SNF-REPORT NO. 58/00

The Management of Complexity

by

Tore Hundsnes

SNF-project No. 6923: "Management of complexity"
The project is financed by Telenor AS

THE ECONOMICS OF TELECOMMUNICATIONS

This report is one of a series of papers and reports on telecommunication economics published by the Foundation for Research in Economics and Business Administration (SNF) as part of its telecommunication economics program. The main focus of the research program is to study the deregulation process of the telecommunication industry, and the economic and organizational consequences of changes in markets, technology and regulation. Being started in 1992, the program is now in its third period ending in 2001/2002. The program is financed by Telenor AS.

FOUNDATION FOR RESEARCH IN ECONOMICS AND BUSINESS ADMINISTRATION

BERGEN, DECEMBER 2000

ISBN 82-491-0089-1
ISSN 0803-4036

Abstract

The complex structure of many business environments, and indeed many of the corporations or organizations operating in them, implies great challenges for managers operating in these systems. What sources generate this complexity, and how can it be managed? Chaos theory and complexity theory represents new perspectives on how to understand the dynamics and behavior of what is referred to as complex adaptive systems, and why it is difficult to predict their future state. These systems create, or inhibits eight sources of complexity for managers; (i) number of constituent elements, (ii) variance in system elements, (iii) lack of lawful regularity, (iv) uncertainty, (v) change and speed of change, (vi) randomness and chance, (vii) interaction and interdependence between system elements, and (viii) understanding and cognitive capacity.

Several mechanisms are suggested to manage the complexity in organizations as complex adaptive systems. Perhaps the most important is self-organization, which is an underlying property of these systems. Self-organization is more about having the right *circumstances* in the organization so that uncertain things may be done, rather than doing certain things. Other mechanisms discussed are strategic flexibility, organizational structure, and the ability to increase information processing capabilities of both organization and managers to manage increased information flows.

Combined in a model of complexity in organizations, the properties of these systems, the sources of complexity, and the mechanisms discussed to manage complexity have important implications for managers. First, instead of reducing complexity, managers should seek to balance the sources and mechanisms to find an optimal level of complexity, where both innovation

and efficiency can be achieved at the same time. Second, planning departments not fulfilling their roles should either be reduced or abandoned. Finally, instead of trying to control the organization, managers should refocus their attention to participation and interaction with other agents where strategies emerge.

Preface

Things may not necessarily be what they always seem to be. What may seem chaotic and complex could in fact have an underlying order beneath its surface. It is our point of view, and our most deep seated beliefs, that often stop us from seeing this hidden order. If you stop and think about it – do you recognize some pattern or hidden order in the real world or in your own life, or does it seem complex, or even some times chaotic? During my work, I have learned to appreciate the thoughts of complexity theory, and how this theory on a fundamental basis departs from every thing I have read before. This was one important reason that intrigued me to start working on this topic in the first place.

Another reason was associate professor Christine B. Meyer at the Norwegian School of Economics and Business Administration, who has been my main advisor, and also inspired me to start on this project. Her interest in, and openness to new topics, and will to interact, communicate and learn new perspectives is a property of a true modern academic. She is always very positive and I'm really looking forward to continuing the good cooperation with her during the rest of my Ph.D. program.

I would also like to thank my colleague Lasse Lien for his valuable comments on an early draft. It is always a comfort when I'm not the only one working late nights :-)

Tore Hundsnes

Bergen, December 2000

Table of Contents

List of Figures

List of Tables

1. Introduction

It is clear that the world's complexity has important implications and ramifications throughout the entire realm of our concerns – and actually not just in philosophy and science, but in everyday life. It impacts profoundly on our understanding of the world – as regards both our knowledge of its doings and the management of our affairs within it

Rescher (1998)

1.1 The Research Problem

The complex structure of many business environments – including financial, technological, operational, economical, political, cultural and emotional aspects, and indeed many of the corporations or organizations operating in them, implies great challenges for managers operating in these systems.

What are the sources generating this complexity in organizations?

How can complexity be managed in organizations?

These questions are of central concern here, but should also concern managers as they realize that the world's complexity has profound implications with regard to how they should run their businesses. Chaos theory and complexity theory represents new perspectives on how to understand the dynamics and behavior of what is referred to as complex adaptive systems, and why it is difficult to predict their future state.

There are several theories on how to manage different strategic issues. How these theories will fit the goal of managing complexity, varies with their assumptions, level of analysis, and the context in which the complexity is to be managed. In their special issue of the Strategic Management Journal, entitled “Strategy: Search for New Paradigms”, Hamel and Prahalad (1994) points to the fact that prior strategy research and traditional strategy paradigms no longer seems to cope with the changing competitive arena we are witnessing just outside our windows. As Hamel and Prahalad (1994: 6-9) notes, “... we believe that during the last 10 years, competitive space has been dramatically altered... [and] industry foresight, an ability to synthesize the collective impact of a complex set of economic, political, regulatory and social changes, is increasingly at a premium. Imagining... the future (viz., providing strategic direction) and developing a transition path towards it... in an industry undergoing complex transition is a crying need.”

Further, Hamel and Prahalad (1994: 14-15) states that “... we believe that the study of complexity is a major opportunity in the strategy field... for example, the study of complex phenomena using tools such as chaos theory, we believe, will increase.” Several theorists in the field of strategy (Axelrod and Cohen 1999; Eisenhardt and Brown 1998; Levy 1994; Lissack and Roos 1999; Sanders 1998; Stacey 1995, 2000) have taken the challenge provided by Hamel and Prahalad (1994), and made an attempt to make the science of complexity a tool for business managers. Have they succeeded?

A variety of authors have described informal, emergent (Mintzberg 1978; Mintzberg and McHugh 1985), and autonomous (Burgelman 1983a, 1983b, 1983c) processes by which firms choose their strategy, in addition, of course, to formal strategic planning systems (Lorange 1980). In complex systems it is "... not possible to specify meaningful pictures of a future state, and any pictures which are specified cannot be connected back to the actions required to realize them because cause-and-effect links disappear" (Stacey 1995: 491). Planning processes and analytical techniques are employed in circumstances in which a moment's reflection shows them to be inappropriate – they are processes which have for a long time been shown to be inapplicable to conditions of great uncertainty and yet they are used in just such circumstances (Stacey 1995). As will be discussed in chapter two and three, uncertainty is only one of several dimensions of complexity.

1.2 Contribution

Chaos theory and complexity theory are two relatively new perspectives in social science. The development with these fields at least applied to organizational science and strategic management theory, are discussed and analyzed through a comprehensive review. From this discussion eight sources of complexity in organizations are identified. To my knowledge, this has not been done in any previous literature.[1] This identification of sources of complexity in organizations give a more profound understanding of the challenge managers are facing, and hence gives input into which mechanisms to use in managing the overall complexity, as well as individual sources of complexity. A discussion of several mechanisms to manage complexity in organizations suggests the linkage to the different sources of complexity. The ability to self-organize is

[1] One exception is Rescher (1998), which identify several modes of complexity in general, but from a philosophical point of view.

perhaps one of the most underrated sectors when it comes to manage complexity in organizations as complex adaptive system.

Through a thorough discussion, the concept of self-organization is elaborated, as well as the implications self-organization may have for organizations and managers. Furthermore, a number of other complexity mechanisms are introduced drawing from a number of different theories. The purpose is to develop a more comprehensive view of the different mechanisms available for managers, and to identify in the forthcoming empirical study which mechanisms are suitable in different circumstances. The framework developed, including identifying and managing complexity in organizations, contributes substantially to a better understanding of how to act as a manager within these systems. The implications from a complexity perspective also give different suggestions for managers compared to previous literature on strategic management.

1.3 Outline

Chapter two gives a thorough discussion on complexity, both as a phenomenon and as a theory. After an overview of its origin in chaos theory, the discussion moves on to the organizational level, and how this fits in the domain of complex systems. This chapter explains how organizations should be understood through the lenses of complexity theory. Chapter three identifies the underlying sources affecting the overall complexity in organizations. Eight sources are discussed through an extended literature review outside the known domain of complexity theory, and then discussed as the overall nature of complexity. It then makes sense to ask the question of how to manage this complexity, based on these sources, and explained through chaos theory and complexity theory. Several mechanisms are discussed in chapter four, again from an extended and thorough literature review, both within and outside the area of chaos and complexity theory. Chapter five summarizes the previous discussion in a research model and the implications for managers, as well as how to conduct further academic research in this area. Finally, chapter six discusses how to design and conduct an empirical study based on the theoretical findings in this thesis.

2. The Science of Complexity

2.1 Introduction

Complex adaptive systems have recently been the subject of significant scientific scrutiny (e.g., Anderson, Arrow and Pines 1988; Holland 1992; Kauffman 1993, 1995; Nicolis and Prigogine 1989; Prigogine and Stengers 1984; Waldrop 1992). Managers should be aware that "complexity theory has much to recommend to organizational science" (Lewin 1999: 215), because ideologically rooted managerial advice is emerging from theoretical foundations in complexity. Not only will complexity theory give managers a better understanding of organizational behavior, emergence, change and adaptation, but also make clear the limits upon which the nature of management is based. This chapter reveals the many aspects of complexity. After a discussion of complexity in general, the science of chaos theory is reviewed. There is a need to elaborate chaos theory because of its foundation in complex adaptive systems. Complexity theory builds on the properties of chaotic systems. Thus, the understanding of complex adaptive systems is closely related to the understanding of the properties and behavior of chaotic systems. The chapter then ends in a discussion of how chaos theory and complexity theory should be used and implemented in organizations as complex adaptive systems.

2.2 Complexity as Phenomenon

What is complexity? To show how diversified the field of complexity is, let us take a short look of the inventory of definitions of complexity computed by the physicist Seth L. Loyal. Loyal's list includes:

information (Shannon); entropy (Gibbs, Boltzman); algorithmic complexity; algorithmic information; Renyi entropy; self-delimiting code length (Huffman, Shannon-Fano); error-correcting code length (Hamming); Chernoff information; minimum description length (Rissanen); number of parameters, or degrees of freedom, or dimensions; Lempel-Ziv complexity; mutual information, or channel capacity; algorithmic mutual information; correlation; stored information (Shaw); conditional information; conditional algorithmic information content; metric entropy; factual dimension; self-similarity; stochastic complexity (Rissanen); sophistication (Koppel, Atlan); topological machine size (Crutchfield); effective or ideal complexity (Gell-Mann); hierarchical complexity (Simon); tree subgraph diversity (Huberman, Hogg); homogeneous complexity (Teich, Mahler); time computations complexity; space computations complexity; information-based complexity (Traub); logical depth (Bennett); thermodynamic depth (Lloyd, Pagels); grammatical complexity (position in Chomsky hierarchy); Kullbach-Liebler information; distinguishability (Wooters, Caves, Fisher); Fisher distance; discriminability (Zee); information distance (Shannon); algorithmic information distance (Zurek); Hamming distance; long-range order; self-organization; complex adaptive systems; edge of chaos.[2]

The list does not exactly give us any more information, except that the term "complex" or "complexity" is in itself complex. There is a well of different meanings to the term, and the lack of clarity and precision in the meaning and understanding of it forces us to be careful when we

---

[2] Quoted in John Horgan, The End of Science (Reading, MA: Addison Wesley, 1996), p. 288. Names indicate the main originators of the definition.

ourselves are going to make or choose a definition of complexity. Most people have a personal understanding of the term “complexity”. Still, the fewer of us are able to explain what it really means. Rescher (1998: 8) clarify the problem at hand:

> There is no agreed upon definition of ”complexity” any more than there is one of ”chair”. In both cases alike we are dealing with one of those things we can generally recognize when we see them, but cannot readily pin down with some straightforward adequate verbal formula. And while we can usually compare things of the same general sort in point of complexity, we certainly do not have anything like a cross-the-board measure of complexity to compare the complexity, say of stories and of machines. What we do know is that complexity is the inverse of simplicity. The latter is a matter of economy, the former of profusion. Simplicity represents economy and orderliness in a thing’s make-up or operations; complexity, it’s elaborateness as reflected in the intricacy or even actual disharmony in these regards. As many writers see it, complexity is determined by the extent to which chance, randomness, and lack of lawful regularity in general is absent. But this cannot be the whole story, since law systems themselves can clearly be more or less complex.[3]

Can we find anything like across-the-board measure of complexity to compare the complexity, say, of stories and of machines? Casti (1994) suggests that complexity is the same as suspense and impredictability. According to Rescher (1998) on the other hand, this is an exaggeration. The concept of complexity should be distinguished from terms like “difficulty” and “uncertainty”. An issue may be difficult to manage, but may still not be very complex. Think, for example of the task of balancing an egg on a table in the vertical direction: it’s not a very complex issue, you know what to do – still it is difficult to make the egg balance in the right direction.

[3] Many authors on the subject of complexity do not bother to define the phenomenon at issue (Rescher 1998). See for example Herbert A. Simon’s (1981) essay on “The Architecture of Complexity”.

Even if the concepts of “difficulty” and “complexity” should be distinguished, they tend to run together. As Rescher (1998: 8) notes, “... whenever present, complexity coordinates with difficulty in cognitive and operational management: the more complex something is the more difficult we have in coming to grips with it and the greater the effort that must be expended for it’s cognitive and/or manipulative control and management. Complex statements are harder to understand; complex arguments harder to follow; complex machines harder to operate.”

Other measures of complexity can be classified as ”computational complexity metrics”, which exhibit structural, organizational, and perspective complexity. In other words, there is a well of definitions and kinds of complexity. Perhaps as important in trying to explain what complexity is, is to explain what complexity is not. What is desirable is to limit the meaning of the term according to the research problem. The definition of complexity should be separated from other terms to avoid misunderstandings. Still, what should be clear by now is that there is no easy way of defining complexity. The concept is, as pointed out earlier, in it self complex. The well of meanings and definitions in the literature makes it perhaps even more confusing. What is meant by complexity here will be clearer as we explain the behavior of chaotic systems, the nature of complex systems, and the sources of complexity. These terms will be explained in the following, and will hopefully give a more elaborate and detailed picture of the world of complexity.

2.3 Chaos Theory

2.3.1 Chaos Theory and Nonlinearity

Chaos theory is the study of complex, nonlinear, dynamic systems. It promises to be a useful conceptual framework that reconciles the essential unpredictability of industries with the emergence of distinctive patterns (Cartwright 1991). In everyday language the word "chaos" is used to describe conditions that appear to be highly disorganized, turbulent and volatile. Chaos theory is the popular name for dynamical systems theory, or nonlinear studies. As it turns out, most of the world is made up of nonlinear systems, and dynamical systems theory, or chaos theory, is a new mathematical approach that allows scientists to study the behavior of nonlinear systems (Sanders 1998). Mathematically, chaotic systems are represented by differential equations that cannot be solved, so that we are unable to calculate the state of the system at a specific time *t* (Levy 1994).

As Levy (1994) emphasizes, to understand the relevance of chaos theory to strategy, we need to conceptualize industries as complex, dynamic, nonlinear systems. Organizations are nonlinear, network feedback systems and it therefore follows logically that the fundamental properties of such systems should apply to organizations (Stacey 1995). System dynamics (Forrester 1958; Hall 1976; Kauffman 1995; Senge 1990) have demonstrated that non-linearity and positive feedback loops are fundamental properties of organizational life and that behavior patterns can emerge without being intended and in fact often emerge contrary to intention, producing unexpected and counter intuitive outcomes (Stacey 1995).

All nonlinear feedback systems, including human organizations, can be expressed in terms of lawful rules and relationships. In organization such laws take the form of decision rules and scripted relations between people within an organization and with people across organization boundaries (Stacey 1995). Hence, chaotic models can be used to suggest ways that people might intervene to achieve certain goals (Levy 1994). That is why we are concerned with the factors that influences such decision processes, and with the mechanisms that can be used to overcome these problems. The fundamental problem is that industries evolve in a dynamic way over time as a result of complex interactions among firms, government, labor, consumers, financial institutions and other elements of the environment (Levy 1994).

Examples of chaos are being found in *biological evolution* (Laszlo (1987), *ecology* (Kauffman 1995), *medicine* (Goldberger, Rigney and West 1990), *economics* (Arthur 1988; Baumol & Benhabib 1989; Brock 1986; Kelsey 1988; Moskilde and Rasmussen 1986), *finance* (Stutzer 1980), *psychology* (Barton 1994), *international relations* (Mayer-Kress and Grossman 1989), *sociology* (Dendrinos and Sonis 1990), physiology (Freeman 1991) and the *physical science* (Prigogine and Sengers 1984).[4] Scientists such as Radzicki (1990) and Butler (1990) amongst others have noted that social, ecological, and economic systems also tend to be characterized by nonlinear relationship and complex interactions that evolve dynamical over time (Levy 1994). In the social world, outcomes are often reflecting very complex underlying relationships that include the interaction of several potentially chaotic systems: crop prices, for

[4] See also special issues of Journal of Economic Theory, 40(1), 1986, and Journal of Economic Behavior and Organization, 8 (3), 1987.

example, are influenced by the interaction of economic and weather systems (Levy 1994).

Dynamical systems theory is a branch of mathematics that can distinguish between four main types of temporal patterns that may exist in a time series of longitudinal data: fixed (static), periodic (cyclical), chaotic (strange), or random chance (Morrison 1991). The basic notion of chaotic processes is that a stable and deterministic non-linear system, possibly consisting of a small number of interacting variables, produces behavior that appears irregular to the degree that it seems random. When this accurse, the resulting behavior has come to be called “chaos”, to distinguish it from truly random behavior (Cheng and Van de Ven 1996).

2.3.2 Nonlinear System Properties and Strange Attractors

Lorenz (1963), one of the pioneers in developing chaos theory, discovered that nonlinear dynamical systems are teeming with creative potential and sensitivity to new influences. In chaotic systems, small disturbances multiply over time because of nonlinear relationships and the dynamic, repetitive nature of chaotic systems. A dynamic system means that the values a variable takes on a given time are a function (at least in part) of that same variable at an earlier time (Koput 1992). As a result, such systems are extremely sensitive to initial conditions, which makes forecasting very difficult (Levy 1994). Sensitivity to initial conditions mean that small initial differences or fluctuations in variables may grow over time into large differences, and as they move further from equilibrium they bifurcate or branch out into numerous possible pathways resembling a complex decision tree (Cheng and Van de Ven 1996; Levy

1994: Lorenz 1963; Sanders 1998; Stacey 1995). This sensitivity to initial conditions starts an interactive process, known metaphorically as the butterfly effect.

Lorenz (1963) made three important discoveries in his work on nonlinear dynamic systems. First, because the system is deterministic, it is possible to know its initial conditions. Second, because the system is also nonlinear, it is difficult to predict its future state. Finally, even if it may not be possible to predict the future state of a nonlinear system, it is possible to provide a qualitative description of its characteristics and behavior over time (Sanders 1998).

A deterministic system means that the relationships themselves do not change or evolve, and hence that the system do not learn. According to Radzicki (1990), deterministic chaos is characterized by self-sustained oscillations whose period and amplitude are non-repetitive and unpredictable. Prigogine (Prigogine and Stengers 1984; Nicolis and Prigogine 1989) takes chaos theory a step further and assumes that the "noise" or "fluctuations" in the form of variations around any average are incorporated into the model. This means that nonlinear systems that are held far from equilibrium holds the capacity of spontaneously move from one attractor to another (Allen 1988).[5] Prigogine shows how this process of "order through fluctuations" occurs through a process of spontaneous self-organization, which is a property of complex adaptive systems as explained by complexity theory, and discussed further in the next section and in section 4.2. This order takes the form of a dissipative structure. Hence, the move from one attractor to another may come from both its

[5] See next page for a definition of attractor.

environment and from within the system itself. Radzicki (1990) simulated how large fluctuations can be generated internally from the dynamics of the systems with his population model based on the logistic difference equation. The size of these fluctuations from one period to the next in chaotic systems has a characteristic probability distribution (Bak and Chen 1991).

The possibility of chaotic patterns in organizational behavior becomes apparent when we recognize the simple requirements for the presence of chaos (Koput 1992):

> Chaos requires a dynamical model. That is, the variables at any given time are a function, at least in part, of the same variables at an earlier time. Also, the functional form of the model must be nonlinear in the variables. It need not be very complicated (May 1976). Non-linearity simply requires that there be at least two not-entirely-compatible underlying forces or sources of demands. Stated differently, this means there must be both positive and negative feedback loops. With this type of system, irregular and unpredictable behavior can arise endogenously – that is, without any exogenous, truly random input. This occurs when the balance between the positive and negative feedback is especially severe.

Nonlinear systems have several properties that make them recognizable. First, beneath seemingly chaotic behavior of a nonlinear system, there is order. Chaos (unlike anarchy) is not an absence of laws but involves a mode of lawfulness so elaborate as to render a system's phenomenology cognitively unmanageable in matters of prediction and explanation (Rescher 1998). One of the major achievements of chaos theory is its ability to demonstrate how a simple set of deterministic relationships can produce patterned yet unpredictable outcomes (Levy 1994). Chaotic systems never return to the same exact state, yet the outcomes are bounded and create patterns that embody mathematical constants (Feigenbaum 1983). Thus, this behavior follows an unpredictable pattern over time, but within given limits, or constraints. These repetitive patterns often provide useful information, especially if we can associate different phases of the system with other characteristics, although we cannot forecast the precise state of a chaotic system in the longer run (Levy 1994).

The pattern or “order” refers to a type of self-organizing shape, or structure. The attraction or active relationship of the variables making up the system creates the shape. An *attractor* is the end state or final behavior toward which a dynamical system moves, and that state is either predictable or unpredictable. A predictable attractor is the end state into which a system settles. Chaotic systems that never settle into a predictable or steady state are said to have *strange attractors*. The term “strange attractor” describes the behavior of the force or forces that hold the system variables in place. Chaos theory describes this behavior of chaotic nonlinear systems and their strange attractors (Sanders 1998).

According to Stacey (1995), organizations are exposed to three “main” attractors: (i) *stable equilibrium*, where the formal system consists of integrated hierarchy, bureaucracy and negative feedback control systems, and the informal system is made of a risk-averse culture, and a strongly shared vision, (ii) *instability/randomness/ fragmentation*, where the formal control system is too decentralized and ineffective, and the informal system is one of high cultural diversity, conflict and widespread political activity, and (iii) *bounded instability edge*, with the formal organizational system as one of integrated hierarchy and bureaucracy with negative feedback control system, and the informal system consisting of high cultural diversity, conflict and widespread political activity and dialog with a weakly shared vision ambiguity and learning.

The connection between attractors and strange attractors, and the state of complex adaptive systems is depicted in Figure 2.1.

