Effect of Lean to Emergence of Complex Systems-Taking Supply Chain as Example

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Abstract: Emergence is the phenomenon, activity and process which creates the new characteristics by the interaction of the elements of complex system. The emergence theory pays attention to the systematic evolution process from simple to complex, and from low to high. The lean thought endeavors to eliminate the system redundancy and pursue system emergence by applying the technology and method of simplification. The lean emergence is the phenomenon, activity and process which creates the new quality in the evolution of from complex to simple, from big to small, from more to less. The lean emergence plays an important role in the systematic evolution. In the lean emergence perspective, this article analysed complex system structural characteristics of the supply chain network, the cooperation between supply chain network enterprises on the complex system structure, the evolution of supply chain system under lean management, this study has a certain practical significance for indicate the emergence management of the supply chain network.

Key words: Supply chain (SC), Emergence theory, Lean thinking, Complexity, System science, Lean emergence

1. INTRODUCTION

Whole emergence is one of the most important concepts in the contemporary complex science. Ludwig.Von. Bertalanffy, the founder of emergence theory, believed that the whole emergence (referred as emergence), plays a very important role in system science, and the study on emergence phenomenon should be fundamental to system science (Dongping,2005). Santa Fe Institute (USA), which is famous for the study on complex, also listed emergence as the theme of its research. They believed that “Complex, indeed, is a science of emergence. The challenge that we are facing now is how to find out the fundamental rule of emergence” (Michel,1997). By now, Emergence has always been a subject of important in the theoretical circle and industry.

Complexity is a kind of space-time structure made up of interactive components or elements within the system, whose carrier is the complex system. After the formation of system by elements, some characteristics will emerge, which is liable to occur in the evolution of the system from lower to higher level, and could not be identified from any element of the system. This phenomenon is thus called emergence vividly. The reason why the system functions are “the whole is greater than the sum of parts”, is due to the occurrence of the new characteristics of the system. The “greater” part is indeed the new characteristics emerged (Ludwig,1987). This lead to emergence theory is usually applied for analyzing the evolution of the system from low to high level. The ideas of Holland, such as “Emergence ----more comes from less” and “Complex comes from simple”, are the vivid description of the initiating process of emergence indeed. However, there are various trends of development in the objective things and the whole world. While the evolutionary trend from simple to complex exists, the collapsing trend from complex to simple also exists. After all, the world is made up of the two interactive trends (Changgen,1997). At the same time, the formation of complexity is not a sustainable add-up of complexity, but rather follows the cycling progress of simple ----complex ---- (re)simple---- (re)complex. The reason we pays attention to the emergence from complex to simple and from more to less, because the emergence is the inevitable link for the development of objects. Since the current theory pays little attention to this, the emergence theory is incomplete and limitation. This article proposes the concept of lean emergence, and explores the formation mechanism of lean emergence by taking the supply chain as example, which makes some contribution to the improvement of emergence theory and the uplift of lean thought.

2. REVIEW OF RESEARCHES

2.1. The Origin and central idea of the emergence theory for complex system

From 1950s, many scholars and research institution, such as Moorer, W. Ross. Ashby, Bertalanffy, Ervin. Laszlo, and “Santa Fe school” (SFI), had been researching on emergence in order to setup theoretical frame for emergence and abide by modern scientific standards. Scholars generally believe that systematic structure, and systematic environment and their relative relationship determine the system’s wholeness and functions. It means that systematic wholeness and functions are the results of comprehensive integration of internal system and
external systematic environment. According to emergence theory, emergency is not only a phenomenon, an activity procedure, but also a peculiar property of complex system. Some representative researches are as follows:

Moorer defined that the two compounds generated by the combination of causes, by the way of studying the combination of powers in physics and the combination phenomenon of hydrogen and oxygen in chemical reaction. And finally, he put forward the criterion for judgment of emergence’s three aspects(Wei, 2010).

In the middle of the nineteenth century, British man, G. H. Lewes and W. Ross. Ashby, started their researches on emergence by studying the phenomenon of chemical synthesis reaction. And W. Ross. Ashby also analyzed the difference between emergence and generation, and put forward the idea that emergence is predictably by analyzing its components and structure.

