

## **Implications of Chaos Theory in Management Science**

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**Abstract.** We live in a dynamic world that is most often described as being “chaotic” and unpredictable. From our human perspective, we do not see the greater framework of the system that we live in, and can only try to approximate its boundaries. However, with technological advances and continued adaptability, this does not limit our progression, because humans are complex creatures that seek to control chaos. It follows that we function in organizations that become complex systems, or systems that provide a balance between rigid order and random chaos. This realization defines a new paradigm for “emergent” leadership and management based on chaos theory, where emergent leaders become “strange attractors”; this means they are leaders that are flexible and have the skill set to accept unpredictability to enable the organization to adapt accordingly.

**Keywords:** Control, Non-linear systems, Uncertainty, Unpredictability, Attractors, Leadership, Emergent leader, Positive motivators.

### **1 Introduction**

When we think of the word “chaos”, the prominent meanings that come to mind are confusion, disorder, and lack of control. However, these definitions represent the modern English meaning of the word. Chaos was first conceptualized and defined through mythology, which described the origins (or birth) of humankind. “Myth is as logical as philosophy and science, although the logic of myth is that of unconscious thought” (Caldwell[3]). The word itself is rooted in Greek origins, its authentic form being *Χάος* (Khaos). In Greek mythology, Chaos is “the embodiment of the primeval Void which existed before Order had been imposed on the universe” (Grimal and Kershaw[4]). In this definition it is evident how humankind had tried to contain a vastness that was (and is) difficult to comprehend in its natural form. Hesiod’s *Theogony* agrees with the undefinable origin concept, as “first of all, the Void came into being, next broad-bosomed Earth, the solid and



eternal home of all... Out of Void came Darkness and black Night” (Brown [1]). The synonymy of “void” and “chaos”, and the birth of darkness from the “embodiment of the primeval void”, implies that chaos is an “impenetrable darkness and unmeasurable totality, of an immense opacity in which order is nonexistent or at least unperceived” (Caldwell[3]); that chaos describes the collection of everything that humankind cannot grasp and cannot control. Now, there is the duality of the controllable and uncontrollable; an unspoken demarcation of what the human mind is capable of elucidating.

However, the characterization of chaos is incomplete without the following line, as “Earth, the solid and eternal home of all” is formed, born as a separate entity and representative as “the primordial maternal symbol” (Caldwell[3]). The key to this is to note the synonymy of the “maternal symbol” and the “solid and eternal home of all”, the implication being that “solidity” and order is established so that the lineage of humankind can be traced back to something tangible. Again, there is a polarity of order and non-order, which can be seen in the chronologic succession of chaos, then the formation of earth. This sequence becomes significant in implying “that Chaos, a state prior to perception, represents the situation of the child in the symbiotic state” and “may be regarded as a representation of the symbiotic phase as un-differentiation and imperception, as a formless totality” (Caldwell[3]). Through this implication, chaos is better defined as being everything before perception, rather than confusion or disorder; chaos is what is unknown or intangible.

## **2 Control in Chaos**

For decades we have repressed this unknown through systems and controls of mathematical equations and patterns. The reduction of chaos began with Sir Isaac Newton, in his attempt to mechanize reality through linearization of (what was later accepted as) a nonlinear, dynamic system. The theory had been based on the idea that with a linear reality, predictions could be made and phenomena could be controlled simply by deconstruction of the universe into its most “basic parts” and “logically” putting them back together (Burns[2]). In truth, this type of linearized reality has helped to advance humankind not only technologically, but also socially. “The social sciences have always attempted to model physical science paradigms” (Burns[2]). This is evident in the early formation of the field of Psychology, where Freud’s developmental stages build upon each other. It was assumed that if one stage is (or becomes) dysfunctional, problems in the human psyche occur. Other human systems, such as the development and function of political parties, economic systems, and the development of children’s concept learning strategies, are also built under the assumption of Newton’s linear reality (Burns[2]). With the help of quantum physicists, and theoretical meteorologist, Edward Lorenz, the way actual reality functions became easier to accept: the reality that the universe is chaotic and

cannot be linearized and deconstructed into simpler mathematics. The realization that *social systems* could no longer be defined as linear.