At the same time as being pulled to stability by the powerful forces of integration, maintenance controls, as well as the need to adapt to the environment, all organizations are also powerfully pulled in the opposite direction by the forces of division and decentralization (Lawrence and Lorsch 1967), i.e. at the edge of bounded instability where the forces of the informal and formal system are balanced. When the formal systems of an organization move too far in this direction, they become fragmented and unstable (Miller 1990), which is represented by the right side in Figure 2.1. The attractor to instability in organizational terms means that the positive feedback behavior such as political interaction and organizational defense mechanisms spread disorder through the system (Argyris 1990).

In nonlinear dynamical systems, the variables cannot be taken apart and added back together again like a child's building blocks; A+B does not

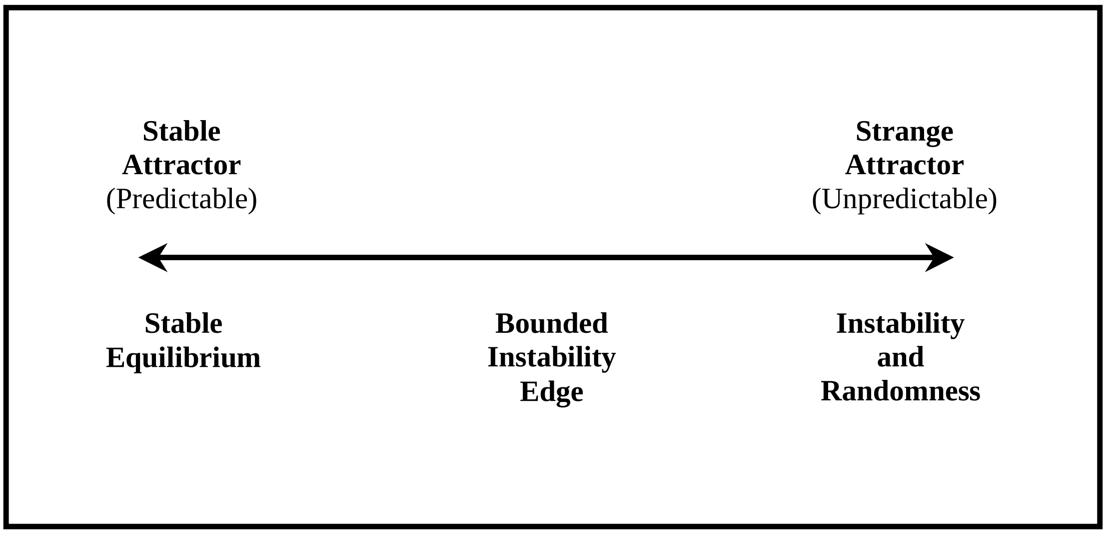

Figure 2.1 Attractors and State of System

equal C. A small change in one variable will create changes in another and another, because the variables are interacting constantly and changing in response to each other (Sanders 1998). Nonlinearity implies that the values of the dynamic feedback loops vary in strength (loose or tight) and direction (positive or negative) over time. Because of the nonlinear interactions, the behavior of the whole system is not even to an approximation a simple sum of the behavior of its parts (Holland 1992: 184). When a non-linear feedback system operates in a state poised at the edge of instability, its behavior is paradoxically both stable and unstable at the same time: there is instability in the sense that specific behavior is inherently unpredictable over the long term, but there is also stability in the sense that behavior and also short-term outcomes are predictable (Levy 1994; Stacey 1995). Hence, the temporal development of variables in a chaotic system is dynamic, nonlinear, and sensitive to initial conditions.

2.4 Complexity Theory and Organizations

2.4.1 Complexity Theory

Complexity theory incorporates the attributes of chaos theory, and hence, is concerned with the dynamical properties of nonlinear and network feedback systems (Gell-Mann 1994; Gleick 1987; Goldstein 1994; Kauffman 1995; Lewin 1999; Nonaka 1988; Peters 1991; Sanders 1998; Stacey 1995, 2000; Waldrop 1992; Wheatley 1992; Zimmermann 1992). This means that all attributes in chaotic systems are also apparent in complex systems, i.e. nonlinear behavior and sensitive dependence on initial conditions. Although there is no generally agreed upon definition, the term “complex system” usually refers to systems in which great many independent agents are interacting with each other in many ways (Waldrop 1992). In chaos theory, the output of the iteration of deterministic nonlinear relationships of an agent becomes the input in the next, and so on. An agent refers to algorithms in computer models or organisms in natural systems. The rules, or models used by the agents in this iteration process to produce these new outcomes is constant, and hence does not change as new outputs are produced and incorporated by the agents comprising the system. It is the input into the next iteration that alters the outcome from one iteration to the next, and creates a new overall pattern of the system, i.e. a strange attractor. What chaos theory suggests then, is that new, more complex organizational forms will appear more frequently than if they were simply the result of random mutations (Levy 1994).

While chaos theory describes the development of a nonlinear system containing only one *single agent*, complexity theory describes the *interaction of separate agents* in nonlinear systems. Here, the output of the iteration of the *interaction* between deterministic nonlinear relationships of separate agents becomes the input in the next iteration, i.e. new agents are revealed as the system continues to (self-) replicate. This interaction between separate, *homogenous* agents create new patterns of interaction. In a complex system with agent *heterogeneity*, the system also inhibits the ability to move from one attractor to another, *and* to internally create new ones. In seeking to adapt to changing circumstances the agents develop “rules” (models) that anticipate the consequences of responses, thus their name complex adaptive system. No individual agent or group of agents determines the pattern or structure of the behavior of the system according to some overall blueprint. Agents interact locally according to their own principles. This is the principle of complex adaptive systems (Stacey 2000). The effect of local anticipations on aggregate behavior is one of the aspects of complex adaptive systems we least understand (Holland 1992). In other words, the iteration of the interactions of agents alters or creates new agents, and hence the rules or models change as new outputs are produced. Their existence and structure depend on the constant flow of energy and new information, making it impossible to know all of the initial conditions at any point in time (Sanders 1998).

This has nothing to do with natural selection. On the contrary, Kauffman (1995: 8) suggests that the very idea of Darwinism, natural selection, is wrong: "… the emergent science of complexity begin to suggest that the order is not at all accidental, that vast veins of spontaneous order lie at hand". And Kauffman (1995: 185) continues, "… The first theme is self-organization. Whether we confront… the origins of life… or the patterns of co-evolution… we have found the signature of law. All these phenomena give signs of nonmysterious but emergent order." It is this order and ability to self-organize that seems to be attractive to researchers in the social science. Kauffman (1995) places emergent novelty at the center of life and as a consequence he accepts that it is impossible to predict the details into the future. Instead, it may be possible to explain, understand and predict the emergent properties of a system.

2.4.2 Organizations as Complex Adaptive Systems

The sum of research done in the twentieth century shows that organizations are complex systems, where individual behavior of managers and employees interact in complex ways with each other and with the environment of the organization (Bettis and Prahalad 1995). Hence, organizations are assumed to be systems, in turn part of larger environmental systems, that evolve through a process of creative destruction (Schumpeter 1934) and spontaneous self-organization (Hayek 1948) through the process of adaptation set in motion by new information (Lorenz 1963). This new information tips the balance and pushes the system into a chaotic episode (Sanders 1998), and implies that a small perturbation in the system can have a dramatic effect on later results (Daft and Lewin 1990; Holland 1992; Nicolis and Prigogine 1989; Prigogine and Stengers 1984; Waldrop 1992). In other words, complexity theory explains why systems like organizations and business environments are difficult to predict. What differentiates this perspective from other perspectives in the field of strategy and organizational science are the assumptions made about system dynamics and its agents – organizations are nonlinear entities with the capability of self-organization.

There seems to be at least three schools in the field of complexity theory applied to strategic management and organizational science. One perspective, represented by Gell-Mann (1994), Holland (1998) and Langton (1996), understand complex systems in somewhat mechanistic, reductionistic terms and is modeled by an objective observer in the interest of predicting its behavior. The agents in these systems represent regularities that are stored in the form of rules and then act on the basis of those rules. According to Gell-Mann (1994: 318), for example, "… complex adaptive systems… are collectives of co-adapting adaptive agents, which constructs schemata to describe and predict one another's behavior." Langton (1996), like Gell-Mann (1994), emphasizes the importance of chance in the evolution of complex adaptive systems.

Another perspective, represented by Goodwin (1994), Kauffman (1995), and Stacey (2000), emphasizes the importance of self-organization, rather than random mutation in the emergence of new forms, which are radically unpredictable. Agency lies not at the level of the individual agent but at the level of the agent *and* the other agents to which the agent respond.

The third perspective differs from the firs two in its origin and fundamental view on complex systems. This perspective draws heavily on Rosen’s (1972, 1978, 1985, 1991, 1996, 1999) work, which devoted much of his research on living organisms, i.e. complex systems in biology. According to Rosen’s view, there are certain key models in complex systems that are formulated in an entirely different way compared to reductionism. These models are made up of functional components, which do not map to the material parts in any one to one manners. The functional component itself is totally dependent on the context of the whole system and has no meaning outside that context. These functional components are the ontological embodiment of the non-fragmentable aspects of the system’s organization (Mikulecky 1999). They are *defined* by their *context* and have no necessary meaning outside that context. Thus, they capture what is lost by reductionism. In other words, a functional component has to be identified by its function in the whole. Often that can be deduced from situations in which it has been disabled or eliminated. The presence of functional components is why reducing the system to its material parts loses information irreversibly (Rosen (1985, 1991), and captures a real difference between complexity and reductionism. According to Rosen (1985, 1991), this distinction makes it impossible to confuse computer models with complex systems. Complex systems contain semantic aspects that can not be reduced to syntax. Therefore they are not simulatable. It also explains how there can be real “objective” aspects of a complex system that are to be considered along with the material parts, but which have a totally different character (Mikulecky 1999).

Rosen’s (1985, 1991, 1999) view on complex adaptive systems differs fundamentally from the two other perspectives (Gell-Mann 1994; Goodwin 1994; Holland 1998; Kauffman 1995; Langton 1996; Stacey 2000), which draws heavily on computer simulations, and how these simulations refer to organizations. However, computer models and simulations have revealed several properties about complex adaptive systems relevant to organizations; nonlinear behavior and sensitive dependence on initial conditions, the ability to move from one strange attractor to another and to create new ones, and how agents interact and respond on a local basis to create new overall global patterns, i.e. self organize. Still, there are some problems attached to the simulation approach, as discussed above, and Rosen’s (1972, 1978, 1985, 1991, 1999) perspective seems to capture and deal with some of these problems.

Even though there seems to be a common understanding that these findings are *properties* of organizational behavior, there seems to be differences in how to interpret these findings to organizations and reality in general. Scientists use computer programs to simulate and experiment with complex adaptive behavior, as it is difficult to experiment with living systems in real life. The problem is, as discussed by Rosen (1985, 1991), that computer models and computer simulations are not complex systems as we realize in real life, only simple models, and should therefore not be confused with them. This is not to say that we cannot learn something from these simulations, as discussed above. Still, according to Rosen (1985, 1991) there are fundamental differences between living organisms, or systems of organisms, i.e. complex adaptive systems, and machines, i.e. computer simulations. Agents in an organization are not mathematical algorithms, but living organisms – intellectual and emotional human beings with the ability to interact and communicate with other human beings in their surroundings and to respond locally to the behavior of these agents. The point is that even though "chaos theory is a theory of deterministic systems, human systems are not deterministic. The behavior of people is not driven by unchanging rules. The "rules", if that is what they are, change as people learn" (Stacey 2000: 312).

This notion becomes especially important when organizational theorists incorporates the role of the manager in organizations when viewed as complex adaptive systems. Researchers in organizational theory and strategic management theory have shown to confuse the role of the manager with that of the computer programmer in computer simulations of complex adaptive systems; as an objective observer standing outside the system and being able to control the parameters of the system. According to Stacey (2000: 323), …this translation occurs, probably, because it all fits so well into orthodox management discourse. The result, however, is old recipes in new vocabulary." In complex adaptive systems managers "are agents in the system, not external observers of it" (Stacey 2000: 299). Still, "...the CEO, as everyone else in the organization have the ability to stand back and understand something of the whole process of which they are a part. Humans are able to reflect on and articulate something about, the whole that is emerging" (Stacey 2000: 335). Even so, managers are not capable of knowing the consequences of their choices, and hence the future state of the organization.

The point made by Stacey (2000: 281) is that "…it is important to take great care in using insights about self-organisation and emergence in relation to organisations. The question becomes one of how to interpret, in organisational terms, the logic of iterative, non-linear interaction between replicating algorithms and their self-organising and emergent properties." Stacey (2000) draws heavily on what he refers to as relationship psychology. The basic proposition of this theory of human knowing and acting is that people relate to each other in the medium of symbols. These symbols are gestures that call forth responses, which are themselves symbols that call forth further responses in a conversation of gestures. Mind and group are one. He argues that these symbols are the human analogue of the digital symbols, or code, that are the medium of computer simulations of complex adaptive systems. Stacey (2000) then implicit see the equations in the computer simulations as the analogue for humans in organizations. What seems to be missing from this perspective is what Rosen (1985, 1991) refers to as the functional component, and complex adaptive systems as living organisms, not machines or computer models. It is the local interaction among agents in a given *context* that creates the properties of the overall complex adaptive system. Removed from its context, these system properties disappear.

2.4.3 Managing Complex Adaptive Systems?

Is it possible to manage complexity in complex adaptive systems, or is the system self-organizing in the sense that the behavior of agents in the system does not matter? Does the system adapt according to its own rules? The answer to these questions should be clear by now – behavior of agents *does* matter. The question is how and why? The problem is that agents do not know in advance how their behavior in the system affects the emergence of the organization according to complexity theory. How are managers to cope with this problem of not being able to make strategic plans for the future? As the system, or organization emerges, so does the complexity within it. This complexity is rooted in some fundamental system properties as discussed in this chapter. However, these systems are based on some common elements, which are the sources of complexity, as will be discussed in chapter three. Through the awareness of these sources, managers may find the answers to some of the challenges of the overall complexity of their organization.

2.5 Summary

Complexity theory rests upon several assumptions about system dynamics. First, there is the agents making up a system. Second, there is agent homogeneity and diversity; i.e. the agents are assumed to be both equal and unequal, and may inhibit differences in rules that influence their behavior. Third, the system may follow equilibrium attractors or strange attractors, and display the capacity to spontaneously move from one attractor to another or to evolve new ones. An attractor is a state to which the system is attracted. This is the process of self-organization that produces emergent novelty and emergent new structures or patterns, created by the interaction of agents, and is a property of complex adaptive systems like organizations. The interaction creates patterns that no agent individually intends or can foresee. This is based on the functional component, that the behavior and pattern of the whole system is more that just the sum of its parts, and is a result not only by the interaction of the elements operating within the system, but in its context as well.

3. Sources of Complexity

3.1 Introduction

We are all living in systems, which are more or less complex. A system in this respect refers to an organization or a population of organizations, and its environment. The sources of complexity that are discussed here affect any system, whether formal or informal, organizational or social, and independent of the presence of a micro- or macro level of analysis. Despite surface dissimilarities, "... all complex adaptive systems exhibit a common kernel of similarities and difficulties, and they all exhibit complexities, that have until now, blocked broadly based attempts at comprehension" (Holland 1992: 184). This kernel of similarities and difficulties that create this complexity vary in strength from system to system, i.e. organizations or social systems, and from agents that acts within and between these systems.

Recent developments in system dynamics, like chaos theory, help us understand why and how complexity is created, how it develops, and how nonlinear systems expand into unpredictable future states. In this chapter we try to reveal the sources of this complexity; i.e. what factors that makes nonlinear systems complex, and hence complex to manage. An extensive literature review will reveal what factors constitute complexity, and hence differentiates the phenomenon from other similar terms like "uncertainty". The first seven sources of complexity are referred to as "objective" sources. Independent of the agents in the system these sources affect the overall complexity of the system. The last identified source of complexity is "limited cognitive capacity", and is of a quite different nature. This source is dependent upon the “eye of the beholder”, and hence is referred to as a “subjective” source of complexity.

3.2 Sources of Complexity

As managers realize their incomplete abilities to manage complex decision processes, the search for the sources of incompleteness continues. These sources are also interacting in a way that makes the process even more complex. Chaos theory, originally from physics (Gleick 1987), and further developed in complexity theory, describe why nonlinear systems are complex, why it is difficult to predict the outcome of nonlinear systems that inhibit chaotic characteristics, and give us some insight about what sources we need to be able to manage in complex systems, as discussed in chapter two. The term “elements” refers to different aspects making up a system, as in chaos theory.

3.2.1 Number of Constituent Elements

According to Rescher (1998), the number of constituent elements or components making up a system, is perhaps the complexity conception’s most striking form. As the number of elements in a system increases, so does the complexity of the system. This is the number of *N* elements comprising a system in what Kauffman (1993) refers to as the *NK* model, where *K* represent the degree of interdependence of these elements, as discussed in section 3.2.7. A play with ten interacting characters will be more complex than one with three when things are otherwise similar – or in organizational terms, an organization consisting of several thousand employees is more complex than an organization consisting of only ten employees. In general, the more elements that constitutes a system, the more complex the system will be. This source of complexity is what Rescher (1998) refers to as constitutional complexity. This dimension should though be distinguished from variance in system elements, which is discussed in the next section. Say, for example, that a system is made of individuals only, and that this system contains two thousand individuals. That is, the *number* of elements in this system is two thousand. Still, in its simplest form, we could distinguish only two *types* of elements in this system – male and female, all other things being equal.

3.2.2 Variance in System Elements

A system that constitutes the number of ten dissimilar elements is more complex than a system with ten similar elements. That is, a system's complexity varies with the variety, or heterogeneity, of its constituent elements. Biologists are especially attached to this dimension of complexity. Bonner (1988), for example, argues that organic complexity should be measured as the number of different cell types in an organism. It is easy to see that "...in general it seems natural to construe the complexity of an issue in terms of the ramifications of the taxonomy that relevantly revolves about it" Rescher (1998: 11). Rescher (1998) refers to this as taxonomical complexity.

This is also the case with organizations. The more diversified their constituent elements, that is, the number of kinds of components in their physical configurations, the more complex the system. The level of detail should also be considered. As we introduce further discriminations –

further distinctions – an initial easy pattern becomes increasingly complex. And this is a standard phenomenon: "... more refined distinction and difficulties never introduce more simplicity than there was before, they can only militate in the direction of greater complexity" (Rescher 1998: 7). According to Stacey (2000: 6), "... different levels of description focus on different levels of detail: the higher the level of description, the more detail has been sheared away.... Furthermore, it is important to remember that macro- and micro-level events are taking place simultaneously and in moving from one level of description to another, one is simply refocusing attention."

This is also the case for an organization's resources. The resources controlled by an organization can be very complex and interdependent (Barney 1991). Often they are implicit, taken for granted by mangers, rather than being subject to explicit analysis (Nelson and Winter 1982; Polanyi 1962; Winter 1988). A wide variety of organizations' resources may be very complex social phenomena (Barney 1991). Examples include the interpersonal relations among managers in an organization (Hambrick 1987), an organization's culture (Barney 1986b), an organization's reputation among suppliers (Porter 1980) and customers (Klein, Crawford and Alchian 1978; Klein and Leffler 1981). As the variety of system elements or, for example, an organizations resource diversity increase, so does the complexity of that system. According to Scott (1981: 211), "... this dimension refers to the number of different items or elements that must be dealt with simultaneously by the organization. Specific measures such as multiplicity and customization of outputs and variability of inputs tap this dimension."

3.2.3 Lack of Lawful Regularity

The lack of lawful regularity is perhaps the most fundamental property of complexity in nonlinear systems, as described by chaos theory and complexity theory in chapter two. As noted earlier, nonlinearity is a fundamental property of organizations (Stacey 1995), which means that cause and effect are not proportional. A large cause might have a minimal effect, while conversely a small cause might have a huge impact on the system (Bettis and Prahalad 1995). In other words, causal ambiguity between system elements creates system complexity. It is the elaborateness and intricacies of the laws governing the phenomena at issue that is at work (Rescher 1998). Thus, the more elaborate a systems law structure, the more complex a system. According to Rescher (1998), who refers to this as nomic complexity, chaos represents an extreme here.

This dimension should be separated from randomness and chance, discussed in section 3.2.6. As in chaos theory, even if a system seems to obtain random behavior, underlying structures or patters difficult to observe might still be present. The problem, as mentioned by Stacey (1995) amongst others, is how to distinguish chaotic systems, which appears to inhibit random behavior and pure chance, from systems with truly random behavior. It is also important to be aware of the difference between the lack of lawful regularity and lack of cognitive capacity, as will be discussed in section 3.2.8. The former will often induce the latter in such a way that also the perceived overall complexity of the system increases, but not the other way around of course.

3.2.4 Uncertainty

The concept of uncertainty is discussed in several theories, and usually refers to the aspect of time, i.e. the future. Transaction cost theory (Coase 1937; Williamson 1975, 1979, 1985, 1991) is perhaps one of the theories where uncertainty has been investigated most thoroughly. In the transaction cost theory, environmental uncertainty refers to "unanticipated changes in circumstances surrounding an exchange" (Noordewier, John and Nevin 1990: 82), i.e. the unpredictability of the environment (Heide and John 1990). What's interesting from a complexity point of view, is that TCA-researchers don't seem to separate between complexity and uncertainty as would be expected from a complexity perspective, as discussed in chapter two. Instead, there seem to be a more or less common understanding – or lack of understanding – that complexity is a source of uncertainty, and not the other way around. For example, Anderson (1985, 1988) uses a nine-item scale of uncertainty that addresses elements related to both the instability associated with environmental turbulence (e.g. complexity, volatility) and the venturing into new activities (e.g. new markets, new sales).

Klein (1989) and Klein, Frazier and Roth (1990) operationalize environmental uncertainty as a two-dimensional concept that entails elements of both unpredictability and changeability. For example, Klein (1989) distinguishes between dynamism and complexity as elements of environmental uncertainty. He defines uncertainty-dynamism as "the rate at which changes in the environment occur," and uncertainty-complexity as "the degree to which the respondent perceived the environment as simple or complex" (Klein 1989: 257). This is quite the opposite of what would be expected from a complexity point of view: uncertainty is one of several sources that increase the complexity at hand, and not the other way around. The more uncertainty – behavioral or environmental – the more complexity. Still, Klein (1989) distinguishes between "simple" and "complex" as opposing terms, which is according to my own understanding of these concepts.

According to Williamson (1991b: 291), "...greater uncertainty could take either of two forms. One is that the probability distribution of disturbances remains unchanged but that more numerous disturbances occur. A second is that disturbances become more consequential" (due, for example, to an increase in the variance). "Disturbances" refers to the external pressure or shocks, which affects an organization. Williamson (1991b) links, in other words, uncertainty to the probability distribution of disturbances in the organizational environment, and the frequency and consequence of these disturbances. The frequency and consequence of disturbances relates to the speed of change, as will be discussed in the next section. As should be clear by now, these disturbances enhance the complexity of decision processes for managers, as they perceive and interpret this information, or lack of information, and how this interpretation vary amongst decision-makers. This is why we need to take the cognitive capacity of decision-makers into account when the sources of complexity are examined, as discussed in section 3.2.8.