Austria American biologist, Bertalanffy, introduced emergence into general system theory. He used Aristotle’s proposition that is “whole greater than the parts” to explain emergence directly, Namely, 1+1>2. He believed “whole greater than the components”, this means that the characteristics collected from isolated components are not equal to the combinational characteristics of the whole. As a result, the characteristics of complexes are newly-added and emerged comparing with its original elements. Bertalanffy was not only the first who introduced emergence concept to modern system science, but also clearly pointed out that the study on emergence phenomenon should be paid much attention to as an fundamental problem in system science. Bertalanffy’s idea demonstrated the development direction of system science.

American systematic philosopher, Ervin. Laszlo expounded that emergence created new qualities. And the qualities of the whole are not a simply qualities summing-up by its components. Based on an interdependent condition, each component makes up the whole and forms certain figurate structure for the whole, at the same time, initiates some new qualities which has overstepped the original qualities and the simple sum of theirs components during their mutual exchanges(Owen, 1985).

Santa Fe Institute (USA) was the first to study complexity according to emergence concept, and pointed out “three typical characteristics” of emergence. In the mid-90s for the 20th century, they clearly pointed out that the study on complexity is indeed a science of emergence... The core of the science is how to find out the fundamental principles of emergence.” Concerning the principle of emergence, John. H. Holland, scholar of Santa Fe Institute, believed that emergence is a complex question, which could not be explained by only a simply definition. According to his point of view, all these phenomena such as big coming from small, more coming from less, complex coming simple, mean emergence(John, 2001).

British Chinese, Ouyang Yingzhi, pointed out that emergence refers to some alternations of objects, and it was not combinations people traditionally believe. She said: “Only the extra characteristics of the system were qualified to be treated as emergence.” And resultant is different from emergence. The characteristics of resultant were connected with the material content of components mostly. The characteristics of emergence come from the organization of system components, and emergence function mostly belong on system structure level(Yingzhi, 2002).

Recent years, the attentions of scholars at china and abroad, had moved on from studying the phenomenon of emergence to studying the mechanism of emergence. With the help of computer information technologies, the study filed of emergence had been enlarging, and the application researches in related fields are getting deeper and deeper.

2.2. The limitation analysis of existing theories

1) The limitations of adduct regulations. Since emergence is a principle come from the study of complex system, many scholars such as Moorer, Lewes, Ashby and Bertalanffy all adopted the principle of “adduction” as “from small to big, from less to more, and from simple to complex”. They emphasized that the inter-functions of a variety of elements initiate emergence. The idea became the main theoretical basis of earlier studies of emergence. Following the development of emergence study, scholars found out that the theoretical basis was clearly limited when explaining the causes of emergence because the complexity is not the inevitable pursuit of system. During the process from disorder to order, the development of complex system will experience a process of element-reducing, element-reorganizing, and element-decomposing. This process is corresponded with the evolution process of “from simple to complex”. It is a kind of transformation from more to less, from big to small and from complex to simple. As a result, extra system characteristics initiates. Namely, there are not only “adduction” can initiate emergence, but also “reduction” and “subduction” can initiate emergence.

2) System hypothesis of emergence. From the sum-up above, a hypothesis premise, that is to say systematic hypothesis, could be found collectively in earlier research. And systematicness means non-adduction character and nonlinearity. Systematic hypothesis paid attention to the heterogeneity of system elements. It emphasized that only those objects, which could initiate emergence, could be called system. Abiding with this strict hypothesis, emergence theory always paid attention to the systematic evolution process from low to high, from simple to complex etc. Nevertheless, there exists energy exchanges with outside environment during the whole system evolution process. The condition of system is not unchangeable. Under some circumstance, a stable
system condition did exist. Bertalanffy defined system science as a science on whole or wholeness, which gained wide public acceptance. However, he still believed the definition was too ambiguous, then he farther divided system in two kinds of molds. Mold one has whole additive property. This mold is the sum up of all the isolated elements, namely non-system without emergence property. Mold two has whole non-additive property, that is system. The identical elements can show different property when it is inside or outside the system. Bertalanffy’s point of view emphasized that system itself could initiate emergence. But he did not emphasize the whole which can initiate the emergence is the system. Whether the whole can initiate emergence or not is not the key point to define it is a system or not. Research on emergence should pay much attention to the transformation from non-systematic whole to systematic whole. In the transformation, the subduction of repetitive elements and the definition of non-systematic elements are essential to finish this process.

