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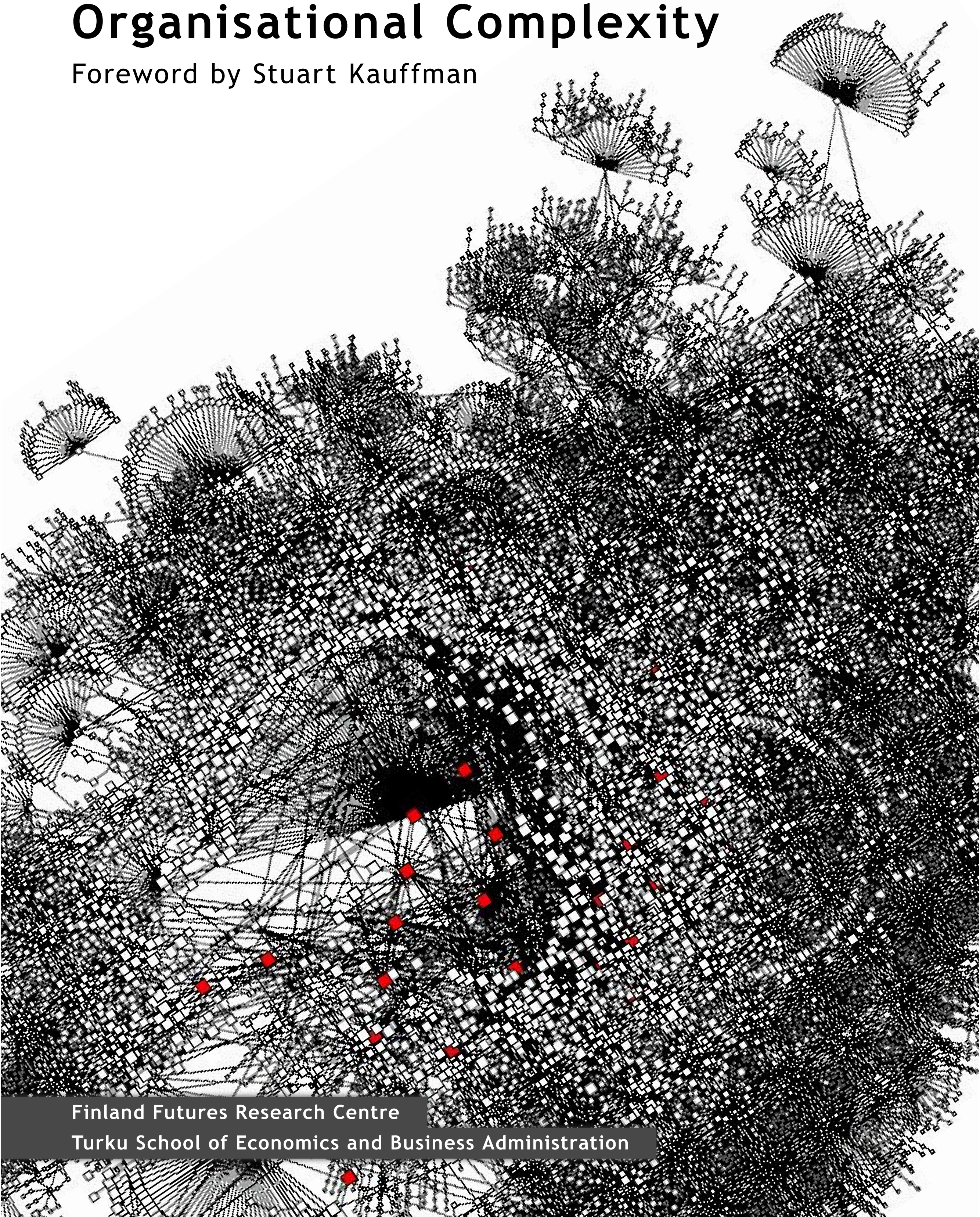
Organisational Complexity

Foreword by Stuart Kauffman



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Organisational Complexity

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Contents

Foreword

The emerging sciences of complexity, which grow out of earlier forays in systems theory, cybernetics, nonlinear dynamics, and chaos theory, constitute a new arena of science, pure and increasingly applied. Its fair to say that the field crystallized out of its forerunners at the Santa Fe Institute in the mid 1980s. I consider myself fortunate to have been able to participate in that initial decade at SFI. Among the topics we became excited about were Brian Arthur's interest in increasing returns and path dependence in economics, Per Bak and colleagues discovery of self organized criticality, which led to many models applying the idea to the distribution of extinction events since the Cambrian explosion, Chris Langton, Norman Packard and my interest in either cellular automata or random Boolean nets, and the phase transition between an ordered regime and a chaotic regime, with the intriguing hypothesis that the most complex coordinated "computation" could take place in the ordered regime near the phase transition, dubbed the "edge of chaos", Jim Crutchfield's work on epsilon machines which examined sequences of state transitions and found minimal machines to reproduce the dynamics, along with jumps between classes of machines as the data required.

In addition much effort was focused on Holland's genetic algorithms and the properties of solution "landscapes" which were successfully searched by that algorithm. Macready and Wolpert established the "no free lunch" theorem showing that, averaged over all fitness landscapes, no search algorithm, on average, outperformed any other. I developed a spin-glass-like model of tuneably rugged fitness landscapes, the NK model, and many of us have used it to analyze the properties of this family of fitness landscapes, and properties of evolution and co-evolution on those landscapes. This tied back into the no free lunch theorem. I and others showed that recombination, the proposed evolutionary selective reason for sex, only works on relatively smooth fitness landscapes. But where do such landscapes come from? God, physics, or is the structure of fitness landscapes itself a consequence of evolution?

In addition to the above arenas, Artificial Life was initiated by Chris Langton, with wonderful models of "boids" following simple rules and exhibiting flocking behavior. Packard, Doyne Farmer I and others studied the emergence of autocatalytic sets of polymers as a phase transition in complex chemical reaction networks and the capacity of such networks to evolve. Walter Fontana extended these ideas with his wonderful Algorithmic Chemistry, in which Lisp expressions act on one another in a computer chemostat, and found two kinds of replicators, single lisp expressions that copied themselves and, like Packard, Farmer and myself, collectively autocatalytic sets of expression. Fontana and Leo Buss used this in an effort to develop a theory of biological organization. More occurred in that decade, including applications of evolutionary algorithms to economic strategy evolution in game theory and other arenas. But this may suffice to give a flavor of the initial work in complexity theory.

Scientifically, complexity is now a teenager, growing into new domains from analysis of network structure, where scale free networks are found in domains ranging from protein-protein interaction networks, cellular metabolism, scientific cross citation indices, and the structure of the world wide web. Much current effort is aimed at understanding the structure, and growth rules for such networks. My own passion is the structure, logic and dynamics of the genetic regulatory networks within cells, where new experimental techniques such as gene expression arrays, and new theory are leading to the founding of "systems biology". This hopes to address the central problem facing cell, developmental and molecular biologists in the coming decades: The integrated structure, behavior, and evolution of cell regulatory systems in health and disease. Other emerging areas include applications of complexity to organizational theory. For example, the NK landscape model has been applied to organizational theory as well as to provide the first microscopic theory of economic learning curves.

Agent based models is yet another arena that is growing by leaps. Perhaps first popularized by agent based models in Artificial Life, such as the Boids model, as well as Langton and colleagues development of the "Swarm" program to "instrument" the agents in such a model, agent based models are now being applied to topics ranging from terrorism, to military models of combating armies, to business problems.

Applications to business, just noted, are growing. Bios Group spun out of the Santa Fe Institute to apply complexity to business, and used agent based models to study problems including the Procter and Gamble supply chain, optimal "orderable arrays" of trucks with different options and manufactured in different ratios, for Ford, cargo handling for Southwest Airlines and perhaps 70 other practical applications. Sister companies, EuroBios, Icosystems, and NuTech Solutions are furthering these efforts. As the biological metaphor replaces the mechanical metaphor to think about the evolution and co-evolution of firms and goods and services, agent based models, complexity theory, and ideas from biology are making their way into the practical world of business. "Adaptive organizations" is now the buzzword. New areas applicable to operations research are being forged.

It is entirely unclear how the field will develop. The bounds on what constitutes a complex system, whether there may or may not be general laws, or at least useful heuristics, governing or emerging from specific classes of complex systems is a matter of debate and varying hopes. The present book brings some of these arenas to your attention. There is much to be invented, new problems to be perceived and explored. Old issues, such as emergence, the adequacy of reductionism, and others, lie to hand for fresh examination. May this book fare well.

Stuart Kauffman

Santa Fe

Nov 1, 2003

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Introduction to Complexity

Auli Keskinen

The new approach to study interdisciplinary phenomena is called Complexity Science. Complexity science spans many disciplines, including physics, biology and systems theory. The development of complexity science is not a single technological innovation, but a *shift in scientific approach* with the potential to profoundly affect business, organisations and government. Complexity science strives to uncover the underlying *principles and emergent behavior of complex systems*. Complex systems are composed of numerous, varied, simultaneously *interacting parts* (or agents). The goal of complexity science is to *understand these complex systems* – what ”rules” govern their behavior, how they adapt to change, learn efficiently, and optimize their own behavior.

Different entities may have different potentialities for developing higher complexity. Something that is not particularly distinguished from similar things by its effective complexity can nevertheless be remarkable for the complexity it may achieve in the future. Therefore it is important to define a new quantity, "potential complexity," as a function of future time, relative to a fixed time, say the present. The new quantity is the effective complexity of the entity at each future time, averaged over the various coarse-grained histories of the universe between the present and that time, weighted according to their probabilities.

The era may not last forever in which more and more complex forms appear as time goes on. If, in the very distant future, virtually all nuclei in the universe decay into electrons and positrons, neutrinos and antineutrinos, and photons, then the era characterized by fairly well-defined individual objects may draw to an end, while self-organization becomes rare and the envelope of complexity begins to shrink.

In an organisational context, complexity provides an explanatory framework of how organisations behave. How individuals and organisations interact, relate and evolve within a larger social ecosystem. Complexity also explains why interventions may have un-anticipated consequences. The intricate interrelationships of elements within a complex system give rise to multiple chains of dependencies. Change happens in the context of this intricate intertwining at all scales. Often one can become aware of change only when a different pattern becomes discernible. But before change at a macro level can be seen, it is taking place at many micro-levels simultaneously. Hence micro-agent change leads to macro system evolution.

Complex Networks and Robustness

The global networking is a rapidly increasing development in all operative systems today – networks of roads, airlines, power transfer, research at universities, data, information and knowledge, and human beings grow rapidly and interconnect in a self-organisational manner. There is no command centre or "dictator" guiding the evolution of networks. Therefore, the challenging new characteristics of all human networked operations – as well as that of nature's networks – is robustness. How well and under what rules such network systems function, grow and tolerate tosses and turns inside and from outside? This is one of the main research focus areas at Santa Fe Institute in the 21st century, in addition to complex adaptive systems and networks.

In a world of uncertainty, rapid change, and increasing complexity, one might think that failure of social processes should prove the rule rather than the exception. And yet both the past and the present provide many examples of social processes that we instinctively label as robust to failure, whether because of the agility with which they have responded to changing circumstances, or because of their record of surviving deliberate internal or external attack, or merely because they have proved so long-lived. Robustness is a term that captures our intuitive sense of one of the key determinants of long-term success or failure, but what do we mean by robustness, and what specific features of a social process contribute to its robustness or fragility?

