ANALYSIS OF THE APPLICABILITY OF CHAOS THEORY IN SUPPLY CHAIN LOGISTICS STRATEGIES

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Abstract

The logistics system can have episodes of chaotic behavior, and thus be studied by chaos theory. Such a system is also supply chain, including his logistics strategy. Taking into account the rationality of action in managing entity, we could be sought to create a logistics strategy, using achievements of complex adaptive systems theory or game theory.

Keywords

Chaos theory, logistic system, supply chain strategies

Chaos theory – introduction

Chaos theory is the popular name of the theory of dynamical systems and non-linear studies [7, pp. 130-141]. Nonlinear means that output isn't directly proportional to input, or that a change in one variable doesn't produce a proportional change or reaction in the related variables. In other words, a system's values at one time aren't proportional to the values at an earlier time. The word dynamics implies force, energy, motion, or change. A dynamical system is anything that moves, changes, or evolves in time. Dynamical systems fall into one of two categories, depending on whether the system loses energy. A conservative dynamical system has no friction; it doesn't lose energy over time. In contrast, a dissipative dynamical system has friction; it loses energy over time and therefore always approaches some asymptotic or limiting condition. That asymptotic or limiting state, under certain conditions, is where chaos occurs [11, pp. 17-19].

Excellent example of chaotic behavior is the experience of coin toss. A toss of a coin or the roll of a die are, in theory, deterministic systems, but yield more or less

random outcomes. Not only is it impossible to toss a coin twice in exactly the same way, but on each toss the coin is subject to slightly different air currents, themselves a result of turbulent air flow [2, pp. 40-47].

Important reasons for analyzing a set of data for chaos are [11, p. 21]:

- analyzing data for chaos can help indicate whether haphazard-looking fluctuations actually represent an orderly system in disguise,
- identifying chaos can lead to greater accuracy in short-term predictions,
- chaos analysis can reveal the time-limits of reliable predictions and can identify conditions where long-term forecasting is largely meaningless,
- recognizing chaos makes modeling easier.

In other words studying chaos has revealed circumstances under which we might want to avoid chaos, guide a system out of it, design a product or system to lead into or against it, stabilize or control it, encourage or enhance it, or even exploit it.

Chaos in the logistics system

The ideas of chaos theory, originating in physics and mathematics, have spread to other disciplines, for example, economics and ecology. Recently, the ideas of chaos theory have been used to suggest approaches to management decision making and to explain the behavior of logistics systems.

A typical logistics system exhibits stable behavior with damped oscillations in response to external disturbances. Unstable phenomena however can arise, due to feedback structure, inherent adjustment delays and nonlinear decision-making processes that go in a supply chain. One of the causes of unstable phenomena is that the information feedback in the system is slow relative to rate of changes that occur in the system [9, p. 2]. In other words, the logistics system can operate in a chaotic manner.

The chaos theory in logistics involves several concepts to be discussed in the context of their importance for the properties and tasks of the logistics systems [3, pp. 37-39; 8, pp. 3-4]:

