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System Dynamic Model of Enterprise Cluster Complex Network Resources Integratability

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Abstract: On the basis of in-depth analysis on influence factors of enterprise cluster complex network resources integratability system as well as interrelation between such factors, this study builds the causality graph and the system dynamic model capable of describing development and change of enterprise cluster complex network resources integratability, realizes the model by Vensim, the system dynamic modeling tool and verifies effectiveness of the model. Results of the experiment show that the data from the model is quite identical with the actual data. It proves that the method of system dynamics can effectively simulate effect of network density, network centricity, network structure equivalence, structural holes, social capita, external environment and the number of enterprise members on enterprise cluster complex network resources integratability. This study will provide reference to the management for decision making.

Key words: Enterprise cluster, complex network, resources integratability, system dynamics

INTRODUCTION

Enterprise cluster is a key existing mode of Chinese economic development, in which all enterprise members appear as a dynamic network integrating cluster resources due to embedding of social network relations, resource sharing and other reasons. In the complex network with increasingly severe competition, it is an urgent problem for the current Chinese manufacturing industry to improve competence of the cluster as a whole and each enterprise as an individual by improving resources integratability of the enterprise cluster.

So far, the researches on enterprise cluster complex network resources integratability system focus on definition of enterprise cluster (Porter, 1998), resources of enterprise cluster (Xiao and Li, 2009), difference of resources endorsement (Wernerfelt, 1984; Barney, 1991), level of resources deployment ability (Prahalad and Hamel, 1990), sharing ability of the enterprises (De Oliveira Wilk and Fensterseifer, 2003), dynamic ability of the enterprises (Teece *et al*., 1997) and local innovation ability (Lou *et al*., 2005),which can promote resources integration and improve competence of the enterprises and enterprise cluster. Some scholars also conduct researches on definition of resources integratability (Xiao and Li, 2009; Koruna, 2004), classification of resources integratability (Zahra *et al*., 2006), relationship of network resources integration and network structure with resources integratability (Tolstoy and Agndal, 2010; Baraldi and Stromsten, 2009; Xiao *et al*., 2010; Xiao *et al*., 2009), assessment of resources integratability (Xiao and Li, 2009) etc. However, the above researches basically focus on resources integration or resources integratability from the perspective of single enterprises or static analysis. Some scholars research industrial cluster effect (Sun, 2007) and industrial cluster evolution (Ning and Liu, 2004; Liu *et al*.,2007; Jia and Huang, 2011). However, no documents have made dynamic and systematic analysis on resources integratability of enterprise clusters.

This study believes that evolution of enterprise cluster complex network resources integratability is a nonlinear, dynamic and complex process, covering many feed-back circuits of material and information. However, system dynamics refers to computer-imitated theories and methodology of research on nonlinear system containing multi-level fed-back information in social and economic fields. It can solve complex problems in situation of incomplete and asymmetric information. It should have proper applicability and development trend predictability to research enterprise cluster resources integratability by method of system dynamics.

As such, based on achievements of the existing literature (Xiao and Li, 2009; Xiao *et al*., 2010; Xiao *et al*., 2009), this study treats complex network of enterprise cluster as an integral system and builds the causality graph and the system dynamic model capable of describing development and change of Enterprise Cluster Complex Network Resources Integratability and verifies effectiveness of the model through simulation in relation to relationship between complex network structure and resources integratability, immediate effect of resources integration, number of enterprise members and effect of environment on resources integration.

ANALYSIS ON CHARACTERISTICS OF ENTERPRISE CLUSTER COMPLEX NETWORK RESOURCES INTEGRATION SYSTEM

Complex network of enterprise cluster is the factor that limits resources integratability: Resources integratability of enterprise cluster is a complex network and complex system (Tolstoy and Agndal, 2010). Complex network structure of enterprise cluster may be considered from network density, network centricity, network structure equivalence, structural hole and social capital. According to the literature, size of resources integratability and complex network of enterprise cluster have complex network relations. Since systematic structure determines systematic function, complex network of enterprise cluster is the most immediate cause of resources integratability.