There are six different robustness areas to be defined for research on complex networks:

1. Robust Decision-making: Robustness of choice with unforeseeable consequences. Discussions will highlight the importance of issues including intentionality and the cognitive ability of social agents to observe outcomes, infer the reasons for those outcomes, and change their behavior accordingly.

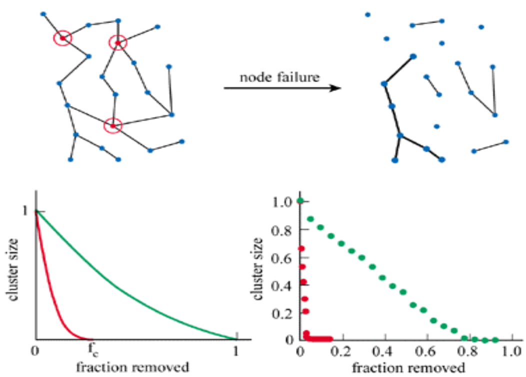
2. Robustness of Business Organizational Structures: Role of network structure in facilitating the dynamics leading to phenomena such as innovation or collapse in a social organization. Specifically, the research will explore the consequences for robustness of the ability of social agents functioning within a hierarchical structure to form social ties across all scales of the organization.
3. Robustness of Political Agreements, States, and Regimes: Robustness of negotiated agreements that define a social structure such as a nation-state. In particular it will address the dynamics that enable some such agreements to survive internal or external shocks (such as events that challenge the beliefs of the involved parties, or shifts in interpretations of the agreements, or organized attempts to disrupt those agreements), while others collapse into conflict.
4. Robust Institutions: Social dynamics that contribute to robustness or fragility of institutions. One set of issues to be explored is the role of competition between groups in favoring those with more robust institutions, and the within-group processes of collective action that can serve to create the range of novel institutional forms on which between-group selection can act.
5. Robust Economies: Issues of scale and levels in robust social processes. Included will be interactions between the slow variables of cultural patterns and the fast variables of economic change; the transference of robustness from one level to another; and mechanisms of robustness in organizations that are so large as to compromise the effectiveness of social norms.

6. Robustness of Cultural Traditions: Question of inference from the historical record. The discussions will attempt to disentangle the two aspects of "staying the same" versus "responding to change" that characterize robustness, with the goal of developing a methodology for examining the history of environmental or internal change, and the response of a social process to this change.

In general, the robustness of a complex system against errors and failures can be tested by investigating the effect of removing nodes. If the most-connected nodes are removed then the scale-free network will break at a small fractions. By randomly removing domains from the Internet, we found that more than 80% of the nodes have to fail before the network fragments (green). However, if hackers targeted the most connected nodes (red), then they could achieve the same effect by removing a small fraction of the nodes.

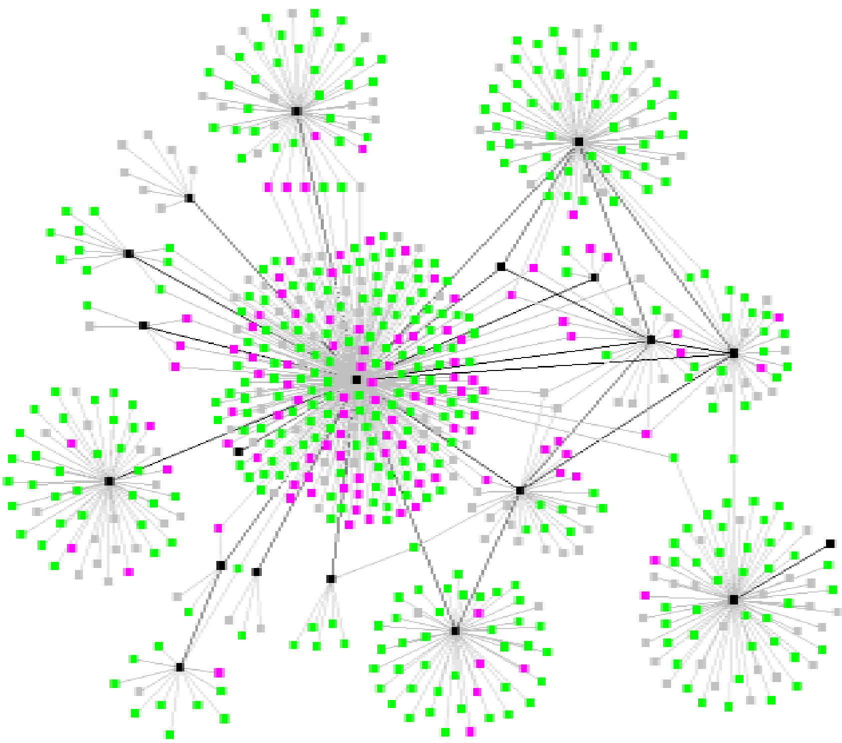
Figure: Error and attack tolerance

Source: Albert-László Barabási : The physics of the Web, Physics World, July 2001. http://physicsweb.org/box/world/14/7/9/pw1407094



A contagion spreads quickly through a human network – aided by well connected nodes. The distribution of links in the network is key to how rapidly a contagion spreads. Some contagions are good – new ideas, innovations. Others are bad – viruses and disease.

Figure: Mapping the Spread of Contagions via Contact Tracing
Source: Valdis Krebs, http://www.orgnet.com/contagion.html



To summarise, these are examples of complex systems. They convey the challenging message that we have to study the complexity in order to better understand the global complex problems in our operational environments, be they economical, socio–cultural, organisational or ecological.

Sources used in this chapter: Stuart Kauffman (NuTech Solutions Inc.), Murray Gell-Mann (Physics Nobel Laureate, Santa Fe), Eve Mitleton-Kelly (London School of Economics), Albert-László Barabási and Réka Albert (University of Notre Dame), Erica Jen and Melanie Mitchell (Santa Fe Institute), 2000–2003

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1. Allowing Complexity Into the Puzzle of Strategic Sensemaking

Mika Aaltonen

Abstract

Unquestioned faith in certainty, rationality, control and linearity, or to put it shorter – in an ordered universe – has laid the basis for strategic decision-making since the beginnings of management science. This paper argues that there is less certainty, rationality and possibility for control, but greater complexity in those settings where strategic decisions are made and implemented, than usually described. This argument has important implications for the concept of strategic management, and for the actions conveyed by those strategic decisions.

Resetting the Scene of Action

In contemporary management theories, there is little space for uncertainty. They concentrate on knowing instead of not-knowing, certainty instead of uncertainty, consensus instead of conflict. This is, because the latter things are understood as "something bad", "something that calls into question a managers competence to control a situation". (Stacey & Griffin & Shaw 2000, Streatfield 2001, Aaltonen 2002).

Rarely however, it is possible to perceive and define a problem or a target carefully, then design an appropriate range of action to improve the situation, and finally select the single course of action that seems to be the best way to solve the problem or reach the target.

More often than not the biggest challenge is to make sense of what is really happening, and identify those factors which success or failure consists of. Too simplistic and too linear a presentation can prevent managers from seeing what is possible and what, in turn, inhibits their ability to act efficiently, and find working solutions for real-life situations.

In recent descriptions of organisations, several different qualities have been attached to them, and the resulting variety of descriptions has been extremely broad. However, some common features can be recognised (Weick 2001):

- There is less to rationality than meets the eye.
- Organisations are segmented rather than monolithic.
- Stable segments within organisations are quite small.
- Connections between segments are of varying strength, and they produce ambiguity.

To explain further; in organisational settings, rationality usually means rationality as seen through the eyes of owners or managers. Yet, every time the perspective changes, the definition of what is rational also changes. There are many kinds of rationality, every individual has their own personal point of view, and this varies with respect to of different things e.g. processes, resources, values, visions inside an organisation, and different signals and trends outside an organisation. (C.f. Mintzberg et al. 1998). Rational decisions from one perspective can be considered less rational from another perspective.

Neither it is correct to talk about an organisation as one big entity, that possesses similar qualities in every branch throughout the world.

Thus it can be stated that organisations do have similar properties, but they are not all alike. Not to mention the fact that, every bigger organisation consists of a various number of smaller parts – individuals, teams, units – that communicate and interact together. An organisation is not necessary entirely tight or entirely loose. It is an imperfect system, a mixture of tightness and looseness, continuously created and re-created through communication and action. (E.g. Weick 1982, Beneviste 1994, Castells 1996, Arbnor & Bjerke 1997, Cilliers 1998).

If the above descriptions of the basic nature of organisational life are agreed upon, then some of the most profound assumptions behind contemporary management theories must be re-evaluated. One of these is the assumption that managers are or should be in control.

In Control	Not In Control
Intended, selected, planned	Evoked, emerging
Goal, target, vision	Exploring, searching
Detecting, correcting	Amplifying
Forming	Being formed
Known	Unknown
Predictable, stable	Unpredictable, uncertain
Order, consensus	Disorder, irregular
Clarity	Confusion
Conscious	Unconscious

Table 1. Conceptions of how the future is formed (Adapted from Streatfield 2001).

Contemporary management theory, and managers who act based on that, tend to simplify the management discussion and have a tendency to give and search for answers that provide absolutes. It would be more pertinent to assess those issues that are under a managers control and, importantly, also those that are not. The result would be the gaining of a fuller understanding of how the future can evolve in institutions, business, politics, etc.

Today's business landscapes are no longer described in terms of stability and continuity. Innovations that once worked well do not guarantee success forever. Rapid changes in environmental factors, emerging technologies, unexpected user patterns, ambiguous consumer demand, and the complex interactions between those variables is producing markets that challenge management theory and previous conceptualisations of the market place. (Brown & Eisenhardt 1997, Eisenhardt & Bourgeois 1998, Bogner & Barr 2000, Aaltonen & Kovalainen 2001).

In these business landscapes the importance of long-term planning, proactive global visions, and top-down management based on master plans has diminished. In the current era linear and restricted models and theories are seen as not being so helpful in making sense of the ongoing development. "Complex phenomena need complex metaphors". (E.g. Venkatesh 1994, Kotter 1995, Casey 1997, Czarniawska 1999).

In accordance with these arguments, the puzzle of strategic management has to be understood as containing more pieces than is often presented. The pieces may be difficult to collect, but the puzzle is continuously becoming more fascinating and reminiscent of life itself.

Strategic Sensemaking

The question of how we make sense of the world is amongst the most significant ones in strategic management. The main question is followed by four additional questions:

- What things (both tangible and intangible) and events do we choose to notice from the huge mass of things and events around us?
- What meanings are given to these things and events?
- How does the selection of meaningful things and events happen?
- How does this selection influence and guide future action?

There is a basic human need for people in their private and in their working lives, to build sensible and meaningful explanations for their existence and the actions they take. Sensible, meaningful explanations are built when evidence is extracted from recent or past events and things that are linked to already existing structures, i.e. mental models, historical events, or artefacts. (March & Olsen 1976, Porac, Thomas & Baden-Fuller 1989, Hopkinson 2001).