According to Eisenhardt (1989a), the information asymmetry and assumed goal conflict between the principal and agent in the principal-agency theory (Berle and Means 1932; Eisenhardt 1989a; Fama and Jensen 1983; Petersen 1993), creates uncertainty, known as the agency problem, which materialize itself through the problem of moral hazard and adverse selection. This type of uncertainty is not different from that discussed above. The lack of information on how other actors inside and outside the organization will act, is a crutial factor. Thus, uncertainty may be distinguished from complexity by means of information available to the decision-maker. For instance, if a decision-maker has full access to all relevant information on an issue, there is no aspect about the issue that is unknown. Still, the information may be of a sort not available to the decision-maker, or it may be of such a volume that the decision-maker is not capable of absorbing it, at least not in his or her given time frame for the decision to be taken. This means that even if the decision-maker has full information about an issue, and hence no uncertainty, he or she may still find the issue extremely complex. As the uncertainty increases, so does the complexity, given two equal decision-makers. Conversely, the complexity exposed to two different decision-makers may not be equal, even if the level of uncertainty is, because of differences in cognitive capacity, as discussion in section 3.2.8.

3.2.5 Change and The Speed of Change

Hayek (1945: 523) insistently argued that "economic problem arise always and only in consequence of change", and that this truth was obscured by those who held that "technological knowledge" is of foremost importance. He disputed the latter and urged that "the economic problem of society is mainly one of rapid adaptation in the particular circumstances of time and place" (Hayek 1945: 524). Barnard (1938) also held that the main concern of an organization was that of adaptation to changing circumstances, but his concern was with adaptation within internal organizations. Confronted with a continuously fluctuating environment, the "survival of an organization depends upon the maintenance of an equilibrium of complex character.... This calls for readjustments of processes internal to the organization..., whence the center of our interest is the processes by which adaptation is accomplished" (Barnard 1938: 6), which seems to fit with the behavior of complex adaptive systems.

The changing environment surrounding a system like an organization, is a factor of disturbance, discussed earlier in section 3.2.4 about uncertainty, and pointed out by Williamson (1991b). As these disturbances increase in frequency or in consequence – or in both, so does the pressure to adapt. Every aspect of the changing process makes the decision process even more complex to managers, as this dimension clearly is affected by the nomic complexity, or the lack of lawful regularity, discussed in section 3.2.3, and adopted from Rescher (1998). Dutton and Duncan (1987) is concerned about how strategic issue *urgency* captures the perceived importance of taking action on an issue, and how the perception of an issue urgency is tied to the perception of time pressure associated with an issue. According to Dutton and Duncan (1987), "... time pressure can arise from deadlines embedded in an issue...[and] is also tied to estimates of anticipated issue duration." Surely, as the estimated duration of an issue fail to be met, so does the pressure to complete the issue, even if the failure might as well be the estimated deadline.

Structural revolutions in an industry – referred to as "Schumpeterian Shocks" by several authors (Barney 1986c; Rumelt and Wensley 1981; Schumpeter 1934, 1950) – is unanticipated changes in the economic structure of an industry that may make what was, at one time, a source of sustained competitive advantage, no longer valuable for a firm, and thus not a source of any competitive advantage. Again, the pressure to adapt to changing circumstances is present. The problem for managers is that continuous change makes this process extremely complex, and hence a significant source of complexity. The more frequent the disturbances and “Shumpetarian Shocks” (Schumpeter 1934, 1950), and the more profound the consequence of these changes, the more complex the decision-process will be.

3.2.6 Randomness and Chance

The science of complexity suggests a focus on how random connections between people and the simple decision rules they use can lead to complex global pattern of behavior taking the form of new strategic direction and organizational renewal (Stacey 1995). According to chaos theory, these global patterns may be recognizable, but hard to predict, even in the short run and at local levels, as the weather system. The nature of organizations inhibits these nonlinear properties, and hence makes prediction very difficult, if not impossible

Anderson and Tushman (1990) shows, through an evolutionary model how random variance and technological discontinuity may enhance the process of innovation in an organization. The technological discontinuity is followed by an era of ferment, in which there is competition amongst the various designs, through social and political processes to meet the random variance. After an era of incremental change, where dominant design is chosen, there is another random variance, and so on. Anderson and Tushman (1990) found that this technological cycle is of a repetitive form, and hence of a recognizable pattern over time. Still, it is difficult, if not impossible, to know when these variances will occur, and how strong they will be. These patterns are recognizable as the patterns that can be observed in complex adaptive systems, and refers to the attractors discussed in chapter two through the butterfly effect. If one were to view a strange attractor in the well-known time series format, one would see only disorder, and hence randomness; if one views it in a topological display, its loose causal geometry is revealed.

Nevertheless, the random variance in any type of system is a source of complexity, as it creates both uncertainty and difficulties for decision-makers to forecast events in their environment. Sastry (1997) supports Anderson and Tushman's (1992) findings, based on a theoretical simulation model, derived from Romanelli and Tushman's (1985) "punctuated change model". The process of change is seen as an evolutionary process, in which stable periods of incremental adjustments and change is "punctuated" through a short period of reorientation (Sastry 1997). How these "punctuations" occur are not explained in the model. The shocks are taken as exogenous to the model and organizations trying to adapt to its environment, which can be argue to be the case in several contexts, for example as "Schumpetarian Shocks" (Schumpeter 1934, 1950), discussed in section 3.2.5 earlier. The problem is when to anticipate these kinds of random shocks, or variances. By their very nature, this can be extremely difficult, and hence is a source of complexity for managers in an organization.

3.2.7 Interaction and Interdependence between System Elements

Complexity is first and foremost a matter of the number and variety of an item's constituent elements and of the elaborateness of their interrelational structure, be it organizational or operational (Rescher 1998). As the interaction among constituent elements in a system increase, so does the complexity of the system. This can easily be seen in Kauffman's (1993) *NK* model, where *K* represents the degree of interdependence in the system, and *N* the number of constituent elements, as discussed in section 3.4.1. The interactions of system elements are by its very nature embedded in all the other sources of complexity discussed earlier, as regards to cognitive capacity that will be discussed in section 3.2.8. At a given level for all sources of complexity, as described in this chapter, there is a responding level of complexity. As the elements in a system start to interact, the complexity of the system increases. Hence, the interaction effect in a system is not a property of the elements in the system, but a property of the overall system, and the complexity associated with it, as discussed in chaos theory and complexity theory in chapter two. According to Stacey (2000: 7), "...interaction is usually thought of as constituting a network or a system and each individual organization as a component of that system.... Each individual organization is also usually thought of as a network or a system and the members, and groupings of members, in that organization as components of the system."

As described in section 2.3 and 2.4 about chaos theory and complexity theory, the elements within a nonlinear system are constantly fluctuating, and the interactions between the system elements are making chaotic patterns. Complex adaptive systems at the edge of chaos "... display the dynamics of order and disorder, stability and instability, regularity and irregularity at the same time" (Stacey 2000: 319). This would not be possible if the elements in these systems where not interacting. The same argument applies for interaction with other systems and their system elements, i.e. the interaction with the organization's environment. This interaction and function of system elements create interdependence between complex adaptive systems and between their elements.

Interdependence between system elements and systems, i.e. the organization's dependence on resources and customers, the agents dependence on each other, and the organizations dependence on coalition partners, increases the complexity of the system or organization. According to Scott (1981: 211-212), "... this dimension refers to the extent to which the items or elements upon which work is performed or the work processes themselves are interrelated so that changes in the state of one element affect the state of the other." Thompson (1967: 54-55) has proposed a useful typology for assessing the degree of interdependence. Three levels are identified: (i) pooled interdependence, in which the work performed is interrelated only in that each element or process contributes to the overall goal; (ii) sequential interdependence, which exists when there is a time-dependent sequence such that some activities must be performed before others can be; and (iii) reciprocal interdependence, which is present to the degree that elements or activities relate to each other as both inputs and outputs.

3.2.8 Understanding and Cognitive Capacity

As an item's complexity increases, so do the cognitive requisites for it's adequate comprehension, although, of course, cognitive ineptitude and mismanagement can manage to complicate even simple issues (Rescher 1998). The findings of cognitive psychology on how people make sense of the world by using partial mental models make it clear that mangers use recipes, or causal maps, that they are usually unaware of (Johnson 1987). The cognitive perspective, which is a part of the "process school" in the change literature on strategic management, is also based on the assumption that managers replace the environment with a cognitive map (Rajagopalan and Spreitzo 1997).

Insights into how strategic issues are activated can be gleaned from a wide range of research endeavors including *environmental scanning* (Aguilar 1967; Kafelas and Schoederbek 1973), *decision-making* (Cyert and March 1963; Mintzberg, Raisinghani and Theoret 1976; Downs 1967; Segev 1976), *problem-formulation* or *sensing* (Kiesler and Sproull 1982; Lyles and Mitroff 1980; Pounds 1969), and normative models of *strategic diagnoses* (Ansoff 1979; Nutt 1979). Decision-makers actively engage in attempts to understand a particular strategic issue, also called the activation of diagnosis (Dutton and Duncan 1987), i.e. the process describing what and how issues are recognized and isolated for further consideration (Mintzberg, Raisinghani and Theoret 1976). Although decision-makers often intend to act rationally, this intention may be circumscribed by their limited information processing and communication ability (Simon 1957a, 1957b). Bounded rationality is also an assumption in the transaction cost theory (Coase 1937; Williamson 1979, 1985, 1991) and principal-agency theory (Berle and Means 1932;

Eisenhardt 1989a; Fama and Jensen 1983; Petersen 1993) about decision-makers that have constraints on their cognitive capabilities and limits on their rationality (Eisenhardt 1989a; Rindfleisch and Heide 1997). Constraints on decision-makers' cognitive capacity have, in other words, been the subject in several well-known theories. What is interesting from a complexity point of view, is to see how these constraints can act as a source of complexity in the decision-process for managers.

Several authors distinguish between managerial belief structure and organizational belief structure. Belief complexity captures the breath and variety of factors, as discussed in this chapter, which are present and legitimate in a particular belief system (Brunsson 1982). Where beliefs are highly varied and complex, a high level of agreement over the broader domain is more difficult to achieve (Dutton and Duncan 1987). Managerial beliefs are critical filters that act to screen in and screen out information relevant to an issue (Beyer 1981). Organizational beliefs represent shared understanding about the relationship between objects, properties and ideas (Sproull 1981). Donaldson and Lorsch (1983) suggest that three categories are important for decision-makers to interpret situations and to make judgements about feasible courses of action: (i) beliefs about risk preference; (ii) beliefs about self-sufficiency, and (iii) vision of distinctive competence. These shared filters act as filters through which management perceives the realities facing the firm (Donaldson and Lorsch 1983).

This is a parallel to what Bettis and Prahalad (1987) call the "Dominant Logic", which is an underlying structure, or a filter, which explains why so many organizations see changes in the surroundings, but is unable to take action. The Dominant Logic, or the information filter, takes the organizations attention away from data that *seems* irrelevant, but may not be so. Thus, this is a cognitive problem, and hence a source of complexity. According to Bettis and Prahalad (1995), this fits in the domain of emergent properties of complex adaptive systems, discussed in chapter two. It is the knowledge, or rater lack of the ability to acknowledge and use relevant information that makes this dimension a source of complexity. As Rescher (1998: 16-17) notes:

> All sorts of things can be more or less complex, but the situation is particularly notable with respect to bodies of knowledge. In fact, complexity, like simplicity, pertains in the first instance to cognitive artifacts: descriptions, explanations, accounts. But this is not without its ontological repercussions. For whenever no satisfactory account of system A manages to be as simple as one that we have of system B, then we have little choice but to say that A is more complex than B. Exactly because cognition is an instrumentality of order-detection, this linkage between complexity and order means that ontological complexity issues an open invitation to cognitive complexity.... Trying to represent a complex system by models that have the conceptual rigidity required for convenient management and manipulation is like trying to wrap a ball with an inflexible board: we cannot achieve the necessary fit.... As creatures of limited capacity, cognitive complexity is of course of particular concern for us humans. Our scientific endeavor to gain understanding of the phenomena of nature confronts the challenges of complexity on every side.

Rescher (1998) refers to what he calls computational complexity, which is the amount of time and effort involved in resolving a problem, and thus the cognitive capacity and capability of problem-solvers or decision-makers to solve a particular problem. An issue that can be solved with a few minutes of paper-and pencil work is rather simple, while one that requires many hours in a super computer is vastly more complex. As will generally be the case, complexity here comes down to the demands of cognitive management (Rescher 1998). Managers are themselves part of the system, as discussed in chapter two. The other sources of complexity are what I refer to as “objective” sources. Limitations on cognitive capacity are of a considerably different nature – they are more of a “subjective” manner, and differs between decision-makers, independent of the “objective” complexity of the organization.

As Rescher (1998: 16) concludes, “...all in all then, the best overall index we have of a system’s complexity is the extent to which resources (of time, energy, ingenuity) must be expanded on its cognitive domestication. Accordingly, complexity is in general not something that is purely ontological or purely epistemic, but involves both sides. It hinges on the relationship of minds and of things – on the ways in which the former can come to term with the latter.” In other words, all the sources identified and discussed in this chapter create the overall (perceived) complexity of an organization and its environment *together*.

3.3 The Nature of Complexity

In general, complexity of one sort consorts with that of another. Thus while separable in theory, the different modes of complexity, i.e. the different sources of complexity, do tend to run together in practice. For example, systems that exhibit compositional and structural complexity will also generally exhibit functional complexity (Rescher 1998). This is also an aspect of the interaction between the system elements that constitutes the system, as described above. Rescher (1998) organizes complexity into three levels, which are organized in two main modes: Epistemic modes, which are divided in one main type of complexity – formulaic complexity that includes descriptive, generative and computational complexity. Second, there is the ontological modes, which are divided into three main types of complexity: (i) compositional complexity, which is represented by constitutional and taxonomical complexity, (ii) structural complexity, which is represented by organizational and hierarchical complexity, and finally (iii) functional complexity, which is represented by operational and nomic complexity.[6] Hence, there are two main modes of complexity according to Rescher (1998): one mode of "things", or a mode independent of the eyes of the beholder or decision-maker, and one of the "minds", which varies with the differences of decision-makers.

Rescher's (1998) approximation is based on the nature of complexity in general, and not upon the general nature of nonlinear systems and organizations. Based on the sources of complexity described above, it is possible to structure the eight sources of complexity recognized here in this respect. We have seen how the number of elements making up a nonlinear system can vary, how they may interact and create the behavior of the overall system as a whole, also together with its environment and other systems, and hence how this can affect the complexity of the system. Even so, for our purpose, such a classification of sources would be inappropriate. The eight sources of complexity described here interact at different levels, at different times or at the same time, and with different decision-makers, i.e. their function and effect varies with the *context*.

What is important to note here, is that complexity cannot arise in a situation of total anarchy, the absence of any and all lawful order – the ultimate of cognitive defeators (Rescher 1998). Emergence and stabilization require order. By contrast, chaos exhibits a high degree of

[6] See Rescher (1998) page 9, Table 1 for further description.

order, albeit order of a particular and distinctly stochastic kind. Here complexity not only can emerge but is indeed even bound to do so. For the very presence of randomness will bring distinctive forms of order in its wake (Kaufmann 1995). Agents should seek the ability to see and understand these patterns in complex adaptive systems, beyond their cognitive constraints.

3.4 Summary

This chapter have discussed eight sources of complexity; (i) number of constituent elements, (ii) variance in system elements, (iii) lack of lawful regularity, (iv) uncertainty, (v) change and the speed of change, (vi) randomness and chance, (vii) interaction and interdependence between system elements, and (viii) understanding and cognitive capacity. These sources of complexity tend to run together, and affect the overall complexity of an organization as a complex adaptive system. All sources may be said to be of the same nature, except for one; understanding and cognitive capacity. This last source of complexity is a specific characteristic of agents, which is also a part of complex adaptive systems, but at the same time capable of changing the direction of the systems together with other agents. The way these agents *perceive* the complexity of the system, may affect the behavior of agents, and hence the systems they operate in.

4. The Management of Complexity

4.1 Introduction

Where the real things of the world are concerned, we not only expect to learn more about them in the course of scientific inquiry, we expect to have to change our minds about their nature and modes of comportment... None can ever manage to tell us everything there is to know about something real – none can say all there is to be said. And this means that our knowledge of reality is incomplete – and invariably so, now or ever. The real has an inner complexity that is human inexhaustible and the range of fact inevitably outruns that of articulable truth...

Rescher (1998)

Throughout history managers have, more or less consciously, been concerned with the challenge of complexity and how to overcome the problems concerned with it. Perceiving organizations as complex adaptive systems have profound implications for decision-makers. How are they to manage in this world of complexity? In this chapter I will make some suggestions on how to manage the complexity of organizations. There is a need to integrate what has been revealed in the research area of strategic management theory and organizational theory, and to expand the perspectives further. Traditionally, these perspectives are built upon the notion that strategic management should reduce the level of uncertainty, diminishing the element of surprise in the development of an organization. The complexity theory framework, however, poses a different question (Stacey 1995): how should managers behave in the presence of irremovable, indeed desirable, uncertainty, surprise, unknowability, and open-endedness?

This chapter starts with a more thorough explanation of the concept of *self-organization* in organizations as complex adaptive systems, as discussed in chapter two. The capacity to self-organize is a property of these systems, and one possible way in which an organization can respond to the overall complexity, both within the organization and the environment, on a local basis. Furthermore, three key mechanisms to manage the sources of complexity are discussed. These are (i) strategic flexibility, (ii) organizational structure, and (iii) information processing capabilities. The implications for managers using these mechanisms in organizations then suggest how managers should act and organize in order to manage the complexity of systems. Finally, the chapter ends in a discussion of limitations, and suggests topics and pathways for future research.

4.2 Self-organization

Self-organization is a property of complex adaptive systems, as discussed in chapter two. These systems create patterns and order through the attraction or active relationship of the variables constituting the complex adaptive system. This is self-organization; the process in which local interaction between agents produces emergent global patterns, the process of continuously changing patterns, the movement from one attractor to another, and the internal capability to create new ones. Patterns, or structures shaped by complex adaptive systems are independent of scale, and can thus be traced whatever horizon is used to view it. These images of patterns within patterns are termed fractals when they are generated by chaotic systems (Levy 1994).

Self-organization is not easily pinned down from chaos theory and complexity theory into organizational language. It may be helpful to explain what self-organization is not, in order to explain what it might mean in an organizational context. The different aspects are summarized in Table 5.1.[7] Self-organization is *not* something that just happens. It does *not* mean that the agent can just wait for destiny to take its course. Everything the agents do, including nothing, affects the pattern of the overall system in one way or another. It is the interaction of the agents on a local basis that co-creates the overall pattern or structure of communication of the global organization. Self-organization does not mean that all agents are equal and have the same influence, i.e. empowerment at lower echelons and disempowerment at higher echelons, which would lead to full democracy and consensus around every issue.

What self-organization is *not*...	**What self-organization *is*...**
• something that happens, no matter what anyone does	• everything one does, including nothing, has potential consequences
• waiting for fate or destiny	• co-creation of all interacting agents
• full democracy; all agents are equal	• not all agents are equal, some pursuing more powerful strategies
• nothing is done without consensus	• no requirement for consensus; tension between competition and cooperation
• anarchy	• agents constrained by other agents
• empowerment in lower echelons	• no connection between empowerment and self-organization
• disempowerment in higher echelons	• no connection between disempowerment and self-organization

Table 4.1 Self-organization

[7] Table 5.1 is based on Stacey (2000: 333-334).

Not all agents are equal. As discussed in section 3.2.2, agents may be heterogeneous, and this characteristic about agents operating in the organization is both a source of complexity, but is also at the same time a property of the system that makes it able to self-organize into different structures, as will be discussed later under conditions for self-organization. The power and knowledge varies between agents, and leads to tension between competition and cooperation in the organization. On the other hand, self-organization is not anarchy either. The agents in the organization are constraining and being constrained by other agents.

It is the overall pattern of relationships between agents that is organizing itself in an organization, at the same time as the nature of the agents is changing (Griffin 1998). It is the structure of the organization and its agents that change through self-organization. The agents are forming and being formed by the overall pattern of relationships. The system and its agents are emerging together, simultaneously constraining and being constrained by each other (Stacey 2000). Thus, “it is not necessary to understand the whole in order to act; it is simply necessary to act on the basis on one’s own local understanding” (Stacey 2000: 411). If a CEO communicates to many others in his or her organization, and “if they responded according to their own local capacities to respond, and their responses had some effect on the CEO, leading to new correspondence from the CEO, then this would be self-organization” (Stacey 2000: 335). In an empirical study, Mahon (1999) found that an Internet Service Provider self-organized through self-organizing activities as informal conversations and action between people, who took it upon themselves to develop the new business without really knowing where it was going. In other words, the business unit was self-organizing, there was no overall blueprint for the members to follow during the process.

Conditions for Self-organization

Mahon (1999) identified the conditions under which the strategy emerged in an Internet Service Provider at Tele Danmark, a European operating telephone company based in Denmark. First, there was the *mess of variety* in which new approaches were tried in the absence of any firm knowledge of where they might lead. This variety was destabilizing but essential to creativity and innovation. Another form of mess was *redundancy*. Redundancy here means slack resources, multi-tasking and loose coupling. Multi-tasking may be obtained through the central function of administration, which is to keep the organization at the nexus of several streams of action; and because the several streams are variable and moving, the nexus is not only moving but also sometimes quite difficult to fathom (Thompson 1967). This loose coupling and ability to perform multi-tasking, combined with slack resources, imparts flexibility on the organization, and is a way of coping with the complexity created by complex adaptive systems, as discussed in section 4.3.1.

The configuration necessary for survival come neither from yielding to any and all pressures nor from manipulating all variables, but from finding the strategic variables (Barnard 1938). These are the variables that are available to the organization and can be manipulated in such a way that interaction with other elements will result in a viable co-alignment (Thompson 1967). The paradox of self-organization becomes clear as we see that the interaction and interdependence between these system elements at the same time as making the system complex also makes it possible for the system to self-organize. According to Mahon (1999), the informal activity upon which the development of the new business depended could not have taken place without resource slack. It is the mess of redundancy that imparts enough stability and robustness to the system. Hence, the importance of *experimentation* and the resources to do so was essential in the emergent strategy of the business unit. Rescher (1998: 189) also points to the importance of experimentation in highly complex situations, but also to the importance of decentralization:

> The fact is that in situations of unmanageable complexity, practice in matters of public policy is often guided more effectively by localized experimental trial-and-error than by the theorizing resources of an intellectual technology unable to cope with the intricacy of interaction feedbacks and impredictable effects.