Degree of resources integratability is the immediate factor that limits resources integratability: Degree of resources integratability covers width, depth, speed and openness. Width reflects scope of cluster integration resources with its size measured by number of members, market share and production scale. Depth reflects the levels of resources integration by a cluster with its size limited by cluster cohesion, utilization rate of production capacity, derivation ratio of enterprise and R and D funds input. Speed reflects the efficiency of cluster integration efficiency with its size measured by new product proportion, labor flow rate and capital turnover. Openness reflects the connections between enterprises within a cluster and between the cluster and outside enterprises during resources integration. Openness can be studied through the degree of information communication and collaboration (Lina *et al*., 2006). As such, degree of resources integratability is the immediate factor the limits resources integratability.

Cluster size (i.e. number of enterprise members) is the principal factory that limits resources integratability: Number of enterprise members plays an important role in public goods supply as an economy of scale with an effect on width of resources integratability, in cluster cohesion with an effect on depth of resources integratability, in flow of labor between cluster enterprises with an effect on speed of resources integratability and in smoothness of communication channels both within and between clusters as well as labor division and collaboration between administrative departments within a cluster, between enterprises on the supply chain and between employees within an enterprise with an effect on resources integration. Therefore, number of enterprise members is the principal factory that limits resources integratability.

External environment is the security for complex network of enterprise cluster to conduct resources integratability: Complex network resources integratability of enterprise cluster is a complex system (Tolstoy and Agndal, 2010). From the perspective of system theory, to effectively integrate resources, an enterprise cluster must meet adaptability of a system to the environment. Environment, as part of complex network of enterprise cluster, is formed on the basis of long-term formal or informal cooperation and communication between behavior principals of enterprise cluster (including universities, institutes, enterprises, local governments and other institutions). Environment is actually all network relations between principals of resources integratability. Excellent environment is the security for resources integratability of enterprise cluster to provide necessary basic conditions for successful resources integration. The more mature it develops, the stronger its competence will become through resources integratability.

DYNAMIC MODEL OF ENTERPRISE CLUSTER COMPLEX NETWORK RESOURCES INTEGRATABILITY SYSTEM

Causality in complex network resources integratability of enterprise cluster: Judged from system characteristics of complex network resources integration of an enterprise cluster, its birth, development and drive to industrial upgrading lie in the complex dynamic network relations between complex network structure (including network density, network centricity, network structure equivalence, social capita and structural holes) and resources integratability of enterprise cluster (in terms of width, depth, speed and openness). Meanwhile, increasing number of members, market share, production and etc will widen resources integratability; stronger degree of information communication and collaboration will increase openness of resources integration; increasing cluster cohesion, production capacity utilization, enterprise deviation rate and research funds input will deepen resources integratability; growing new product ratio, labor flow and funds turnover frequency will speed up resources integratability. In addition, any change of external environment will have an impact on width, depth, speed and openness of resources integration and further, resources integratability.

Base on the above analysis, we can build the causality chart of enterprise cluster complex network resources integratability (Fig. 1).

