to achieve coordination and optimization of its functions.

Entropy Evaluation Model of Knowledge application is

$$H_3 = C_3 \sum P_{3i} \ln P_{3i} \quad (7)$$

$H_3$ ——Entropy of knowledge application

$C_3$ — — Proportion of revenue from knowledge application, revenue from knowledge transition $\Delta E_3$ /Total revenue from knowledge integration $\Delta E$ , namely $C_3 = \frac{\Delta E_3}{\Delta E}$ , $C_3$ can be positive, negative or zero.

$P_{3i}$ ——Probability of knowledge application

### D. Entropy Evaluation Model of Knowledge Innovation

The core of knowledge integration is knowledge innovation. And knowledge innovation is not only the fundamental way to create new value, but also the most viable strategy to generate and maintain competitive advantage of supply chain [25]. From the perspective of knowledge pattern, knowledge innovation is mainly come from explicit knowledge. In the process of knowledge innovation, it's not alll knowledge to participate in or lead any innovation [23]. In the event of knowledge innovation, only high-quality knowledge product can meet market demand, eliminate the random fluctuations, so that knowledge flow reach a temporary equilibrium ordered state. But new knowledge needs impact the dynamic balance system of further knowledge to generate new random fluctuation, so that the system has an unstable disordered state. Then, this spiral cycle update knowledge continuously [26], and to improve knowledge in supply chain to more advanced and orderly phase.

Entropy Evaluation Model of Knowledge innovation is

$$H_4 = C_4 \sum P_{4i} \ln P_{4i} \quad (8)$$

$H_4$ ——Entropy of knowledge innovation

$C_4$ — — Proportion of revenue from knowledge innovation, revenue from knowledge innovation $\Delta E_4$ /Total revenue from knowledge integration $\Delta E$ , namely $C_4 = \frac{\Delta E_4}{\Delta E}$ , $C_4$ can be positive, negative or zero.

$P_{4i}$ ——Probability of knowledge innovation

### E. The Relationship Entropy Evaluation model of Knowledge Transition

With the development of IT, organization structure as information channels is also changed accordingly. In the process of knowledge flow is to achieve knowledge conversion and application between tacit and explicit. In the diffusion process of knowledge flow, there are many obstacles frm time and space, so that knowledge can not flow without any resistance [26]. How to effectively circle in organizational structure and to make entropy production is least, is the most important element of supply chain. Therefore, this section focuses on building the relationship entropy model of knowledge in the organizational structure to test the efficiency and superiority of fractal integration of knowledge.

Knowledge transformation in supply chain is the process to share knowledge in the node module of organization structure. The process is reflected mainly on innovative subject driving knowledge to under knowledge transformation, conversion, sharing and application. As knowledge in supply chain is embedded in organization structure, knowledge transformation must be exchanged by communication in node modules in order to achieve knowledge to transfer among various carriers. At the same time, with the direction of knowledge transfortion usually is from high to low geographical location. So, the sender's knowledge, experience, attitude and ability to send knowledge will affect their choices and order, and the sender sends out the knowledge will inevitably contain noise, and knowledge transfer via organizaiton structure that would be further to the receiver absorb all kinds of noise in environment. Therefore, the receiver must select and filter of knowledge containing a lot of noise, according to their experience and their needs receiving and repairing knowledge source. Moreover, in the process of knowledge transfering, feedback is very important. From this perspective, the needs of recipient is not always clearly to be conveied to the sender, and knowledge of the sender is not able to send out all the way, and do not lose shape to pass to the receiver, and knowledge and experience from two sides will affect the efficiency and effectiveness of knowledge transfortion [28].

In this paper, the effectivenesse and quality entropy model of order degree of system [29] is to be expanded. By calculating the effectivenesse and quality entrpy of

fractal knowledge inegrated flowing in organization structure, establish the relationship entropy evaluation model of knowledge transition, that refers to the efficiency of knowledge flowing in organization structure of supply chain.

Structure entropy $H$ of biological system in [30] as reference is defined as structure description, so, the systematization degree can be shown,

$$R = 1 - H / H_m \tag{9}$$

$H$ —Structure entropy of system

$H_m$ —Maximum entropy of system

If $R$ is the greater, the order degree that system is the higher, organization is the more effective.

In this paper, the number of primary individuals is $n$ and management levels is $m$ after knowledge integrated, as shown in Fig.1. So, any module can directly access necessary knowledge, not via middle levels, therefore, knowledge can flow beyond the middle levels.

*(1) The effectivenesse entropy*

In this paper, it's called the effectivenesse of structure of supply chain system that circulation speed of knowledge flows in organization structure of supply chain, and the measure of the uncertainty of the effectivenesse of knowledge circulation is called the effectivenesse entropy of supply chain.

