Title: **Complexity**
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This version: pre-press
Originally published in: Bevir, M. (Ed.), Encyclopedia of Governance (pp. 131-135)
Date: 2007

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Introduction and Definition

Complexity theory or the science of complexity is the label for a collection of theories that are building blocks for a system-oriented approach to (social) reality. This body of theories challenges the ideas of linearity and order and focusses on non-linearity, interconnectivity, unpredictability and the major impact that may be caused by seemingly insignificant factors. 'Order' is a characteristic of the practice of governance with its rules and regulations, fixed schemes and schedules, assigned roles, and expectations concerning the behaviour of actors. 'Chaos', on the other hand, can also be observed: projects that run out of control and do not finish, budgets that are exceeded despite strict bookkeeping, minor issues that – once raised – result in politicians resigning and processes of interactive decision-making that end up in situations never expected. The notions of complexity theory can help to understand how and why the practice of governance is capricious as it often is, despite attempts to control it. 'Complexity' indicates situations where order and chaos in governance keep each other in balance. This is also called the 'edge of chaos'.

Before turning to the application of complexity theory in social science in general and governance in particular, the background of these theories is introduced.

Background and Development of Complexity Theory

Complexity theory originates in physics, mathematics, chemistry, biology and economics that focusses on the dynamics of systems. A number of important observations in all these fields of science caused the emergence of theoretical notions that later on founded complexity theory. For example, it was observed that the whole is more than the parts, that therefore the properties of the whole can't be predicted out of the properties of the constituent parts, that elements can act without guidance of an authority and that processes are not time-reversible. In other words: the mechanistic, Newtonian worldview that has dominated science for such a long time was challenged by these observations and led to ideas about non-linearity that became known as complexity theory. Founding fathers include Arthur, Dawkins, Gell-Mann, Holland, Kauffman, Langton, Prigogine, and others.

The theories encompass ideas and notions about how and why systems develop (e.g. Gell-Mann, Kauffman, Prigogine), and ideas and notions about the behaviour of elements in such systems (e.g. Langton, Holland).
The notion ‘systems’ lies at the heart of the complexity theory. Systems can be everything, from populations to chemical compositions and from economies to a set of genes. These systems are called ‘complex adaptive systems’ or CAS. Systems consist of active elements that are different in form, capabilities and behaviour. These active elements are interconnected, which means that if one element develops, it will affect other elements. This brings about a chain of reactions but the magnitude of the effects may be diminished by the resilience of the environment. This resilience comes from the capacity of other elements to absorb or because these elements were also triggered by other, contravening, events.
Elements are called agents or actors if complexity theory is applied to social reality. They act according to a limited set of rules that evoke self-organising behaviour. These rules are often referred to as simple rules of behaviour or schemata. Self-organising behaviour emerges out of interaction with other agents by application of these rules. Using these schemata (in interaction) results in complex patterns of interaction called ‘emergences’ and the subsequent complex development of the system of which the actors are part (Goldstein, 1999). This is why such systems are deemed ‘complex’. They are deemed ‘adaptive’ because these systems are able to adapt themselves to new situations through the flexibility or ‘adaptiveness’ of its constituent parts, i.e. the elements or agents (Holland, 1995), hence complex adaptive systems.
The afore-mentioned mechanisms stem from observations of the development of populations, chemical responses, economic and computated systems. In turn, they lead to the idea that the ability to adapt is crucial for elements as lack of adaptiveness results in deadlocks. Adaptation to the environment happens through the mechanisms of negative and positive feedback loops. Negative feedback loops diminish the gap between the actual situation and the desired situation, whereas positive feedback loops increase this gap, sometimes unintentionally. Both forms of feedback can produce a positive or negative outcome. Feedback loops do not occur sequentially but simultaneously, thereby adding to the complexity.
As time progresses, agents attempt to adapt themselves to the changing environment. This can be regarded as a ‘walk’ of an agent through a space-of-possibilities where the agent can select a certain possibility, or being forced to do so. The number of possibilities to choose from is not unlimited. There are possibilities that are only theoretical possibilities: far from feasible or harmful for the agent in question. There are possibilities that disappear when time progresses or when a choice from an agent rules out other possibilities. Over time, possibilities that are more likely to be chosen will (re-) appear and possibilities that are not that attractive will disappear.. Certain possibilities that are chosen more frequently than others – for whatever reason – are called