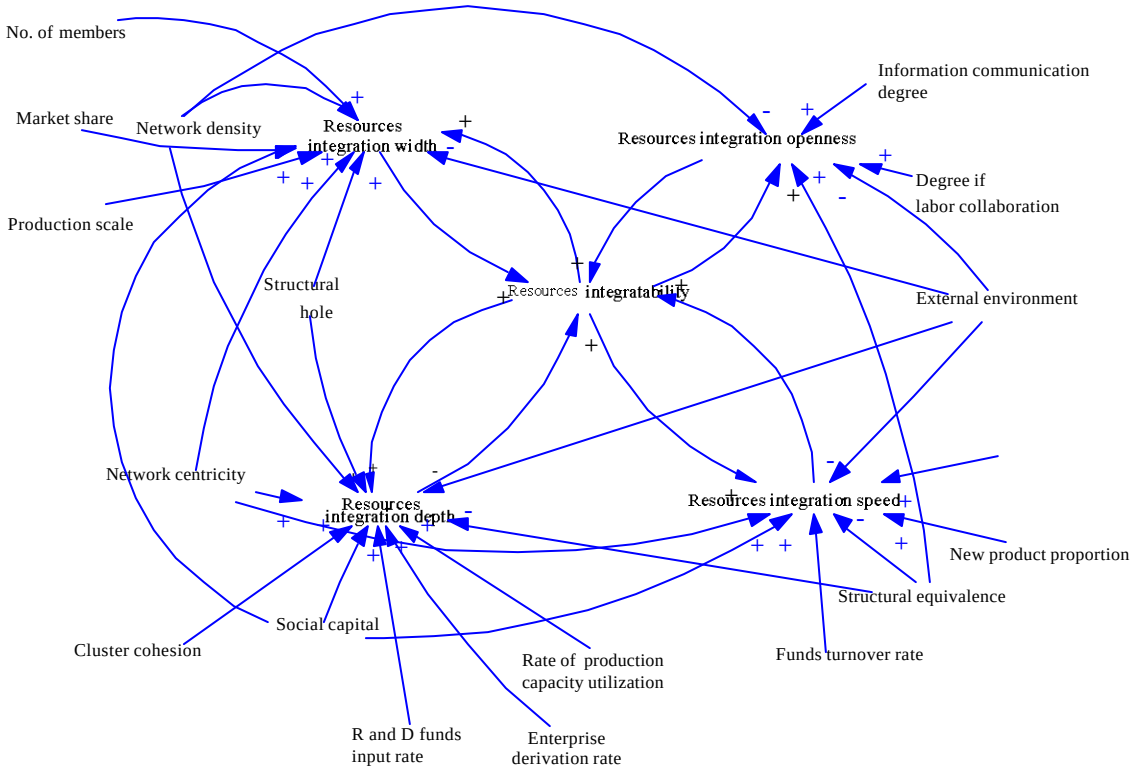

Fig. 1: Causality chart of enterprise cluster complex network resources integratability

Flow chart of enterprise cluster complex network resources integratability: Based on the above Causality Chart in addition to other necessary variables introduced for resources integratability operation, we build the dynamic flow chart of Enterprise Cluster Complex Network Resources Integratability (Fig. 2).

Description of models: The research on this system dynamic model is joined by four subsystems, i.e. resources integratability width, resources integratability depth, resources integratability speed and resources integration openness.

Resources integratability width: In the subsystem of resources integratability width, increase and restriction of resources integratability width are set as speed variables. As resources integratability width receives indirect effect from social capital, network centrality, structural hole and other factors and direct effect from external environment restriction (e.g. by government), market share, production scale, number of members and other factors, all of these are treated as auxiliary variables.

Resources integratability depth: In the subsystem of resources integratability depth, resources integratability depth increase and resources integratability depth decrease are set as speed variables. As resources integratability depth receives indirect effect from structural hole, social capital, structural equivalence, network centrality, network density and other factors and direct effect from external environment restriction (e.g. by government), production capacity utilization, enterprise derivation, cluster cohesion, R and D funds input rate and other factors, all of these are treated as auxiliary variables.

Resources integratability speed: In the subsystem of resources integratability speed, resources integratability speed increase and resources integratability speed decrease are set as speed variables. As resources integratability speed receives indirect effect from social capital, structural equivalence, network centrality and other factors and direct effect from external environment restriction (e.g. by government), new product ratio, funds turnover rate, labor flow rate and other factors, all of these are treated as auxiliary variables.