Finally, the study of reality no longer models the constrained limitations of a linear way of thinking, and instead begins to model non-linear, dynamic chaos. By extension, because organizations exist in reality, it can be assumed that social systems develop within a chaotic system. Therefore, “organizations are nonlinear, dynamic systems” (Otten and Chen[10]) that make it imperative for leadership, and leadership practices, to be constructed through chaotic-system thinking. “In chaos theory leadership is not reduced to the ‘leadership’ behavior of a key position holder or team of ‘top’ people. Leadership is conducted throughout the organization, through all agents... Leadership is broadly conducted precisely because in chaotic systems, all agents have potential access to vital information from the environment” (Burns[2]).

The very definition of an organization is a body of people who share a purpose, vision, or mission. The primary functions of leadership within the organization are to: a) ensure that the agents of the organization keep the purpose and core values in mind, and b) ensure that the primary mission and values adapt (continuously) with environmental demands. By empowering all levels of the organization, the environment is monitored constantly and the overall mission is clarified because it is continuously evaluated and defined from different perspectives (Burns[2]). The acceptance of chaos in social systems is the basis that leaders must begin with. The assumption that outcomes are predictable is parallel to the assumption that chaos can be predicted. However, if chaos is defined as the unknown, the assumption that chaos is predictable is illogical. Therefore, it is the prerogative of leaders to influence the perspectives of the agents to accept unpredictability, so as to allow them to develop the capability to receive information and adapt accordingly. Leaders must have the skill set to shift thought processes in order to focus on the possibilities of outcomes and choose which ones are “desirable” to the organization, rather than fixate on a single possibility and try to control and direct chaos to produce this outcome.

### **3 Chaos Theory and Complex Systems Defined**

Chaos theory states that the behavior of complex systems are highly sensitive to the slightest changes in conditions, which results in small changes to giving rise to more unpredictable, prominent effects on the system. With the introduction of quantum mechanics came a better understanding of how chaos theory applies to the real world. “Chaos theory, in essence, is an attempt to remove some of the darkness and mystery which permeates the classical concept of chaos by explaining, at least in some dynamic systems, how the system exhibits chaotic behavior” (Hite[7]). Chaos theory emphasizes that the conditions and state of change are no longer simple linear

cause-and-effect relations; instead it assumes that both the cause and effect can originate and result from a multitude of variables that could come from various directions. This implies that a chaotic system is a flexible macro-structure that is vulnerable to the slightest disturbances on the micro level, although these changes are bounded by a pre-established framework.

Within the framework of an organization, chaos theory implies (but is not limited to) six critical points: 1) organizational life is predictable and unpredictable; 2) it is virtually impossible to define a single cause for any reactions; 3) diversity provides a more productive base; 4) self-organization will reduce concern for anarchy prevailing over chaos; 5) individual action in combination with a multiplier effect will focus responsibility on the individual; and 6) “scale-invariant properties and irreversibility are components of all chaotic organizations” (Grint[5]).

Organizational life may be predictable on the macro-level, as there will appear to be repetitive behaviors or patterns that appear aperiodically. On the other hand, at the micro-level of an organization, it will seem unpredictable because humans, as individuals, will appear to be random and to express unconnected, chaotic tendencies. One example found in nature is seen in the actions of ants; the activities of a single ant will appear random and disconnected, but the greater picture shows that it is a part of a larger social organization that has a single value. Because of this type of reasoning, the second critical point holds true: to define a single cause to explain an effect is impossible, as there could be many causes that occur simultaneously to produce an outcome. Every individual agent of the organization will establish multiple links, or connections, with other agents and various sources of information from the environment. Therefore, multiple reasons behind following directives or strategies will develop over time or simultaneously. Each unique link and motive must be taken into account when trying to align the goals of the organization with that of the individual. The strategies that are established should be aimed towards the acceptance of unpredictability and uncertainty, so as to give the impression “that they have control over something which is inherently uncontrollable” (Grint[5]).