So, define the longitudinal link between higher and lower elements is the effectivenesse entropy $H_{ij5}$,.

$$H_{5ij} = -P_{5ij} \ln P_{5ij} \quad (i, j = 1,2,\cdots,n+m) \tag{10}$$

$P_{5ij}$ — The probability of micro-state of the effectivenesse is achieved, when knowledge flows between the $i$ th and $j$ th node module.

$$P_{5ij} = \frac{1}{n+m} \tag{11}$$

Because knowledge can flow beyond the middle levels, knowledge transition is knowledge sharing of one -step not knowledge transition of point by point, example, the information of market demand will be shared by all nodes.

By (9) and (10), total effectiveness entropy $H_5$ is

$$H_5 = H_{5ij} = -P_{5ij} \ln P_{5ij} = -\frac{1}{n+m} \ln \frac{1}{n+m}$$

$$= \frac{1}{n+m} \ln(n+m) \tag{12}$$

The Maximum effectivenesse entropy of system is

$$H_{5m} = \ln A_5 = H_5 = \ln(n+m) \tag{13}$$

$A_5$ — Total number of micro-state of the effectivenesse [29]

By (9), (12) and (13), the definition of the effectivenesse of system is

$$R_5 = 1 - \frac{H_5}{H_{5m}} = 1 - \frac{1}{n+m} \qquad R_5 \in [0,1] \tag{14}$$

*(2) The quality entropy*

It's called the quality of supply chain system that circulation accuracy of knowledge flows in organization structure of supply chain, and the measure of the uncertainty of the quality of knowledge circulation is called the effectivenesse entropy of supply chain.

The quality entropy of node of supply chain $H_{i6}$ is the description of uncertainty of error of this node in the process of knowledge circulation.

$$H_{6i} = -P_{6i} \ln P_{6i} \tag{15}$$

$P_{6i}$ —The probability of micro-state of the quality is achieved, when knowledge flows in the $i$ th node module.

Total quality entropy $H_6(x)$ is

$$H_6 = -\sum_{i=1}^{n+m} H_{6i} = -\sum_{i=1}^{n+m} P_{6i} \ln P_{6i} \tag{16}$$

Here, the link span of node modules is $k_i$ that refers to the number of nodes linking to the $i$ st node directly.

$$\text{So, } k_i = n + m - 1 \tag{17}$$

By (17), total number of micro-state of the quality [29] is

$$A_6 = \sum_i k_i = (n+m-1)^{n+m} \tag{18}$$

So, The Maximum quality entropy of system is defined as

$$H_{6m} = \ln A_6 = \ln(n+m-1)^{n+m} \tag{19}$$

By (17) and (18),

$$P_{6i} = k_i / A_6 = \frac{1}{(n+m-1)^{n+m-1}} \tag{20}$$

By (15) and (20),

$$H_{6i} = -\frac{1}{(n+m-1)^{n+m-1}} \ln \frac{1}{(n+m-1)^{n+m-1}}$$

$$= \frac{1}{(n+m-1)^{n+m-2}} \ln(n+m-1) \tag{21}$$

By (16) and (21), the total quality entropy is

$$H_6 = \sum_{i=1}^{n+m} \frac{1}{(n+m-1)^{n+m-2}} \ln(n+m-1) = \frac{(n+m)\ln(n+m-1)}{(n+m-1)^{n+m-2}} \tag{22}$$

By (9), (19) and (22), the quality of supply chain is

$$R_6 = 1 - \frac{H_6}{H_{6m}} = 1 - \frac{\dfrac{(n+m)\ln(n+m-1)}{(n+m-1)^{n+m-2}}}{\ln(n+m-1)^{n+m}}$$

$$= 1 - \frac{1}{(n+m-1)^{n+m-2}}, \ R_6 \in [0,1] \tag{23}$$

So, order degree of system structure is

$$R = \alpha R_5 + \beta R_6 \tag{24}$$

$\alpha, \beta$ — the weight factors on the system of effectiveness and quality, $\alpha, \beta \in [0,1]$.

So, as long as take different weights of $\alpha$ and $\beta$, degree of order of supply chain can be calculated.

## V. EMPIRICAL STUDY

GE supply chain was established in 1993, has become China's largest home product supply chain, has more than 200 suppliers, manufacturers and direct sales business, more than 60,000 employees in Beijing, Tianjin, Shanghai, Chengdu, Chongqing, Xi'an, Guangzhou, Shenzhen, more than 160 cities in China and Hong Kong, Macau, and has formed the core of GE supply chain group. The top-managers of GE Supply chain has been fully aware of deficiencies and defects of traditional information management, and integrate knowledge by building the network of modular fractal integration of knowledge, moreover apply entropy evaluation model of knowledge to evaluate the effect of knowledge integration. And some outcomes are achieved.