attractors in complexity theory. Attractors are states within the space-of-possibilities that appear to – literally – attract agents.
As time progresses and agents follow their rules, they may face the mechanism of path-dependency: history determines the actual position of agents. Lock-in effects refer to situations from which it is difficult to leave because the effort needed to abandon this situation is exceedingly high. These situations may be optimal but often they are considered to be inferior. Lock-in effects can be avoided by being adaptive (Arthur 1994).
From observations it is found that systems develop towards an equilibrium but that there is no single best equilibrium for a system but rather multiple equilibriums that provide temporally best situations - and this can change over time. If systems cannot keep themselves in a state of dynamic equilibrium, they tend towards a state of chaos (too much interconnected to its environment and too little stability) or inertia (too isolated from its environment, too much stability) (Nicolis and Prigogine, 1989). Both situations provide less potential for prosperity. So far, the notions ‘systems’ and ‘agents’ have been used interchangeable. This is because of another characteristic of complexity theory, where systems are essentially regarded as nested systems. That is: systems are elements or agents within bigger systems that are elements or agents in even bigger systems. The division into ‘systems’ and ‘agents’ is therefore fuzzy (Gell-Mann, 1995). The mutual interaction of systems and agents is called co-evolution (Van den Bergh and Gowdy 2000).
The mechanisms and developments described before can be considered as the basic mechanisms in complexity. So-called fitness landscapes can help to comprehend the development of complexity. A fitness landscape is a three-dimensional rendering where every agent (of a system) has an unique position of the x-, y-, and z-axis. In this landscape each system (or agent) seeks a local optimum. It is a dynamic landscape because of the afore-mentioned mechanisms that ensure ongoing developments. The initial position of an agent, but also the subsequent actions from other agents in response to the move of that agent, determine new positions (see for instance Kauffmann, 1995). A good position is depicted as peak whereas an inferior position is depicted as a valley. As all agents move all the time, the fitness landscape moves accordingly, making it harder to reach a peak (i.e. an optimal situation) and to avoid a valley (i.e. a suboptimal situation).

Complexity Theory and Social Science

The main ideas and notions discussed before started to seep through in social sciences by the late 1990’s. Prominent advocates of complexity theory in social science in general and governance in particular include Byrne, Haynes, Maquire, McKelvey, Mittleton-Kelly, Parker, and Stacey.

Benefits of Complexity Theory in Social Sciences

Perhaps less dominated by a Newtonian worldview, social sciences can still take advantage of complexity theory. It challenges the ideas of linearity, predictability, certainty and dichotomy between order and chaos, and focuses on the (co-)evolutionary nature of systems and agents – often called actors in social science – and the mechanisms mentioned before. Complexity theory can be applied in all disciplines in social sciences, providing opportunities for crossing the boundaries between disciplines. The limits to the application of complexity theory in social sciences are yet to be explored but this way of thinking can mean a thorough change of perspective on social processes (Byrne 1998). For governance, it may help to understand why and how matters appear to shirk away from order, no matter which instruments for control such – as laws – are applied.

Criticism on Complexity Theory in Social Sciences

Complexity theory has received considerable criticism from social scientists. There are two main lines of criticism. The first line deals with the question whether complexity theory is something 'new'. The second line is the question whether concepts from scientific disciplines such as physics and chemistry apply to social phenomenon. As far as the matter of 'new ideas' is concerned: complexity theory bears resemblance with systems theory as put forward by (among others) Checkland and Flood. It also comes to certain conclusions concerning governance and public management that other authors have reached as well, from very different theoretical angles. Nevertheless, complexity theory is still a new way of thinking, although sometimes the differences lie in the details (Murray, 2003).

The second line of criticism is caused by inconsiderate application of the scientific concepts into social science. Notions and methodologies from complexity theory that have value in natural science may not be valid in social science. For example: cells will behave fundamentally different from humans. This doesn't allow using the principles of how cells behave to understand how humans behave. Early applications of complexity theory to social research often resulted in the use of the main notions as an analogy, rather than as an empirical description.