The acceptance of uncertainty and unpredictably will help agents to recognize the value of dissenting voices and contrary cultures. The idea behind this is to shift the organization from a hierarchical top-down structure to a self-organizing structure, where the environment is defined by fundamental, interactive guidelines that allow for the flexibility in handling each situation uniquely. This idea is akin to giving an organization a set of standards and regulations that *suggest* how to handle general issues, instead of stating rigorous rules on how things should and should not be. It would be ideal to just hint at the overall culture and let each experimental, self-organizing group within the structure contribute to the definition of organizational life by facilitating their own resolutions (because it would be unique to each group) instead of following orders. The allowance of this kind of problem solving will enable the agents to voice their opinions and implement

actions without reprimand, unlike positive- and negative-reinforcement managerial styles that may dissolve the organization into anarchy. Agents who do not feel constrained by rules and regulations feel that they are contributing to the overall system, and are less likely to cause destructive disorder. From this point, it is up to the leader or manager to be able to allow the loss of total control, and to allow for the birth and decay of motivational schemes in order to become effectively adaptive.

With the loss of control, it usually follows that there is a loss of responsibility placed solely on the leader of an organization. This happens because the agents create and form the culture, and therefore have the obligation to uphold the culture. The leader or manager, and even the individual agents, must also understand the irreversibility of individual actions; the multiple connections that form between various agents will contribute greatly to the multiplier effect, and propel smaller-scale decisions and strategies into larger arrangements. A component of chaotic structures that this is commonly compared to is called a fractal, where similar ordering properties can be seen at different levels of the organization, and be recognizable to all levels. And, like a fractal, these similar patterns will build upon each other to create a complex structure.

#### **4 The “Strange” Attractor**

The development of Lorenz’s mathematical model of a chaotic system emphasized the idea that dynamic, complex systems are highly dependent on initial conditions; his model of the system demonstrated that a slight change in the input values produced very different outputs. However, no matter what changes were made, the visual pattern that computers generated based on Lorenz’s model reflected that of butterfly wings. “The resulting figure displays a curve that weaves itself into a circular pattern, but never repeats itself exactly. Because it never returns to the initial state, though it may come arbitrarily close, the system is aperiodic” (Singh and Singh[12]). An embedded circular shape within the “wings” forms as the model continues; however, it is almost like a void space – the pathways never cross through this space. This void space is an “attractor” that will draw “point trajectories into its orbit, yet two arbitrarily close points may diverge away from each other and still remain within the attractor” (Burns[2]).

“Conventional theory asserts that the world is predictable and stable, and able to be explained by causal links that can be measured and monitored. Chaos theory implies that in the short term anything can happen, but that in the long term patterns, or ‘strange attractors’, are discernible” (Grint[5]). These strange attractors represent a key concept in this definition of chaos theory. “A system attractor, in essence, operates like a magnet in a system. It is the point or locus around which dynamical system activity coalesces... It is the attractor that provides the system with some sense of unity, if not uniformity. The attractor may be strong and

definite, as with a fixed point, or it may be weak and indefinite, as with strange attractors” (Hite[7]). The strange attractor is not “weak” as in the classical sense of the definition. It is weak in the sense that it is flexible in its structure and has the ability to adapt infinitely. The strange attractor is better conceptualized as the pinpoint where the basis of the new or current dynamic system begins; this is similar to agents and how they interact within an organization. The difference between the agent and the attractor is that the attractor is an individual who possesses innate qualities that other agents may eventually gravitate towards.

In essence, the strange attractors of the organization are the values and vision that is shared, and “attractor” agents will exemplify these values and vision; but it is unlikely that individual agents will “orbit” the vision and values in the same way. This will result in the creation of multiple pathways to achieve the same overall mission of the organization. The “Butterfly Effect” theory was named after complexity science “where a butterfly flapping its wings in one location gives rise to a tornado or similar event occurring in another remote part of the world... the butterfly effect is nonlinear and amplifies the condition upon each iteration” (Osborn *et al.* [9]). And, as the butterfly effect explains, because these paths differ, these small changes in trajectories will result in larger changes to the overall system, though it will still be within the same framework. However, the timeframe of these changes, and to what extent the changes will have an effect, will be unknown; something small can begin a chain of events that will cause something relatively larger or smaller, in another part of the world or in close vicinity; but how quickly or slowly that happens will be unpredictable. At this point the difference between a complex system and chaotic system becomes difficult to define.