3) Causes of the limitations of existing theories. Since the study on emergence was initiated by the study on complexity, it mainly paid attention to its static characteristics, namely, the performance status of emergence and the relationships among different levels of complex system at the initial period. The research purpose of this period was emergence recognition and found out the characteristics of emergence and its elements. The study was mainly on the cognition issue. At this time, it was unnecessary to explain the emergence phenomenon in the process from complex to simple. Following the penetration, step by step, the emergence study’s attention changed from “static state” to “dynamic state”. And the research was focused on dynamic mechanisms, such as “How did emergence initiate”, “the causes of emergence”, “and “the route of emergence”. At this time, the original basic theoretical study could no longer be enough to explain everything, because there are a lot of emergence phenomenon in the transformation from complex system to simple system. For example, in the organ function degradation during the process of biological evolution, in the decomposition and cracking of chemical reaction, in the transformation process of disintegrating, reducing, and reorganizing of social organization. In order to setup a complete emergence theory, all these should be considered and included in the study. And only then, the study, on how to find out better methods to explore the development route of complex objects, and on how to control the forward and backward emergence in development based on the understanding of the formation of complex objects and the changing laws would be able to achieve.

3. THE INTEGRATION ANALYSIS ON EMERGENCE THEORY AND LEAN THOUGHT

3.1. The characteristics of systematic emergence

The British emergentism school summarized four characteristics of emergence from the angle of philosophy. Firstly, emergence is a new property only in the high level; secondly, emergence has a characteristic of unpredictable novelty; thirdly, emergence is characterized by irreducibility among different levels; fourthly, emergence is characterized by causal relationships between the high-level and the low level.

Scholars from Santa Fe Institute put forward that emergence at least has the following characteristics: 1) Universality. From inanimate society to life world, from nature world to human society, from social activities to mental activities, emergence can be found everywhere. 2) Systematicness. Objects having emergence phenomenon are not only made up of a lot of components, but also is the result of the interaction of these components. It is a kind of systematic phenomenon with systematic characteristic. 3) Novelty. Unpredictability and unawareness are the important characteristics of emergence.

Mr. Moorer proposed three criterions about emergence, which helps us understand the characteristics of emergence: Firstly, emergence characteristics as whole are not the sum of the characteristics of its each parts; secondly, the types of emergence’s characteristics are far different from the types of components’; thirdly, the characteristics of emergence cannot be deduced or forecasted by observing the components’ activities alone.

3.2. The put forward of the concept of lean emergence

The core thought of emergence is to eliminate waste, raise speed, and improve mobility. And the essential aim of emergence is to eliminate the wastes of every segment. Lean thought is the result of the transformation of production mode. Lean thought can be summarized as: 1) The precise definition of value; 2) to identify each product’s monetary value flow; 3) to keep the monetary value flow running; 4) to create values only customers can pull; 5) to seek perfect solutions forever.

Lean thought comes from the production mode of Toyota. The practice of “lean manufacture” in the field of manufacture plays an important role in lowering manufacturing cost, reducing development and manufacture period, and evidently improving the compatibilities. The practice of lean thought is the third milestone in the transformation of human being’s modern production mode, after scale production mode. In the late 1990s, lean thought stepped out its birthplace—manufacture, and started to spread and practice in different industries, as a common management philosophy. Into the 21st Century, the practices of lean thought had got a great and rapid progress, which wrecked and kept recreating the scale production and hierarchical management concepts people
were accustomed to in the nearly a hundred years; and enhanced the efficiency of human being’s social activities, saved resources, improved efficiency and quality and people’s production and lives. Lean thought has become the leading thought in a new round of management revolution.