The relationship entropy evaluation model of knowledge transition is stressed in the case study, that compare and analyze the difference between the ffectiveness and quality of knowledge transition in before and after knowledge integration.Before knowledge integration, the pattern of knowledge transition is the same the Fig.4-1 of [29]. In the figure, knowledge transfer in $N$ primary elements and $M$ management levels. ○ is node, and — is the direct link between nodes. There is only information link between the upper and lower levels, and in some systems may also have horizontal information links. The link numbers via two elements is called the link length. Two indicators in circulation of knowledge is the effectiveness and quality of system in order to calculate the order degree of system structure.

So, compare and analyze the parameters of the relationship entropy evaluation model of knowledge transition before knowledge integration with ones after integration, and some results.

(1) Before knowledge integration of GE supply chain, the effectiveness entropy $H_1$, the maximum effectiveness entropy $H_{1m}$ and he effectiveness $R_1$ are respectively

$$H_{1m} = \ln A_1$$

$$H_1 = \ln A_1 - \frac{2[N + M(M-1) + N/M]^2}{A_1} - \frac{6(M-1)N}{A_1}\ln 3 - \frac{8(N^2 - N^2/M)}{A_1} \quad (25)$$

$$R_1 = 1 - 1 + \frac{2[N + M(M-1) + N/M]^2}{A_1 \ln A_1} + \frac{6(M-1)N}{A_1 \ln A_1}\ln 3 + \frac{8(N^2 - N^2/M)}{A_1 \ln A_1} \quad (26)$$

$$A_1 = 2(M+N)(M + 2N - N/M)$$

And the quality entropy $H_2$, maximum quality entropy $H_{2m}$ and quality $R_2$ are respectively

$$H_{2m} = \ln A_2$$

$$H_2 = \ln A_2 - (M/A_2)\ln M - 1/2 \ln N + M/M \quad (27)$$

$$A_2 = 2(N+M)$$

Due to $N$ =471， $M$ =7 from investigation, then

By (25), $H_1$=12.60

By (26), $R_1$=0.077

By (27), $H_2$ =4.77

By (28), $R_2$ =0.30

Take $\alpha = \beta$ =0.5， by (24),

$$R' = \alpha R_1 + \beta R_2 = 0.19$$

(2) After knowledge integration of GE supply chain, the pattern of knowledge transition is as shown in Fig1. And the effectiveness entropy $H_5$, the effectiveness $R_5$, the quality entropy $H_6$ and the quality $R_6$ are respectively.

Due to $n = 232$， $m = 4$ from investigation, then

By (12), $H_5$ =0.02

By (14), $R_5 = 0.99$

By (22), $H_6 \to 0$

By (23), $R_6 \to 1$

Similarly, take $\alpha = \beta$ =0.5， by (24),

$$R = \alpha R_5 + \beta R_6 = 0.995$$

## VI. CONCLUSIONS

Due to the effectiveness entropy, $H_5 < H_1$

The effectiveness, $R_5 > R_1$

The quality entropy, $H_6 < H_2$， and $H_6 \to 0$

The quality, $R_6 > R_2$， and $R_6 \to 1$

The order degree of system structure, $R > R'$

(1)After knowledge integration, the effectivenesse entropy and the quality entropy are decreased significantly than before,. And the entropy of calculation process is more simple, intuitive and clear.

(2) Due to $H_6 \to 0$ and $R_6 \to 1$, the quality or the accuracy of knowledge flowing is almost 100%, that is no knowledge distortion, delay, or latency.

(3) Due to $R > R'$ and $R \to 1$, it has higher structure order degree after knowledge integration than before.

It's also shows that the network of modular fractal integration of knowledge independent of outside organization structure of supply chain contributes to flow among nodes for knowledge element transparently.

In this paper, the view is proposed that information integration of supply chain directly exceed to the knowledge integration. On one hand, it's favorable to accumulate knowledge, on the other hand, it can further promote knowledge innovation, and produce mutation fluctuation of knowledge to promote supply chain. And the fractal integration mechanism of knowledge are conducive to converse from implicit to explicit knowledge and the growth of knowledge accumulation, so that the efficiency of knowledge flow is improved significantly. On one hand, NMFIK heighten the effectivenesse and the quality and maximize the role of knowledge, on the other hand, improve transparency of information and knowledge sharing scope in node enterprises, and reduce many uncertainties of dynamic supply chain.

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