People continuously search for answers to questions about who they are, how they should act and interact, and what their future holds for them. Although a person will ask such questions it remains true that a human being's basic model of reasoning is not scientific, it is, in fact, narrative. That means that a person's most important mental models are often expressed in the form of a story. Thus, if we are unable to place a piece of information in the meaningful context of a coherent and plausible story, the meaning of that information is lost. As a result stories that explain the past and present, and imagine the future are extremely valuable in strategic sensemaking. (Aaltonen & Heikkilä 2003).

In his attempts to make sense of strategic decision-making Igor Ansoff (1975) focused on scope and process filters. Both can be used to determine the decision-making process in a variety of ways. Scope filters are observation and cognitive filters which ask; what kind of targets are to be set for the process, what issues are to be considered, and what kind of information is to be processed? Process filters are more or less power filters that deal with; what kind of process is chosen, who will be allowed to participate, and what kinds of methods are to be used? It is evident that different answers to above questions explain the differences in strategic processes set by different people.

The seven characteristics of sensemaking Karl Weick (1995, 2001) has distinguished, offer both a different type of explanation to Ansoff´s filter theory but one which is complementary. The characteristics show how a weak signal, or a piece of extracted evidence, leads to a change in the perceptions people have about themselves or organisations have about themselves. A change in perception subsequently demands a change in action. In other words, sensemaking occurs. That is, a new event becomes integrated into a narrative. From that it becomes understandable in relation to the context of what has happened (Czarniawska 1997, 1999), through at least seven reference points. Sensemaking is *grounded on the construction of identity*, it is *retrospective*, *enactive*, *social*, *ongoing*, it is *based on extracted evidence* and focuses on finding supporting evidence for that, and it is *driven by plausibility* rather than accuracy. Through all those elements plausible explanations are found and made.

In Weick´s presentation, the properties of sensemaking are, perhaps implicitly, considered universal, i.e. they are supposed to be valid in every organisation, in every culture. Even if Weick´s work is on solid ground, it is worth the effort of seeking out more context specific arguments for such accepted explanations. For example, Sony´s "hobbyism" uses everyday life to build persuasive arguments and considers them so valuable that they often lead to corporate action. An example would be a marketing director arguing that "I tested this toy with my nephew, and he really liked it. I think we have a good product here". Alternatively, in an academic organisation (e.g. Nokia), a persuasive argument that results in organisational change is often based on a book or an article by a recognised expert. In other multinational companies, e.g in heavy industry, a similar kind of argument, would probably pass by without comment. (Kontro & Pantzar 2002, Aaltonen & Wilenius 2002). Nevertheless, sensemaking is always about change, speed of change, and organisational effectiveness in adapting to new information and new situations.

The puzzle of strategic sensemaking can be played out within figure 1. There are several factors and possible choices that influence the strategy process, and shape the possible outcomes of the strategy process.

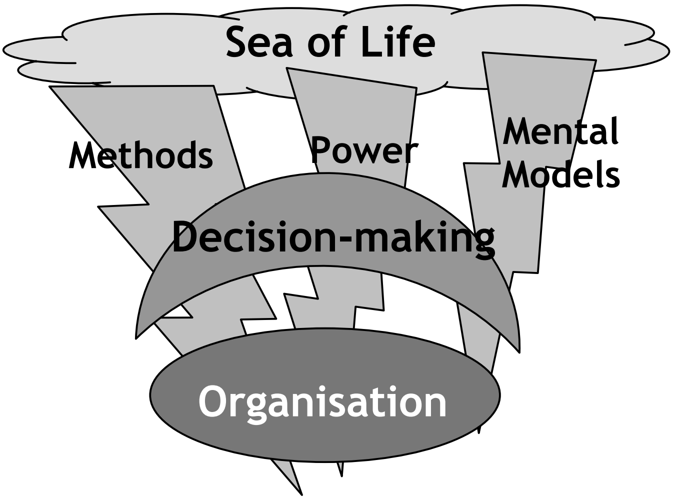

Figure 1. Strategic sensemaking (Aaltonen & Noorkõiv 2003).

In the sea of life we experience many things happen, some of them highly relevant for an actor's organisation and activities, some completely irrelevant, while others lie somewhere in between. The same broad, spread applies to emerging threats and possibilities i.e. some of which are noticed in time, while others are not.

The consequence of the above for the development of the theory proposed in this article suggests the methods used so far, the usage of power, and mental models all contribute to raising the following questions:

- What things are considered worth noticing?
- What kinds of interpretations will be given to these things?
- What kinds of action will be taken?

On the basis of those questions a strategic analysis can be produced. For multinational companies the most commonly used methods of strategic analyses were, in this order, SWOT, competitor, customer, life-cycle, cost-benefit, scenario and risk analysis. (Näsi & Aunola 2001).

In contrast to multinational companies, within foresight practice, the most popular long-term methods were trend analysis, scenario techniques, weak signal analysis and Delphi panel studies. In medium-term studies cluster analysis was frequently used and in the short-term the different futures barometers and survey studies were most frequently used. (Kaivo-oja & Marttinen & Varelius 2002, Aaltonen & Noorkõiv 2003).

With regard to trend impact analysis, cross-impact analysis, case-based reasoning, agent-based modelling, narrative modelling, decision modelling, interactive scenarios, simulation and games many approaches are not able to effectively handle middle- and long-term prospects and multiple stakeholder views.

In addition to the power to choose the methods and concepts that will be used, the people who are allowed to participate in the strategy process also shape the outcomes significantly. Decisions and actions are often based on only a few conceptions, whilst communication and discussion is established from sometimes slight evidence. Also when crucial decisions have to be taken the power, or the ability to define such slight evidence is a point of departure for any leadership.

The final point to be made here states that how managers make sense of and act within their environments is tied to their mental models or cognitive frameworks. (Abelson 1976, Starbuck & Milliken 1988, Gilbert 1989, Fiske & Taylor 1991). They influence in a very significant way the strategic sense-making process. However, when a manager abandons strategic reductionism, and allows for complexity, unique cognitive challenges are then directed towards managers' ability to adapt, and renew their mental models.

Towards Multiple Histories, the Present, and a Futures Perspective in a Co-evolving World

This chapter links concepts about how the future is formed to concepts of how an individual's understanding of the past and the present is formed. These ideas are elaborated upon by discussing and referring to the landscape where this evolution takes place.

"The history of the universe is by no means determined, because the law is quantum-mechanical, thus yielding only probabilities for alternative histories" (Gell-Mann 1995). Hence, it makes sense to talk about futures, which are realised through a (constrained) release of energy, and are arbitrarily sensitive to tiny changes in present conditions.

If we turn our focus to the past, we discover the historical narratives, events and event structures that are the elements of history. Historical accounts of events tend to have a uniform appearance. But in the place of a single history, it would be better to talk about multiple histories, where general macro-events flow into a narrower stream of specific micro-events. Consequently, the stronger and more uniform, the description, the more reductive it is.

However, some events and ideas about certain individuals people are shared by all, or at least by many others, but the meaning of these events for different people depends on the position that they held, or still hold, in such a sequence of inter-related events, i.e. histories. (Aaltonen & Heikkilä 2003).

Both the final conditions and the initial conditions simultaneously affect the sensitivity of the system. The final conditions guide the choices made along the way, whilst the initial conditions create the constraints found in the landscapes, where the future's evolution will ultimately take place.

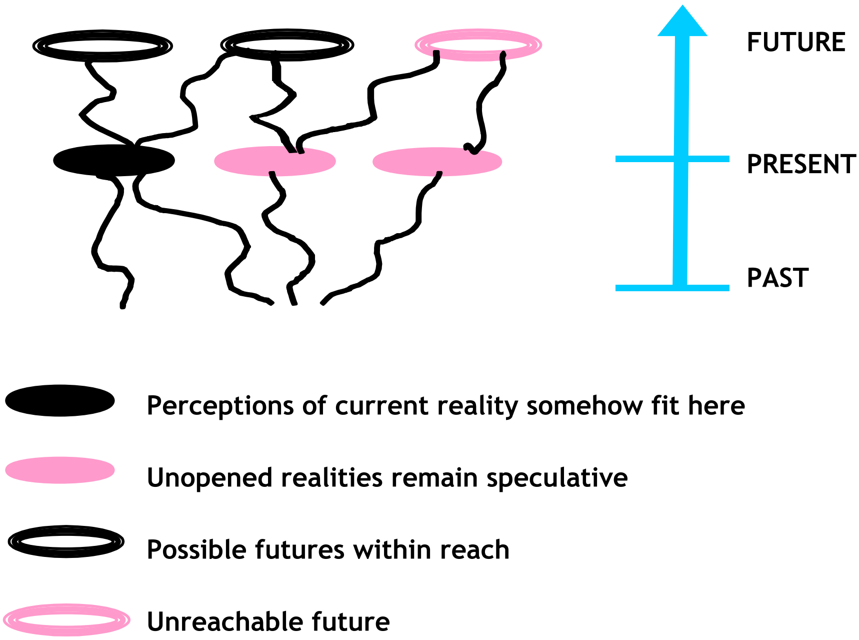

Figure 2. A futures perspective based on multiple pasts, presents and the potentialities held by the future.

Figure 2 depicts history (the past), the present, and the future in CAS or complex adaptive systems. These systems consist of a large number of agents, each of which behaves according to its own principles of local interaction, local logic, and local rationality. They all have their own history, present, and future.

Our life, the life of other human beings, and the life of organisations is built and understood as a series of tiny decisions and actions in time. Our life is a story, wherein everyday we write a page, upon which the next day builds. The difference with writing a book is that in life we can not take back our words or actions, we can not rewrite a day. Once a word has been uttered and the action taken, it is no longer possible to go back to the previous situation.

Some situations, as explained earlier, are more crucial to the development of a narrative. They resemble crossroads, or bifurcation points (e.g. Strogatz 1994), for different potential futures.

The landscape, or the reality as described in figure 2, is not stable, it undergoes and sets in motion continuous change created by actors and their actions, which subsequently affects all other actors and their actions. In a strategic process this means that not only do the actors shift position, but the landscape in which the action takes place alters too.

Even this is not explanatory enough. A better understanding of the success and failure of a single actor, or single actor's strategy, is created by considering a landscape's co-evolutionary features, not just its evolutionary ones, as has been the case, and still is, with many strategists. In co-evolving landscapes, the adaptive moves of one actor impact upon and change the landscapes of that actor's co-evolutionary partners. (Kauffman 1995).

In his recent work Jim Collins (2001) tried to find out what makes good companies great. After careful research work, one of his conclusions was "get the right people on the bus". The conclusion is right, but its logic is incorrect. The companies that have succeeded have had the right "people on the bus". The reason why that has occurred though is not properly explained and a more enlightened explanation is called for. Though it seems clear that when the predictability of the future becomes extremely hazardous even over a short period, the adaptive, self-organising abilities of single actors becomes ever more vital. Furthermore, a co-evolutionary approach would add that; not only does who is on the bus matter, but who is on the same road is of equal importance.

The properties of landscapes where (organisational) dynamics happen are rarely described properly. At least one major feature is usually missing. Since its beginning, management science has painted a picture of an ordered universe, where everything is or should occur in orderly fashion. This has affected management thinking and business practices.

It is important to rethink the properties of the landscape. Even if some of the things and events happen in orderly fashion, many of them do not. A more precise description is presented in figure 3.