Lean emergence is to help the system (especially production and operation system) to generate emergence by lean operation and management. Lean emergence is different from the traditional “adduct” thought of emergence. It abides by ‘reduction’ thought. Namely, the thought pays attention to the change of environmental elements, keeps eliminating redundancies in the elements of the system, in order to achieve sustainable excellence and stable operation, on the basis of identifying the values correctly. In other words, the thought is to keep the system on forward emergence development, by achieving "N-1 > N, N-M > N". As a result, the thought is suitable for every type of system (see Fig. 1).

3.3. The theoretical basis of lean emergence

1) Duality Theory. According to duality theory, all systems in objective world have two sides, they are both opposite and unified with each other simultaneously, namely duality structure. In the structure, the two sides intermingle with each other, rise and fall mutually, and perfectly complement each other. In the whole process, antagonism generates motivation for the system to achieve development; conformity generates stability for the system to keep developing. According to this theory, there are systematic emergence from simple to complex, and also system emergence from complex to simple in objective world. The emergencies can be two systems with duality, and can also be two sides of one system. As a result, adduct can generate emergence, and its counterpart of duality----such as subduction of lean can also generates emergence.

![System Transfer](image)

**Figure 1.** The conceptual model systematic lean emergence

2) The development concept of dialectical materialism. The systematic and non-systematic overall concept, proposed by Mr. Bertalanfy, is to classify systems in order to give a better explanation to the generation of emergence. In other words, Non-systems do not have emergence. According to dialectics theory, all objects keep changing all the time. System and non-system are relative and transform each other. In reality, systems in all fields, such as in social field, in economic field and in biological field, keep changing from time to time. From this point of view, systematic hypothesis of emergence shall be based on a kind of ideal condition. In most cases, the problem which people have to deal mostly is how to identify the value of systematic elements, how to eliminate worthless elements (elements with negative value) from systems, and how to realize the organism combination of elements, and so on. Generally speaking, the whole of non-systematicness and the redundancy phenomenon in the whole of systematicness are constant states. Lean thought can optimize systems, eliminate negative factors, keep positive factors, and create conditions for the realization of emergence. Namely, the subtraction principle can initiate emergence also.

3) Biochemical view. In biological evolution process, it has a common principle that single-celled organism evolves into multi-celled organism. Namely, it is an evolution principle from simple to complex. And at the same time, a phenomenon of degenerating exists also. This kind of degeneration is still a kind of emergence, which it good for the organisms to suit their outside environments. Mr. Moorer used chemical reaction as an example to explain that there is a kind of heterogeneous relationship between the result of the main cause and the sub-causes. The chemical compound properties consisting of two elements was named generation or emergence. Along Mr. Moorer’s train of thought, in the chemical reaction process, so-called decomposition and pyrolysis is to decompose complex chemical material into simple chemical material. Anyhow, new material coming into being is its final result, which shows characteristics of emergence.

4) Organization view of economic society. In economic and social system, phenomenon such as factor recombination, reduction and so on always exist. Big system divides into small systems, complex system divides into simple systems. For the primary systems, elements reduced, new organizations with exuberant vitality come into being. According to the characteristics of emergence, these phenomenons can be called emergence.
4. THE FORMATION MECHANISM ANALYSIS OF THE LEAN EMERGENCE OF SUPPLY CHAIN SYSTEM

With the deepening of global integration, supply chain management faced problems become more and more complex, the internal and external environment of the supply chain enterprises become more complex, which requires the supply chain managers to apply new theories and methods to examine the problems of supply chain and research the supply chain management in a complex situation. The supply chain is in the competition, cooperation, complexity and dynamically changing market environment, it's a dynamic supply and demand networks by raw material suppliers, manufacturers, distributors, retailers, end customers constitute and quickly respond to the changing market environment, it's a typical complex system. It's complexity not only represent as the complexity of the supply chain entities, the complexity of the supply chain link structure, the complexity of the various aspects interactions between the supply chain, the openness of the supply chain, the emergence of the supply chain and other aspects, more importantly, it's complexity represent as the constituent entities in the supply chain and constitute a complex interplay between the entity with which the supply chain environment, and the resulting complex dynamic behavior of the supply chain system.