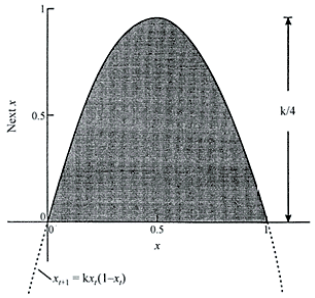
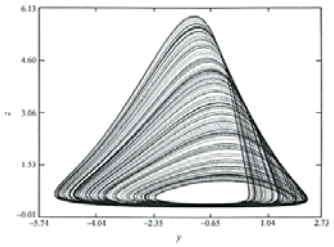
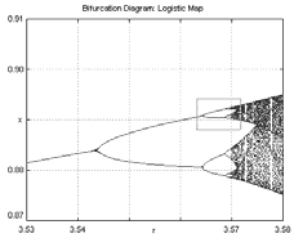
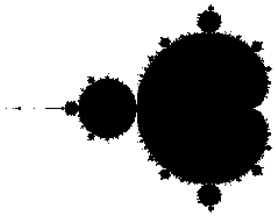
- attractor - a point or set, which in the process attracting points lying in its environment. A strange attractor is the distinguished state, to which all trajectories tend in nonlinear way. It has a complicated fractal geometrical and topological structure and also interesting holistic properties and order independent of the local interaction part. In logistics such an attractor can be any of the basic system parameters such as time, cost or quality.
- bifurcation - means a condition in which each system is partly deterministic and partly random, so says about the dichotomy of the system. Literature cites the example of the phenomenon of "bullwhip effect" as such dichotomies.
- fractal - is a complex geometric shape of structure, in which enlargement of the fragment of any result reproduces the original object, and that means self-similarity. In logistics, it is difficult to talk about the similarity of systems.
- fluctuation - it is enormous sensitivity of the system to initial conditions, which under certain conditions can also exist in the logistics system.

Basic terms of chaos theory are presented graphically in Table 1.

It can be concluded that the greatest source of chaos and at the same time greatest source of power to stop chaos is the same logistics system. Its components in the form of infra- and suprastructure, as well as human resources, materials, information, money, etc., are involved in carrying out certain activities, because in another case only generate costs to maintain them in readiness to perform these tasks. Therefore, in addition to quantitative and qualitative characteristics of the logistics system elements, their specific interaction in the form of real logistics process, including control activities, integrating, coordinating, harmonizing, etc., are probably this factors that critically affect the appearance, thus liquidation signs of chaos. Another source of chaos, and while ways to reduce him, are the elements of the logistics system environment. This applies in particular functional areas with which logistics often comes in the interaction, in example trade, manufacturing, finance, operational management, strategy, etc. In this case, the conflicts at the interface of these functions are the primary source chaos, usually both in the field of logistics, as well as beyond-logistics areas, sometimes resulting in whole entity disfunctions and even the entire

chain, part of which is the entity. [8, pp. 5-6]. These "source of chaos" are only a place of its occurrence, the reason for the chaos should be considered primarily a man (logistician) and its behavior. In this sense the chaos results from over-reactions, unnecessary interventions, second-guessing, mistrust, and distorted information.

Table 1. **The therminology used in theory and logistics**

Type	Example graphic form
One-dimensional map of logistic equation	
Strange atractor (two-dimensional projection of the Rössler strange attractor)	
Bifurkacion	
Fractal (Maldenbrot's)	

Source: Wilding R.D., Chaos Theory: Implications for Supply Chain Management, *International Journal of Logistics Management*, Vol. 9, No 1, 1998.

Key implications of operating in a chaotic logistics system are [10, pp. 13-14]:

• Dramatic change can occur unexpectedly. Chaotic spikes in demand can occur which are generated by the system and not as the result of external events.

• Long term planning is very difficult. If long-term plans are made they need to be reviewed on a regular basis.

• Supply chains do not reach stable equilibrium. Small perturbations will always prevent equilibrium being achieved.

• Short-term forecasts and prediction of patterns can be made. It is better to allocate resource to the development of effective short-term decision making processes rather than long term.

• Supply chain is as a complete system. Small changes made to optimize one echelon of the supply chain can result in massive changes in other parts of the supply chain. For example driving down inventory and lead-times may not always improve performance; it could result in the system slipping into chaos.

• Chaos may be remove by focusing on the customer.

• Simulation of systems and non-linear dynamic analysis of key outputs should be a mandatory part of any supply chain re-engineering proposal. If a simplified model of the system generates chaos the real system with increased complexity will also.