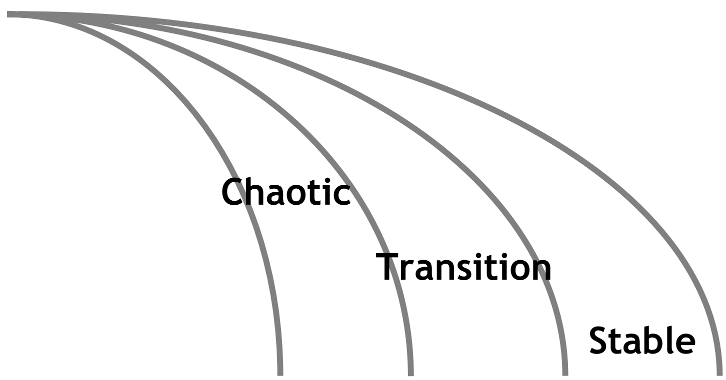

Figure 3. (Adapted from Kauffman 1995).

If we accept the idea of a disordered universe (to whatever degree), it could be presented as in figure 3. In stable or ordered conditions causal relationships are known or knowable. In a transition phase or complex era, causal relationships exist, but are evident only after the era is finished. In a chaotic era causal relationships are generally not perceivable. (Kurtz & Snowden 2002).

If we believe that the three regimes are significantly different due to the properties they convey, then strategic sensemaking with regard to the boundaries between the eras becomes extremely important, i.e. the puzzle of strategic sensemaking should be built differently in every era. This is because the dynamics of action, and therefore the action strategies should be different depending on the strategic sensemaking that is to be used with reference to the boundaries between the three eras. (C.f. Kaplan & Glass 1995, Juarrero 1999, Watts 2003).

Hence, the answers to the following questions should differ from one regime to another (Arbnor & Bjerke 1997, Stacey & Griffin & Shaw 2000, Aaltonen & Heikkilä 2003):

- What are the factors that will influence how an organisation is structured in the future?
- How far is it possible to know and predict the future?
- How much of the organisation can be built by itself?
- What are the processes by which the organization builds itself?

The Puzzle

To illustrate the idea of the narrative and this building of reason it helps to make use and borrow the idea of a puzzle. In it we place a bewildered, individual actor who has been confronted by the information you dear reader have. In effect the actor must solve the puzzle by constructing a narrative that will help make sense of all that has been read – if that actor wants to make better management decisions.

In the puzzle, little by little the actor's confidence in traditional management models has been weakened, or to state it more precisely, the basic assumptions it was built on no longer exist as they have failed or fallen short of the demands set for accurately assessing the future.

The strategic game within figure 1 contains all the methods the actor is aware of, all the theories ever written about management, or relative sciences and the analysis of power. Yet, even if all were known the strategic puzzle could not be solved, because the strategic puzzle can not be solved inside one dimension.

To solve the puzzle the level of complexity must be taken into account. According to the theory the complexity axis must first be stretched from order to chaos. The actor will then probably conclude that the axis is infinite, as it is certainly not always easy to tell whether the scene of action is ordered or slightly complex. However, if the same game played within figure1 is played out within figure 3 it will be found to be more successful there.
This will probably not satisfy the actor because merely describing better strategies is not enough, realising them is the aim. This brings the actor to the second axis, which would be termed emergence. Theories from Taylor to Barabási, from natural selection to self-organisation are remembered, and considered by the actor. As will how organisations become what they are, how situations develop into states, all the while not forgetting the lessons of figure 2. By using all that the actor's understanding of the scheme of things will become clearer.

This would still not satisfy the actor if a truly challenging cognitive sensemaking strategy is to be constructed. The actor would then realise something is lacking, so a third element is brought in – timing. Time is absolute and objective, i.e. independent of human action, and the relative concept. The actor is interested in the relative concept, which is dependent on what must done or made. Based on that the actor will ask if we should act according to a schedule or wait until the time seems right. To do this one must determine whether the events in question are cyclical, or linear. (Kamppinen 2000, 2001).

In turn this raises the question of timing and asymmetries in timing. These are considered issues that determinate success and failure in many strategic questions, inside and outside companies, e.g. with respect to competitive strategies, marketing, bargaining, R&D investment and the timing of commercial issues. (Firer & Sandler & Ward 1992, Midgley & Marks & Cooper 1997, Epstein 1998, Davis 2001, Guth & Ritzberger & van damme 2003).

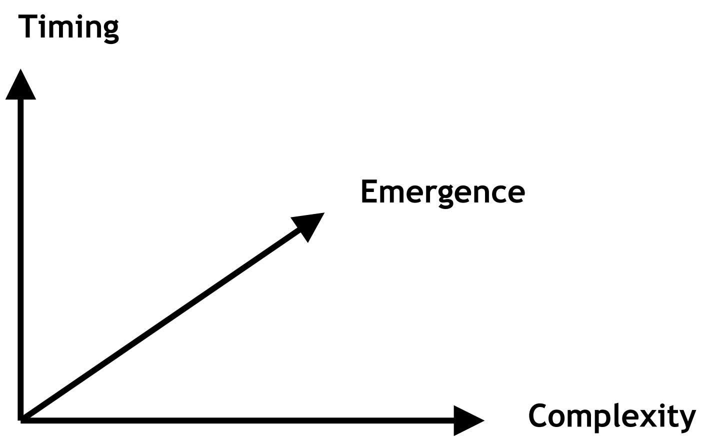

Figure 4. The puzzle.

Almost all the aspects of complexity would then be in place. Therefore, at this juncture the actor should evaluate the work accomplished so far and note that the single elements relevant to strategic questions at hand must be revisited frequently and that the three axes are of a more permanent nature.

Further inspection would reveal that some managers seem to handle the puzzle better than others, though the abilities of others can be developed. The element of luck would also be recognised as having a role in some managers' success – if they just happen to be in the right place, at the right time and events occur irrespective of their merits as a manager. Constant observation would reveal that they often fail to repeat the success.

Next the actor would comprehend, as more awareness is developed, that not all the combinations make sense. In fact, some are more coherent and plausible than others, yet the majority of people have a natural awareness and affinity for these combinations. Then there are those combinations that need to be considered with great attention to detail.

Finally the actor would conclude that being sensitive to the puzzle's different combinations, and understanding the consequences they entail is going to demand all his due consideration of all the puzzle's (or any other puzzle's) features and the use of all critical powers. In summary the actor will decide that the effort is worth doing all that.

In fact all that has been done is the allowing of complexity into the puzzle of strategic sensemaking. That though is going to ultimately produce a better piece of strategic sensemaking and improve actions and decisions made with regard to the future.

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2. Complexity and Networks — from Berge to Barabási

Auli Keskinen

The development of network theories has gained much momentum with the development of information and communications technology creating a greater chance of understanding dynamic networks than ever before. Since Claude Berge's days half a century ago, new network theory has been presented by Albert-László Barabási and his colleagues to describe the behaviour of dynamic, or complex networks that are characterised by the connectivity of the hubs (highly-connected nodes) and the power-law distribution of nodes and links between them.

Introduction

Network Theories have a long development path. Only today when the Internet has provided excellent possibilities for studying the dynamics of self-organising networks – self-organising in the sense that it has not been steered from any central point – has a new understanding on the networks been acquired. In 1935 Denes König wrote his book on the *Theory of Finite and Infinite Graphs*. His and Claude Berge's (1962) understanding of networks are presented here. Berge's monograph on the graphs theory *The Theory of Graphs and its Applications* was published in 1958. It is worth noticing that Prof. Berge died in June 2002 when Barabási prepared his book *Linked*.

While *Linked* is the book that is presented here as the source of our latest understanding of networks, it can be regarded as a tribute to Berge's work as well.

In 1967 Stanley Milgram started to study the length of paths between two randomly selected nodes in a network and discovered the famous "six degrees". Tim Berners-Lee in 1980 at Cern thought that there should be links between data files and records in order to study any dependencies between information. His insight began the web, that has now given – with its 10 billion plus documents – ample grounds for studying the laws of networks. Recently, Albert-László Barabási and his team have interconnected many earlier theories and brought fresh understanding and discoveries about the nature and dynamics of complex networks. The understanding is that there are two rules guiding networks – on the one hand random and on the other scale-free, i.e. the power-law type.

Peter Checkland's famous book (1985) of systems thinking gives the clearest understanding of networks as systems. The only things that define a network are that: there are "identifiable entities and identifiable connections linking them". From this basic assumption the road from Berg to Barabási is discussed in this article.

Theory of Graphs

First, it is important to know in more detail what the understanding of networks was before the time of Milgram, Checkland and Barabási. In this chapter the earliest description of networks – the Theory of Graphs – is discussed (Keskinen, 1999).

The basic elements and characteristics of graphs are the building blocks of networks as found in Claude Berge's and Dénes König's introductions. (Berge 1962, König 1990, English translation, the original was printed in 1935). Berge explains in his introduction that König was the first to suggest the name *graph* be used for all kinds of web-line and net-line diagrams, such as sociograms, simplexes, circuit diagrams, organisational structures, communication networks, family trees, and so on, that König was to pioneer in making the first systematic study of their properties in 1932.

König defines a graph as follows. Let A, B, C... be a set of points. If certain pairs of these points are connected by one or more lines the resulting configuration is called a graph. (1990,1). Berge uses the concept of mapping function: Given two sets of points (individuals) X (x_1, x_2,...,x_n) and Y (y_1, y_2,...,y_n), a law σ that associates to each element $x \in X$ a well-defined element $\sigma x \in Y$ is called a single-valued mapping of X into Y or a function defined on X whose values lie in Y, and a respective multivalued function Γ mapping X into Y. A graph $G = (X,\Gamma)$ is the pair consisting of the set X and the function Γ mapping X into X (Berge 1962, 5). A point on a graph is called a *vertex*, and a line connecting two distinct vertices is called an *edge* (assuming a two-way connection) or an *arc* (assuming a one-way connection). König defines that an edge can be assigned a direction thus making the subgraph a directed graph (König 1990, 4), whereas Berge uses the name of arc for a directed edge (Berge 1962, 6). It is useful to define some central concepts and characteristics of graphs for the discussion on networks as follows. Consider a graph G and one of its vertex P. The cardinal number of edges, which go to the vertex P of the graph G is called the *degree* of P in G (this is the form of a *star*). A vertex of degree 1 is called the endpoint of the graph, and the edge that ends in the endpoint of the graph is called the end edge of the graph. Based on the definition of a graph it is assumed that "every edge connects two distinct vertices with each other". (König 1990, 3–4.)

Consider a graph G with points A, B, C,..., M. If all the edges of a graph (or a subgraph) can be listed in the form AB, BC, CD,..., KL, LM, where each vertex and each edge can occur arbitrarily (but finitely) often, then the graph is characterised as a walk (a way). The walk is called open or closed depending on whether A ≠ M or A = M. If no edge occurs twice, the walk is called a trail, and if all vertices are distinct from one another the walk is called a path. If A = M but A, B,..., L are distinct from one another the closed walk is called a cycle or a circuit. (König 1990, 6–7, Berge 1962, 7). In a symmetric graph two adjacent vertices x and y are always connected by two oppositely directed arcs, meaning that all vertices are two-way connections. In a complete graph, every pair of vertices is connected in at least one of the two possible directions. A graph is said to be strongly connected, if there is a path joining any pair of arbitrary distinct vertices. In an information network, if every node can communicate with any other, the graph (of this network) is strongly connected. (Berge 1962, 8.).