Chandler (1962) argues that organizations adapt their structures to handle constraints and contingencies. Here decentralization plays a major role. According to Thompson (1967: 78), "... the decentralized version is, of course, conditionally autonomous, with central headquarters providing some of the premises for decision and, usually, some resources including financial and research." By allowing managers to rearrange resources between corporate modules, the central corporate headquarter imposes constraints upon the different divisions, at the same time as removing some of the uncertainty for each division as a part of a larger system. Decentralization of responsibility give the agents in the organization the freedom to experiment and make their own local decisions more efficient as the interaction between agents become more elaborate. At the same time decentralization works as a constraint on local agents interaction and actions in the sense that their local responsibility increase.

However, the efficiency of decentralization and experimentation could not have taken place without a constant flow of energy and information throughout the system (Sanders 1998). Several authors focus the attention to the importance of trust in organizations so that effective and efficient communication among agents are possible (Allison and Kelly 1999; Lissack and Roos 1999). Axelrod (1984) and Macneil (1980) also point to the importance of trust in inter-organizational relationships. Trust in complex adaptive systems should be present as a mechanism of survival (Axelrod 1984). Stacey (2000) also stresses the importance of trust between participants in an organization. Trust makes it possible for participants to seek new meanings, and thus change the presence. With a comfortable level of trust, the level of anxiety is reduced so that this can be achieved.

The size and the structure of the organization reflects both the number of agents operating in it and their various properties. The self-organizing capacity of the organization depends both on the number of elements operating in the system and their various capacities to respond on a local basis. Hence, the capacity to self-organize is related to the understanding and cognitive capacity of individuals and their human knowledge operating in the system. This should not be interpreted as the capacity of the system to self-organize increases with the number of agents operating in the system. It only means that the global patterns created by interaction of local responses between agents will emerge differently, and hence may create other patterns.

Self-organization and Management of Complexity

Under conditions of high complexity, the capacity to self-organize is a way of responding to the overall complexity in the internal and external environment, i.e. both within the organization as well as to complexity in other systems. This is the very essence of complex adaptive systems, as discussed in chapter two. Prediction of the behavior of complex systems is by their very nature at best difficult, if not impossible. Still, the agents in the system respond according to their own local capacity to respond, and in doing so, interacting to other's responses, they self-organize. Based on chaos theory and complexity theory, together with what is referred to as relationship psychology, Stacey (2000) has developed the theory of human complex responsive processes, which is the analogue to an organization as a complex adaptive system. This is not a prescriptive theory, as strategic choice and learning organization theories, but rather a descriptive theory. What makes this theory valuable is its ability to refocus attention on the quality of participation, conversational life, diversity, unpredictability and paradox (Stacey 2000). Through the theory of human complex responsive processes emphasis is on the quality of participation in self-organizing conversations from which management choices and the responses to them emerge.

According to Sanders (1998), the challenge of solving the complexity of complex adaptive systems is to find a way to engage our visual processing abilities to see and understand the multiple complexities – the unseen relationships, connections, and patterns of interaction – that are creating the dynamics of the real world in which our decisions are being made, i.e. increase the ability to absorb information and see the patterns underlying the surface of complex adaptive systems, as discussed in section 4.3.3.[8] Consensus around some picture of a future state removes the chaos which changeable systems must experience if they are to innovate (Stacey 1995).

In situations characterized by great complexity, trying to figure out what to do may simply be impractical, due to the lack of resources, for example in time and cognitive capacity. Rescher (1998: 189) suggests one way decision processes in complex environments can be managed:

> ... here, often as not, the best strategy is to let "matters run their course" and use the observation of its processes as a guide for the formation of our policies and programs. Where calculation based on theory is impracticable, the best we can usually do is to keep an eye on the broad tendencies of the case and let the course of experience be our guide in responding to them... In circumstances that are incalculable for us because of excess complications, or where the requisite data cannot be had on a sufficiently timely basis, such a resource to the practice of "watchful waiting," of simply seeing how the mattes work themselves out when left to their own devices, is a variant of sometimes highly useful cognitive resources.

Hence, self-organization seems to be one central mechanism for managing complexity on a local basis, and should not be underestimated as a course of action, even though this is not something the members of an organization can choose explicitly. Self-organization emerges, it creates the organizational structure or patterns of communication as a consequence of the interaction between employees. Managers can set constraints, for example through the commitment of resources, together with other agents in the organization. What Mahon (1999) finds in his empirical study is that being "poised at the edge of chaos" not so much is a matter of doing certain things, rather than a matter of having the right circumstances to make *uncertain things happen*. Rescher (1998: 201) suggests that "... life in a realm of complexity... deserves emphasis – and reemphasis – that the answer to the question of how to conduct life in a complex world is: very carefully."

---

[8] Sanders (1998) have developed what she refers to as a "FutureScape", which may be explained as a form of advanced mind-map technique to create a picture of the future. See Sanders (1998: 157-158) for an explanation.

Self-organization and the manager

From a complexity perspective it may seem that in a world of complex adaptive systems there is little point in making choices concerning the direction of the organization. The manager is a participant in the system and not an objective observer standing outside the system, as discussed in chapter two. On the other hand, some agents in a system do tend to have the capacity to respond more effectively and efficiently than others according to their own local principles of interaction, which means that they have more knowledge, more understanding and more power than others. Stacey (2000) does not argue that senior executives do not, cannot, or should not make strategic choices. On the contrary, "... they do, they can, and they should. What I am arguing is that these choices are gestures out of which the evolution of organizations emerges" Stacey (2000: 413). Thompson (1967: 142-143) also notes that in complex organizations there are the possibility of human individuals being more powerful than others, but that these figures alone are in no way capable of being in "control" of the organization, or its preferred direction:

> It seems clear, then, that in the highly complex organization, an individual can be powerful, can symbolize the power of the organization, and can exercise significant leadership; but we would predict, as in the case of the inner circle, that he can do so only with the consent and approval of the dominant coalition. Thus the highly complex organization is not the place for the dictator or commander to emerge. In the highly complex organization, in our opinion, neither the central power figure nor the inner circle (nor their combination) can reverse the direction of organizational movement at will.

This is one of the principles of self-organization in complexity theory in which emergence of new strategies are the result. Effective managers then "... are those who notice the repetitive themes that block free-flowing conversation and participate in such a way as to assist in shifting those themes... Effective managers will seek opportunities to talk to people in other communities and bring themes from those conversations into the conversational life of their own organisation" (Stacey 2000: 408), thus, increasing the flow of energy and new information into the system. Managers then should be aware of the principles of self-organization, and how their behavior and interaction with other agents in the organization creates new emergent structures as a response to the overall complexity. This awareness – the understanding of system properties and conditions for self-organization, is a key to manage all sources of complexity at all levels, at the same time.

4.3 The Management of Sources of Complexity

The perspective presented earlier draws on a rather radical perspective on organizations as complex adaptive systems, taken from chaos theory and complexity theory. Chapter three discussed eight sources of complexity derived from this perspective. Together with self-organization, these sources are the key to understand how to *participate* as a manager in organizations as complex adaptive systems, because even if the challenge is to manage the sources of complexity, the manager is not in control of the organization as would be expected form a traditional strategic management perspective, as discussed in chapter two. The framework described here draws on theories from several disciplines, from physics, biology, psychology, organizational theory, strategy and finance. When using these theories to build a framework for managing sources of complexity, there is always the possibility of using theories that are incompatible, building on contradictory assumptions. The awareness of this possibility will, hopefully, make it possible to avoid the fallacies associated with this integration.

4.3.1 Strategic Flexibility

If organizations are to survive in high velocity markets with great complexity, both human mind and organizational structure must be flexible. Even though there are differences in definitions of strategic flexibility, most definitions involve *a firm's alignment to changing environmental conditions* (Evans 1991; Sanchez 1993, 1995; Volberda 1996). The concept of flexibility, at least in an organizational context, "...refers to the ability to precipitate intentional changes, to continuously respond to unanticipated changes, and to adjust to the unexpected consequences of predictable changes" (Bahrami 1992: 36). This fits very well in the domain of complex adaptive systems, as discussed in chapter two and the previous section about self-organization.

According to Evans (1991), terms related to flexibility are *adaptability* (repositioning to deal with a new environment; a property of complex adaptive systems), *agility* (ability to move rapidly; a property of complex adaptive systems), *versatility* (able to do different things and apply different capabilities depending on needs of the organization, i.e. multi-tasking; a condition for self-organization), *robustness* (ability to absorb, deflect or endure the impacts of unanticipated changes; i.e. a propery of self-organization), and *liquidity* (assets that readily can be turned into rebound or recoil, showing recuperative power, and the capacity to withstand shocks without permanent damage, i.e. slack resources; a condition for self-organization in complex adaptive systems).

Volberda (1996) distinguish between four types of flexibility: *steady-state*, *operational*, *structural* and *strategic* flexibility (Ansoff and Brandenburg 1971), and argues that organizations should apply an appropriate mix between these types of flexibility. Each type represents a simple combination of more or less variety of capabilities and fast or slow response, as depicted in Figure 4.1. In complex adaptive systems both the potential of high variety and high speed of change is present. Hence, it is first and foremost the move towards strategic flexibility that is desirable in organizations as complex adaptive systems, even though other types, as structural and operational flexibility also may be useful.

However, strategic flexibility implies both structural and operational flexibili-ty, and hence is a natural extension of these types of flexibility. Steady-state flexibility "... hardly seems to be a real type of flexibility, because under steady-state conditions there is only minor change... and speed of response to external conditions" (Voldberda 1996: 362). Operational flexibility consists of routine capabilities, and promotes rapid responses to changes that are familiar and environment is predictable. Structural flexibility concerns the ability to adapt to uncertain environment in an evolutionary way. Strategic flexibility denotes the ability of the firm to fundamentally renew its strategies, and should be applied in hypercompetitive en-

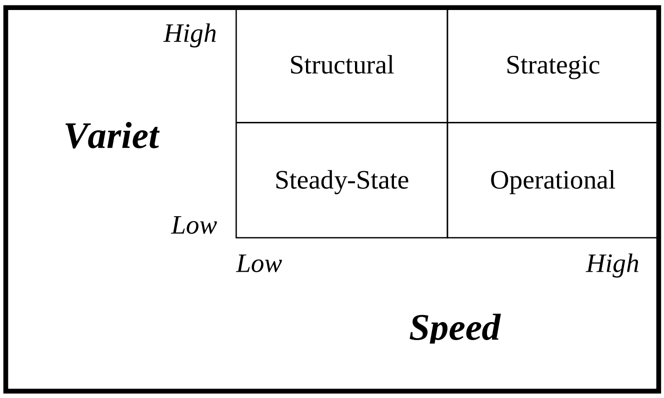

Figure 4.1 Types of Flexibility

vironments where the organization must be partially or completely transformed.

Conditions for Strategic Flexibility

Four categories of flexibility often act as building blocks in approaches to strategic flexibility (Lunnan 1999). These are (i) *resource flexibility* (Cyert and March 1963; Evans 1991; Leonard-Barton 1992; Sanchez 1995; Winter 1987), (ii) *technological flexibility* (Aggarwal 1995; Fiegenbaum and Karnani 1991; Gerwin 1989; Richardson 1996; Suarez, Cusumano and Fine 1995; Upton 1995), (iii) *organizational flexibility* (Eccles and Crane 1987; Hedberg 1997; Lipnack and Stamps 1997; Miles and Snow 1992; Mintzberg 1979), and (iv*) labor flexibility* (Atkinson 1985; Harrison 1994). Thus, to gain strategic flexibility, other parts of the organization must contribute on an equal *flexible* level. Lunnan (1999) identifies at least three common dimensions that are present in these building blocks: In general, a unit is more flexible if its activity level and overall volume can vary, it can be put to use in many different application areas, and if it has or creates alternatives. A unit here may for example refer to a worker, a resource, a technology, or an organization, and is only a matter of level of analysis, or level of description, as discussed in section 3.2.2.

Lunnan (1999) moderates the definition of strategic flexibility and identifies three main approaches to achieve flexibility for the overall organization, or strategic flexibility; (i) strategic flexibility as maneuvers, (ii) strategic flexibility as repositioning, and (iii) strategic flexibility as options. *Strategic flexibility as maneuvers* includes reacting to smaller changes as well as restructuring all major activities as a response to major shocks, together with the ability to align internal structures to prepare for or adapt to external pressure (Evans 1991). There is nothing in this perspective which can not fit in the domain of strategic flexibility as repositioning. It is just a matter of detail. Hence, strategic flexibility as maneuvers and strategic flexibility as repositioning should be understood as one type of strategic flexibility, at least in organizations as complex adaptive systems, as discussed in the next section.

Strategic Flexibility as Repositioning

Taken to the extreme, strategic flexibility is only viable under conditions of hypercompetition, or in situations where the environment is fundamentally unpredictable, dynamic and complex (DÁveni 1994).[9] This is a rather radical perspective of the concept of strategic flexibility. Complex adaptive systems inhibit the capacity to self-organize, as discussed in section 4.2. This does not mean that they are chaotic, but that they inhibit the properties of chaotic systems, as discussed in chapter two. Thus, strategic flexibility should be understood as an ability to change the structure or pattern of the organization. One way of building such strategic flexibility as repositioning is through patching, which is the strategic process by which corporate executives remap businesses to changing market opportunities (Brown and Eisenhardt 1998, 1999). At its core is the ability for managers to reconfigure resources in the organization at the right scale to address shifting market opportunities. It is a well of small changes of the organizational structure more than reorganizations, which may take the form of splits and additions, combinations, transfers and exits. Patching is relevant in high-velocity, intensely competitive industries. According to Brown and Eisenhardt (1999: 78), "... the uncertainty of a market also affects optimal patch size. As a focus of thumb, more turbulent markets favor focus and agility – and hence small size – whereas more static markets favor economies of scale – and hence large size."

Conditions for Strategic Flexibility as Repositioning

What is important is that the company's infrastructure supports the process of patching. The essence is what is referred to as modularity. Sanchez and Mahoney (1996) argue that strategic flexibility is obtained through modularity in both product designs and organizational designs. By standardizing component *interfaces*, they argue that management time and resources can be greatly reduced, and that learning is stimulated both within the different components and in coordination between these modules. The corporation is seen as a collection of modules, or building blocks, that constitutes the organization. The lesser these modules share of common resources, the more flexible the organization will be, and hence have the opportunity to exploit new market opportunities. A patching company's business units need to be focused and discrete so that they can be combined seamlessly. A complicated organizational structure – in particular, one with lots of shared services or cross-business committees – will slow patching down (Brown and Eisenhardt 1999). Thompson (1967) suggests that modules in organizations designed especially for flexibility and adaptability, may be under such labels as

---

[9] See Special Issue of Organization Science (1996) on hypercompetition.

task force or project management, divided into homogenous group for "housekeeping", but deployed into task forces for operational purposes.

If the organization or its representatives are to be able to interact, or "contract" with elements of the task environment (Hawkes 1961), the organizational recourses and the managerial layers must afford capacity – and deliverable or unfrozen capacity (Thompson 1967; Mahon 1999). As opposed to operational management literature, which stresses the importance of streamlined organizations without slack resources (Eppen, Gould and Schmidt 1993; Chambers, Harrison, Harland and Slack 1997), organizations operating in high volatile markets and exposed to a high degree of complexity should quite contradictory enforce slack resources on the organization. To be able to meet the unexpected future under conditions of great complexity, slack resources is necessary to make the organization strategic flexible. Still, strategic flexibility is not an easy attribute to manage in an organization operating under conditions of fast changing environments. There are several issues to consider (Thompson 1967: 150):

> The paradox of administration, the dual searches for certainty and flexibility, to a large extent revolves around the dimension of time. In the short run, administration seeks the reduction or elimination of uncertainty in order to score well on assessments of technical rationality. In the long run, however, we would expect administration to strive for flexibility through freedom from commitment – i.e., slack – for the larger the fund of uncommitted capacities, the greater the organization's assurance of self-control in an uncertain future.

Strategic Flexibility as Repositioning and Management of Complexity

The flexibility created by business modules means that speed of change and change in general, together with uncertainty, is of less importance. The organization has the ability to continuously create new structures, which is a property of complex adaptive systems. For example, the administrative hierarchy, often described as "channels", appears to be a dual-purpose mechanism, progressively eliminating or absorbing uncertainty (March and Simon 1958), as we move from higher to lower levels, and progressively affording flexibility as we move from lower to higher levels (Thompson 1967). In organizations as complex adaptive systems these levels refers to different levels of details. As Thompson (1967: 149-150) argues, the implications for strategic management should not be one of a chief executive that makes all the decisions:

> ... administration is not something done by an administrator except in the simple organization, but instead is a process flowing through the actions of various members. Also from this point of view, administration is not something done at one level in the organization, but is a process spanning and linking levels. Finally, from this point of view, administration is not a process which simply flows down from one level to the next, but a process related to the interaction of levels and components.

Hence, the organization of systems as modules, and the repositioning of these modules – the emergence of new structures in the organization – is a way of responding to several of the sources of complexity identified in chapter three. Strategic flexibility as repositioning reduces the importance and influence of uncertainty, change, lack of lawful regularity, randomness and chance. It also may contribute to the ease of interaction and lower the interdependence between system elements. At the same time, strategic flexibility as repositioning creates opportunity for change and the ability to self-organize.

Strategic Flexibility as Options

According to Levy (1994), long-term planning in chaotic systems is impossible, and should therefore take into account a number of possible scenarios, rather than expend large amounts of resources on forecasting. Levy (1994), amongst others, points to the danger of focusing too much on a firm's core products and markets, as will reduce the ability of the organization to adapt and be flexible in the face of change. Joint-ventures and the acquisition by large firms of stakes in entrepreneurial enterprises are mentioned as examples of attempts to keep a foothold in a number of potential scenarios in the face of uncertainty and accelerating change in highly complex environments.

According to Emerson (1962), dependency between organizations is an attribute of organizational *relationships*, and not an attribute of the organization itself. The environment is defined by the dependence of the organization, which introduces both constraints and contingencies, such that the problem for the organization is to avoid becoming subservient to elements of the environment (Thompson 1967). Organizations seek to minimize the power and influence of elements operating in the environment by maintaining alternative possibilities (Thompson 1967). Ansoff (1965: 66) argues that aggressive flexibility can be measured as participation in areas of technology that are in ferment, stressing the innovative aspect of flexibility in investing in real options, because "... even if the firm does not make the actual breakthrough, ...it can exploit expeditiously and intelligently breakthroughs made by others." Real options are defined by Myers (1977) as the firm's opportunities for growth.

Hence, under conditions of complexity, organizations should invest in real options, which reasoning speaks to classes of investments in real assets that have a similar structure and investment logic as do investments in financial options (Dixit and Pindyck 1994). Initial investments create the right but not the obligation to participate in future opportunity (Dubini and McGrath 1999). The often-substantial follow-on investments to capture the opportunity are usually referred to as investments in exercising the real option (Trigeorgis 1997). Managers invest in real options not because they are acting as rent-or-profit seekers alone, but because they recognize the option potential inherent in investments with high variance in expected outcomes (Mitchell and Hamilton 1988; Bowman and Hurry 1993; Dixit and Pindyck 1994; Trigeorgis 1997; McGrath 1997; Kumaraswamy 1996). The flexibility value of a strategic option is described as "... the extra value expected from being able to take advantage of revision possibilities it offers as opposed to persisting with it through thick and thin" (Ghemawat 1991: 116). According to the empirical findings of Dubini and McGrath (1999), option potential can play an important role in securing resource commitment for uncertain projects, even after the project's potential for generating rents is taken into account.

Conditions for Strategic Flexibility as Options

At the same time as investments in strategic options creates flexibility for the future and opportunities for growth, commitment to some options over others at the same time generates dependence on the past, i.e. a path-dependency (Bowman and Hurry 1993). Hence, even if these options create flexibility, they do so only up to some point where commitment to future projects are made within the organization. This is one of the paradoxes concerning strategic options. Still, contrary to the new industrial paradigm and game theory (Brandenburger and Nalebuff 1995; Camerer 1991; Shapiro 1989; Sorgar 1997), organizations operating under conditions of great complexity should not make strong and credible commitments, but should instead enhance the strategic flexibility of the organization through investments in strategic options.

According to Scott (1981: 222) “... one way to manage greater task complexity is not to subdivide the work and parcel it out among differentiated work groups or departments, but to confront the complexity with more highly qualified and flexible performers – with professionals. This response is particular effective when: (1) the work is also uncertain, a condition that mitigates against subdivision; and (2) the work does not involve high levels of interdependence among workers.” Since unpredictability implies that results cannot be known in advance, the quality of actions is often used as a basis for judging the quality of these outcomes and the decisions one thought made them possible. If uncertainty makes judgement of outcome quality impossible, other measures have to be interpreted, like the quality of actions leading to outcomes. According to Stacey (2000: 410), “... in a highly uncertain world a quality action is one that keeps options open for as long as possible. A quality action is one which creates a position from which further actions are possible."

Strategic Flexibility as Options and Management of Complexity

Barlett (1993) critiques the option approach by pointing to problems of applying a financial concept to a largely human process. He argues that "... developing company-specific capabilities involve much more than simply acquiring and assembling different packages of inputs; it requires the development and management of complex linkages of various assets and resources through organizational routines that are particular to the specific application" (Barlett 1993: 296). Hence, the human mind also needs to be flexible, which implies new learning or actions. Perhaps the most important aspects of learning is unlearning, which happens far from an equilibrium state. The system and its agents must operate in unstable environments to innovate. However, in these environments the ability to unlearn and learn does not guarantee success due to the several sources of complexity discussed in chapter three, as lack of lawful regularity, randomness and chance, uncertainty, change, and interdependence. Hence, investments in strategic options will create opportunities for the future, and reduce the impact of these sources of complexity, even if the conditions alter, together with the value of the strategic options.

Strategic Flexibility and Complex Adaptive Systems

There is one problem associated with strategic flexibility and organizations as complex adaptive systems. It is the view and assumptions of the manager, and his or her ability to easily alter conditions and structures in the organization. In complex adaptive systems, managers are seen as participants in the system, and not as an objective observer standing outside controlling the actions of other agents. Even if the manager may have a greater influence on the behavior of the organization, it is the overall pattern of *interaction* with other agents that determine the emergent structure of the system. The manager can not easily change the structure of the organization using "building blocks" to reposition the structure to meet new demands in turbulent markets entirely on his or her own. However, there is nothing contradictory in doing this in complex adaptive systems. It is the *process* by which the strategic flexibility is achieved that differs between these views, not the strategic flexibility itself. In organizations as complex adaptive systems the emerging structure of the organization, the interaction between the manager and other agents set the pace for how strategic flexibility can be achieved. The same principles apply when gaining strategic flexibility through investments in strategic options, which create opportunities for growth in the future.