The supply chain is a very complicated and self-adaptive system in the system, the inter-reactions and dependency relationships among the inner companies, and with the outside environment make up the overall situation of the supply chain. Inside the supply chain, each company improves its outside development environment by communicating with the other related companies, and also benefit from this kind of communications. New efficiency and effectiveness emerges, caused by the inter-reactions among the supply chain members based on the win-win idea. The achievement of this kind of efficiency and effectiveness gets far more benefit than the inter-reactions among independent companies. The supply chain’s emergence mechanism shows the trends of the integrating, networking and scaling development of the supply chain, which mainly reflects in 3 elements as: ① The feature of supply chain emergence is not a simple addition, which can achieve a result as 1+1>2; ② The types of supply chain’s feature is far different from the feature of any single companies. The combination of contributions, the supply chain companies supplied based on the monetary value flow, generates new values; ③ The feature of emergence cannot be derivatized from simply observing a certain company’s activities. It is the result of combined actions of all the elements within the system. SC’s lean emergence is about using the lean thought and its operation method to achieve the supply chain emergence. Its basic theories is as:

4.1 The core of SC lean emergence ---the monetary value flow

The self organization is divided in two kinds of structures by Mr. Prigogine as equilibrium structure and dissipative structure. Equilibrium structure is an ordered structure, which is created by the phase transition during equilibrium. Dissipative structure is an ordered structure, which is created by the phase transition when the system is under a condition of far from equilibrium. Keeping its own structure without exchanging with outside environment is the basic characteristics of equilibrium structure. And only by keeping exchanging materials, energies and information with outside environment can the dissipative structure keep its ordered structure. Obviously, supply chain structure is a kind of dissipative structure, because it is a typical nonlinear character, and also an ever-balanced open system. Abiding by the core proposition as “Non-balance is the source of order”, each product’s monetary value need be correctly defined, And its monetary value flow need identified, the elements, which can influence the monetary value and the monetary value flow’s running, need be eliminated, during the process from disorder to order, in order to keep a high efficient running of monetary value flow. Supply chain is a complex system, which keeps exchanging energies with outside environment. Dynamic interactions exist among the elements inside the system. Lean thought is to supply basic conditions for forward emergence, by paying attention to the monetary values coming from consumers, and help the result of dynamic interactions to achieve forward development during system evolution.

4.2 The foundation of SC lean emergence---redundancy

The aim of system construction is seeking emergence. Namely, the interaction of system elements conducts new functions. In team of supply chain system, treating a certain product as a communication link, the construction of supply chain is to unite resources belong to different enterprises, construct a supply chain system concerning the whole process from raw materials, accessories, components, to finished goods, including all the flows as, logistics flow, information flow and monetary flow. As a result, the quick responding ability towards outside consumer demands emerges. During actual operation process, the construction of high-efficiency supply chain system is the most difficult part. All elements, such as overstock inventory, bloated organization, overmuch suppliers, extensive management model, could become the obstruct blocking the construction of a high-efficient supply chain. The whole emergence could only realized by implementing lean management,
paying close attention to consumer values, erasing inventory redundancies, organization redundancies, and non-value-added processes.

Lean operation is the basis of whole supply chain emergence. Emergence could not be realized without solid foundation. For SC system, a certain optimum model, which can realize emergence, do exist theoretically. Namely, the optimum allocation condition of the elements, concerning the organization and construction of supply chain, can be achieved, under certain external conditions. But in reality, there is not a shortcut towards achieving the optimum model. Leap from quantitative change to qualitative change could only be achieved, by standing on solid ground, abiding with Lean management principle, realizing sustainable excellence, and stable operation.