Information Networks as Graphs Systems

On a very general level an information network can be seen as a system consisting of actors (nodes) linked to each other with the aim of transporting information. Both concepts of information and networks are very general and have multiple content, and therefore the notion of an information network can be regarded as a framework of the highest order (Keskinen 1995, 63, see also Tarkka & Hintikka & Mäkelä 1996, Hintikka 1993). An information network is an operational interaction system of connected nodes. The nodes can be people, groups of people, institutions, computers or clusters of computers, also called actors. A network is an organisational model where the information exchange between the nodes functions, thus forming an interactive communications system. Networks are multi-directional, and cannot be referred to by using vertical or horizontal concepts. The nodes and their interconnections are in three-dimensional space only in a physical sense, whereas the operations of the network require a multidimensional metaphor. The digitalisation levels of information networks vary according to the technology used in information processing and transportation, both within a network and between networks. Generally speaking, the information networks are a variety of 'man-machine-mix' interaction systems of people and electronic devices developed by people. (Keskinen 1995, 63)

Topology of Information Networks

Before applying these concepts to information networks, it is useful to discuss the topology first. An information network is a concept with various meanings. It can be argued that there have always been information networks, starting for example from the European postal network of the Middle Ages, where the nodes were the Post inns and connections were gravel roads and forest paths, and the transfer protocol consisted of horses, carriages and riders. In each case, information, which resided spatially in different locations, was carried (literally) to another place in an orderly manner and in a certain time frame. What has changed from those days? The principal building blocks of networks have enhanced, i.e. the transmission speed and the amount of actors (nodes and information) have increased. Naturally, ICT and its applications have changed too, but technology has been in the mediating role, which, in systems terms, still prevails. Thus, without employing proper technology the speed and number of actors would not have increased.

In today's discussions, the information network concept actually means all networked information systems, which allow for users varying access modes and methods of utilising ICT. These include: the postal network (postal networks should be included since although information resides mostly on paper, ICT is applied in many operations, and it is the most global network in the world), the telephone network, telex networks, television and radio networks, and data and information networks such as the Internet. This is not a comparable list, however, since it is important to see the difference between technical networks and network operations, i.e. the physical and logical components.

In the course of history, the different types and models of technologies used for information processing and transfer have continuously increased. It is worth noticing that new technologies are invented and developed all the time without the old ones disappearing. For example, telex is still used even though there are also far more sophisticated means available and at a fair price. The point is that all information processing and transfer technologies have their uses, meaning that different needs can be fulfilled by using different technological aids. It is important to see that the more diversified technological solutions there are, the more tailored their uses become, thus resulting in a change from mass media to target media. In target media, one can process and transfer information with the particular technology depending on what one has access to, what skills one uses, what finances one can afford, and what the abilities of the counterpart are. (Keskinen 1995, 67.)

In the 80's and 90's, information technologies have developed rapidly to increase the transparency of physical networks. This means that systems have been developed so as to have ways to exploit various existing technologies and to build services accordingly. For example, the telex network is a physical network, but also a service. Telephone networks have a certain technology of connections and information transfer but this equipment can be utilised for several types of services, such as voice, text, image, and data transfer. Email is a good example of an information network service; email is a logical network (a service) which can use any electronic network technology and equipment (hardware), if proper programmes (software) are available.

All in all, information networks can be divided into physical and logical network components. These two combined form the basic construction of the information network. (Keskinen 1999, 48).

Applying Theory of Graphs into Information Networks

The concepts of the graph are now utilised in describing the information networks. *In information networks, a point or a vertex is called a node, and the edge or the arc is called a link or a connection.* In general, information networks are infinite graphs, since they can have infinitely many edges (links) and infinitely many vertices (nodes). A net can be a directed graph if the links are one-way connections. This is true for example in ordinary television networks. An information network has the general systemic structure of a graph. However, the overall structure of a network is loosely defined: "The only things that need be common to all systems are identifiable entities and identifiable connections between them" (Checkland 1985, 107). This is the basic idea of the graph that has the components of nodes (identifiable entities) and edges (identifiable connections). A complete network is a graph, where all nodes have simple two-way connections to all others. Information networks are not complete networks because the user nodes cannot directly connect to other user nodes. Many networks have one-way connections (television), and some have multiple connections (the Internet) (Keskinen 1999, 49).

On the other hand, an information network can be regarded as an operational interaction system of independent objects. The objects are nodes that can be individuals, groups of individuals, institutions, computers, sets of computers, DINK (Data, Information and Knowledge, (see Keskinen 1999, 41)) systems, and subnets. These all are called the actors of the network. A network system is thus an organisational model, which allows for interaction between the actors by assuring the information flow between the actors along the mutually agreed connecting systems.

Information networks are symmetric, but not strongly connected graphs, in that the connections are two-way, and that there are no unconnected nodes. The network consists of connected subgraphs, which can have the basic forms of a *star, way, ring, net,* and *net of nets*) (for more details, Keskinen 1999, 49-52). In addition, the hierarchical pyramid model is a simplified *star*, where the connections are one-way. There are also *walks*, *trails*, *paths* and *cycles* that in most cases can be considered as their counterparts in general graphs as follows: i) *a star* is a graph with degree of p, where p is the number of links from the connected nodes to the centre node, ii) *a way* can be *walk, trail* or *path*, depending on the amount of links between each connected node, and iii) *a ring* is a *cycle* at least physically, but sometimes also logically as in the case of the most common early LAN product of IBM, the Token Ring (a topological cycle). (Keskinen 1999).

Barabási's Network Theory Development

Albert-László BARABÁSI explains where the development of network theories has lead us in the introduction to his book *Linked* (2002):

> "... We have been trained to study atoms and superstrings to understand the universe; molecules to comprehend life; individual genes to understand complex human behaviour; prophets to see the origins of fads and religions. Now we are close to knowing just about everything there is to know about the pieces. But we are as far as we have ever been from understanding nature as a whole... The reason is simple: Riding reductionism, we run into the hard wall of complexity. We have learned that nature is not a well-designed puzzle with only one way to put it back together... Today we increasingly recognize that nothing happens in isolation. Most events and phenomena are connected, caused by, and interacting with a huge number of other pieces of a complex universal puzzle. We have come to see that we live in a small world, where everything is linked to everything else... We have come to grasp the importance of networks."

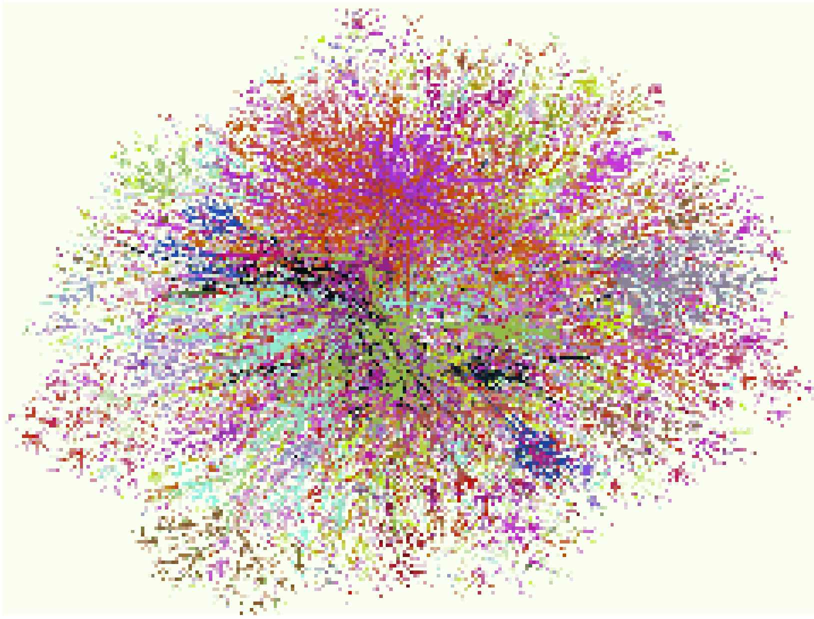
It is evident that the development of information and communications technology has provided opportunities for understanding dynamic networks better than ever before. Barabási explains (Barabási 2002) the bias that lead mathematicians Paul Erdös and Alfred Renyi to understand networks as random resulted because they never planned to provide a universal theory of network formation. They wrote in 1959 that "the evolution of graphs may be considered as a rather simplified model of the evolution of certain communications nets (railway, road or electric network systems, etc.) (Barabási 2002, 23). Barabási's studies have brought a quite new and different understanding to the dynamics of networks.

Stanley Milgram in 1967 discovered the "six degrees", when he became interested in finding the "network distance" between any two people in the United States. His studies resulted in the much celebrated, groundbreaking model on our interconnectivity. He found that the median number of intermediate persons needed to connect two randomly chosen individuals was 5.5, a very small number indeed: "Everybody on this planet is separated by only six other people. Six degrees of separation...." (Barabási 2002, 29).

Six degrees of separation is intriguing because it suggests that, despite our society's enormous size, it can easily be navigated by following social links from one person to another – a network of six billion nodes in which any pair of nodes are on average six links from each other. (Barabási 2002, 30). Six degrees of separation is today called the "small world" (see e.g. Watts, Newman) A famous sociological network "game" is called the "Erdös number". In this game scientists count their shortest path to Erdös through links that are defined: "if you have published an academic article with Erdös, your Erdös number is one, and if you have written an article with someone whose Erdös number is 1, your Erdös number is 2, etc.". In the net the scientist catalogue themselves according to Erdös number, see http://www.oak-land.edu/~grossman/erdoshp.html. Also any Finnish scientist can look themself up on the net and see who are already listed there and then define their own Erdös number.

When comparing the random networks and scale-free networks, according to Barabási, the Poisson degree distribution of a random network means that the network is similar to a highway system. In contrast, networks with a power law degree distribution (scale-free) are similar to the airline routing map: they are held together by a few highly connected hubs. This is the new understanding of the dynamic of networksn as can be seen in the figure at http://www.nd.edu /~networks/linked/highway_airline.jpg

Barabási and his colleagues have explored a number of well-known networks and they have set up a nice gallery of their network pictures. In these pictures the simple rule is as follows: describe nodes, and define connections between them and draw the picture of the network colouring the components according to a simple rule. The results are amazing and convincing in the sense that really many networks, be they human, physical, technical or biological, have quite simple rules of dynamics – connectivity, growth, collapse, paths between nodes etc. Here is an example of internet web (Picture 1) (also called a network, graph) from http://www.nd.edu/~networks/gallery.htm.



Picture 1: A Map of the Internet : coloured by IP addresses.

By William R. Cheswick

http://www.cs.bell-labs.com/~ches/map/index.html

But how large is the Web (Internet) today? This question intrigued Barabási and his research group. How many Web documents and links are out there? NEC Research Institute at Princeton studied these questions in 1998, and their result was more than 1 billion documents. Today, the Google search engine claims to cover links to more than 3 billion documents. Barabási's group found that the average number of links from any node in the Web to any other node was 19. Barabási's colleague in this work was Réka Albert, a graduate student at Notre Dame. She was the first to publish the 19 degrees paper (Barabási & Albert, 1999).