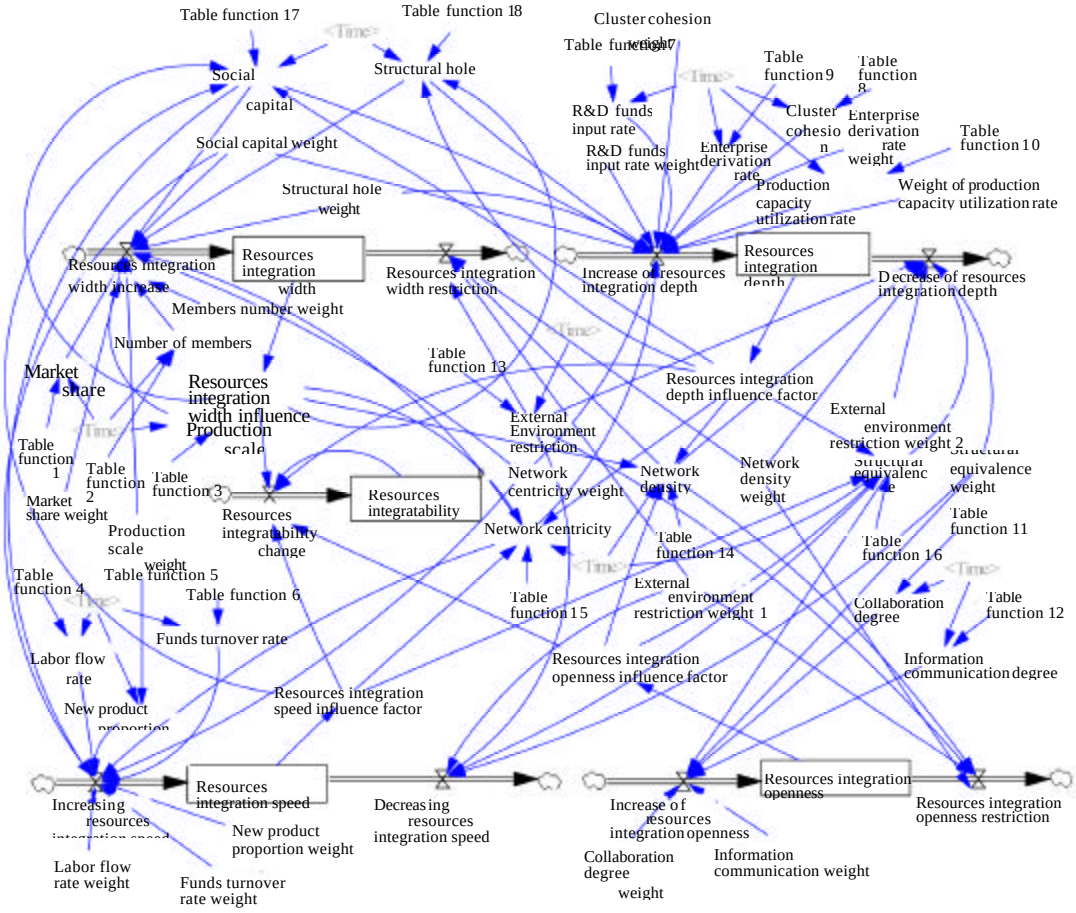

Fig. 2: Flow chart of enterprise cluster complex network resources integratability

Resources integration openness: In the subsystem of resources integration openness, resources integration openness increase and resources integration openness restriction are set as openness variables. As resources integration openness receives indirect effect from network density, structural equivalence and other factors and direct effect from external environment restriction (e.g. by government), information communicability, collaboration and other factors, all of these are treated as auxiliary variables.

Since structure and behavior of the system changes with time, the auxiliary variables must adopt time to show interrelations and changes between time and all variables. We can set <Time> as a hidden variable and adopt graph editor provided by Vensim version5.8 to build systematic flow chart for enterprise cluster resources integratability (Fig. 2).

SIMULATION AND APPLICATION OF DYNAMIC MODEL OF ENTERPRISE CLUSTER COMPLEX NETWORK RESOURCES INTEGRATABILITY

Parameters setting of the model: According to the system flow chart shown on Fig. 2 and in consideration of actual economic meaning of horizontal variables, speed variables and auxiliary variables as well as actual situation and experience of questionnaires, initial value of resources integratability is set as 1 and initial value of resource integration width, resources integratability speed and resources integration openness as 0.1.