## **5 The Line between Chaotic and Complex Systems**

“Where chaos theory addresses systems that appear to have high degrees of randomness and are sensitive to initial conditions, complexity theory has to do with systems that operate just at the line of separating coherence from chaos” (Hite[7]). Returning to the definition that chaos is everything unknown to humankind, it was also seen that the state of chaos thrives within the condition of symbiosis, by undifferentiating or non-delineating the self from the total. Now, instead of chaos being the unknown, as in uncertainty or ambiguity, it is transformed into being the unknown, as in the unawareness of individuality; there is no self or other, there is only totality; there is only interdependence in oneness (Singh [11]). Complex systems operate between order and chaos, where the state of symbiosis exists, but the conditions surrounding the symbiotic relationship are defined.

By extension of this thought, the theory of the “Butterfly Effect” is emphasized. The initial conditions put into the system are known, which is representative of imposing a type of order into the system. However, the outcome

will always be unpredictable in the short-term. Nevertheless, in the long-term, there will be aperiodic behaviors that a complex system will adapt to. Thus, if new initial conditions based upon these behaviors are inputted into the system, no matter how unpredictable the outcomes, the system will iterate and adapt to try to return to a flexible state of equilibrium, even if the speed of this change is unknown. It must also be accepted that this state of equilibrium is fleeting, as there will be another change in the system occurring somewhere else at any given point in time, giving credence to the idea that complex systems are dynamic in nature. And, because the system will always be in flux and dynamic, it is logical to say that how leadership is defined and how management is applied also need to be continuously dynamic.

## **6 Leadership Actualized**

There is no universal explanation for what leadership is, or how to define it -- only contextual examples of what leadership accomplishes. Through the understanding of chaos and complexity, it becomes easier to digest that a solid definition for leadership may never be found; the essence of leadership is continuously adapted and remolded to fit what the organization needs. There are a few reasons behind why leadership is so difficult to define. Like the Butterfly Effect, the extent, speed, and actual dimensions of the response(s) to leadership will never be clearly known, and so cannot be clearly defined. However, the connotations of leadership are known to be adaptable to the culture of the organization.

Therefore, defining the culture would mean determining the style of leadership that is needed. Because culture varies from organization to organization, what defines a leader will also differ, as they will need to adapt to specific and unique organizational needs. And, as a leader, it is important to note that leadership is not delivered by a single individual, but rather, is dependent on the interaction between an agent and its organization and is constructed from social recognition (Osborn *et al.* [9]). “The point of leadership is to initiate change and make it feel like progress... Leadership is what takes us and other people into a better world. Leadership insists that things must be done differently. Leadership rides the forces that are pulling individuals, groups, organizations, markets, economies, and societies in different directions, and lends a coherence that will enable us to benefit from the change around us. Leadership says, ‘We cannot just carry on doing what we have done before. See all these forces of change around us; they are not just threats, they are also opportunities. But we must do this rather than that’” (Yudelowitz *et al.* [13]). Leadership seems to represent the “space between” what a leader does and how the organization responds; leadership manifests itself in the interaction, and what makes someone a leader is the leader’s awareness of this fact and to what extent his or her influence can be recognized.

## 7 Organizations are Complex Adaptive Systems

In an adaptive organization, leaders monitor the overall well-being of the system, both internally and externally. Attractors influence the organization's culture and dynamics, while agents drive the system. A relatively new understanding of an organization is that it follows a "complex adaptive system" theory [CAST] -- a framework for explaining the emergence of system-level order that arises through the interactions of the system's interdependent components (agents)" (Lichtenstein and Plowman[8]). Because these interactions and influences can begin from anywhere within an organization, the model of an organization that seems to emerge is a decentralized structure that allows change to originate from anywhere, at any time. However, this does not mean that the unity and cohesiveness of the structure will become affected. What a complex adaptive system offers is a flexible structure that allows for the input of all the variables from the environment to influence the system, then adapts accordingly by beginning with individual agents. This is very reflective of the Butterfly Effect; "when an agent adjusts to new information, the agent expands his/her own behavioral repertoire, which, in effect, expands the behavioral repertoire of the system itself" (Lichtenstein and Plowman[8]).