Barabási says that nineteen degrees may appear to be drastically far from six degrees but it is not. What is important is that huge networks with hundreds of millions of nodes, collapse, displaying separation for far shorter that the number of nodes that they have. Our society, a network of six billion nodes, has a separation of six, while the Internet, a network of hundreds of thousands of routers, has a separation of ten, and the Web – the network of linked documents has a separation of 19. (Barabási 2002, 34) But why is this? The answer lies in the highly interconnected nature of these networks. But the real issue is not the overall size of the Web. It is the distance between any two documents. How many clicks does it take to get from the home page of a high-school student in Omaha to the Webpage of a Boston stockbroker? Despite the billion nodes, could the Web be a "small world"?

Conclusion

The Development of network theories has been discussed. It is evident that the development of information and communications technology has created a greater chance of understanding dynamic networks than ever before. Until recently we had no alternative way to describe our interlinked universe other than to assume the networks to be random. Today, the development of network theories seems to lead to the understanding that most dynamic, or complex networks are indeed not random, but rather are characterised by the connectivity of the hubs (highly-connected nodes) and the power-law distribution of nodes and links between them. The work goes on...

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3. Complexity Research — Approaches and Methods: The LSE Complexity Group Integrated Methodology

Eve Mitleton-Kelly

Abstract

If organisations are seen as complex evolving systems (CES), then the approaches, methods and tools that we use to study them and to help them evolve need to be appropriate – for example, they need to take the characteristics of organisations as CES into account; they need to track changes over time; and they need to address both the qualitative and the quantitative aspects of the organisation under study as well as its broader environment.

The Complexity Group at the London School of Economics has been working collaboratively with organisations since 1995 to develop such a methodology and the paper will describe the different qualitative and quantitative tools and methods that make up the integrated methodology. At the same time the Group has been developing a theory of complex social systems. Both the methodology and the theory have been developed and tested in practice in a series of projects looking at real problems faced by our business partners. They include BT, BAe Systems, Citibank (New York), Glaxo-

SmithKline, the Humberside TEC, Legal & General, MoD, Mondragon Cooperative Corporation (Basque Country), the Modernisation Agency of the NHS, Norwich Union, Rolls-Royce Marine, Shell (International, Finance and Shell Internet Works), the World Bank (Washington DC), AstraZeneca and several companies in the Aerospace industry.

What is a 'Methodology'?

What we call a 'methodology' is a set of tools and methods using a *collaborative, action research* approach. It is *collaborative* in the sense that we work closely with our business partners. We do not just observe them and then tell them what to do. The whole approach emphasises *co-creation.* This is not easy either for researchers trained in more traditional approaches or for our business partners who often expect us to act like consultants providing them with a report and a list of recommendations. It is *action research* in the sense that we are part of the process and the research directly influences our partner. But this is not a one-way process. We also learn and are influenced in the process. Collaboration and action research are necessarily interdependent. The one cannot take place in the absence of the other.

The Problem

We start with a specific issue or practical problem, or at least with the *perception* of such a problem. In the process of analysis, triangulation, validation, etc the problem may appear in a different light, but initially we have to start with what our business partners *see* as a problem. For example, when we were studying the IT Legacy issue (i.e. to what extent information technology systems supported and continued to support changes in business strategy and direction, such as providing new products or services or by entering new markets) the dominant assumption was that the problem lay largely with the technology and the question raised was: how can we design and develop information systems that can be constantly upgraded to meet changing business demands? Twenty eight projects were funded by the British Government through the EPSRC (Engineering and Physical Science Research Council) to look at this issue that was costing industry a great deal of time, effort and money. Most of the projects started by taking a purely technical approach as they accepted the dominant assumption. The LSE project started by looking at the relationship between the information systems and the business domains, or to put it another way, at the *co-evolution* of the two domains. This included the technology, the strategy changes and the relationship between the individuals involved.

One of our key findings, in due course supported by most of the other projects, was that the problem was not just technical, but *socio*-technical. In other words, the legacy issue could not be confined to the design and development of computer software and hardware; these aspects were necessary but not sufficient to reduce the legacy problem. We found that the *relationship* between the IS professionals, the business strategists and the user community was critical. Another finding was that legacy was not a function of age. Brand new IT systems could quickly become legacy in the sense that they did not fully support the business process. However, when the right environment was created, the difficult dialogue between IS professionals and business strategists improved.

This in turn, led to greater understanding of (a) what the technology was capable of delivering and (b) where the business wanted to go and what it wanted to achieve. This reciprocal understanding actually helped to resolve some of the technical issues and to reduce the legacy problem (Mitleton-Kelly and Papaefthimiou 2000, 2001).

The initial perception of the problem both by the business partners and by other researchers was modified by the findings, and this in turn led to a change in working practices that improved the problem. If the original perception of the problem had remained intact then the problem would have persisted. Technical improvements would have made a temporary difference, but the next version of the system or the installation of a new system would have re-created the problem.

Natural Experiments

An important insight from that project was the confirmation that a combination of social, technical and cultural conditions was necessary. Together they created an enabling environment that facilitated the co-evolution of the two domains and our work since then has emphasised the *co-creation of enabling environments*. But there was another insight that was critical. The example or case that we identified was what may be called a *'natural experiment'*. A natural experiment is part of an organisation that wants to change. It is not an experiment in the scientific sense where the researcher is testing something and is able to control the experimental situation; a natural experiment cannot be controlled and there is no closure, as it is ongoing. A natural experiment is one where the organisation itself wants to experiment and to explore different *ways of working and relating*. That is, the way that people interact, communicate and work together – the 'way of relating' reflects the informal structure of the organisation and if this changes it could have significant implications on ways of working or how work is done, how procedures and processes are undertaken. To use the language of complexity, when individual agents change their patterns of interaction new structures or new properties *emerge*. This process may also affect the culture of that part of the organisation.

These insights resonate with the logic of complexity. Organisational change cannot be designed top-down and cannot be determined in advance in full detail. The constant failure of major restructuring initiatives and of merger and acquisition activity, where a highly specified organisational design is involved, indicates that the approach may be flawed. We are working on the hypothesis that a robust organisation evolves its social and organisational relationships and is capable of guiding and supporting its co-evolution with a changing environment. This kind of organisation has a relatively high degree of self-organisation and is comfortable that some procedures, processes and relationships will emerge and cannot be predetermined. It can live with this type of uncertainty and does not find it threatening. It also encourages the exploration of the space of possibilities by acknowledging that exploration means that some attempts will 'fail'. But without experimenting and running the risk of failure, a new order cannot emerge. This is not easy to put into practice, as it requires a different style of leadership and management, as well as a high degree of personal responsibility from all employees. But it has been achieved with remarkable outcomes[1] and is the longer-term objective of our approach – i.e. to help organisations become fitter and more sustainable by learning to co-evolve effectively with their changing environment, or to become aware of *co-evolutionary sustainability*. If the organisation does not continue to co-evolve in an aware and purposeful manner the systems, procedures, etc may become legacy in the sense that they are what has been 'left over'. Co-evolution does not stop, it is an ongoing process, but it may become reactive and change its emphasis from co-evolution with to adaptation to a changing environment (Mitleton-Kelly 2003). The distinction is between strong and weak reciprocal influence and in the way the organisation thinks about and responds to changes in its environment.

Necessary Conditions

But how can this 'holy grail' of organisational fitness be achieved? First of all the organisation should *want* to experiment; secondly it needs to spend some

[1] The Humberside Training and Enterprise Council in the UK worked with these principles for over 5 years and achieved remarkable results. A paper describing this case study is forthcoming.

time and effort in trying to *understand in depth* where it is and what are its capabilities; thirdly it needs to know *how to set up* the natural experiment, to facilitate its success; and fourthly it needs to create an *enabling environment* that will help it achieve its goal, while understanding that the goal may itself change. The following qualitative and quantitative tools and methods provide the material and the processes on which that understanding may be built. They each provide different but complementary information about the organisation, so when all the tools and methods are used the organisation ends up with a very rich and deep understanding of itself. The findings can then be used as an informed basis to identify the conditions for building the enabling infrastructure.

To begin with, the researchers meet some of the key people involved and discuss the background to that particular 'natural experiment'. This gives us some context and identifies the key questions, concerns or problems. We explain the research process and our business partner is then in a better position to identify potential interviewees, who will take part in Phase One of the project. This phase includes (a) a set of **semi-structured interviews**, taking the key questions and concerns into account; (b) an introduction to **complexity thinking** by using the principles of complex evolving systems; (c) use of the **other tools and methods**; (d) analysis and presentation of the initial findings from the interviews at a **Reflect-Back workshop**; (e) findings from other tools and methods, may also be incorporated in the workshop presentation; (f) working with a core group to identify the **enabling conditions**, and to co-create the enabling framework that will be implemented in

Phase Two. This will facilitate the emergence of a new way of organising or even a new organisational form.

Semi-Structured Interviews

Semi-structured interviews provide a narrative analysis. They are based on only eight topics that stimulate reflection on the central problem and on related issues. They take 1.5 hours; they are recorded with the express permission of the interviewee and are conducted by two interviewers. The lead interviewer asks the set questions (not seen by the interviewee) while the second interviewer explores some broader issues. The analysis uses direct and full transcripts, as the language used by the interviewee is an important element in the narrative analysis. Some researchers use the software Atlas for the analysis while others prefer to work directly with the scripts. The first analysis identifies *common themes, dilemmas* and *key questions.*

The interviews are analysed by at least three researchers and each researcher will analyse interviews done by him/her as well as interviews done by the other researchers to gain as broad experience of the interview data as possible. All the researchers will then meet for one or more whole days to share their initial findings. The themes and dilemmas are clustered in related groups with their associated questions. All papers are then put aside and after a break the team reconvenes to identify some underlying assumptions. This is the hardest part of the analysis. Assumptions are not voiced. They are tacit. They are based on impression and interpretation and are the most 'subjective' elements in the analysis. But they are extremely valuable as they highlight how the organisations 'shows' itself to others.

During this process several things happen: (a) interpretation bias is reduced by checking each other's reading; (b) by offering several perspectives, the understanding of each individual researcher and of the team is deepened; (c) patterns emerge and connections are made leading to some significant insights. The process is so powerful that we can identify key themes and dilemmas with only 6 interviews. In practice however we usually conduct 12-20 interviews. Interviewees are not seen as an average sample in a population, but as fractal representatives of the whole, offering different and overlapping perspectives.

Experience of the organisation is not confined to interviews. We join our partners in conferences, workshops and other meetings. We spend time over lunch with them and we keep in touch by telephone and email. Building and nurturing of these relationships is essential. We also scan the press for articles involving our partners; we visit their websites and generally keep ourselves informed through the literature and the media.

The Reflect-Back Workshop

These initial findings are then presented at a Reflect-Back Workshop. They offer a 'mirror' to the organisation and they provide an informed starting point for the identification of the social, cultural and technical conditions (as well as the political and economic conditions, where appropriate) to create an *enabling environment* for integration after a merger or acquisition, or to achieve organisational change, or to promote the generation and creation of knowledge, etc.