4.3.2 Complexity and Structure

Increasing or decreasing the number of constituent elements, as well as changing the variance between system elements, can alter the structure of an organization. By increasing the overall number of constituent system elements in an organization it grows, and hence, the overall complexity in the organization increases, as discussed in section 3.2.1. One important reason why complex organizations grow, for example through mergers and acquisitions, is to incorporate what otherwise would be serious contingencies (Thompson 1967). This is what is known as *vertical* or *horizontal integration*, and is a major way of expanding organizational domains.

In an empirical study, Klein (1989) shows that high levels of environmental complexity encourages exporters to exert high levels of vertical control, whereas environmental dynamism (i.e. the rate of change) encourages exporters to exert lower levels of control. Environmental uncertainty is a multidimensional construct, as discussed in section 3.2.4, and firms are hesitant to adopt a hierarchical governance structure when this uncertainty entails risks of either unfamiliar operating environments or technological obsolescence (Rindfleisch and Heide 1997). From this perspective, overall complexity may seem to encourage integration, whereas uncertainty at the same time encourages the opposite. There are forces pulling in opposite directions, which make this distinction difficult to evaluate. Pfeffer and Salancik (1978: 139) summarizes the advantages of growth and size to an organization:

> Organizations that are large have more power and leverage over their environments. They are more able to resist immediate pressures for change and, moreover, have time in which to recognize external threats and adapt to meet them. Growth enhances the organization's survival value, then, by providing a cushion, or slack, against organizational failure.

Organization uses bridging strategies – bargaining, contracting, cooptation, joint ventures, mergers, acquisitions, associations, governmental connections, and institutional linkages – to enhance their security by increasing the number and variety of linkages with competitors and exchange partners (Scott 1981). However, at the same time as reducing the impact of the environment, the organization imposes complexity on itself by introducing new elements into the system, and increase the interaction and interdependence effect discussed in chapter three. The increasing complexity of the task environment is adapted to by increased structural complexity – differentiation – on the part of the organization (Scott 1981).

Meyer and Rowan (1977: 350-352) argue that organizations which exists in highly elaborated institutional environments enhance their own chances for survival and resource acquisition by adhering closely to the institutionally defined patterns, by incorporating them in their own structures, by becoming structurally isomorphic with them and hence gain the legitimacy needed to survive, i.e. by adaptation. With an increasing number of elements with varying properties interacting with the existing elements in the organization, the overall complexity increases, as discussed in chapter three. According to Pfeffer and Salancik (1978: 43), ”... the typical solution to problems of interdependence and uncertainty involves increasing coordination,” as will be discussed in section 4.3.3. The organization becomes too complex to manage, and must then be reduced into smaller units and responsibility shared away to lower levels, hence introducing multidivisional forms (Chandler 1962). Thompson (1967: 70) suggests that:

> ... if adjustments or adaptability is the hallmark of boundary-spanning components of organizations, we would expect that fact to be reflected in the number and nature of the units established to handle boundary-spanning matters. Generally, we would expect the complexity of the structure, the number and variety of units, to reflect the complexity of the environment.

Structure and Complex Adaptive Systems

The same argument discussed in the previous section concerning strategic flexibility is also valid on organizational structure and complex adaptive systems. Organizations *choose* formal structures to guide their formal flow of information. However, how did this structure evolve in the first place? Organizational structures emerge continuously through interaction between its agents. It is the view on process and behavior of the system that differ in complexity theory from the perspectives discussed in this section. Still, formal structures and coordinating principles in organizations are a part of the overall system, and is also important in understanding the dynamics of organizational life. Formal structures constrain agents and their interaction with others, also in the informal system of interaction. It is the tension between these systems that creates the energy and information flows in the system so that new strange attractors can be created. This dimension is discussed more thoroughly in chapter five.

4.3.3 Information Processing Capabilities

Along with the roadway of technological progress, ever more tracks branch off before us into different sectors of the realm of possibility. More choices means more decisions which require more information... Our best available judgements – not only as to the actualities of things but also as regards their plausibilities and probabilities – will always be conditional judgements formed in the context and against the background of the then-available information as best we can determine it. And in this sphere future changes are presently unforeseeable...

Rescher (1998)

The complexity of a system increases the amount of information that must be processed during the course of a task performance (Scott 1981).

Thus, as complexity increase, “structural modifications need to be made that will either reduce the need for information processing, for example, by lowering the level of interdependence...” or “... increase the capacity of the information processing system, by increasing the channel and node capacity of the hierarchy or by legitimating lateral connections among participants” (Scott 1981: 233). As discussed earlier in section 4.2 about self-organization in complex adaptive systems, access to new information through interaction between agents is also a condition for self-organization. Thus, the ability to efficiently process information lies both at the level of the organization *and* the individual agent at the *same time*, and may have an important impact on the emergent strategies of the organization.

Information Processing Capabilities at the Organizational Level

Galbraith (1973, 1977) has usefully argued that one way in which the varying kinds of demands made by technologies on structures can be summarized, is to ask how much information must be processed during the execution of a task sequence. He argues that information requirements increase as a function of increasing diversity, uncertainty and interdependence of workflows. Using this simple formula to gauge information processing demands, Galbraith (1973, 1977) then outline a series of structural modifications organizations can make as a means of adapting to increased demands for processing information. Beginning with the simpler structures and moving to the more complex forms, nine structures may be employed to manage the workflow (Galbraith 1973, 1977). These are (i) rules and programs, (ii) schedules, (iii) departmentalization, (iv) hierarchy, (v) delegation, (vi) slack resources,

(vii) self-contained tasks, (viii) augmented hierarchies, and (ix) lateral connections.

Some of these structures were discussed in section 4.3.2, and also how the increase or decrease in the number of elements constituting the organization could alter the complexity of the system. Here, focus is on how these structures may alter the need for information, or increase the capability of processing more information. The last three of the above mentioned structures are all coordination mechanism to increase the organization's capability of managing increased information flows. The first six structures are first and foremost coordination mechanisms to reduce the information-processing demands required. Mechanisms for managing complexity should not be seen isolated. One mechanism for managing complexity affects the impact of other mechanisms in the system. Reducing the number of constituent elements and/or their variance – for example through divisionalization and delegation – in a system also reduces the interaction and interdependence effects of the overall system, and hence the need for information in the system.

As suggested by Galbraith (1973, 1977), lateral connections increase organizations' ability of processing information. Organizations group positions to minimize coordination costs. It is the task of structure to facilitate the exercise of the appropriate coordinating processes. Because first groupings do not entirely handle interdependence, organizations link the groups involved into higher-order groups, thus introducing further discrimination in the system (Thompson 1967). These distinctions between linked levels in the organization serves to make complexity manageable by furnishing the bonding glue that enables enduring complex structures to be realized and present (Rescher 1998).

Organizations may inhibit three distinct levels of responsibility and control – technical, managerial, and institutional, as suggested by Parsons (1960). Reducing the number of constituent elements comprising a system not only reduces the complexity at the level of reduction, for example the resources deployed at the technical core, as discussed in chapter three, but also the complexity of the overall organization. Another coordinating mechanism in organizations is the *matrix* form, which allows professionals to move back and forth between different projects in an organization (Miles and Snow 1992). However, it is really just a more flexible and decentralized version of the divisionalized structure; for example, a matrix structure can be imposed within a division.

Conditions for Enhancing Information Processing Capabilities

According to Thompson (1967: 9), "... to deal with situations of such great complexity, the organization must develop processes for *searching* and *learning*, as well as for *deciding*." Searching and learning processes is complementary and incorporated into the theory of organizations as complex adaptive systems. Members of the organization, in which emergent structures arise, should continuously search for information. There is nothing contradictory in doing this as well as for making decisions. It is the responses to these decisions managers and other members of the organization finds difficult to anticipate and control (Stacey 2000). The learning process continues as additional data are added to the context, and as new contexts prevail (Rescher 1998: 167-170):

> In any and every domain, the rational resolution of problems is highly context-sensitive to the information in hand in such a way that what is a patently sensible and appropriate resolution

> in a given data-situation can cease to be so in the light of additional data, but simply augments it. Often as not, additional ramifications complicate matters by destabilizing seemingly obvious resolutions. For exactly what qualifies as the most rational resolution of a particular problem of belief, action, or evaluation is bound to depend upon the precise content of our data about the circumstances... All we can ever actually manage to do is to be rational in the circumstances as best we can determine them to be. If rationality were only possible in the light of complete information it would perforce become totally irrelevant for us... We have to be realistic in our understanding of rationality – recognizing that we must practice this virtue in real rather than ideal circumstances.

Managers and Models of Reality

Bettis and Prahalad (1986, 1995) believe that what they call the dominant logic is one emergent property of complex organizations seeking to adapt to changing environments. It provides a set of heuristics that simplify and speed decision-making. This inherently results in "adaptive ability", so long as changes in the underlying logic are not necessary. It allows the organization to "anticipate" the environment (Bettis and Prahalad 1995). According to Bettis and Prahalad (1995), one of the most interesting ties between organizations as complex adaptive systems and the concept of dominant logic concern the concept of unlearning. The point is that such systems must operate far from equilibrium to anticipate learning. As Prigogine and Stengers (1984) points out, when such a system is in equilibrium it acts as though it is "blind". Its behavior becomes repetitive. To learn, and hence adapt to changing environments or spontaneously create new attractors, such systems must operate far from equilibrium.

The dominant logic (Bettis and Prahalad 1986, 1995) is created trough a common mindset, cognitive maps and earlier experience. These cognitive maps are central in the cognitive process school, one of the main areas in the strategic change literature (Rajagopalan and Spreizo 1997).

According to this school the environment is replaced by the manager's cognitive map. This cognitive map then represents the manager's knowledge structure, not just of the environment of the organization, but also of the organization, i.e. the *manager's* environment. An organization as an open system adapts to more complex environments by itself becoming more complex; that it is a type of system "whose persistence and elaboration to higher levels depends upon a successful mapping of some of the environmental variety and constraints into its own organization on at least a semipermanent basis" (Buckley 1967: 63).

The process of mapping environments is also in accordance with Gavetti and Levinthal's (2000) expansion of Kauffman's (1993) *NK* model, where managers are allowed to use cognitive maps to navigate the landscape. Here *N* represents the number of elements and *K* the interdependence between system elements comprising the system, as discussed in chapter three. Like roadmaps, these cognitive maps lack the detail of the actual landscape, but provide managers with a rough picture of topography. Gavetti and Levinthal (2000) find that these cognitive maps improve search outcomes for higher fitness peaks (better strategies) even when they do not represent the landscape well. The intuition for this finding lies in the search process itself. According to Rescher (1998: 26), "... the details often do not matter to the particular issue on the agenda – that fine-grained differences produce no large consequences here." Often, this may be the case. On the other hand, complex adaptive systems' sensitive dependence on initial conditions shows that sometimes fine-grained differences may play a substantially difference.

These cognitive maps and management searches are also confirmed in an empirical study conducted by Fleming and Sorenson (2000a). They also develop and test a theory based on Kauffman's (1993) *NK* model. This model represents invention as a process of recombinant searches over technology landscapes, and finds empirical support for complex adaptive systems theory. They find that the interdependence and size of search space impacts the likelihood of successful search more than any other characteristic of the invention process, although local searches also impacts the process. The results shows that the effect of interdependence *K* and the number of components *N* can make the difference between a median invention and one in the top 6%. In another empirical study Fleming and Sorenson (2000b) found that scientific knowledge provides inventors with an understanding of the underlying technological landscape. This allows them to exploit the benefits and avoid the uncertainties of combining interdependent components. Thus, this knowledge reduces the probability of failure by common trial-and-error method. Hence, the impact of pure randomness and chance are reduced.

How Decision-Makers Cope With Limited Cognitive Capacity

Several theories concerning decision making have been proposed to explain *how* and *how well* people make decisions. These are *expected utility theory* (Coombs 1975; Fishburn 1984; Karmarkar 1978; von Neumann and Morgenstern 1947; Payne 1973), *prospect theory* (Khaneman and Tversky 1979; Khaneman, Knetsch and Thaler 1990; Quattrone and Tversky 1988), *pseudocertainty* (Khaneman and Tversky 1981; Slovic Fischhoff and Lichtenstein 1982), *regret theory* (Bell 1982, 1985; Loomes and Sugden 1982, 1983, 1987), and *multi attribute choice*

(Payne 1982; Hogarth 1987; Plous 1993) amongst others.[10] A more comprehensive insight into how to manage complex decision processes still remains. However, some theories, or rather strategies, i.e. rules or models, have been suggested on how to cope with limited cognitive capacity in complex decision contexts. These models focus first and foremost on the dimension of uncertainty, and are referred to as *noncompensatory strategies* (Plous 1993). Four well-known examples of noncompensatory strategies are the *conjunctive rule*, the *disjunctive rule*, the *lexicographic strategy* and *elimination-by-aspects* (Hogarth 1987). Decision makers using the *conjunctive rule* eliminate any alternatives that fall outside certain predefined boundaries, and is an example of a satisfying rather than an optimizing rule. According to the *disjunctive rule*, each alternative is evaluated in terms of its best attribute, regardless of how poor other aspects of the alternatives may be.

The third noncompensatory choice strategy, or rule, is *lexicographic*. Decision-makers using this strategy begin by identifying the most important dimension for comparison, and choose the most desirable alternative or alternatives on this dimension. If more than one alternative remains, the alternatives are compared on the next most important dimension, then the next, and so on until only one alternative remains (Plous 1993). The fourth noncompensatory choice strategy, proposed by Tversky (1972), is known as *elimination-by-aspects*, and is essentially a probabilistic variation of the lexicographic strategy. According to elimination-by-aspects, each dimension – or aspect – of comparison is selected with a probability proportional to its importance. The alternatives is first compared with respect to a selected aspect, inferior alternatives are

[10] See Plous (1993) for an explanation on the several theories.

then eliminated, another aspect of comparison is selected, additional alternatives are eliminated and so forth until only one alternative remains (Plous 1993). Even though few empirical studies have been conducted concerning these theories, Slovic (1975) found in an experiment that people do not choose randomly when faced with equally valued alternatives, but usually select the alternative that is superior on the most important dimension under consideration.

Still, all the above presented theories deal with normative principles of rationality, but what if decision makers are not rational? By which processes does decision-makers reach their conclusions? Faced with complex judgements or decision processes, people often simplify the task by relying on *heuristics*, or general rules of thumb, which in many cases yield very close approximations to the "optimal" answers suggested by normative theories (Kahneman and Tversky 1974). The advantage is that they reduce the time and effort required to make reasonably good judgements and decisions. According to Kahneman and Tversky (1974: 1124), people often judge probabilities "by the degree to which A is representative of B, that is, by the degree to which A resembles B", and is referred to as the *representativeness heuristic*. From experiments, Kahneman and Tversky (1982: 98) concludes that:

> ... as the amount of detail in a scenario increase [and hence its complexity], its probability can only decrease steadily, but its representativeness and hence its apparent likelihood may increase. The reliance on representativeness, we believe, is a primary reason for the unwarranted appeal of detailed scenarios and the illusory sense of insight that such constructions often provide...

Kahneman and Tversky (1982) found that specific actions *appear* more likely than general ones because they are more representative of how we imagine particular events. Thus, the more detailed the scenarios, the more likely they may seem, as would be the case in many organizations carrying out detailed scenario planning, and is therefore easily misleading. The only thing that is certain is that these scenarios will never prevail.

According to Kahneman and Tversky (1974: 1127), the *availability heuristic* is a rule of thumb in which decision-makers "... assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind." Usually this heuristic works quite well; all things being equal, common events are easier to remember or imagine than are uncommon events. By relying on availability to estimate frequency and probability, decision-makers are able to simplify what might otherwise be very difficult judgements (Plous 1993). However, people forget, and this may lead to serious biases in relying on the availability heuristic, as well as the representative heuristic.

In probability theory, single events are known as "simple" events, and multiple events are known as "compound events" (Plous 1993). If two or more events must occur if the results are to be achieved, the events are referred to as "conjunctive events". If only one of several events has to occur to achieve desired result, the event is called "disjunctive". Experiments conducted by several researchers have documented the tendency decision makers have to systematically overestimate the probability of conjunctive events when the event is comprised of many simple events, and underestimate the probability of disjunctive events under the same conditions (Barclay and Beach 1972; Bar-Hillel 1973; Cohen, Chesnick and Haran 1971; Wyer1976).

The tendency to overestimate the probability of conjunctive events is especially important when people are asked to estimate the probability that a complex system will function properly (Plous 1993). This phenomena is due to the effect referred to as “anchoring” – that is, the insufficient adjustment up or down from an original starting value, or “anchor” (Tversky and Kahneman 1974; Wright and Anderson 1989; Quattrone, Lawrens, Warren, Souza-Silva, Finkel and Andrus 1984). To avoid this over and under estimation of compound events, decision-makers should break such compound events into simple events (Plous 1993). This method does, on the other hand, function only when compound events are made up of statistically independent events, i.e. in linear systems where there is a clear cause and effect relationship, and hence not under conditions of nonlinearity, as in complex adaptive systems.

Empirical studies conducted by Einhorn and Hogart (1986) and McGill (1986) found that people cannot attend to all possible stimuli. Thus, attending to differences, i.e. relating causes (or effects) to a point of reference, is an effective strategy for dealing with informational complexity (Hogarth 1987). People also assume that causes precede effects; we use evidence of covariation to suggest which variables are causally relevant; and our expectations about contiguity reinforce the notion that whereas some variables could be causally relevant, others are not. This ability to direct attention in causal reasoning is referred to as “cues-to-causality” (Hogart 1987). Given the complexity of the environment relative to human information-processing capability, “... the advantages of the causal field and the cues-to-causality should not be underestimated. They help decision-makers direct attention and help us create order out of the mass of information which we are confronted”

(Hogarth 1987: 161). Still, the ambiguity of causal relationships in nonlinear systems, as discussed in chapter two, may be the fallacy for managers as they see relationships that simply are not present.

The complexity of system dynamics in nonlinear systems creates uncertainty, and thus risk in information and decision making for managers. As Shapira (1995) finds in his empirical study, mangers are exposed to several different sources that complicate the decision process even further. They have to define their role in the social system as well as in the organization, and balance the conflicting goals between these systems, together with the problems in information processing, perception, understanding and awareness of alternatives. These issues create uncertain events, which creates anxiety and can thus inhibit action.

According to Shapira (1995), managers only focus on a few key discrete variables; in particular accumulated resources, a "survival point" and an aspiration level, which guide managerial attention and risk taking. This process of managerial decision-making "... is dynamic and history dependent, and allows for more complexity when the aspiration level is adjusted to reflect previous achievements" (Shapira 1995: 105). Thus, "... managerial risk taking is affected by cognitive mechanisms..." (Shapira 1995: 119), and is resolved through the focus on the few aspects that may seem most important in the decision process. Shapira (1995) also finds in his empirical study that manager incentives lead to the salience of single project rather than to the consideration of portfolios of projects. Furthermore, "... the tendency in organizations to focus on realized (versus potential) opportunities appears to drive managers to become risk avers, a tendency that may be heightened in hierarchical organizations and may lead to excessive risk aversion" (Shapira 1995: 119). The result can be the failure of not achieve the desired strategic flexibility through real options due to the lack of investments in the needed assets and hence, lost opportunities for growth, as discussed in section 4.3.1.

Uncertain events create anxiety and can thus inhibit action. Furthermore, “avoiding uncertainty is one way of reducing the complexity of the environment” (Hogarth 1987: 228). Even if “the capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behavior in the real world” (Simon 1957), decision-makers have several ways of coping with this limited cognitive capacity, as discussed in this section. Even though we may never be able to fully understand the complex world we live in, we should not stop searching for a more complete understanding of people, organizations and other systems which may have an impact on our ability to make better decisions in complex environments.

Information Processing Capabilities and Complex Adaptive Systems

Limits on the cognitive capability of managers as decision-makers are a major source of complexity, as discussed in chapter three. Both the structure of the organization and the mind of the managers can be altered to increase processing capabilities or decrease the need for information. Hence, managers must learn how to participate and interact with others to achieve the needed structure in order to increase their ability to manage complex environments. Several of the experiments discussed above shows that decision-maker rely on heuristics in complex environments.

This is a category of different “rules” an agent can have in interacting with other agents, as discussed in chapter two and in this section. The real world is replaced by the managers’ own maps or models of reality. These rules change and evolve as the manager achieves experience through interaction with other agents within and outside the organization, and is thus path-dependent. Still, it fits well in the domain of complex adaptive systems.

4.4 Summary

No one can be “in control” in the traditional sense of the term, but must shift focus from competition and control, to cooperation and participation in order to understanding the inherent capacity of living systems like organization to change spontaneously and creatively because of their own internal dynamics. This chapter discusses several mechanisms for managing complexity in organizations; self-organization, strategic flexibility, new structures, and how managers may cope with their limited cognitive capacity or enhance the information processing capabilities of the organization or as individuals. These mechanisms for managing complexity should not be seen isolated. One mechanism for managing complexity affects the impact of other mechanisms in the system, as well as the contexts they are applied to, i.e. the complexity of the systems.

The different aspects of mechanisms and how they relate are summarized in Table 4.1. The mechanisms are evaluated in terms of which conditions that must be present for the mechanisms to work, which sources the different mechanisms are able to manage, which role the manager are assumed to play in the organization, which assumptions are present about system dynamics and the behavior of the system, and assumptions about the rationality of agents operating in the system. As discussed earlier in this chapter, even if the mechanisms vary in their assumptions, none of them contradict each other directly, at least as discussed and implied here.

However, there are two assumptions that may seem to be pulling in opposite directions; the role of the manager, and the linearity of system dynamics. In complex adaptive systems, strategic flexibility will be a result of the behavior of the system, due to its properties and given the right circumstances, whereas strategic flexibility as a pure tool for rational managers will create organizations able to meet complex environments. There is, on the other hand, nothing contradictory in this.

Mechanism	Self-organization	Strategic Flexibility	Structure	Information Processing
Conditions	• Redundancy • Interaction • Info. flow • Experimentation • Trust • Decentralization	• Resource flex • Technological flexibility • System flex • Agent flex • Reduce interdepend	• System can adapt to environ-ments • Structures easily changeable	• Coordi-nation between elements • Learning capabilities • Path-dependency
Link to sources of complexity	• All sources • Overall complexity	All sources, except cognitive capacity	• Number • Variance • Interde-pendency	• Cognitive capacity • Uncertainty
Role of managers	• Participant in system • Co-creation with other agents	• Objective observer • Controller	• Objective observer • Controller	• Objective observer • Controller
Assumptions of system dynamics and rationality of participants	• Nonlinear • Sensitive dependence on initial conditions • Limits on rationality	• Nonlinear • Partly rational agents	• Nonlinear • Rational agents	• Partly rationality • Reality created by managers through models

Table 4.2 Mechanisms for Managing Complexity in Organizations

The only difference is the point of view from which flexibility is achieved. Organizations are constantly changing their structures, both formal and informal, and the lack of clear cause and effect relationship does not change this.

