Complexity and chaos in organisations: complex management

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Complexity and chaos in organisations: complex management

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Abstract: In the present work we analyse the implications of complexity in the behaviour of organisations, and how they should adapt to this complexity instead of trying to exclude it. We divide the paper in seven different sections: after a brief introduction (Section 1) we comment the influence of complexity in the evolution of scientific paradigms (Section 2); in Section 3 we analyse the meaning of the term 'complexity' and the characteristics of a complex system; in Section 4 complexity and chaos are related, conforming what is named chaordic system thinking; in Section 5 we analyse the shift of paradigm in management and the implications of the new complex paradigm in organisations; in Section 6 we analyse the meaning of complex organisation; at last, in Section 7 we expose the new tools in organisation to cope with complexity.

Keywords: chaos; chaordic systems; complex adaptive systems; strategic management; complexity; complex management; complex skills.

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Biographical notes: Elena Olmedo Fernández received her Bachelor of Science in General Economics from the University of Sevilla in 1995. She received her PhD from the University of Sevilla in 2001 with the doctoral thesis entitled 'Time series analysis in nonlinear chaotic economic dynamics. Application to Spanish data'. At present, she is working as an Assistant Lecturer at the University of Sevilla where she has worked since 1995. She has published works in applied economics in journals such as *Cuadernos de Economia*. *Latin American Journal of Economics*, *Artificial Inteligence*. *Revista Iberoamericana de Inteliencia Artificial*, *Estudios de Economia Aplicada* and different studies about implications of complexity in organisations, published in journals such as *Emergence: Complexity and Organizations* or *Complexity International*.

1 Introduction

The notion or organisation has evolved along time, from a rigid state to a flexible one. This new organisation has a new dynamics, characterised by adaptation and emergence. Leadership and management skills have to evolve to cope with this new environment.

Complexity science tries to study, describe and explain the behaviour of complex adaptative systems. This is a multidisciplinary science, compounded by different interrelated blocks and, as Schneider and Somers (2006) points out, there are three inter-related building blocks of complexity science: non-linear dynamics, chaos theory and adaptation/evolution. Complexity science is concerned with complex dynamic systems which are unpredictable and, at the same time, generate new properties and spontaneously self-organise into new structures. As Stacey points out, organisations are non-linear webs or human interactions, capable of stable and unstable behaviours. The successful organisation works in the creative intermediate zone between stability and instability, the named 'chaotic zone' (Stacey, 1993). Managers do not have to seek equilibrium, but rather to scope with change and innovation, being flexible and adaptative.

2 Evolution of scientific paradigms

The current interest in the complexity sciences is so great that we could suggest a paradigm shift, which has evolved from Newtonian paradigm to complexity paradigm (see Mateos et al., 2002).

Since the 18th century, the Newtonian paradigm has been predominant, characterise by determinism, supported by Cartesian reductionism. This determinism constitutes the base of the modern scientific method in which any system could be studied analysing its constituting parts. The Principle of Strong Causation state that the same causes result in the same consequences, so the precise description, comprehension and knowledge of any system implies directly the capacity of predicting the past and the future evolution of the system with absolute accuracy.

But since the perfect knowledge is no possible, the Principle of Strong Causation is replaced by the Principle of Weak Causation that states that approximately the same cause's result in approximately the same consequences. This Principle justifies prediction in statistical terms. The deterministic laws are replaced by statistical laws, and this new paradigm is called the simplification or statistical paradigm. These two paradigms coexisted and were applied to different fields, developing models (deterministic or statistical) characterised by concepts such us independence between observer and observed, isolated systems, equilibrium, linearity, order, energy conservation and reversibility.

The economy as a science was based on these principles, even though its inherent complexity -it is difficult to maintain the existence of closed systems in equilibrium, or linear relationships between causes and consequences. The unquestionable success in the application of the Newtonian paradigm to natural phenomena fails for social sciences because of good fit models usually fails in forecasting (what is called 'forecasting paradox').