Complexity Theory and Governance

So far, the discussion covered the fundamental principles of complexity and their positions within the theory. There are also applications to the analysis and practices of governance and public management. It can help to derive directives concerning these actual practices (Haynes, 2003). These practices include strategies, structures and operational management approaches.

Governmental organizations can be seen as complex adaptive systems, interacting with and within a dynamic environment of other organisations (White, 2001). By themselves they are nested systems: agencies are part of

ministries, which are part of the larger central government, which is part of a political system, which as such is part of international systems.
Public organizations try to influence each other and actors within society in order to realise their policy ambitions. The difficulty of realising collective action and implementing policy can be explained through the logic of complex systems. Agents, or actors, within a policy system act according to their own schemata with which they interpret external messages. They can chose to respond to the messages in a number of ways. Sometimes, their response reinforce steering attempts of governmental organizations (positive feedback), sometimes they extinguish them (negative feedback).
Governance, then, is dealing with the complexity of co-evolving agents and systems. The governing organisation is not steering other actors but engages in an adaptive walk through different landscapes, such as the landscape of international negotiation or the regional landscape of urban planning and so. Each landscape is populated by highly diverse actors: governmental organisations, societal organisations, interest groups, private businesses, and citizens. These actors all have their own schemata and ambitions. Strategic operations of one actor influence the position and possibilities of the other actors within this particular landscape. Agents need to handle difficult dilemmas of cooperation versus competition, exploration versus exploitation, openness versus closeness effectively in order to reach ones goals and collective action.

Managing Complexity in Public Organisations
Complexity demands a dedicated managerial approach in public organisations. The argument is that (public) managers find themselves in a qualitatively different world than in the past, where traditional managerial approaches are not suitable anymore. The traditional approach includes hierarchical structures, bureaucratic routines, centralisation of power and decision-making, and the desire to plan and to reduce uncertainty. This different world is characterised by uncertainty, nonlinearity, unpredictability, and high dynamics (Maguire and McKelvey, 1999). Recognising the complexity of the environment of public organization, and indeed the complexity of the organisation itself, has important implications for public management. Complexity theory then turns from a descriptive theory into a prescriptive theory.
There are three motives to adopt managerial tools from complexity theory: to assert ones situation at the edge of chaos (because that is the condition in which organisations flourish), to stimulate self-organising behaviour (because one can’t organise and control everything by oneself), and to deal with the inherent uncertainty of the dynamic environment (because denying or attempting to control these dynamics reduces ones capacity to move along with the dynamics).
These goals are very demanding for public managers. Maintaining ones organisation at ‘the edge of chaos’ requires the ability to maintain enough

order to avoid loss in chaos and to open up for chaos to avoid getting stuck in order and to allow progress. Governance is about influencing the behaviour of citizens, societal and private actors, through the interactive development and implementation of policies. When public organisations, unilaterally, stick to their own ambitions, it is not likely that they get the support of their environment for realising these ambitions. The same applies for other actors. Only through a process of mutual adaptation, collective action is possible. Governance can be regarded as an attempt to organise a process of co-evolution between the different ambitions and visions which are present in a dynamic society.

It is a traditional reflex from governmental organisations to attempt to control processes within and outside the organisation. The dynamics of the environment as discussed before learn that such attempts will be in vain. In such cases, self-organisation can help to create a degree of order in the chaos without needing to control everything. In practice, this means that operating rules and regulations should not be too extended in order to cover all eventualities, but would rather give general directions thereby providing room to improvise in ever-changing conditions. Interactive processes are necessary because they will result in a joint vision on a specific policy problem that will be accepted by all actors, rather than imposed upon by the governmental organisation. Managers should establish the boundaries of such a process in cooperation with other actors but should refrain from detailed regulations.

Managers also need to deal with uncertainty. Traditionally, this is done through planning and control and other techniques that are used in attempts to reduce uncertainty. Complexity theory states, however, that this uncertainty will never disappear and preferably should be taken advantage of when it opens up new unforeseen possibilities.

By abandoning a linear and mechanistic world view, complexity theory provides a different way of looking (social) reality that is under development in social sciences and in practices of governance.

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See also

Autopoesis, dilemma, multi-level governance, path dependence, self-organizing system, steering, top-down approach (opposite)

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