In parallel with the interviews and before the Reflect-Back Workshop the following may also take place:

Complexity Thinking Workshops

Introduce complexity thinking to all those interested in exploring the theory and how to apply it in practice. Participants are introduced to ten principles of complex evolving systems within an organisational context (Mitleton-Kelly 2003). Figure 1 shows the 10 principles and the main theories that have contributed to their development. If we understand the characteristics of organisations as CES, we can work with them rather than against them. This kind of understanding can help change mind-sets and bring about quite fundamental changes in ways of organising and relating. Workshop participants are encouraged to use the principles of complexity within their own organisational context and this may provide insights as well as practical benefits, when applied to day-to-day operations. This introduction will provide the theoretical framework for the findings presented at the Reflect-Back Workshop.

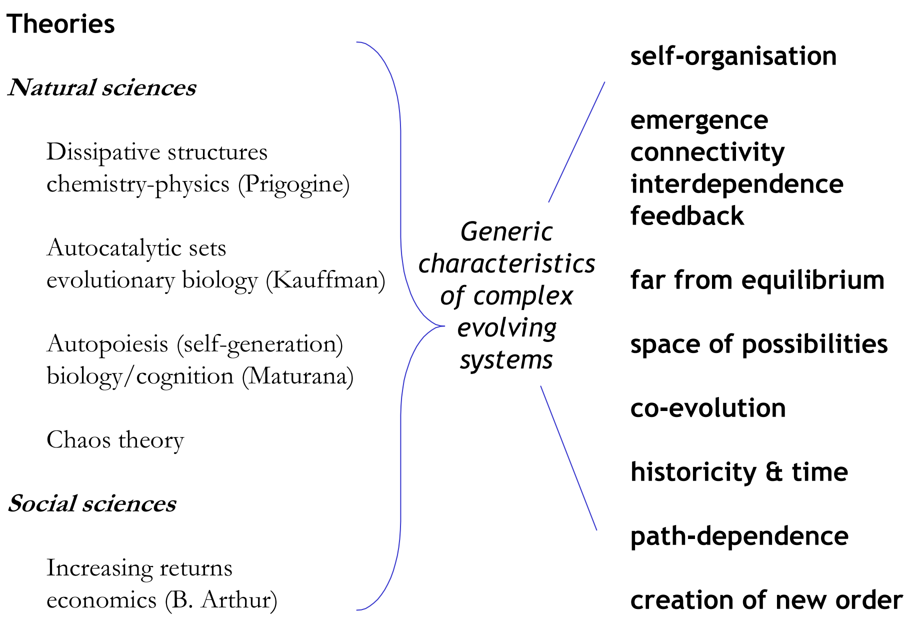

Figure 1.

Landscape of the Mind (LoM)

We can also look at the cognitive preferences of individuals and teams, in the way that they make decisions, exchange information, create new ideas and how they implement them, etc. This is done through a tool called Landscape of the Mind (LoM) developed by Kate Hopkinson, which is based on an email questionnaire completed by the participants themselves. The findings help to triangulate the interview data, but individual details are never given to anyone other than the person concerned. Presentations only show findings for whole groups. In fact, findings from all tools are non-attributable and neither the interviewees nor the LoM respondents are identified.

Individuals and teams use different ‘conceptual architectures’ to think when taking decisions, generating knowledge, etc. These architectures can act as potential constraints or enablers in the decision taking process, in strategic thinking, in knowledge generation, etc. The tool identifies and shows in diagrammatic form, both individual and group profiles of the ‘Landscape of the Mind’. Figure 2 shows a high level description of LoM, but there are several levels of analysis providing greater detail on specific preferences. It is not only the architecture itself which is important, it is also a question of how individuals, teams and organisations move around within an architecture – the “inner skills strategies” they use to progress, for instance, from a new idea to implementing it.

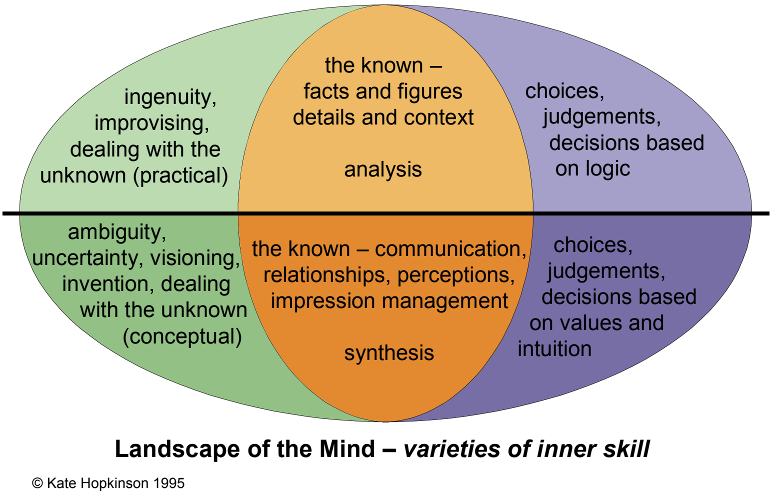

Figure 2: Landscapeof the Mind (LoM)

Visual Representation

During the analysis our resident artist, Julian Burton, will capture some of the themes, dilemmas and underlying assumptions in a picture. This has several advantages: many related aspects that are difficult to think about at the same time, can be captured in one picture; and very sensitive issues that are difficult to talk about, can be presented diagrammatically to workshop participants, before the presentation begins. Once they recognise what is being shown they may laugh and thus break the tension and open the issue(s) to discussion. One of Julian's pictures created for one of our business partners is at figure 3.

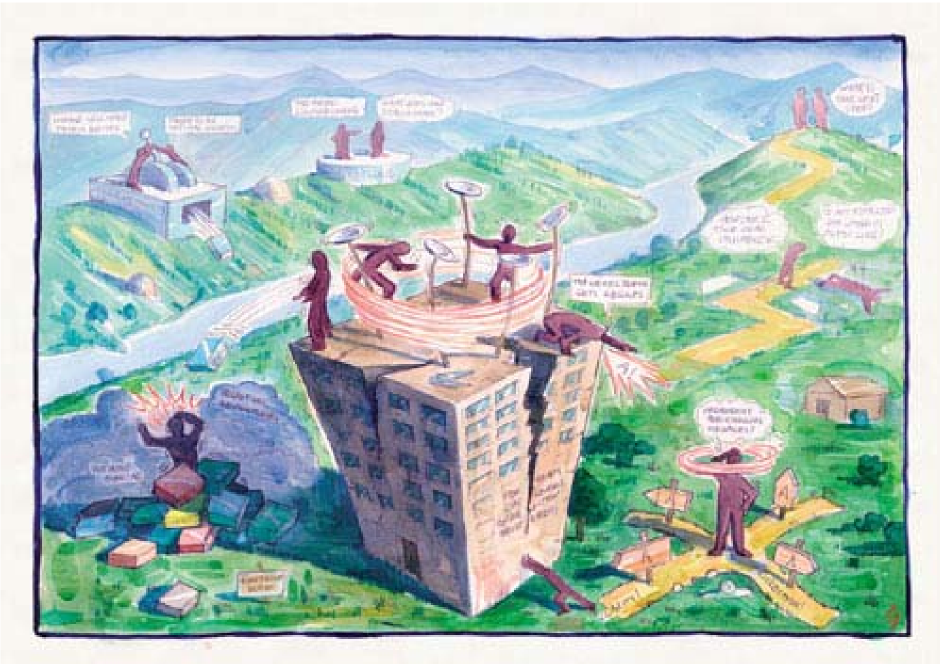

Figure 3. Julian Burton's illustration of themes, dilemmas and assumptions of a workshop.

In addition, Julian Burton uses art to facilitate the process called 'Visual Dialogue'. This provides a visual perspective on important issues and challenges before, during and after meetings. The method can (a) capture the ideas, meanings, concerns and issues expressed in meetings, reflecting back emergent themes visually, as a catalyst for further discussion; (b) provide a visual overview of a current situation, expressing and conveying complex interrelated issues in context symbolically and engage a group's attention thus enabling them to quickly grasp the main issues and focus on relevant elements; and (c) structure problems to facilitate shared sense-making, developing novel perspectives that can open up new possibilities in meetings. The difference between the two approaches is that the visual *representation* of themes etc is used as part of a presentation that will incorporate the interview analysis and LoM, while in the *Visual Dialogue* art is the only tool being used.

The interviews, narrative analysis, reflect-back workshops, LoM and visual representation are all qualitative tools and methods. The quantitative tools are agent- based-models (ABM) and simulations and a tool called NetMap, which maps email exchange. Each tool also expands the area of application – e.g. we may do 20 interviews, apply LoM to 70, ABM to 100–200 respondents and NetMap to several thousand email exchanges.

Agent-Based-Models (ABM) and Simulations

The agent-based-models and simulations, built by Dr Ugur Bilge, show connectivity using all media (email, face-to-face meetings, virtual conferencing, etc). The simulations help with 'what if' exploration. When repeated, they also show the evolution or development of connectivity. The data is collected through an email questionnaire, which is refined and tailored to each individual business partner, after the initial interviews. The tool enriches the insights and data set derived through the interviews and shows the different and inter-related informal and formal, social and work-related networks within the organisation. They can also show how ideas spread, how new ideas may lead to innovation or be blocked from being developed.

NetMap

The models and simulations are complemented by another tool called NetMap, developed by **Prof. John Galloway**, which maps email exchange. This tool is extremely powerful and shows in graphic form email connectivity. Figure 4 shows a high level representation of such connectivity, but the tool allows zooming-in at many levels to look at the connectivity patterns. Exploring these patterns with our partners helps them to understand the formal and informal networks within the organisation as well as connections with suppliers, customers, etc. It will again show the evolution of connectivity when repeated during the life of the project. NetMap only requires access to a server and only looks at the exchange of emails not at content.

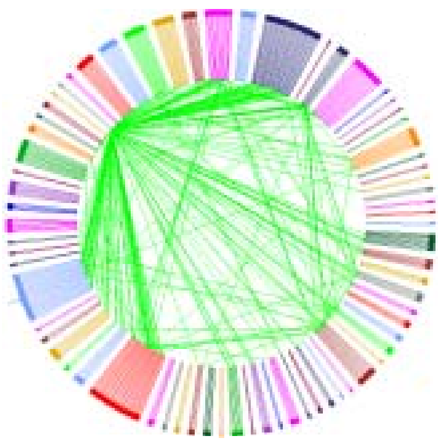

Figure 4: NetMap

The simulations and NetMap both show connectivity patterns and identify 'lynchpins' or highly connected individuals or groups. If you are doing any kind of restructuring you certainly need to know about these individuals or groups. In addition they show lack of connectivity where it should be taking place. ABM and NetMap could provide a useful metric of social capital, by showing changes in connectivity as a means of tracking the exchange of information over time.

Why So Many Tools?

We use so many tools because they triangulate the data and provide robust and rigorous findings. But that is not the only reason. They each provide different but complementary information about the organisation. So when all the tools and methods are used the organisation ends up with a very rich and deep understanding of itself. The findings can then be used as an informed basis for building the enabling infrastructure. This last part is a **co-creation** activity. We work with a core team of 'volunteers who can make a difference' to identify the social, cultural and technical (also political and economic) conditions that together will help the organisation create the kind of environment conducive to change and the emergence of new ways of organising (ways of working and relating). But this is not a one-off process, the new way of thinking based on complexity, the new relationships, procedures, processes, structures, etc need to become sustainable. Ideally, the organisation will help its employees to develop the capacity to continue the process of co-evolutionary sustainability.