5. Summary and Implications: A Research Model

5.1 Introduction

All models are mental models. They reside only in our minds. Computer simulations and experiments can only be models of life – not life itself. A model is only a simplified picture of a part of the real world (Lave and March 1975), but can never *be* the real world (Frankfort-Nachmias and Nachmias 1996). This is because system thinking models only symbolic variables, as is usually the case in the social sciences (Frankfort-Nachmias and Nachmias 1996; Helmer 1966). The world around us is something we take for granted, and the process results in what we call awareness. We perceive the world we live in, and this “perception of the world” is merely the way that humans turn sensory information into awareness (Mikulecky 1999). Fischler and Firschein (1987: 233) explains what the implications of this perception may mean to science:

> No finite organism can completely model the infinite universe, but even more to the point, the senses can only provide a subset of the needed information; the organism must correct the measured values and guess at the needed missing ones... Indeed, even the best guesses can only be an approximation to reality – perception is a creative process...

This chapter starts with an explanation of the modeling process and why this process is important both in understanding the underlying principles in building a model, but also how this process relates to managers and decision-making in organizations. The model of complexity in organizations as complex adaptive systems summarize, link and discuss previous chapters, and the implications for managers and researchers in the field of strategic management. The closing remarks discusses the limits of the model and the different aspects discussed throughout the entire thesis, and then suggests ways for future research on organizations from a complexity perspective.

5.2 The Modeling Relation

The modeling relation is based on the belief that the world has some sort of order associated with it; it is not a collection of seemingly random happenings, as discussed in chapter two. It depicts the elements of assigning interpretations to events in the real world, which is the process of modeling. A model is an abstraction from reality that orders and simplifies our view of reality by representing its essential characteristics (Helmer 1966: 127):

> A characteristic feature in the construction of a model is abstraction; certain elements of the situation may be deliberately omitted because they are judged irrelevant, and the resulting simplification in the description of the situation may be helpful in analyzing and understanding it. In addition to abstraction, model building sometimes involves a conceptual transference. Instead of discussing the situation directly, ... its relevant properties and relation to other elements are mirrored by corresponding simulative properties and relations.

A model then, is a representation of reality; it delineates those aspects of the real world the scientists consider to be relevant to the problem investigated, it makes explicit the significant relationships among those aspects, and it enables the researcher to formulate empirically testable propositions regarding the nature of these relationships (Frankfort-Nachmias and Nachmias 1996). Models are also used to gain insight into phenomena that cannot be observed directly, and hence provide a more systematic basis for analysis than do subjective judgements (Frankfort-Nachmias and Nachmias 1996; Lave and March 1975; Smith 1973).

The modeling relation consists of two systems, a natural system and a formal system, related by a set of arrows depicting processes and/or mappings, as depicted in Figure 5.1. The assumption is that when we “correctly” perceive our world, we are carrying out a special set of processes that this diagram represents (Rosen 1985). The natural system is something we wish to understand, and arrow 1 depicts causality in this natural world. On the right side is some creation of our mind or something our mind uses in order to try to deal with observations or experiences we have. Arrow 3 is called “implication” and represents some way in which we manipulate the formal system to try to mimic causal events observed or hypothesized in the natural system on the left.

Arrow 2 is some way we have devised to encode the natural system or, more likely selected aspects of it into the formal system. Finally, the arrow 4 is a way we have devised to decode the result of the implication event in the formal system to see if it represents the causal event’s result in the natural system. Clearly, this is a delicate process and has many

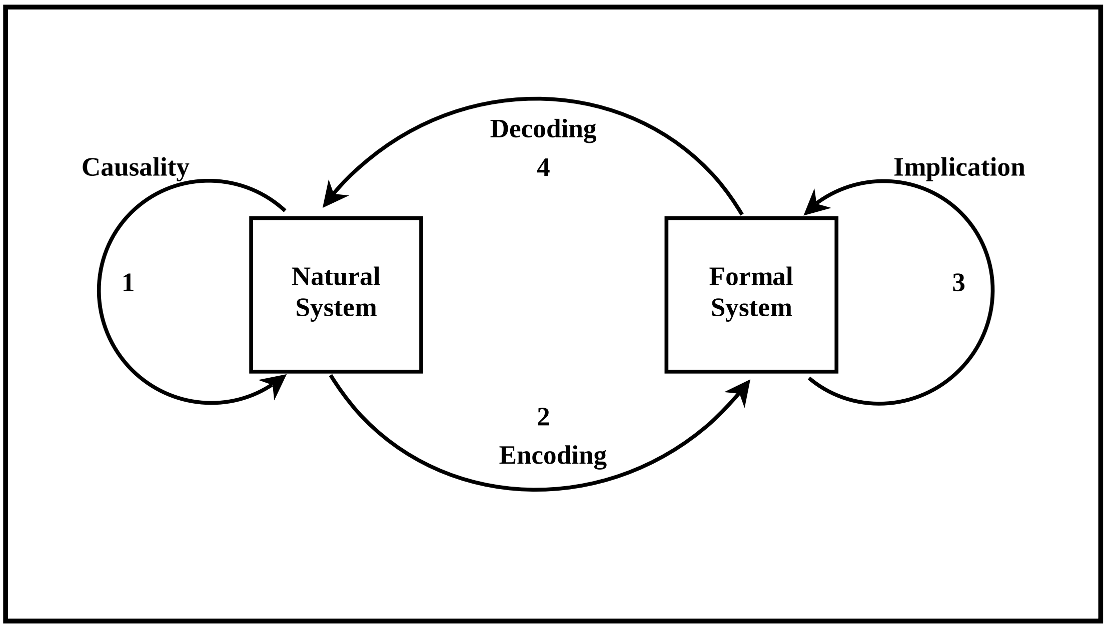

Figure 5.1 The Modeling Relation (Rosen

potential points of failure. When we have avoided all these failures, we actually have succeeded in having the following relationship be true (Rosen 1985):

$$1 = 2 + 3 + 4$$

When this is true, we say that the diagram commutes and that we have produced a model of our world (Rosen 1985). The encoding and decoding mappings are independent of the formal and/or natural system. In other words, there is no way to arrive at them from within the formal system or the natural system. This makes modeling as much an art as it is a part of science. Theories, and hence models, can only be reached by intuition, based upon something like an intellectual love of the object of experience (Popper 1968). The art of modeling also corresponds to the ability to enhance the information processing capabilities as a manager. How we perceive, and hence model the real world and its complexity as managers is a central aspect of complexity, as discussed in chapter three and four.

At the same time as restricting management of complexity, the awareness of the errors made in creating a model of the organization and/or the environment should also help managers to get a better picture and understanding of this reality, and hence evaluate and change their perception of the real world as new information comes to their mind. A model of complexity in organizations should therefore not just be seen as a summary of the previous chapters, but rather as a natural extension of the previous discussions. It is a link to understand how and why the process of complexity affects the overall organization as well as its elements, at the same time as it depicts the connection of how, and under what conditions, it can be managed.

5.3 A Model of Complexity in Organizations

The research model presented in Figure 5.2 link the different aspects of complexity in organizations as discussed in chapter two, three and four, and hence summarizes the findings in these previous discussions. To some extent, the distinction between endogenous and exogenous variables in a model is only one of convenience: a factor that is exogenous in a simple model might become endogenous in a more complex and comprehensive one (Levy 1994). For example, exogenous factors may be included as random variables in chaotic systems for modeling purposes (Kelsey 1988).

The Origin of Complexity

Chapter two discussed chaos theory and complexity theory and how the properties of complex adaptive systems relate to organizations and their environments. It was also argued that these systems create several sources of complexity for managers operating in these systems, as discussed in chapter three, and indicated in Figure 5.2. Numbers indicate the chapter of discussion.

Chapter three discussed eight sources of complexity for managers in operating in organizations as complex adaptive systems; (i) *number of constituent system elements* comprising the organization; the larger the number of system elements, the more complex the organization; (ii) *variance in system elements*; the more heterogeneous the system elements comprising the organization, the more complex the organization; (iii) *lack of lawful regularity*; nonlinear regularity governing the behavior of the system increase the complexity of managing the organization; (iv)

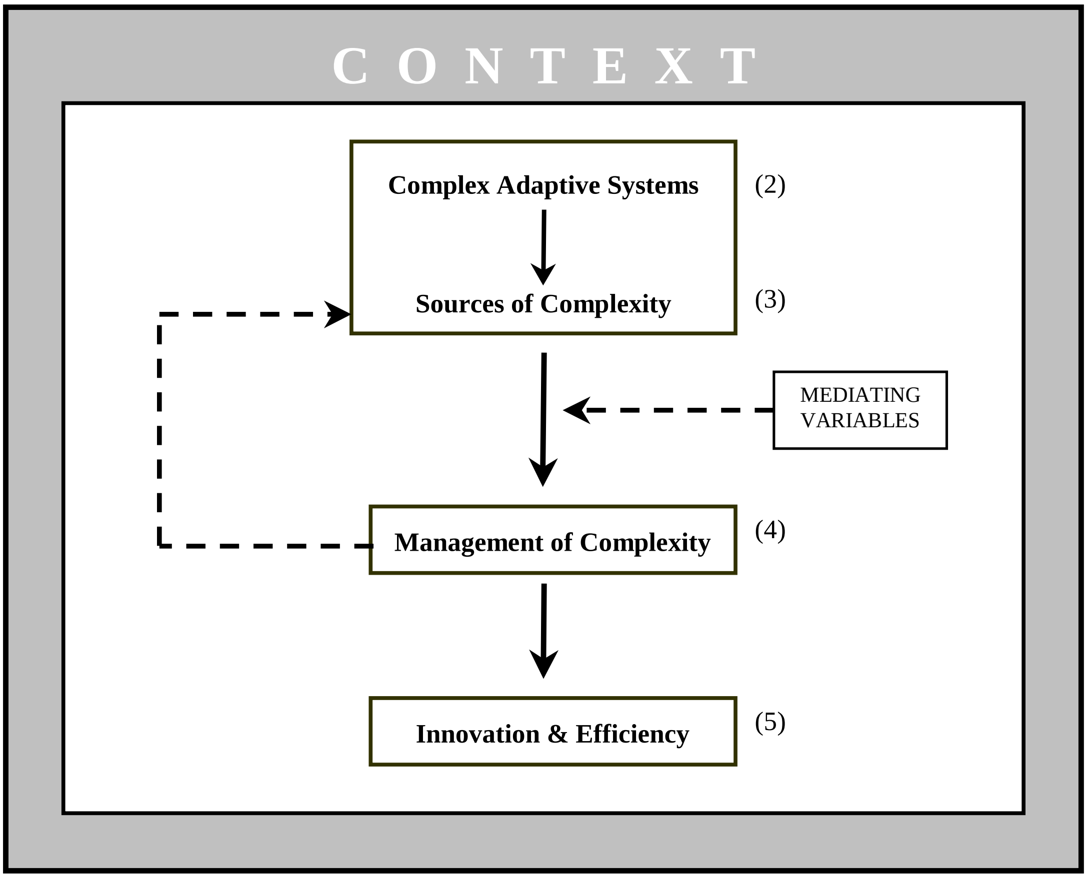

Figure 5.2 Complexity in Organizations

uncertainty; the unpredictability of the future increase the complexity of managing the organization; (v) *change and the speed of change*; the continuous and spontaneous creation of new, strange attractors towards which the system moves increase the complexity of the organization; (vi) *randomness and chance*; the unknown influence of random events increase the complexity of the organization; (vii) *interaction and interdependence between system elements*; the more interaction and interdependence between system elements comprising the organization, the more complex the organization; and (viii) *understanding and cognitive capacity*; limits on the cognitive capacity of managers increase the complexity of managing the organization. These eight sources affect the overall level of complexity exposed to managers, and hence how the complexity in organizations should be managed as illustrated in Figure 5.2.

The Management Complexity

Chapter four discussed several mechanisms on how to manage the complexity in organizations as complex adaptive systems, discussed in chapter two and three. First, these systems have the ability to *self-organize* in turbulent and highly volatile environments. Self-organization means that local interaction within the organization creates an overall pattern of behavior and order, i.e. a structure of activities is created to meet internal and external demands. However, the agents in the organization are constraining and being constrained by each other, at the same time as the nature of the agents are changing. How the agents are self-organizing depends on the various mediating variables constraining and influencing the interaction between the agents in the organization. Self-organization then is not so much about *how* strategies emerge, but *why* they emerge. It is more about having the right circumstances so that self-organizing structures can prevail, which is indicated as mediating variables in Figure 5.2. This includes available slack resources, the ability of multi-tasking, experimental activities, thrust between interacting agents, decentralization of responsibility for decision making, and loose coupling between system elements.

The awareness of seeing managers as participants, rather than as objective observers is also important as they engage in self-organizing activities, as well as anyone else. This way of managing complexity may create new levels of complexity as the overall pattern changes as a result of self-organization, and hence, is a way of coping as well as changing the existing complexity of the organization, as illustrated by feedback arrow on the left side in Figure 5.2.

Organizations operating in complex environments should enhance their *strategic flexibility* so as to be able to continuously change its structure to adapt to changing circumstances. This is one of the characteristics of complex adaptive organizations; their complex structure often reflects the complexity of their environment. The interdependence discussed in chapter three may, on the other hand, make it difficult to achieve the desired strategic flexibility to survive as rapid changes in organizational structure may be of great importance. Thus, reduction of interdependence between constituent elements comprising the organization is one way of enhancing the flexibility of the organization and hence managing complexity.

Less interdependence between system elements also increases the ability of what is referred to as patching. The essence of patching lies in modularity – the organization constructed as a collection of modules, or building blocks, which enables the organization to change structures as the modules are repositioned to face new conditions in complex environments. Investments in *strategic options* reduce the importance of uncertainty facing the organization in the environment. These organizational options point from the future to the presence, and make it possible to change the organization’s direction if necessary. Thus, organizations operating in complex environments with rapidly changing characteristics should not induce the organization to make commitments that will create a lock-in situation. On the contrary, these organizations should invest in strategic options that will make it possible to meet uncertainty in the future and create opportunities for growth in dynamic and complex environments.

Several organizational structures have been introduced as a way of dealing with increasing complexity in the environment; the functional structure, the divisionalized structure, and the matrix structure. Introducing different formalized organizational structures on an organization constrains different agents' ability to interact on a more informal basis, and hence impinges constraints on the ability to self-organize. The same applies to the nature of vertical and horizontal integration, as well as degree of formalized hierarchical governance. Facilitating different structures on an organization implies the alternation and change in the number and variance of constituent system elements. The different organizational structures should facilitate the appropriate coordinating processes in the organizational context. This will enhance the ability to self-organize into new emergent organizational structures.

To deal with limits on cognitive capabilities and constraints in the understanding of complex organizations and their environment, managers should either reduce the need for information or increase the *information processing capability*, both for the organization and the manager as an individual agent. The sources of complexity exposed to managers in terms of cognitive constraints, and the key to enhance these enduring capabilities can be viewed through the modeling relation discussed earlier in this chapter and illustrated in Figure 5.1. The modeling relation explains how managers replace reality with cognitive maps, and hence may loose relevant information due to complexity. The biases usually related to these processes also concerns the concept of unlearning. Organizations as complex adaptive systems must operate far from an equilibrium state to anticipate learning, and hence increase the possibility of incorporate the new information that may alter the structure or pattern of the system. Managers unable to participate in these processes seem to rely on heuristics in situations characterized by great complexity. All these issues have several implications, for example for innovation and efficiency, as will be discussed in the next section. The context relation indicated in Figure 5.2 is discussed in section 5.5.

5.4 Implications: The Model of Complexity Continues

Seeing organizations as complex adaptive systems have far reaching implications for managers. Not only should it reflect how managers should run their businesses, but also how they interact with other agents in the system. Several issues discussed earlier implies change in managerial behavior; the systems' sensitivity to initial conditions, the systems' ability to move between strange attractors and spontaneously create new ones, interaction between agents which create new global patterns through self-organization, and how and why the right conditions for these processes is important to facilitate in order to use them efficiently in highly turbulent environments.

The awareness of participation is also important in the process of understanding how to behave as a manger. Understanding how and why local interaction with other agents in the organization affects the overall pattern of the system should imply new managerial behavior; not as an objective observer standing outside trying to control the behavior of the system, but as an agent influencing the emergent strategy of the organization *together* with other agents in the organization.

These systems are by their very nature “uncontrollable” in the sense that predicting their future state is at best extremely difficult. This implies that many organizations should put “... a stop to many initiatives and abandoning control systems and procedures that are not fulfilling their purposes they are supposed to fulfill. The savings in time, resources and human stress might be considerable” (Stacey 2000: 411). Instead of focusing on control systems and detailed planning and scenario building, the focus should be on participation and coordination, and where to set boundaries for interaction space exposed to agents operating both within the organization and with the environment.

Innovation and Efficiency

The different sources of complexity imply different mechanisms to deal with the complexity created in these systems, as discussed earlier. One of the major implications for managers operating in these systems is how the mechanisms to manage the complexity in the organization affects the sources and overall level of complexity, and hence the effectiveness and efficiency of the organization. Implicit in managing complexity as discussed here is the assumption that managing complexity is reducing complexity. If this is impossible, the organization should create structures and conditions to cope with the complexity exposed to the overall organization, the different levels of the organization, and the different agents operating in the organization, including managers. As indicated in Figure 5.2, how to manage the complexity created by the sources of complexity depends on both the overall complexity of the organization, but also on the distinct sources of complexity. The mechanisms applied to manage the complexity and its sources will affect both the sources and indirectly the overall level of complexity at the same time in a continuously process, as illustrated on the left side of the model.

However, reduction of complexity may not always be the desired outcome, because "...contrary to some of our most deep-seated beliefs, mess is the material from which life and creativity are built..." (Stacey 2000: 294). This is one of the "key messages" in the science of complexity (Stacey 2000: 321):

> The result [of reducing complexity] could be stability for a long time, but it will be the death of creativity and innovation and hence, ultimately, the death of the system. So, organisations cannot survive by following some blueprint. Instead the potential for, but not the guarantee of, survival is created by the capacity to produce emergent new outcomes. This is controlled by the process of spontaneous self-organisation itself.

There is an optimal level of complexity between the boundaries of total chaos and complexity, and an absolutely stable and simple system; on the frontier of bounded instability, which is not necessarily the lowest level of complexity. Here, the tension and interaction between elements create enough energy and information for the system to be innovative and creative, at the same time as being stable enough to be efficient. Creativity and innovation are activities in systems, or organizations, operating far from equilibrium and stability. However, too much instability will lead to inefficiency. The challenge is to balance the sources of complexity and the mechanisms to manage them on the edge of instability, where new resources and capabilities can be created, and stability for a long time and hence the death of creativity can be avoided. It is the capacity of these systems to move from one strange attractor to another or to spontaneously create new ones, which ensures the continuously emerging process of innovation.

5.5 Limitations and Further Research

There are several limitations and branches to further research in the framework presented earlier. For example, how can managers find the "optimal" level of complexity to ensure creativity and innovation at the same time as ensuring efficiency? According to Axelrod and Cohen (1999: 156), managers should "... arrange organizational routines to generate a good balance between exploration and exploitation," but what is a "good" balance? Clearly, this optimal level of complexity is context dependent, and should be evaluated in relation to the sources of complexity and behavior of the organization as derived from complexity theory. The mechanisms available to manage the complexity of the environment and the organization, and the constraints set by managers and other agents operating in the organization create the framework for operation. Still, it is not easy to give any explicit information or guidance about where an optimal level of complexity at the boundary of instability should be on a *general* basis.

With an initial basis in chaos theory and complexity theory, the previous discussions identified eight sources of complexity exposed to managers operating in organizations as complex adaptive systems through an extensive literature review in the field of strategic management theory, organizational theory and psychology. Are there other sources that may be important to identify and explain complexity in organizations, and how this may affect the innovation and efficiency processes in these systems? Also, do some sources of complexity have a greater impact of the overall complexity, i.e. are some sources of complexity more important than others, and in that case which sources, and why? This discussion also relates to the discussion of mechanisms to manage the complexity in the system; are other mechanisms available, and are some mechanisms to manage complexity in organizations more important and efficient than others?

As discussed in chapter four, another challenge is to integrate the identified mechanisms in a more thorough way with complexity theory and the concept of organizations as complex adaptive systems. Some mechanisms are derived from theories that assume that managers are capable of being complete rational individuals. Also, the ability of managers to stand outside the system as an objective observer and easily change the structure of the organization is probably an exaggeration, for example as is the case with patching, discussed in section 4.3.1.

Context and Causality

Models always ignore a lot of complexity. They are themselves simplifications aimed at particular purposes. Causational relationships are extremely difficult – if not impossible – to model in complexity theory due to the very nature of these systems, i.e. because of the different aspects of properties concerning nonlinear dynamics in organizations, as discussed in previous chapters. Is there any point in making propositions in a world of complexity where causational relationships are fuzzy? Propositions reside only in our minds, and are the requisites for the anticipated causal links in the real world, as discussed in the modeling relation earlier in this chapter. This should not scare us from making assumptions of causality in a complex reality. Still, it implies that we should do so very carefully.

What is lost when systems are reduced to its constituent elements is a clue to causal relations. Rosen (1985) defined the “functional component” in this way. Functional components are context dependent and only have definition in a specific context. By identifying these functional components, the causal relations can be worked out. In machines the parts and functional components are context independent and the causes separate. Organizations as complex adaptive systems have interdependent causes, as described in chapter two and three, and the functional components no longer relate to the parts in any obvious way, and certainly not in any one to one manner. Still, “... it is possible, with much effort, for someone, or some small group of powerful people, to predict the outcomes of group, organizational and societal behavior” (Stacey 2000: 321), at least in the short run. This is why *context* is important in analyzing these systems, as indicated in Figure 5.2.

One of the major critiques against many models in economics, finance, and strategic management literature has been the lack of predictive capability. The reality does not evolve as predicted by these models. Why? The clear cause and effect relationships depicted in the models disappear in the real world. Complexity theory explains why. However, the challenges concerning causal relationships in organizations as complex adaptive systems are tremendous for both researchers and managers.

There is a need to develop complexity theory further, especially applied to organizational behavior, to increase our understanding of how the behavior in organizations evolve, and how strategies in these systems emerge. As discussed in earlier chapters, the integration between the sciences of physics, biology, organizational theory, strategic management and cognitive psychology is no straightforward exercise, and is associated with several problems. Another challenge for scientists doing research on these topics is how to do empirical research in organizations based on complexity theory. How can self-organization be distinguished from truly random behavior? Even though some of the challenges facing managers have partly been discussed throughout this thesis, the research agenda ahead have many interesting questions yet to be answered.

6. Research Method

6.1 Introduction

Management research is often a look at the past to gather sufficient quantity of data to be able to form theories of management practice. The research is aimed at creating models, which reflects the dynamics of one or more management science objects. The lack of predictive capability suggests a problem in this modeling approach, where the key stumbling block seems to be prediction itself – the relationship between observed past and anticipated future. This has important implications for how to do empirical research on organizations as complex adaptive systems.