4.3 The source of SC lean emergence----the lean motivation

Whole system emergence comes from three elements, as component, structure, and environment. And four elements, material effect, scale effect, structural effect and environment effect, jointly achieve the whole system emergence (Dongseng, 2006). After the financial crisis, three enterprises cause the world’s attention, as Toyota, Wal-Mart Stores, Inc., and Southwest Airlines, they still keep their stable and booming development momentum, when their court-parts are still suffering the chaos. From the view of whole system emergence, the environment effect of financial crisis inevitably causes negative emergence among enterprises. The reason for the three enterprises to achieve successes is that they chose a far different way to fight back. They realize that the world has changed fundamentally. Uncertainties and crises are no longer treated as exceptions, but regular patterns. The assumption, as operation in an environment with stable outside demand during the past years, has become the past. And a disordered system is into reality. So, according to their correct assume, the three enterprises abandoned traditional management models, employed Lean principle and method, constructed their own lean motivation mechanism, defined the consumer demands as the purpose, paid attention to the fluctuation, combated dynamic with dynamic, then forced the interaction results of enterprise supply chain elements on a positive emergence. Lean motivation mechanism includes five elements, such as taking precautions before it is too late, achieving flood management, creating dynamic equilibrium, eliminating emergence culture, and keeping compatibilities. By coping with environmental effects as a breakthrough point, the practices of the five elements brought material effect, scale effect and structure effect into lean emergence thought. As a result, Supply chain keeps sustainable emergence.

5. THE CONTRIBUTION OF THIS ARTICLE

5.1. The contribution to lean thinking

Following the scale production mode putting into operation, lean production mode had become the main production mode among modern enterprises, step by step. Lean thought and lean management merged as require. Although a lot of scholars practiced many studies on lean, lean theory was still incomplete. And the studies were still focused on the application field. Lean theory and system science were paid less attention to. As a result, the spread and development of lean thought and lean theory were limited. Based on the analysis on lean theory and systematic emergence mechanism, this article paid attention to the study on enterprise supply chain, was to define lean emergence, and find out the lean emergence mechanism. Lean was an inseparable project of system science, and shared same study target with system science. The aim of lean production, lean management and lean operation was to pursuing emergence. Article not only promoted the study on lean theory: Lean was no longer being treated as application tools only, it was also a complete theory, which should be carefully studied and carried out.

5.2. The contribution to emergence theory

The core thought of lean emergence was that lean can promote system to initiate emergence. The theory was based on the idea that system elements and their interactions kept changing from time to time. In the development process from disorder to order, the principle of reduction was indispensable, which made up the shortage of traditional emergence adduction theory basis, and explained properly the phenomenon, such as systematic organization evolution, and the disintegration and re-organization of non-systematic organization, and also enlarged emergence theory’s field of application.

This article pointed out the shortcomings of the traditional theory, as the objects, which had whole emergence, could be treated as system, since the idea, which was not fitted to Bertalanfly’s point of view, as studying emergence phenomenon was the essential practice for studying system science, confused cause and effect, simplified the system emergence phenomenon. As an example, we were notified that the fish (target) we demanded was in some pool. And then we were asked to pay attention to the pool. In reality, the relations was not that simple between system target and system element. The environmental changes and disorderly changes among elements, all could force system far away from target. The raise of lean emergence was to put both systematic whole and non-systematic whole together, keep completing system emergence theory, and give
Theoretical support for solving the difficult problems as system construction and optimization, and so on, which were exist commonly in real lives, by making system changes as the background. Furthermore, according to system emergence theory, lean emergence was an ascending and spiraling dialectical materialism philosophy.

5.3. The contribution to SC theory

The modern enterprise competitions were not the competitions among enterprises physically, but the competitions among supply chains. In reality, there were only a few enterprises could achieve real supply chain operation and management worldwide, since most enterprises did not have the quality to practice supply chain operation. Most enterprises could carry out “adduction” in form, but could not practice lean operation properly. As a result, there were no supply chain system emergence initiated in most companies’ operations. For enterprises, there more lean emergences than adductive emergences in real life. For this point of view, lean emergence theory played an important role in the development and practices of supply chain management theory.

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