In terms of horizontal variables, calculation becomes more difficult due to dimension inconsistency of resources integratability, integration width, resources integratability speed and resources integration openness. The final output of horizontal

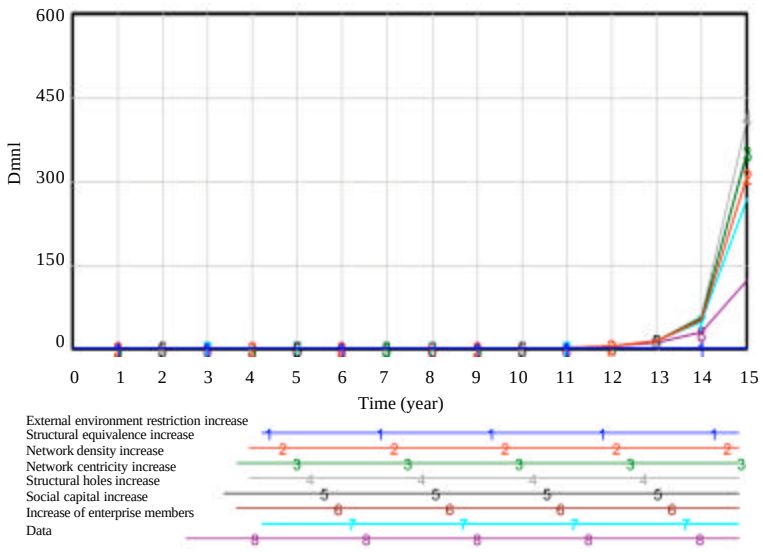

Fig. 3: Analysis on sensitivity of resources integratability variables

Table 1: Comparison of horizontal variables data from different periods

	Year					
Horizonal variables	1	3	6	9	12	15
Resources integratability width	0.1	0.188477	0.315116	0.510658	0.82920	1.37712
Resources integratability depth	0.1	0.239415	0.543981	0.921553	1.31674	1.67938
Resources integratability speed	0.1	0.204065	0.434487	0.699690	1.04376	1.47322
Resources integration openness	0.1	0.145042	0.362618	0.709740	1.20094	1.62412
Resources integratability	1.0001	1.000620	1.017940	1.256590	4.01958	123.135

variables is shown by relative values. For speed variables and auxiliary variables, the value range is set as (0, 1).

Effectiveness test of model: According to a survey over students of the MBA Program of Jinan University as well as the company managers and government officials participating in the Chinese Merchants' Forum, a high-end interview held by Jinan University, customized questionnaires issued at So Jump Net and the data from actual field investigations over some enterprise clusters, we simulate horizontal variables of resources integratability and resources integratability with Chinese enterprise clusters of the last 15 years and test effectiveness of historical data over the model (Table 1 for actual data).

According to Table 1, (1) resources integratability width, resources integratability depth, resources integratability speed and resources integration openness grow steadily; (2) enterprise cluster resources integratability keeps at a low level during the past 12 years. When resources integratability width, resources integratability depth, resources integratability speed and resources integration openness grow steadily to reach certain level, resources integratability rapidly increases and economy of enterprise cluster enters a benign development period. Therefore, in general, this model has sound fitting degree and high predictability largely in line with the features expressed at all stages of actual enterprise cluster resources integratability. Therefore, the model is effective.

Results and application of simulation: During simulation calculation of the enterprise cluster complex network resources integratability system, this Study adopts Vensim version 5.8. Figure 3 and 4 for simulation calculation results. Resources integratability increases with width, depth, speed and openness of resources integratability. It can be properly fitted to the application of model largely includes the following two aspects: (1) investigation actual enterprise cluster resources integratability. Over enterprise cluster resources integratability process; (2) analysis on sensitivity of variables (e.g. enterprise cluster size (i.e. number of