6.2 Research Design

The dominant frame of reference for research in organizations is the reductionist one of testing cause and effect (Stacey 1995). The most usual method for testing these hypotheses is the use of cross-sectional data on organizations obtained from statistics, public reports, questionnaires, and interviews. As for chaotic systems, there is considerable debate in the economics and finance literature about how to test a data series to determine whether it is chaotic or simply subject to random influences (Brock and Malliaris 1989; Hsieh 1991). There is a growing emphasis in the field of complexity science to strengthen the empirical research done on organizations as complex adaptive systems, and to expand the empirical research beyond modeling and experiments (Allison and Kelly 1998; Brown and Eisenhardt 1998; Fleming and Sorenson 2000a, 2000b; Gavetti and Levinthal 2000; Kelsey 1988; Levy 1994; Mahon 1999; Stacey 1995).

Behavior in organizations driven by theories-in-use often differs dramatically from espoused theories (Argyris and Schon 1978). People say one thing and do another, which – of course – makes empirical investigations particularly challenging. It is also clear that behavior in organizations is significantly influenced by culture; that is, shared assumptions below the level of awareness on what to think and do and how to think and do it (Schein 1985). Furthermore, findings in cognitive psychology shows how people make sense of the world by using partial mental models, i.e. recipes, or causal maps, that they are usually unaware of (Johnson 1987). The growing emphasis on what is tacit, below the level of awareness and contradictory, makes it unlikely that the straightforward application of questionnaire, public reports and interview data to the testing of hypotheses can be all that reliable (Stacey 1995).

Given the nature of organizations as complex adaptive systems, the reductionist approach to research is likely to produce misleading conclusions. Stacey (1995: 493) suggests that instead of using cross-sectional tests when investigating organizations, "... research will have to focus on the meanings of the irregular patterns of behavior observed and on reasoning about the kind of system those patterns are being generated by. Instead of looking for causes and effects it is necessary to look for patterns and their systemic implications." Data need not be viewed as the tracing of a dynamic, but rather as the scatter readings of an attractor in state-space, as discussed in chapter two.

However, there might be a problem in using the language from a complexity science perspective. The language used in communicating with respondents should be worded so that the respondents understand its meaning (Frankfort-Nachmias and Nachmias 1996). For example, most managers would not recognize the term “attractor”. There are several ways of doing this. Mahon (1999) used the term “areas of focus” instead of “attractor”, and a wide terminology of metaphors in his empirical study from a complexity point of view. Attractor models do not predict what happens next, but outline the rough boundaries of space of action. Models of time become models of space, for example conditions for self-organization and strategic flexibility, as discussed in chapter four. The task of managerial research is aimed at identifying relevant attractors, i.e. their boundaries and conditions, and to explore the dynamics of moving from one attractor to another. Thus, questions of predictions no longer take the center stage.

From a complexity perspective, “... the method is one of gathering data from free floating discussions and informal interpretation, avoiding the temptation to “intellectualize”; that is, force experience into neat models and, by so doing, erect defenses against considering what the new experience itself might mean... Researchers need to be primarily concerned not with factual concretely descriptive language, but with the metaphors and the images people uses” Stacey (1995: 493). An example may illustrate the point from a complexity perspective:[11]

> If I wish to learn about a forest, I would look briefly at many trees, but eventually select a single tree for a really good look. I learn something and then I look at a second tree. I go about learning about the second tree in the same manner as studying the first, except that now I can begin to compare and contrast. This is not deductive, this is inductive observation, the opposite of the “scientific method”. I don't have a hypothesis to test yet, just a rapidly growing fund of information. This is when creativity arrives on the scene, when I begin to propose possibilities of how the first tree and the second tree are alike, or not. Then a most remarkable

[11] Example provided by A.M. de Lange (2000) to discussion group ”COMPLEX-M”.

> thing sometimes happens: A third idea reveals, which encompasses the essential properties of the first two. This is at the "heart" of complexity thinking, this emergence of the third idea.

Clearly, empirical research on organizations as complex adaptive systems could derive great value from conducting qualitative and comparative studies, avoiding the limitations (reductionism) associated with more quantitative oriented studies. Several methods apply to this kind of investigation; longitudinal field studies, action research, the ethnographic approach, and clinical methods (Stacey 1995), amongst others.

One approach often mentioned is the case study (Yin 1989). Case studies are widely used in organizational studies in the social science disciplines of sociology, industrial relations and anthropology (Hartley 1994). According to Hartley (1994), case studies are useful when there is a need to explore new processes or behaviors that are little understood. Furthermore, case studies can capture the contextual and processual nature of the study, starting off with a conceptual framework (Meyer 2000). Two main approaches are available to the researcher conducting case studies; longitudinal field studies to capture processes, and comparative case studies to capture differences and similarities between cases and hence, gain a better understanding of each individual case. Pettigrew (1990) suggests a longitudinal *and* comparative case study design to conduct in-depth exploration of complex issues.

There is a growing emphasis on how complexity theory should be interpreted in organizations, as discussed in chapter two. Several problems were addressed; for example, what is the analogue for an algorithm in a data simulation of a complex adaptive system in an organization? The point is that these questions should not be taken for granted when imposing these theories – originally from physics – into organizational science. The lack of well-defined concepts, together with limited knowledge of interpretation, implies a need to explore the phenomena of organizations as complex adaptive systems very carefully through an in-depth analysis.

As discussed in chapter five, the functional components are context dependent and only have definition in a specific context (Rosen 1985). Organizations as complex adaptive systems have interdependent causal relationships, as described in chapter two and three, and the functional components no longer relate to the parts in any obvious way, and certainly not in any one to one manner. This is why *context* is important in analyzing these systems, as indicated in Figure 5.2. The contextual nature of the case study is illustrated in Yin’s (1993: 59) definition of a case study as an empirical inquiry that:

> Investigates a contemporary phenomenon within its real-life context, addresses a situation in which the boundaries between phenomenon and context are not clearly evident, and uses multiple sources of evidence.

Hence, the case study is a useful approach when it is important to understand those social processes in their organizational and environmental *context* (Hartley 1994), as in complex adaptive systems.

To capture the processual dynamics of the cases, data should be collected over an extensive time period, i.e. a longitudinal research design (Pettigrew 1990; Van de Ven and Huber 1990). Furthermore, a multi-case study is needed to conduct a comparative analysis. By looking at a range of similar and contrasting cases, we can understand the single-case finding, grounding it by specifying how, where and if possible why it carries on as it does (Miles and Huberman 1994). However, the desire for in-depth analysis and resources required implies that the study can contain only a few cases (Pettigrew 1990; Van de Ven and Huber 1990).

6.3 Empirical Study

The logic in case studies is theoretical sampling where the goal is to choose cases that are likely to replicate or extend the emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types (Eisenhardt 1989), based on the researchers own judgements. Hence, whereas quantitative sampling concerns itself with representativeness, qualitative sampling seeks information richness and selects the cases purposefully rather than randomly (Crabtree and Miller 1992). Based on previous discussions, cases are selected where the dynamics of the organization and its different environments are expected to be extremely complex. Access has now been given to Telenor ASA, Norway's largest telecommunication company. Three cases within Telenor creates the basis for this study; Telenor ASA (corporate level), Telenor Horizon (international unit of mobile phones), and EDB Business Partner (Norway's largest it-company, partly owned by Telenor).

In case studies the researcher has the choice between a holistic or embedded design (Yin 1989). A holistic design examines the global nature of the phenomenon, whereas an embedded design also pays attention to sub units (Meyer 2000). Besides developing contrasts between cases, researchers can then also focus on contrasts within the cases (Hartley 1994). The opportunity of going in-depth in different units at different levels will be available in all the three cases in Telenor. In fact, two of the cases (Telenor Horizons and EDB Business Partner) are an in-depth study of the third one (Telenor ASA; corporate level). With this three case study design, it is not only possible to explore one of the cases more in-depth, but it also creates the opportunity to compare the two in-depth cases, which are parallels within the corporate level case. Furthermore, the corporate level case gives us access to well-informed respondents. This information will be valuable in the initial phase of the study, before conducting further in-depth-analysis. Access to previous data sampled in another project also creates the opportunity to conduct a longitudinal study of analysis in one of the cases (EDB Business Partner).

6.4 Data Collection Procedures

Although approaches to data collection continually expand in the *qualitative area* (see Creswell 1994), there are four basic types of information to collect (Creswell 1998): observations (ranging from nonparticipant to participant), interviews (ranging from semistructured to open-ended), documents (ranging from private to public), and audio-visual materials (including materials such as photographs, compact discs, and videotapes). A *case study* involves the widest array of data collection as the researcher attempts to build an in-depth picture of the case (Creswell 1998). Yin (1989) suggests six forms of data collection in a case study; documents, archival records, interviews, direct observation, participant observation, and physical artifacts. Due to the nature of the study and theoretical basis discussed in earlier chapters, as well as recommendations made by Creswell (1998), Mahon (1999) and Stacey (1995) amongst others, three main sources of data collection are chosen;

(i) documents (public and private) available, (ii) unstructured, open-ended interviews, and (iii) observation as a participant within the cases.

Documents

As noted by Creswell (1998), documents represent one of the basic types of data collection procedures in case studies. These documents may take the form of private notes made by the researcher or an insider, to public available information, i.e. from primary to secondary available data. For example, the initial public offering of Telenor this year produced several public reports, but highly possible also many private reports and notes, available just for insiders in Telenor. The documents can be a source first and foremost to the tracing of historical events, but also official statements made by representatives within the cases and in counteracting the biases of the interviews.

Interviews

According to Creswell (1998), one might see interviewing as a series of steps in a procedure. First we need to determine what kind of interview is practical and will get the most useful information. Telephone interviews and mail questionnaires are unsuitable for unstructured, open-ended interviews (Frankfort-Nachmias and Nachmias 1996). What is wanted is to reveal the respondents own experiences and definitions of their own situations, and their opinions and attitudes as they see fit. Also, the opportunity of probing will be important to elicit additional information from the respondents during the process, at the same time as it gives him or her the opportunity to elaborate on or clarify an answer or to explain the reason behind the answer.[12] Thus, the personal interview will be most suitable. This gives the interviewer great flexibility in the questioning process, great control of the interview situation, high response rate *and* the opportunity to collect supplementary information (Frankfort-Nachmias and Nachmias 1996).

Second, interviewees are identified based on one of the purposeful sampling procedures mentioned by Miles and Huberman (1994), i.e. that is most likely to have and give us access to the wanted information, based on the theoretical discussion in previous chapters. For one-on-one interviewing, the researcher needs individuals who are not hesitant to speak and share ideas and needs to determine a setting in which this is possible (Creswell 1998).

Interviewees are first selected due to their position in the organization and familiarity towards strategic questions. Corporate managers are being interviewed on an overall general level to give a broad view on what is understood about the phenomenon of complexity in the corporation. To ensure the richness of data, the interviews are tape-recorded. Transcripts of these first explorative interviews are then prepared and structured as to make a basis to conduct further interviews in each of the three cases. Recording procedures should include a protocol to organize thoughts and log information learned during the interview (Creswell 1998).

[12] See Survey Research Center (1976): *Interviewer's Manual*. Ann Arbor, Mich.: Institute for Social Research, University of Michigan.

Observation

The method of data collection most closely associated with contemporary field research is "... participant observation, whereby the investigator attempts to attain some kind of membership in or close attachment to the group that he or she whishes to study" (Wax 1968: 238). The participant observer's role is that of "... conscious and systematic sharing, insofar as circumstances permit, in the life activities, and on occasion, in the interests and effects of a group of persons" (Kluckhohn 1940: 331). Observing in a setting is a special skill that requires management of issues such as the potential deception of the people being interviewed, impression management, and the potential marginality of the researcher in a strange setting (Hammersley and Atkinson 1995). The role of an observer can range from that of complete participant to that of a complete observer (Creswell 1998; Frankfort-Nachmias and Nachmias 1996).

The complete participant interacts with the observed "... as naturally as possible in what ever areas of their living interest him and are accessible to him" (Gold 1958: 219). However, this type of observation role is associated with several problems, as self-consciousness or "going native", difficult to decide what to observe, and time lags in recording information (Creswell 1998; Frankfort-Nachmias and Nachmias 1996; Gold 1958), as well as ethical problems (Campbell and Stanley 1963). In view of these limitations, contemporary fieldworkers most often assume the participant-as-observer role (Frankfort-Nachmias and Nachmias 1996). Due to the nature of the study, a participant-as-observer role is also probably a more valuable approach, at least after the initial face of the study. In this role, "... researchers make long-term commitments to becoming members of the group and attempt to establish close relationships with its members who subsequently serve as both informants and respondents" (Frankfort-Nachmias and Nachmias 1996: 285). With this method, "... the fieldworker gains a deeper appreciation of the group and its way of life and may also gain different levels of insight by actually participating rather than only observing" (Bingham and Gibson 1979: 270). Another possibility is to start initially as a complete outsider followed by becoming an insider over time (Creswell 1998).

6.5 Data Analysis

For a case study, analysis consists of making a detailed *description* of the case and its setting (Creswell 1998). Stake (1995) advocates four forms of data analysis and interpretation in case study research: (i) *categorical aggregation* of data, (ii) *direct interpretation*, in which a single event or instance is focused, (iii) establish *patterns*, look for correspondence between two or more categories, and (iv) develop *naturalistic generalizations* from analyzing the data. All forms are relevant in our study. As discussed earlier in this chapter, the identification of patterns, and the attractors and boundary space associated with it is especially important, and hence the categorical aggregation of the collected data. However, the direct interpretation of single events will also be valuable in identifying initial conditions in which the organization is sensitive dependent, as discussed in chapter two and four. Furthermore, the analysis of data in a case study is an ongoing, continually evolving process throughout the entire project as new information enters the scene (Frankfort-Nachmias and Nachmias 1996).

Eisenhardt (1989b) suggests a process where the findings in the analysis and emerging theories are compared to existing literature. This is important for two reasons (Eisenhardt 1989b: 544):

> First if the researcher ignores conflicting findings, then confidence in the findings is reduced. Secondly, and perhaps more importantly, conflicting literature represents an opportunity. The juxtaposition of conflicting results forces the researcher into a more creative, framebreaking mode of thinking than they might otherwise be able to achieve. The result can be deeper insight into the emergent theory and conflicting literature, as well as sharpening the limits of generalizability of the focal research.

This linking of emergent theory to existing literature enhances the internal validity, generalizability, and theoretical and conceptual level of theory building from case research (Meyer 2000). To help researchers in this process, computer programs, such as NUD•IST, may play a substantial role in the analysis of qualitative data (Creswell 1998). They usually reduce and simplify the ease of analysis for the researcher. These programs may help the researcher to store and organize files, search for themes, cross themes, diagram the themes into a visual picture, and to create a template – basically an a priori codebook for organizing information (Creswell 1998). This will be important features when patterns and categories are to be identified in the data set, as discussed above.

6.6 Summary

Organizations as complex adaptive systems suggest new approaches to empirical research. Instead of looking for causes and effects, looking for boundary space takes the center stage. Three cases have been chosen – and given access to – within Telenor, Norway's largest telecommunication company, to study the phenomena of complexity as discussed in previous chapters. A multi case study creates the opportunity to conduct a comparative analysis. Open-ended, unstructured interviews and a participant-as-observation role are chosen as appropriate data collection procedures. These procedures can reveal the in-depth information needed in the study for further analysis, which in case studies is an ongoing continually evolving process as new information enters the stage. The linking of the analysis and results to existing literature enhance the internal and external validity of the empirical study.

References

Aggarwal, S. (1995): Flexibility management: The ultimate strategy. *Industrial Management*, 37 (6), p. 20-26.

Aguilar, F. (1967): *Scanning the Business Environment*. Macmillan, New York.

Allen, P.M. (1988): Dynamics models of evolving systems. *System Dynamics Review, 4*, Summer, p. 109-130.

Allison, M.A. and S. Kelly (1999): *The Complexity Advantage: How the Science of Complexity Can Help Your Business Achieve Peak Performance*. New York: McGraw-Hill.

Anderson, E. (1985): The Salesperson as Outside Agent or Employee: A Transaction Cost Analysis. *Marketing Science*, 4, p. 234-254.

Anderson, E. (1988): Transaction Costs as Determinants of Opportunism in Integrated and Independent Sales Forces. *Journal of Economic Behavior and Organization*, 9, p. 247-264.

Anderson, P.W., K.J. Arrow and D. Pines (1988): *The Economy as an Evolving Complex System*. Addison-Wesley, Reading, MA:

Anderson, P. and M. Tushman (1990): Technological Discontinuities and Dominant Design. *Administrative Science Quarterly*, 35, p. 604-633.

Ansoff, H.I. (1965): *Corporate strategy*. London: Penguin Books.

Ansoff, H.I. (1979): *Strategic Management*. New York: Wiley.

Ansoff, H.I. and R.G. Brandenburg (1971): A Language for Organizational Design: Parts I and II. *Management Science*, August, p. 393-428.

Argyris, C. (1990*): Overcoming Organizational Defenses: Facilitating Organizational Learning*. Boston MA: Allyn & Bacon/Prentice-Hall.

Argyris, C. and D. Schon (1978): *Organizational Learning: A Theory of Action Perspective*. Reading, MA: Addison-Wesley,

Arthur, W.B. (1988): Self-reinforcing mechanisms in economics. In P.W. Anderson, K.J. Arrow and D. Pines (Eds.), *The Economy as an Evolving Complex System*, Reading MA, p. 9-32.

Atkinson, J. (1985): *Flexibility, uncertainty and manpower management*. Brighton: Institute of Manpower studies.

Axelrod, R. (1984): *The Evolution of the Cooperation*. New York: Basic Books.

Axelrod, R. and M.D. Cohen (1999): *Harnessing Complexity. Organizational Implications of a scientific Frontier*. The Free Press. New York.

Bahrami, H. (1992). The emerging flexible organizatin: Perspectives from Silicon Valley. *California Management Review*, Vol. 34 (4), p. 33-51.

Bak, P. and K. Chen (1991): Self-organized criticality. *Scientific American, 264 (1),* p. 46-53.

Barclay, S. and L.R. Beach (1972): Combinatorial properties of personal probabilities. *Organizational Behavior and Human Performance, 8,* p. 176-183.

Bar-Hillel, M. (1973): On the subjective probability of compound events. *Organizational Behavior and Human Performance, 9,* p. 936-406.

Barnard, C.I. (1938): *The Functions of the Executive*, Cambridge, Mass.: Harvard University Press.

Barney, J.B. (1986b): Organizational culture: Can it be a source of sustained competitive advantage? *Academy of Management Review*, 11, p. 656-665.

Barney, J.B. (1986c): Types of competition and the theory of strategy: Toward an integrative framework. *Academy of Management Review,* 11, p. 791-800.

Barney, J.B. (1991): Firm Resources and Sustained Competitive Advantage. *Journal of Management*, Vol. 17, No. 1.

Bartlett, C.A. (1993): Commentary: Strategic flexibility, firm organization, and managerial work in dynamic markets. *Advances in Strategic Management*, 9, p. 293-298.

Barton, S. (1994): Chaos, Self-Organization, and Psychology. *American Psychologist, 49 (1),* p. 5-14.

Baumol, W. and J. Beinhabib (1989): Chaos: Significance, mechanism, and economic applications. *Journal of Economic Perspectives, 3,* p. 77-105.

Bell, D.E. (1982): Regret in decision making under uncertainty. *Operations Research, 30,* p. 961-981.

Bell, D.E. (1985): Disappointment in decision making under uncertainty. *Operations Research, 33,* p. 1-27.

Bell, D., H. Raiffa and A. Tversky (1988): Descriptive, normative and prescriptive interactions in decision making. In D. Bell, H. Raiffa, and A. Tversky (Eds.), *Decision Making*. New York: Cambridge University Press.

Berle, A. and G. Means (1932): *The modern corporation and private property*. New York: Macmillan.

Bettis, R.A. and C.K. Prahalad (1986): The Dominant Logic. *Strategic Management Journal*, Vol. 7, Iss. 6, p. 485-501.

Bettis, R.A. and C.K. Prahalad (1995): The Dominant Logic: Retrospective and Extension. *Strategic Management Journal*, Vol. 16, p. 5-14.

Beyer, J.M. (1981): Ideologies, values and decision making in organizations. In Nystrom, P. and W Starbuck (Eds.), *Handbook of Organizational Design*, Vol. 1, Oxford University Press, London, 1981, p. 166-202.

Bingham, R.D. and J.L. Gibson (1979): *Conditions of Commitment to Civil Liberties*. Unpublished. Milwaukee: Department of Political Science, University of Wisconsin.

Bonner, J.T. (1988): *The Evolution of Complexity. Princeton*, NJ: Princetion University Press.

Bowman, E.H. and D. Hurry (1993): Strategy through the Option Lens: An integrated view of resource investments and the incremental-choice process. *Academy of Management Review*, 18, p. 760-782.

Brandenburger, A.M. and B.J. Nalebuff (1995): The Right Game: Use Game Theory to Shape Strategy. *Harvard Business Review*, Jul-Aug, p. 57-71.

Brock, W.A. (1986): Distinguishing Random and Deterministic Systems. *Journal of Economic Theory*, *40*, p. 168-195.

Brock, W. and A. Malliaris (1989): *Differential Equations, Stability and Chaos in Dynamic Systems*. New York: North-Holland.

Brown, S.L. and K.M. Eisenhardt (1998): *Competing on the Edge: Strategy as Structured Chaos*. Harvard Business School Press, Boston, Massachusetts.

Brown, S.L. and K.M. Eisenhardt (1999): Patching: Restricting Business Portfolios in Dynamic Markets. *Harvard Business Review*, 8/9, p. 72-82.

Brunsson, N. (1982): The irrationality of action and action rationality decisions: ideologies and organizational actions. *Journal of Management Studies, 19*, p. 29-44.

Buckley, W. (1967): *Sociology and Modern Systems Theory*. Englewood Cliffs, N.J.: Prentice-Hall.

Burgelman, R.A. (1983a): A Model of the Interaction of Strategic Behavior, Corporate Context, and the Concept of Strategy. *The Academy Of Management Review, Vol. 8*, Iss. 1, pg. 61-71.

Burgelman, R.A. (1983b): A Process Model of Internal Corporate Venturing in the Diversified Major Firm. *Administrative Science Quarterly, Vol. 28*, Iss. 2; pg. 223-245.

Burgelman, R.A. (1983c): Corporate Entrepreneurship and Strategic Management: Insights from a Process Study. *Management Science,* Vol. 29, Iss. 12, pg. 1349-1365.

Butler, A. (1990): A methodological approach to chaos: Are economists missing the point? *Federal Reserve Bank of St. Louis, 72 (13)*, p. 36-48.

Camerer, C.F. (1991): Does Strategy Research Need Game Theory? *Strategic Management Journal,* Special Issue Winter, p. 137-152.