But these principles have been even questioned in 'hard' sciences since the beginning of the 20th century, due to the Heisenberg's uncertainty principle. This principle states that the independence between the observer and the observed is not real and observer changes inherently what is observed. Later, the Chaos Theory focused on linearity because approximately the same causes not necessarily origins approximately the same consequences. The property of sensitivity of initial conditions, present in some non-linear

systems, amplifies insignificant divergences in the initial conditions in an exponential way. These two principles conclude that accurate descriptions do not guarantee accurate predictions. So a new concept of complexity has arisen, which shows that 'complex' is qualitatively different from 'simple', giving rise to a new paradigm, in which hard and soft sciences work together with concepts such as feedback, adaptability… initially more 'suitable' for the last ones. This complex paradigm breaks with the determinism-randomness duality, and is not opposed to the Newtonian paradigm, but completes it with new concepts (Prigogine, 1993, 1997). The Complexity Theory is not unified and homogeneous, as stated in the introduction, but there is a broad agreement on the characteristics of the phenomena studied. Particularly, these phenomena (see Teisman and Klijn, 2008) are more 'dynamic' than the traditional approach assumed, evolve endogenously, are not isolated and are compound by self-organising agents. So we can counterpart the key concepts of simplification paradigm versus complexity paradigm in the table below:

Table 1 Simplification versus complexity paradigm

Simplification paradigm	*Complexity paradigm*
Independence between observer and observed	Dependence between observer and observed
Closed systems: systems are considered isolated structures	Opened systems: systems are constituted by agents interconnected and connected with environment
Equilibrium: systems are considered structures in equilibrium	Dis-equilibrium: systems are considered structures far from equilibrium
Linearity: the whole is approximately the sum of constituting parts	Non-linearity: the whole is more than the sum of constituting parts
Energy conservation, as a consequence of being closed systems	Energy dissipation, as a consequence of being opened systems
Reversibility: time is exogenous and external to the system	Irreversibility: time is endogenous and internal to the system
Order	Disorder

What are the reasons for the inclusion of these concepts in social sciences? We state the following (Mathews et al., 1999):

- environmental complexity and uncertainty is increasing, and complexity sciences could help us to face with them
- complexity science tries to understand dynamic behaviours, and now the world is essentially dynamic, characterised by change and evolution
- the models that produce complex behaviour in biology and physics are similar to models used in the study of social behaviour, so some new possibilities are opened due to complexity science
- the traditional perspectives have not been fruitful.

3 What is complexity?

The current world is characterised by the complexity of the problems it must face and solve. We have to make a distinction between complex and merely complicated. Complicated systems have a large number of components with well-defined relations and roles, which are linear and fixed along time. Complex systems have usually a large number of components with non-linear relations and roles that evolve along time.

As complexity science, complexity is a heterogeneous concept. As Rosser (1999) points out, there is no general agreement about its definition. In fact, following Rosser (1999), every definition focuses on different features of the concept, and hence we necessarily have to admit that the concept of complexity is connected with different scientific disciplines, such us mathematics (day), systemic theory (Pryor and Stodder), computation (Leijonhufvud, Stodder, Albin and Foley), information theory (Horgan). But there are some figures (Edmonds, 1995) associated with complexity, such as the size and diversity of the system, the impossibility of perfect knowledge, and the oscillation between order and disorder. Are we now capable to define a complex system? A single definition does not exist, as it happens with complexity, (see for instance the special issue of *Science* devoted to this topic, Vol. 284, No. 5411) but there are some properties common in all complex systems (Pavard and Dugdale, 2000; Snowden and Boone, 2007) stated below.

3.1 Emergence and auto-organisation, the whole is greater than the sum of its parts

A complex system is characterised by emergence. The interactions between the elements of the system and with the environment create new properties. These properties, named emergent properties, create new structures and changes in the roles of the elements and their behavioural patterns. This is what is called auto-organisation. These are the reason to state that we couldn't study the system by studying its constituting parts.

3.1.1 Open systems

Complex systems are open systems, where energy and information flow through the system and beyond its frontiers. For this reason, complex systems are generally evolving continuously but in states far away from equilibrium.

3.1.2 Limited descomponibility

A complex system has a dynamic structure. The permanent interaction among the elements of the system, and with the environment, induces the system to restructure itself and generate auto-organisation properties. The parts of the system are unable to reproduce the whole system and cannot take it over.