The implications of chaotic system for supply chain strategy

Firms interact with each other and with other actors in their environments, such a consumers, labor, the government, and financial institutions. These interactions are strategic in the sense that decisions by one actor take into account anticipated reactions by others, and thus reflect a recognition of interdependence [6, p. 170]. Chaos theory suggests that the payoff in terms of better forecasts of building more complex and more accurate models may be small. Similarly, we cannot learn too much about the future by studying the past: if history is the sum of complex and nonlinear interactions among people and nations, then history does not repeat itself.

This approach reject most frequently quoted, the classical meaning of the strategy, which defines it as the process of determining long-term goals and objectives of the organization and the adoption of policies, but also the allocation of resources necessary to achieve these goals [1, p 10].

No possibility of long-term forecasting and the creation of such models results in the simultaneous inability to determine appropriate courses of action and allocation of resources in the long term. Thus, the postulate of reduction in time of operation of logistics strategy should be considered as legitimate.

The question then arises: if the supply chain and logistics strategy should be the product of dynamic, adjusting to a constantly changing environment, whether its construction should be necessary according to the principles of chaos theory? Certainly it may be, and an example of such a solution are described below complex adaptive systems. In the logistic system are fluctuations, but it is difficult to recognize that they are unpredictable. Chaos result from over-reactions, unnecessary interventions, second-guessing, mistrust, and distorted information. These problems can rule out, assuming reasonableness of operation of supply chain managers. If not, there would not have to deal with the growing number of cases to build partnerships in logistics.

This reference opens the way of activities to other theories that are criticized by proponents of chaos theory as inaccurately reflecting the dynamics of the system. Game theory, because mostly speech of her, also allows to build a supply chain strategies based on the likelihood of events. Thus also applies to dynamic systems, but assumes a continuous system behavior under certain conditions. These behaviors are the result of human response, and therefore by definition unpredictable, but the conditions of the rationality of enforcement activities, and ultimately correct or repair the system, give rise to claims about the effectiveness of this method.

Complex Adaptive Systems

Logistics strategy of supply chain in the context of chaos theory has to be a product of dynamic, adapts to the changes caused by information feedback. In other

words, understood other than the classical strategy. Searching methods to solve this problem in the achievements of chaos theory lead us to the concept of complex adaptive systems.

Complex adaptive systems are open systems of nonlinear evolution, which continually process and bring new information. Their existence and structure depend on the continuing impact of new information, which makes the initial conditions at any point in time are impossible to determine. These are the systems that exist between chaos and order. In view of this, chaos theory describes how the sensitive dependence on initial information has the potential to change through a feedback loop that causes small changes can produce complex results. The complexity theory describes how is created order and structure through a process of adaptation caused by a new set of information which would disturb the balance and push the system in a chaotic episode. In other words, chaos is a mechanism used to induce change and the organization [5, pp. 122-123].

Supply chains, performing its functions considered in the category of complex adaptative systems, is a collection of production and logistics hubs connected by relations, that exhibit adaptation in response to changes in the environment and in response to changes in the same hubs. These activities include both the reacting on each hubs, and in the relations between them. These hubs can therefore evolve in time according to the organization teaching. Feature of supply chains treated as complex adaptative sytems (simultaneous response patterns of each organization and through a relationship formed between the hubs) cause that changes in environment cause a nonlinear response of the network as system [4, p. 8].

Summary

In chaotic systems, small disturbances multiply over time because of nonlinear relationships and the dynamic, repetitive nature of chaotic systems. As a result, such systems are extremely sensitive to initial conditions, which makes forecasting very difficult. This causes a change in the perception of strategy as a long term plan. Should be viewed her rather as a set of objectives and lines of action, with the change

of the system are subject to verification. For this reason, tools for creating supply chain strategy should be the methods of taking into account the randomness of certain events. Those tools include, derived from chaos theory, concept of complex adaptive systems, but also theory of games. One should remember that game theory is a less complicated tool, but sometimes criticized because of the difficulty in adapting to information feedback. According to the author, however, these imperfections can be omitted assuming rationality of action in supply chain.

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