In an empirical study, B.B. Lichtenstein and D.A. Plowmen found that there are four sequential conditions that form an element termed "emergence". Multiple cases were examined, where each case exemplified an organization undergoing the process of adaptation and how they "emerged" to be able to survive within the present environmental conditions. The four prevailing, sequential conditions found in each case are: dis-equilibrium, amplification of actions, recombination or self-organization, and stabilizing feedback.

Dis-equilibrium describes the system when it is in a state of dynamism and is usually initiated by the occurrence of an incongruity or change. This disruption can be caused by external or internal influences, such as, competition or new opportunities, and can be volatile enough to push the system beyond the existing perceptions of the norm. The study found that this state must be sustained for a long period of time in order to be considered a precursor to an emergent ordered system.

The second condition, amplifying actions, is when the dis-equilibrium caused by small actions and events begins to fluctuate and amplify throughout the system, seemingly to move toward a "new attractor", and grows until a threshold is reached. And, as learned from chaos theory, these actions and alterations will not follow a linear path throughout the organization; the change will easily "jump

channels” (because all the agents are interconnected in some way) and can escalate in unpredictable, and unexpected ways (Lichtenstein and Plowman[8]).

The recombination, or self-organization, is the third (and most defining) condition that must be reached, as this is where a new order is established that increases the efficiency and capacity of the entire system. Once the organization has crossed the aforementioned threshold, it “emerges” as a “new entity with qualities that are not [yet] reflected in the interactions of each agent within the system” (Lichtenstein and Plowman[8]). The hope of this self-organization is that the system will recombine in such a way that new patterns of interaction between agents will improve the functions and capacity of the organization. In truth, this critical step will determine the survivability of the organization because, instead of restructuring progressively, the system could collapse or self-disorganize. This could be due to a) the lack of innovative ideas, b) poor assessment of the environment (because the reconstruction is dependent on reform), c) an inadequate “strategic fit” or core competency to handle the changes made, or d) a resistance to change (which is characteristic of a stable system) (Yukl and Lepsinger [14]).

The final condition of this emergent ordered system is the stabilizing feedback (“damping feedback”), or the anchors that keep the change in place and slow the amplification that produced the emergence in the initial stages. This anchoring is important, as it is reflective of how the interactions between agents sustain the change successfully and solidify legitimacy to the new paradigm. The new emergent order will dramatically increase “the capacity of the system to achieve its goals” (Lichtenstein and Plowman[8]). The study also surmised that leaders with certain characteristics will enable this emergence in an organization.

## **8 Characteristics of Leaders of Emergence**

Leaders of emergence will generate or “enable” circumstances that will purposefully create the conditions needed to bring about the new emergent order. Lichtenstein and Plowman noticed that certain characteristics were prominent and recognizable within each case used in the study. To achieve the dis-equilibrium condition, a leader will need to disrupt existing patterns and rally support for the uncertainty in the disturbance. Most importantly, a leader will need to acknowledge these conflicts and controversies with the intention that the farther the “ripple” spreads, the more perspective and diverse solutions will be generated. In this case, it is not the “people at the top” of the formal hierarchy that will brainstorm and decide what solution to take. Instead, the role of the leader becomes distributed through all branches of the organizations, where conflict and diversity are acknowledged, and can be accepted,

equally. Next, it becomes the role of these emerging leaders to “amplify” the perspectives and conflict through the rest of the organization by encouraging innovative ideas and solutions, in order to instigate the second condition. By allowing experimental procedures, for example, to be enacted in a certain part of the organization, new ideas can be tested instead of just talked about; the belief or disbelief in the success of an experiment is only truly forged when the results are attainable. And, by encouraging the expression of innovation, “new attractors” may be birthed, and a type of “relational space” can be created, where “a certain high quality of interactions, reflecting a shared context of mutual respect, trust, and psychological safety in the relationship” is created (Lichtenstein and Plowman[8]). And, “as predicted by complexity theory (and managerial psychology), these rich interactions strengthened interpersonal networks, which helped to amplify the changes as they emerged” (Lichtenstein and Plowman[8]).