3.1.3 Non-linear adaptative relationships

Relationships between elements of the system are usually non-linear, so the relation cause-effect is not clear. Additionally, positive or negative feedbacks are usual so the

non-linear relations may evolve with system evolution: we speak about non-linear adaptative relations.

3.2 Long-term dependence, the system has a history, and evolution is irreversible

Due to the sensibility to initial conditions recent alterations are very important in the system evolution. And due to the presence of non-linear adaptative relationships, past alterations continue having effects in current state of the system. So the knowledge of the past evolution in complex system is very important.

3.2.1 Absence of determinism

It is not possible to forecast with certainty the future evolution of a system, even though we know the behaviour of their elements and their relationships, due to all the properties stated above.

3.2.2 Complex systems connection

Complex systems are usually nested in other complex systems. Hence, the elements of a complex system are, likewise, complex systems; these complex systems are components of other complex system as well, and so on.

4 Chaos and complexity

As it happens with complexity, there is not a clear definition of chaos, but we can state that Chaos Theory works with systems characterised as complex, non-linear, dynamic and far from equilibrium, unforecastable and ordered.

Chaos and complexity are usually considered as synonymous, but there are substantial differences between them. First of all, their historical roots are different. Chaos Theory was born in California University-Santa Cruz, where sensibility to initial conditions was discovered. But Complexity Theory couldn't be attributable to any singular group nor any singular moment, because it embraces different areas, one of them is Chaos Theory.

There are some subtle differences between them (Fitzgerald and Eijnatten, 2002a):

Table 2 Chaos versus complexity

Chaos	*Complexity*
How simple systems could generate complex behaviours?	How simple behaviours emerge from complex systems?
Simple non-linear systems produce extremely complicated behaviours (sensibility to initial conditions)	Simple interactions produce higher-lever patterns
How to recognise, describe and forecast systems with sensibility to initial conditions?	How to discover recognisable patterns when the complicated system is looked at a whole?

But chaos and complexity are intimately related. As much it is so that a new concept has been created: Chaordic system (Fitzgerald and Eijnatten, 2002b) which amalgamates chaos and order, signifying the fact that these two seemingly opposite concepts are so interpenetrated that neither can exist without the other: *a chaordic system is a complex and dynamic set of connexions between elements which conforms an unified whole, which behaviour is simultaneously unpredictable (chaotic) and patternly (orderly)*.

Chaordic systems thinking is a framework for seeing and interpreting reality according to chaotic and complexity principles. This new perspective could be considered as complementary to conventional focus, to explain phenomena that could not be studied using traditional tools. It helps to give us a new perspective to look at phenomena; clarifying situations we can not understand before thanks to the use of new concepts such us (Fitzgerald, 2002) consciousness, connectivity, indeterminism, emergence and dissipation, opposed to traditional ones such as positivism, reductionism, determinism, mechanism and conservation (see Table 3).

Table 3 Traditional versus Chaordic assumptions

Tradicional assumptions	*Chaordic assumptions*
Materialism or positivism:	Consciousness:
What we could not measure, do not exist?	There is so much information underlying the apparent material world
Reductionism:	Connectivity:
The whole is the sum of its parts	The universe is one, and all is interconnected
Determinism:	Indeterminism:
Cause-Effect relationships are linearly co-related, so forecasting and control is possible	Due to sensibility to initial conditions and interconnectivity, cause-effect relationships are not forecastable, but present is past-dependent
Mechanism:	Emergence:
People organise simple elements into increasingly more complex phenomena	There are properties that arise in the whole that are not present in its parts, due to inter-related capacities. The whole is more than the sum of its parts
Conservatism:	Dissipation:
Dissipation jeans to dissolve, to disintegrate and to disappear	Open systems are dynamic and continuously inter-related with environment

This Chaordic systems thinking entails to open our minds to new concepts and to move towards understanding the complex (Morin, 2008). This implies knowing how to accept ambiguity, interconnections, contradiction, lack of precision and unpredictability and the importance of emergence, self-organisation, learning and adaptation to succeed. This kind of systems, Chaordic and with capacity to learn from experience to adapt to new scenarios is called *complex adaptive systems*. So we go a step ahead to state that Complexity Science is the field that has grown up around the study of complex adaptive systems.

5 The shift of paradigm in management

All we stated in the evolution of scientific paradigms could be translated into the evolution of management paradigms (see Table 4).