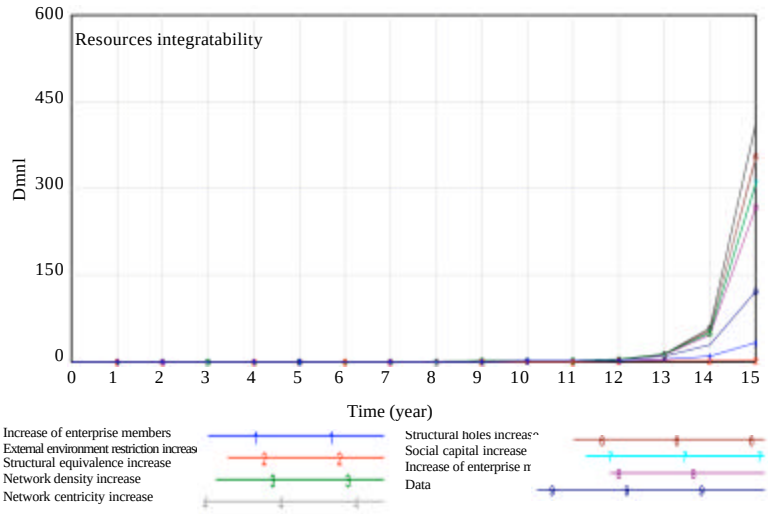

Fig. 4: Effect of number of enterprise members on resources integration

enterprise members), external environment restriction (e.g. of government policies), network density, network centricity, network structure equivalence, structural holes, social capita, etc) during enterprise cluster resources integratability.

With the second aspect of model application as an example, we adopt data in Table 1 as initial simulation value and increase restriction of external environment to acquire the 1st set of simulation values; further increase structural equivalence on basis of the above to acquire the 2nd set of simulation values; then increase network density, network centricity, structural holes, social capital and number of enterprise members to acquire the 3rd, the 4th, the 5th, the 6th and the 7th sets of simulation values to test sensitivity of the variables. Figure 3 for analysis results.

When size of enterprise cluster further increases and number of enterprise members exceeds certain value, resources integratability may drop. See Fig. 4.

As shown by Fig. 3, with increasing number of enterprise members, resources integratability growth may be slow at but will become rapid when the members reach certain number. Meanwhile, resources integratability may receive little effect from increasing social capital, structural holes and network centricity during the first few years. However, when social capital, structural holes and network centricity increase to certain level, resources integratability will have remarkable growth; resources integratability may receive little effect from increasing network density and structural equivalence during the first few years. However, when network density and structural equivalence increase to certain level, resources integratability will significantly drop. With increasing restriction of external environment, resources integratability will significantly decrease. According to the above analysis, resources integratability is sensitive to size of enterprise cluster, social capital, structural holes, network density, network centricity, structure equivalence and external environment, actually most significant to change of external environment. However, larger enterprise cluster doesn't mean better, because when number of enterprise members exceeds certain value, enterprise cluster resources integratability may drop. Therefore, it is crucial to appropriately control the size of enterprise clusters. According to the results of simulation, this study gives the following suggestions:

- Enterprise cluster members and governments shall adopt certain measures to optimize network structures of clusters and enhance enterprise upgrading. From network density of enterprise clusters, we shall strengthen relations between members within the enterprise clusters, urge the enterprises within the clusters to acquire resources from outside, actively improve intermediary institutions within the clusters and speed up information circulation of enterprises; cultivate leading enterprises and increase resources integratability through increasing network centricity; cultivate and utilize social capital and make full use of structural holes as an advantage to strengthen resources integratability; encourage large quantity of

participating institutions to join the clusters, create vertical labor division and avoid too high network structure equivalence. The government shall create a sound resources integratability environment, while the enterprise clusters shall control their sizes together with the government. The enterprises shall replace the size-oriented operation to specialization

CONCLUSION

This study adopts the system dynamics method to build the causality model with all elements of resources integratability interacting with each other as well as the model of enterprise cluster complex network resources integratability system, tests effectiveness of the models and proves that the key factors for effect on resources integratability are network density, network structure equivalence, social capital, structural holes, network centricity, external environment (government) and number of enterprise members.

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