A leader who seeks the creation of a new emergent structure will assess the feasibility of the new structure that this attractor presents and not blindly following the new internal trend. Some points that a leader may ask about the proposed system are a) if it is attainable, b) if it will fit within the environment, and c) if it is progressive or retrogressive to the organization’s values and vision. If the leader is fairly sure that the new regime is “better” for the organization, he or she will need to begin to rally other agents to support it, so that collective action can contribute to a solidified installment of the changes made.

The final condition of this complex adaptive system depends on the ability of the leaders to re-stabilize the structure. To do this, the leaders must remind the organization of the values and vision of the organization, and promote awareness of the cultural and environmental constraints that will affect the new emergent structure. It is the leader’s job to keep the structure grounded in reality while allowing it to thrive at the increased capacity that was achieved. And, while it is true that these four sequential conditions and characteristics were founded upon a limited number of case studies, this model for understanding the functions and reactions of a complex adaptive system are relevant and supported by aspects grounded in chaos theory, presenting an “underlying order in chaos” (Ottens and Chen[10]).

## **9 Possible Motivators for an Emergent System**

Both models have only scratched the surface of the new order of leadership and management in an organization. They very clearly express that leaders are no longer the apex of the organization, but, instead, are more effective when they are “orbited” and “in-plane” with the agents. However, in order for the agents to begin to collect around a supported attractor, they must be motivated to do so. The leader will need to give purpose and meaning to the new attractor that will make sense to the emerging paradigm. The empirical study of the emergent system found that the creation of correlated language and symbols helped to initiate recombination or “self-organization”. These symbols resonated the most when performed through symbolic actions that legitimize the change, while the language used helps to relate emotionally on a personal level with each agent. Another way to inspire meaning and connection to the new structure is to consolidate or recombine important resources, such as, capital, space, or skills, so as to give the impression that the system is expanding towards a “better” paradigm. The idea is that self-organization will be supported, and, thus, gain favor throughout the system. And, because there is not only a centralized leader within the structure of this complex system, the multiple leaders who emerge become symbols (Lichtenstein and Plowman[8]).

Hamel [6], discusses a management style called “Management 2.0” that humanizes the structure of an organization, acknowledges the autonomy of the individual, and sets a complex system motivated by humanistic, not materialistic, ideals: it redefines the language of the system, supporting ideals such as justice, community, and collaboration, as opposed to corruption, profit, and rivalry. The motivators behind this foundation are unique and requires a distinct leadership style to achieve it. One technique to increase motivation to uphold these ideals is to “reduce fear and increase trust”. To reduce fear means to eliminate positive-negative reinforcement of actions, and encourage risk-taking innovations. With autonomy, now, comes an inherent trust between the leader and agents, where a leader trusts the agents of the organization to function within the values and boundaries established, and the agents trust the leader to provide stability and dynamism, without erasure of the individuality of the agent. And, democratization of information allows agents to act independently, thus preserving autonomy.

## **Summary and Conclusions**

Empowering the agents allows them to have the capability to drive the system. However, without the presence of the attractors to influence the culture, the system may not emerge according to values of the organization. Ultimately, the obligation of the leader is to bridge the values with the vision and mission of the entity, and give purpose to the organization. Leaders will also need to monitor the internal and external influences to the system. The use of complex adaptive systems theory will enable the leaders to guide the adaptation of a system by creating an emergent structure that reconfigures the organization into new patterns that improve the function and capacity of the system, while still aligning with its core competency. Although it is fundamentally impossible to control chaos, it is possible to increase the survivability of an organization to adapt to the chaotic environment through complex adaptive systems theory.

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