The Three Phases

To summarise, the end of phase one is the identification of the conditions for co-creating the enabling infrastructure. The second phase involves experimenting with that infrastructure and implementation. There is a lot of learning in this phase and this is where working with ICoSS and a number of business partners, is advantageous and beneficial, because the partners will learn from each other's experiments and will support each other during implementation, as well as getting support from the research team.

The final phase – phase three, runs in parallel with the other two phases and continues to the end of the project. It is the documentation and dissemination of the research process and the findings. This is interesting at two levels. First of all we will be looking at the research process at a meta-level. The researchers, business partners and advisors make a good natural experiment – we are exploring new ways of working and different ways of relating; and we want to capture this. The other level of course is to do with dissemination and this paper is part of that dissemination process – so that others may benefit from our work. Since the project is funded by a Research Council its ultimate aim is to benefit industry as a whole, not just the few business partners and the research team. We will therefore provide handbooks, write papers, make presentations, etc. to document and disseminate the findings.

Summary & Conclusion

The paper described the tools and methods that make up the LSE Complexity Group's integrated methodology. Some of these tools and methods are not new, but the way that they have been brought together is quite unique. Not only do they complement each other by providing different but overlapping perspectives on the organisation, they also ensure that both the qualitative and quantitative characteristics of organisations are considered as part of the whole. In addition, the approach places each organisation within its broader environment by emphasising the co-evolutionary process and the reciprocal influence exercised by the organisation within its social ecosystem.

The approach is underpinned by the theory of complex social systems, developed by the Group, which is based on the sciences of complexity and on organisational theory. The logic of this approach argues for the co-creation of enabling environments that facilitate the creation of new order in the form of new ways or working and relating, new structures, cultures, etc.

At the end of our complexity thinking workshops we summarise the characteristics that an organisation needs to enable, from a complexity perspective, to provoke discussion. One of our business partners has called them the 'Holy Grail', they are:

A successful CES organisation:

Facilitates (does not inhibit) emergence

Encourages self-organisation

Explores its space-of-possibilities

Facilitates co-evolution

Understands connectivity and interdependence (e.g. relationships, not isolation, fosters a collaborative culture)

Creates variability – large repertoire of responses (diversity – people, cultures, products, markets; speed and cost, cope with change)

Copes in unpredictable environments

Not too organised and not too random ("fuzzy matrix")

Emphasises enabling infrastructures

Facilitates the emergence of:

– New ways of working and relating

– New organisational forms

– Generation and sharing of knowledge

Continuously re-invents the organisation

Acknowledgements

The LSE Complexity Group's research and the development of the methodology have been enabled by the support of our business partners and by four **EPSRC** (Engineering and Physical Science Research Council) awards, including the current 3-year collaborative action research project ICoSS under the Systems Integration Initiative entitled *'Enabling the Integration of Diverse Socio-cultural and Technical Systems within a Turbulent Social Ecosystem'* (GR/R37753). The ICoSS Business Partners are BT, the Modernisation Agency of the NHS, Norwich Union Life, Rolls-Royce Marine and Shell. Detail of the LSE Complexity Research Programme and the ICoSS Project can be found at http://www.lse.ac.uk/complexity

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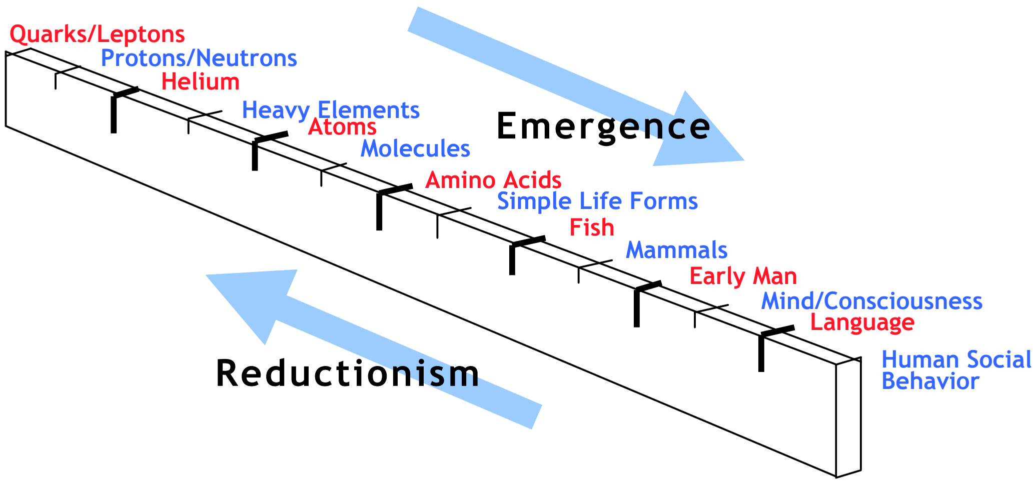
4. Conclusion: Organisational Complexity

Mika Aaltonen and Auli Keskinen

Complexity has lot to do with a much larger subject known as dynamics. Dynamics deals with change, with systems that evolve in time; whether the system in question settles down to equilibrium, repeats in cycles, or does something more complicated. We have been exposed to dynamical ideas all our lives, we are actually surrounded by them in our everyday lives.



Emergence and reductionism of some systems.

The degree of complexity grows, and the degree of reductionism reduces, the further right we move in the picture. Human social behavior is described as the most complex phenomena in the picture, and it is naturally in the heart of organisational complexity approach.

In this work we have concentrated on organisational dynamics by concentrating on organisational complexity that take place in various organisations while they again and again try to find out who they are, while they struggle for surviving, and do their best to succeed. Interesting and relevant targets for us are also markets, and economics.

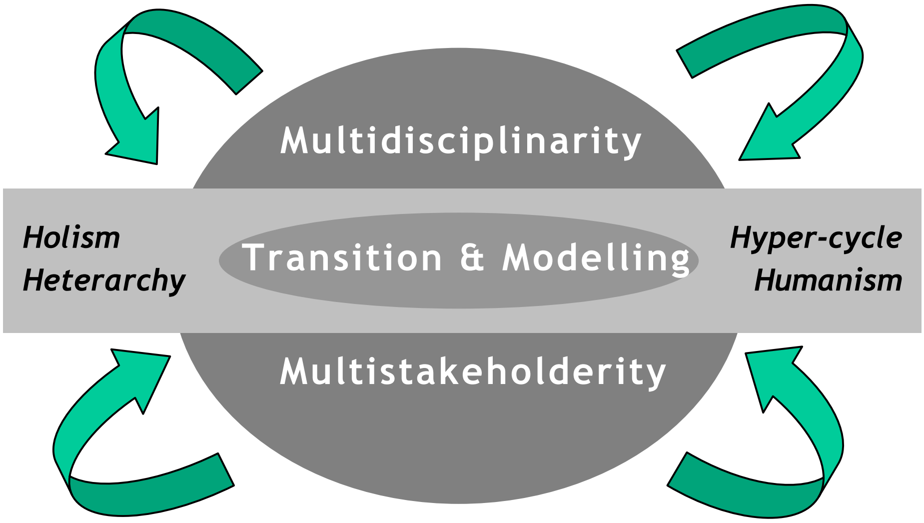
All these targets share a common feature which is vital in organisational complexity approach – they all are complex adaptive systems, i.e. systems that consist of a large number of agents, who act logically but according to their own principles, according to their own logic, not one "big" logic shared by and agreed on everyone. This results in a different understanding how things happen. A lot of things evolve because of carefully laid out plans and visions, but a larger amount of things in organisational settings emerge as a consequence of local interaction between agents. And in these conditions nobody, not the CEO nor anyone else, can completely determine the patterns of behavior.

Organisational complexity means the end of linear management approaches, that count on that any system can be broken down and solved analytically. This maybe true in some circumstances, but most of our everyday life is nonlinear and therefore it can not be solved by using linear models.

Complexity and Futures Research

The interests of futures research paradigm are in multidisciplinary and multi-stakeholder socio–econo–cultural phenomena and their interdependencies. Typically these phenomena are complex adaptive systems. From systems theoretical point of view, these phenomena are open systems, in particular in Checklandian terms mixed technological and human systems that are in continuous interaction with their operational environments. Thus, as a science, the futures research is horizontal in that its main focus is in the cross-impacts and joint impacts of multidimensional phenomena. This means, that the paradigm of Futures research is practical, integrative and collective – metaphorically speaking it resembles an octopus – gathering together with its tentacles many pieces of data, information and knowledge within its reach and digesting it all-in-one to bring holistic satisfaction to itself – i.e. understanding and integrating itself and its surrounding to as a full extent as possible.

Futures research's emphasis is in working from two main approaches – transition and modelling. This means that futures research studies the change – and whenever there is a change in an open system the effects are multidisciplinary, since the change whether coming from system's inner developments or various prompts from its operational environment will have an effect on the activities of the systems. The time-dependent outcome of the change is heavily dependent on the system's degree of robustness. Whenever the system "digests" the elements of change, its complexity increases and eventually will bring the system to an unstable state and if "bombarded" heavily, under transition. Modelling of this complex behaviour in order to be able to proactively prepare strategies for the future is one of the major challenges of futures research.



Holism, heterarchy, humanism, and hyper-cycle.

The R&D methodologies of studying complex phenomena can be illustrated with 4H's: Holism, Heterarchy, Humanism and Hyper-cycle. The aim in futures research is always to bring more holistic understanding on phenomena it studies, i.e. to build insightful knowledge on bits and pieces of data and information. For this task, hyper-cycle is one of the processing tools. Hyper-cycle cherishes the understanding, together with humanism, that in societal and organisational decision making processes people make decisions that are value-rationally argued. Typically then, the emotions and needs of different Maslowian levels come into play together with facts and fiction, thus increasing the unpredictability of decisions. Human beings make mistakes, but they also learn. This makes an open system is adaptive. In the modern information society, open human systems are complex adaptive networks. Hyper-cycle process methodology takes this into account by allowing continuous feed-back to be incorporated into the process, i.e. the output of a process cycle is inserted back into process calculations as input – thus building an iterative method of creating new knowledge and innovations.

Heterarchy is the organisational model for self-organised ad-hoc decision making, much employed by expert teams and networks of excellence. The challenge for future societies, and indeed private and public organisations and is in multidisciplinary creation of new innovative ways of re-thinking the decision making – how to incorporate ad-hoc decision making with official and representative one, and how to enhance deliberative decision making to the benefit of the organisations' robustness in its ever more indeterministic development of the system's complex operational environment. This is an especially important set of global features to be understood by the strategic corporate management.

The development of complexity science is a shift in scientific approach towards an interdisciplinary paradigm with the potential to profoundly affect business, organisations and government. The goal of complexity science is to understand complex systems: what ”rules” govern their behaviour, how they manage change, learn efficiently and optimise their own behaviour.

This publication focuses on organisational complexity with the understanding that organisations are complex systems composed of numerous, varied, simultaneously interacting agents. The articles enhance the current understanding of organisational complexity from the approaches of strategic management, complex adaptive networks and qualitative and quantitative tools and methods.

Representing a variety of domains, disciplines and methodologies, the authors are among the topmost experts in this new field of research.

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