5.1 First stage: Newtonian paradigm

Traditional organisation management, developed during the 18th century, has been influenced by Newtonian deterministic paradigm, which is directed by three key assumptions:

1 reality is objective (positivism)

2 cause and effect relationships are linear, and therefore the results are predictable (determinism)

3 knowledge is acquired through the senses: data collection and analysis (reductionism) and focused in prediction and control.

In fact, business companies that emerged with industrialisation were organised according to the above mentioned guidelines. The machine metaphor was employed to characterise organisations as great machines and their workers as pieces that could be directed, controlled or, merely, replaced. So companies were considered stable entities that functioned in a linear and predictable manner. The role of the administration manager was to observe, establish and understand the cause-effect relationships to get the control (Stacey et al., 2000). The key concepts are locality, order and equilibrium.

In this first stage (Nieto de Alba, 1998, 1999, 2000), management assumes a closed organisation, with a stable dynamic. Changes are forecastable and managers should anticipate to them and react properly, what is named *a priori* adaptation. This produce risk aversion and, as a consequence, managers create rigid, centralised and hierarquical organisations, putting limits between different levels and ranks clearly established. The values of the organisation are generated from top to bottom, and control tools are external.

5.2 Second stage: randomness paradigm

The randomness paradigm implies recognising the presence of uncertainty and the substitution of the principle of strong causation by the principle of weak causation. Cause-effect relations are still linear, but approximate. So the basic hypotheses are that control is still possible increasing information to determine these relations: (simple) learning is principal. Management is therefore still anticipative, but the necessity of information makes horizontal nets replace hierarchy. The success is therefore consequence of groups rather than individuals, so tasks take precedence over ranks. The values emerge from the base to the top and give rise to self-control, rather than external control.

5.3 Third stage: complexity paradigm

In contrast with the previous stage, forecasting is not possible. Non-linearity and sensibility to initial conditions break the principle of weak causation, so increasing

information do not guarantee the determination of cause-effect relationships. Organisations are characterised by dis-equilibrium, non-linearity and emergence. Management must be creative and innovative: the future is no longer anticipated, it is now created. The key concepts now are chaos, conflict, instability, complex learning and dialogue to favour spontaneous self-organisation. Values can be both ascending or descending. Generative or complex learning becomes fundamental for management. So there are not fixed rules, but better broad, adaptive and simple guidelines, and rules that emerge from interacting too.

Table 4 Evolution of management paradigms

	Newtonian paradigm	*Randomness paradigm*	*Complexity paradigm*
Theoretical background	Strong causation	Weak causation	Chaos, complexity, emergence
Organisation structure	Organisation is unique and isolated, rigid and hierarquical	Organisation is form by different agents interrelated at different levels	Organisation is a complex adaptive system
Management	Cause and effect are linearly related, so perfect knowledge is possible. Success comes from managers' capacity to anticipate, making perfect forecasting and enumerate fixed rules to guide organisation	Cause and effect are related approximately linear. Increasing information is necessary to make forecasting so horizontal nets are fundamental. Success comes from groups rather from individuals	Cause and effect are non-linear related. Sensibility to initial conditions invalidates perfect knowledge and forecasting. Organisations are unstable and dramatic changes can occur unexpectedly. Success comes from learning, emergence and adaptive properties
Sources of information and control	From top to down, anticipative	From down to top. control emerge through habitualisation of routines and norms	From down to top and from top to down. There are general, simple adaptive guidelines, and rules that emerge from interactions

6 Organisations as complex adaptive systems

Given that complexity is the science of non-linear, complex, dynamical, self-organised, far-from-equilibrium system which is be able to learn from experience to adapt to new scenarios –what is called complex adaptive systems (Schneider and Somers, 2006), and organisations fulfils all stated up, we can state that complexity is the science of management for the 21st century.

The applications of these concepts in organisations usually mix complexity with chaotic and learning concepts, using Chaordic systems thinking, unifying unpredecibility with the existence of orderly emergent patterns.

Really, we can think about companies as dynamic adaptive systems, complex and non-linear, characterised by a great number of interacting elements each other and with environment in a complex way, which evolve and learn through time creating new emergent properties and structures and with sensibility to initial conditions, so their evolution is hardly predictable.

Traditional managerial models seek for stability, equilibrium and control to reduce complexity, with decisions devised at the top or organisation, based on logical and analytical instruments with experts' assessment and formal teams directly controlled by senior management. On the other hand, complexity managerial models work with complexity instead of trying to reduce it. Success implies to take advantage of dis-equilibrium, change and innovation. Decisions devised at all levels or organisations, based on intuitive instruments in informal teams within boundaries of discretion. It is important the creation of environments to favour emergence and to use methods that can help to generate ideas, increasing levels of interaction and communication.

If companies are considered complex systems, there are some key implications (Levy, 1994; McMillan and Carlisle, 2007). First of all, traditional long-term planning using rules is actually impossible: small disturbances amplify over time because of sensitivity of initial conditions, so that perfect and rigid forecasting is impossible. This implies a change in strategy, changing strategic planning by strategic thinking: rather than try to forecast, is better to take into account different scenarios, substituting static rules by broad guidelines, and forecasting of precise future behaviour by forecasting of pattern of behaviour.

Equilibrium is not a key concept anymore. The traditional approach is focused in equilibrium, so models are useful only if they predict equilibrium outcomes. But chaotic systems are always changing, and can spontaneous and endogenously form new complex structures. So strategy thinking shouldn't try to reach equilibrium, and should encourage the possibility of emergent behaviours or structures.

The organisation moves in a changeable environment and dramatic changes can occur unexpectedly. Traditionally, large changes in outcomes only occur because of large changes in initial conditions. But in chaotic dynamics, small changes can generate very different outcomes. So that strategic thinking should take into account not only natural disasters or wars, but small changes in scenarios too. The organisation should be able to react and adapt to these small changes and to take advantage of them.

All stated does not mean the disappearance of rules but to their substitution by general guidelines. These broad guidelines are needed because of the necessity of taking into account different scenarios. And because of the possibility of dramatic changes, these guidelines have to be adaptive.

7 Conclusions: tools for complex management

After all stated above, we have to reconsider traditional organisation and therefore traditional management too. The new manager's skills have to be able to cope with complexity, taking advantage of it instead of unsuccessfully trying to escape.

So the tools for managing under complexity are (Snowden and Boone, 2007; Olmedo et al., 2007): favour discussion, dissent and diversity to encourage the emergence of patterns and ideas; set general barriers to delineate behaviours, not to eliminate the necessary uncertainty to let the system self-organise, because an excessive control may

inhibit progress possibilities; combine common, everyday management with complex, non-ordinary management making use not only of quantitative but, also and fundamentally, qualitative experience; stimulate creativity to favour success requires continuous creativity, generating uncertainty in a deliberate way to favour creativity and innovation, stimulating attractors, emergent structures to gain coherence; create environment appropriate to take advantage of new unexpected opportunities that may emerge; allow time for communication and reflection; provide clear and easy communication tools; stimulate adaptation and flexibility, to substitute general qualitative thinking models instead to govern organisation dynamics instead of forecasting and control and stimulate ethical values in organisations.

And with respect to new complex managerial skills (Shelton and Darling, 2003, Olmedo et al., 2007; Kiel, 1994; Nieto de Alba, 2000 and Stacey, 1995) they are related with the characteristic points of complexity paradigm (Table 1) and Chaordic assumptions (Table 3). The dependence between observed and observer shows that reality is subjective and managers should take it into account, so they should favour discussions and diversity to count on diverse opinions derived from different ways to see the same reality. The consideration of organisations as complex opened systems far from equilibrium, makes that traditional linear concepts are not appropriate to work so managers should learn to think in a complex way combining apparently opposite concepts such as order and disorder. The chaordic assumptions consciousness, connectivity, emergence and dissipation lead to the managers to stimulate intuitive thinking, communication and reflection, to stimulate ethical values, to generate amiable environment to create and learn. Due to these assumptions managers should trust in self-organisation to cope with complexity. They should emphasise interconnections in all levels to favour emergence and learning. Due to all said, besides non-linearity and indeterminism justifies the substitution of models of strategic planning by qualitative models of strategic thinking, changing fixed rules by broad guidelines, proposing new scenarios and problems to favour adaption and learning.

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