Campbell, D.T. and J.C. Stanley (1963): *Experimental and Quasi-experimental Designs for Research*. Skokie, Ill.: Rand McNally.

Cartwright, T.J. (1991): Planning and chaos theory. *Journal of the American Planning Association, 57 (1)*, p. 44-56.

Casti, J.L. (1994): *Complexification: Explaining a Paradoxical World through the Science of Surprice*. New York: Harper Collins.

Chambers, S., C. Harland, A. Harrison and N. Slack (1997): *Operations Management*, 2nd ed. UK: Longman Group.

Chandler, A.D. Jr. (1962): *Strategy and Structure*, Cambridge, Mass.: The M.I.T. Press.

Cheng, Y. and A.H. Van de Ven (1996): Learning the Innovation Journey. *Organization Science, Vol. 7 (6)*, p. 593-614.

Coase, R.H. (1937): *The Nature of The Firm*. Economica N.S., 4, p. 386-405.

Cohen, J., E.I. Chesnick and D.A. Haran (1972): A confirmation of the inertial ψ-effect in sequential choice and decision, *British Journal of Psychology, 63*, p. 41-46.

Coombs, C.H. (1975): Portfolio theory and the measurement of risk. In M.F. Kaplan and S. Schwartz (Eds.), *Human judgement and decision processes*. New York: Academic Press.

Crabtree, B.F. and W.L. Miller (1992): Primary Care Research: A Multimethod Typology and Qualitative Road Map. In B.F. Crabtree and W.L. Miller (Eds.): *Doing Qualitative Research: Methods for Primary Care*. Sage Publications.

Crane, D.B. and R.G. Eccles (1987): Commercial Banks: Taking Shape for Turbulent Times. *Harvard Business Review*, Vol. 65 (6), p. 94-101.

Creswell, J.W. (1994): *Research design: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications.

Creswell, J.W. (1998*): Qualitative Inquiry and Research Design: Choosing Among Five Traditions*. California: Sage Publications.

Cyert, R.M. and J.G. March (1963). *A Behavioral Theory of the Firm*. Englewood Cliffs, N.J.: Prentice-Hall.

Daft, R.L. and A.Y. Lewin (1990): Can organizations begin to break out of the normal science straightjacket? An editorial essay. *Organization Science, 1*, p. 1-9.

DÁveni, R. (1994): *Hypercompetition: Managing the dynamics of strategic manufacturing*. New York: The Free Press.

Dendrinos, D. and M. Sonis (1990): *Chaos and Socio-Spatial Dynamics*. New York: Springer-Verlag.

Dill, W.R. (1958): Environment as an Influence on Managerial Autonomy. *Administrative Science Quarterly*, Vol. 2, p. 409-443.

Dixit, A. and R. Pindyck (1994): *Investment Under Uncertainty*. Princeton, NJ: Princeton University Press.

Donaldson, G. and J. Lorsch (1983): *Decision Making and the Top: The Shaping of Strategic Direction*. Basic Books, New York.

Downs, A. (1967): *Inside Bureaucracy*. Boston: Little Brown.

Dubini, P. and R.G. McGrath (1999): Option Potential and The Innovators’ Dilemma: Resource Commitment to Uncertain New Projects. Columbia Business School, Working Paper.

Dutton, J.E. and R.B. Duncan (1987): The creation of momentum for change through the process of strategic issue diagnosis. *Strategic Management Journal, 8*, p. 279-295.

Einhorn, H.J. and R.J. Hogart (1986): Backward and forward thinking in decision making. *Selected Paper No. 62*. Chicago: Graduate School of Business, University of Chicago.

Eisenhardt, K.M. (1989a): Agency Theory: An Assessment and Review. *Academy of Management Review*, Vol. 14, No. 1, p. 57-74.

Eisenhardt, K.M. (1989b): Building Theories from Case Study Research. *Academy of Management Review*, Vol. 14 (4), p. 532-550.

Emerson, R.M. (1962): Power-Dependence Relations. *American Sociological Review*, Vol. 27, p. 31-40.

Eppen, G.D., F.J. Gould and C.P. Schmidt (1993): *Introductory Management Science*. Englewood Cliffs: Prentice-Hall.

Evans, J.S. (1991): Strategic Flexibility for high technology maneuvers: A conceptual framework. *Journal of Management Studies*, 28, p. 69-89.

Fama, E. and M. Jensen (1983): Separation of ownership and control. *Journal of Law and Economics*, 26, p. 301-325.

Feigenbaum, M.J. (1979): Universal Metric Properties of Non-linear Transformation. *Journal of Statistical Physics, 21*, p. 669-706.

Fiegenbaum, A. and A. Karnani (1991): Output flexibility – A competitive advantage for small firms. *Strategic Management Journal*, 12, p. 101-114.

Fischler, M.A. and O. Firschein (1987): *Intelligence: The eye, the brain, and the computer*. Reading: Addison Wesley.

Fishburn, P.C. (1984): SSB utility theory and decision making under uncertainty. *Mathematical Social Sciences, 8*, p. 253-285.

Fleming, L. and O. Sorenson (2000a): Technology as a Complex Adaptive System: Evicence from Patent Data. Unpublished paper presented at the Academy of Management, Toronto 2000.

Fleming, L. and O. Sorenson (2000b): Science as a Map in Technological Search. Unpublished paper presented at the Academy of Management, Toronto 2000.

Forrester, J. (1958): Industrial dynamics: A major breakthrough for decision-making. *Harvard Business Review, 36 (4)*, p. 37-66.

Frankfort-Nachmias, C. and D. Nachmias (1996): *Research Methods in the Social Sciences*, 5th ed. London: Arnold

Freeman, W. (1991): The Physiology of Perception. *Scientific American, 264 (2)*, p. 78-85.

Galbraith, J. (1973): *Designing Complex Organizations*. Reading, Mass.: Addison-Wesley.

Galbraith, J. (1973): *Organization Design*. Reading, Mass.: Addison-Wesley.

Gavetti, G. and D. Levinthal (2000): Looking forward and looking backward: Cognitive and experimental search. *Administrative Science Quarterly*, 45, (1), p. 113-139.

Gell-Mann, M. (1994): *The Quark and the Jaguar*. New York: Freeman.

Gerwin, D. (1989): Manufacturing flexibility in the CAM era. *Business Horizons*, 32, p. 78-84.

Ghemawat, P. (1991): *Commitment: The dynamic of strategy*. New York: The Free Press.

Gleick, J. (1987): *Chaos: Making a New Science*. New York: Viking.

Gold, R.L. (1958): Roles in Sociological Field Observation. *Social Forces*, Vol. 36.

Goldberger, A.L., D.R. Rigney and B.J. West (1990): Chaos and fractals in Physiology. *Scientific American, 263*, p. 43-49.

Goldstein, J. (1994): *The Unshackled Organization: Facing the Challenge of Unpredictability through Spontaneous Reorganization*. Portland, OR: Productivity Press.

Goodwin, B. (1994): *How the Leopard Changed its Spots*. London: Weidenfeld and Nicolson.

Griffin, J.D. (1998): *Dealing with the paradox of culture in management theory*. Unpublished thesis, University of Hertfordshire.

Hall, R.I. (1976): A system pathology of an organization: the rise and fall of the Saturday Evening Post. *Administrative Science Quarterly, 21*, p. 185-211.

Hambrick, D. (1987): Top management teams: Key to strategic success. *California Management Review*, 30, p. 88-108.

Hamel, G. and C.K. Prahalad (1994): Strategy as a field of study: Why search for a new paradigm? *Strategic Management Journal, Vol. 15*, p. 5-17.

Hammersley, M. and P. Atkinson (1995): *Ethnography: Principles in practice*, 2nd ed. New York: Routledge.

Harrison, B. (1994): *Lean and mean: The changing landscape of corporate power in the age of flexibility*. New York: Basic Books.

Hartley, J.F. (1994): Case Studies in Organizational Research. In C. Cassel and G. Symon (Eds.): *Qualitative Methods in Organizational Research: A Practical Guide*. Sage Publications.

Hawkes, R.W. (1961): The Role of the Psychiatric Administrator. *Administrative Science Quarterly*, Vol. 6, p. 89-106.

Hayek, F.A. (1945): *The Counter-Revolution of Science: Studies on the Abuse of Reasons*. 2nd ed., Indianapolis, IN: The Free Press, 1979.

Hayek, R. (1948): *Individualism and Economic Order*. University of Chicago Press, Chicago, IL.

Hedberg, B. (1997): *Virtual organizations and beyond: Discover imaginary systems*. Chichester: John Wiley.

Heide, J.B. and G. John (1990): Alliances in Industrial Purchasing: The Determinants of Joint Action in Buyer- Seller Relationships. *Journal of Marketing Research*, 27, p. 24-36.

Heide, J.B. and G. John (1992): Do Normas Matter in Marketing Relationships? *Journal of Marketing*, 56, p. 32-44.

Helmer, O. (1966): *Social Technology*. New York: Basic Books.

Hogarth, R. (1987): *Judgement and Choice* (2nd ed.). New York: John Wiley and Sons.

Holland, J.H. (1992): *Adaptation in Natural and Artificial Systems*. MIT Press, Cambridge, MA.

Holland, J.H. (1998): *Emergence: From Chaos to Order*. New York: Oxford University Press.

Horgan, J (1996): *The End of Science*. Reading MA: Addison Wesley.

Jones, (1991):

Hsieh, D.A. (1991): Chaos and nonlinear dynamics: Application to financial markets. *Journal of Finance*, 46 (5), p. 1839-1877.

Johnson, G. (1987): Strategic change and the management process. New York: Basil Blackwell.

Kafelas, A. and P.P. Schoederbek (1973): Application and implementations: scanning and the business environment – some empirical results. *Decision Science*, *4*, p. 63-74.

Kahneman, D. and A. Tversky (1974): Judgement under uncertainty: Heuristics and biases, *Science, 185*, p. 1124-1131.

Kahneman, D. and A. Tversky (1979): Prospect theory: An analysis of decision under risk. Econometrica, 47, p. 263-291.

Kahneman, D. and A. Tversky (1981): The framing of decisions and the psychology of choice, *Science, 211*, p. 453-458.

Kahneman, D. and A. Tversky (1982): *Judgement Under Uncertainty: Heuristics and Biases*. Cambridge University Press, Cambridge, MA.

Kahneman, D., J.L. Knetsch and R.H. Thaler (1990): Experimental tests of the endowment effect and the Coase theorem. *Journal of Political Economy, 98*, p. 1325-1348.

Karmarkar, U. (1978): Subjectively weighted utility: A descriptive extension of the expected utility model. *Organizational Behavior and Human Performance, 21*, p. 1966-1981.

Kauffman, S.A. (1993): *The Origins of Order: Self-organization and Selection in Evolution*. New York: Oxford University Press.

Kauffman, S.A. (1995): *At Home in the Universe: The search for the Laws of Self-organization and Complexity*. New York: Oxford University Press.

Kelsey, D. (1988): The economics of chaos or the chaos of economics. *Oxford Economic Papers, 40*, p- 1-31.

Kiesler, I.S. and L. Sproull (1982): Managerial Response to Changing Environments: Perspectives on Problem Sensing from Social Cognition. *Administrative Science Quarterly*, Vol. 27, p. 548-570.

Klein, S. (1989): A Transaction Cost Explanation of Vertical Control in International Markets. *Journal of the Academy of Marketing Science*, 17, p. 253-260.

Klein, B., R.G. Crawford and A. Alchian (1978): Vertical integration, appropriable rents, and the competitive contracting process. *Journal of Law and Economics*, 21, p. 297-326

Klein, B., G.L. Frazier and V. Roth (1990): A Transaction Cost Analysis Model of Channel Integration in International Markets. *Journal of Marketing Research*, 27, p. 196-208.

Klein, B. and K. Leffler (1981): The role of price in guaranteeing quality. *Journal of Political Economy*, 89, p. 615-641.

Kluckhohn, F. (1940): The Participant-Observer Technique in Small Communities. *American Journal of Sociology*, Vol. 46.

Koput, K. (1992*): Dynamics of Innovation Idea Generation in Organizations: Randomness and Chos in the Development of a New Medical Device*. Unpublished Ph.D. Dissertation, School of Business, University of California Berkely.

Kumaraswamy, A. (1996): A Real Options Perspective of Firms' R & D Investments. Unpublished doctoral dissertation, New York University.

Langton, C.G. (1996): Artificial Life. In M.A: Boden (Ed.): *The Philosophy of Artificial Life*. Oxford: Oxford University Press.

Laszlo, E. (1987): *Evolution: The Grand Synthesis*. Boston MA: Shambhala.

Lave, C.A. and J.G. March (1975): *An Introduction to Models of the Social Sciences*. New York: Harper and Row, Inc.

Lawrence, P.R. and J.W. Lorsch (1967): *Organization and Environment*. Harvard University Press, Cambridge, MA:

Leonard-Barton, D. (1992): Core capabilities and core rigidities: A paradox in managing new product development. *Strategic Management Journal*, 13, p. 111-125.

Levy, D. (1994): Chaos Theory and Strategy: Theory, Application, and Managerial Implications. *Strategic Management Journal*, Vol. 15. p. 167-178.

Lewin, R. (1999): *Complexity: Life at the Edge of Chaos*. Chicago: The University of Chicago Press, 2nd Edition.

Lipnack, J. and J. Stamps (1997). *Virtual teams: Reaching across space, time and organizations with technology*. New York: John Wiley.

Lissack, M. and J. Roos (1999): *The Next Common Sense: Mastering Corporate Complexity through Coherence*. London: Nicholas Brealey Publishing.

Loomes, G. and R. Sugden (1982): Regret theory: An alternative theory of rational choice under uncertainty. *Economical Journal*, *92*, p. 805-824.

Loomes, G. and R. Sugden (1983): A rationale for preferences reversal. *American Economic Review, 73*, p. 428-432.

Loomes, G. and R. Sugden (1987): Some implications of a more general form of regret theory. *Journal of Economic Theory, 41*, p. 270-287.

Lorange, P. (1980): Roles of the CEO in strategic planning and control Processes. Presented in a seminar on The Role of General Management in Strategy Formulation and Evaluation, Cergey, France: April.

Lorenz, E.N. (1963): Deterministic Nonperiodic Flow. *Journal of Atmospheric Sciences. March*, p. 130-141.

Lunnan, R. (1999): *Strategic Flexibility and Alliances*. Unpublished Ph.D. Thesis. Bergen: Norwegian School of Economics and Business Administration.

Lyles, M. and I. Mitroff (1980): Organizational problem formulation: an empirical study. *Administrative Science Quarterly,* 25, p. 10-119.

Macneil, I.R. (1980): *The New Social Contract*, New Haven: Yale University Press.

Mahon, C.J. (1999): *Charting Complexity*. Copenhagen: Fredriksberg Bogtrykkeri A/S

March, J.G. and H.A. Simon (1958): *Organizations*. New York: John Wiley & Sons, Inc.

May, R.M. (1976): Simple Mthematical Models with Very Complicated Dynamics. *Nature, 261*, p. 459-467.

Mayer-Kress, G. and S. Grossmann (1989): Chaos in international arms race. *Nature*, 337, p. 701-704.

McGill, A. (1986): *Context Effects in Judgements of Causation*. Unpublished Ph.D. thesis, University of Chicago.

McGrath, R.G. (1997): A real options logic for initiating technology positioning investments. *Academy of Management Review*, 22, p. 974-996.

Merton, R.K. (1957a): Bureaucratic Structure and Personality. In Merton, R.K. (Eds.), *Social Theory and Social Structure*, New York: The Free Press of Glencoe.

Meyer, C.B. (2000): A Case in Case Study Methodology. Bergen: Unpublished paper, available at the Norwegian School of Economics and Business Administration, Department of Strategy and Management.

Meyer, J.W. and B Rowan (1977): Institutionalized Organizations: Formal Structure as Myth and Ceremony. *American Journal of Sociology*, 83, p. 340-63.

Mikulecky, D.C. (1999): Robert Rosen: The Well Posed Question and its Answer- Why Are Organisms Different From Machines? Paper presented at the *43rd Meeting of the International Society for the Systems Sciences,* June 27 – July 2 1999, Asilomar Conference Center, Pacific Grove, California USA

Miles, M.B. and A.M. Huberman (1994): *Qualitative Data Analysis*, 2nd ed. Sage Publications.

Miles, R.E. and C.C. Snow (1992): Causes of failure in network organizations. *California Management Review*, Vol. 34 (4), p. 53-72.

Miller, D. (1990): *The Icarus paradox: How Excellent Organizations Can Bring About Their Own Down-fall*. New York: Harper Business.

Mintzberg, H. (1978): Patterns in Strategy Formation. *Management Science, Vol. 24,* Iss. 9; pg. 934.

Mintzberg, H. (1979): *The structuring of organizations*. Englewood Cliffs, NJ: Prentice-Hall.

Mintzberg, H. and A. McHugh (1978): Strategy Formation in an Adhocracy. *Administrative Science Quarterly, Vol. 30,* Iss. 2, p. 160-198.

Mintzberg, H., D. Raisinghani and A. Theoret (1976): The structure of “unstructured” decision processes. *Administrative Science Quarterly*. 21, p. 246-275.

Mitchell, G.R. and W.F. Hamilton (1988): Managing R & D as a strategic option. *Research-Technology Management*, 27, p. 15-22.

Morrison, F. (1991): *The Art of Modeling Dynamic Systems*. New York: Wiley.

Moskilde, E. and S. Rasmussen (1986): Technical economic succession and the economic long wave. *European Journal of Operational Research, 25*, p. 27-38.

Myers, S.C. (1977): Determinants of corporate borrowing. *Journal of Financial Economics*, 5, p. 147-175.

Nelson, R. and S. Winter (1982): *An evolutional theory of economic change*. Cambridge: Harvard University Press.

Nicolis, I. and G Prigogine (1989): *Exploring Complexity: An Introduction*. New York: W.H. Freeman.

Nonaka, I. (1988): Creating organizational order out of chaos: self renewal in Japanese firms. *California Management Review*, Spring, p. 57-73.

Noordewier, T.G., G. John and J.R. Nevin (1990): Performance Outcomes of Purchasing Arrangements in Industrial Buyer-Vendor Relationships. *Journal of Marketing*, 54, p. 80-93.

Nutt, P.C. (1979): Calling out and callng off the dogs: managerial diagnosis in public service organizations. *Academy of management review, 4*, p. 203-214.

Parsons, T. (1960): *Structure and Process in Modern Societies*. New York: The Free Press of Glencoe.

Payne, J.W. (1973): Alternative approaches to decision making under risk: Momentus versus dimensions. *Psychological Bulletin, 80*, p. 439-453.

Payne, J.W. (1982): Contingent decision behavior. *Psychological Bulletin, 80*, p. 439-453.

Peters, E.E. (1991): *Chaos and Order in the Capital Markets: A New View of Cycles, Prices and Market Volatility*. New York: John Wiley.

Petersen, T. (1993): The Economics of Organization: The Principal-Agent Relationships. *Acta Sociologica*, Vol. 36 (3), p. 277-293.

Pettigrew, A.M. (1990): Longitudinal Field Research on Change: Theory and Practice. *Organization Science*, Vol. 1 (3), p. 267-292.

Pfeffer, J. and G.R. Salancik (1978): *The External Control of Organizations*. New York: Harper &Row, Pub.

Plous, S. (1993): *The Psychology of Judgement and Decision Making*. McGraw-Hill, Inc.

Polany, M. (1962): *Personal knowledge: towards a post critical philosophy*. London: Routledge.

Popper, K.R. (1968): *Conjectures and Refutations: The Growth of Scientific Knowledge*. New York: Harper and Row.

Porter, M. (1980): *Competitive Strategy*. New York: Free Press.

Pounds, W.F. (1969): The process of problem finding. *Industrial Management Review, II*, p. 1-19.

Prigogine, I. and I. Stengers (1984): *Order out of Cahos*. New York: Bantman Books.

Quattrone, G.A., C.P. Lawrens, D.L. Warren, K. Souza-Silva, S.E. Finkel and D.E. Andrus (1984*): Explorations in anchoring: The effects of prior range, anchor extremity, and suggestive hints*. Unpublished manuscript, Stanford University, Stanford.

Quattrone, G.A. and A. Tversky (1988): Contrasting rational and psychologicalanalyses of political choice. *American Political Science Review, 82*, p. 719-736.

Radzicki, M.J. (1990): Institutional dynamics, deterministic chaos, and self-organizing systems. *Journal of Economic Issues, 24 (1)*, p. 57-102.

Rajagopalan, N. and G.M. Spreitzo (1997): Toward a theory of strategic change: A multi-lens perspective and integrative framework. *Academy of Management Review*, Vol. 22, No. 1, p. 48-79.

Rescher, N. (1998): *Complexity: A Philosophical Overview*. New Brunswick, New Jersey: Transaction Publishers.

Richardson, J. (1996): Vertical integration and rapid response in fshion apparel. *Organizational Science*, 7 (4), p. 400-411.

Rindfleish, A. and J.B. Heide (1997): Transaction Cost Analysis: Past, Present, and Future Applications. *Journal of Marketing*, Vol. 61, p. 30-54.

Romanelli, M.L. and E. Tushman (1985): Organizational evolution: A metamorphosis model of convergence and reorientation. In L.L. Cummings and B.M. Staw (Eds.): *Research in Organizational Behavior*, 7: p. 171-222. Greenwich, CT.: JAI Press.

Rosen, R. (1972): Some relational Cell models: The metabolism-repair systems. In R. Rosen (Ed.): *Foundations of Mathematical Biology*, Vol. II, New York: Academic Press.

Rosen, R. (1978): *Fundamentals of Measurement and Representation of Natural Systems*. New York: North-Holland.

Rosen, R. (1985): *Anticipatory Systems: Philosophical, Mathematical and Methodological*. New York: Pergamont Press.

Rosen, R. (1991): *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Colombia University Press.

Rosen, R. (1996): On the Limits of Scientific Knowledge. In J. Casti and A. Karlqvist (Eds.): *Boundaries and Barriers: On the Limits to Scientific Knowledge*. Reading: Addison-Wesley, p. 199-214.

Rosen, R. (1999): *Essays on Life Itself*. New York: Colombia University Press.

Rumelt, R. and R. Wensley (1981): In Search of the Market Share Effect. In Chung, K. (Ed.), *Academy of Management Proceedings 1981*: 2-6.

Sanchez, R. (1993). Strategic flexibility, firm organization and managerial work in dynamic markets. *Advances in Strategic Management*, 9, p. 251-291.

Sanchez, R. (1995): Strategic flexibility in product competition. *Strategic Management Journal*, 16, p. 135-159.

Sanchez, R. and J.T. Mahoney (1996): Modularity, flexibility and knowledge management in product and organization design. *Strategic Management Journal*, 17 (Winter Special Issue), p. 63-76.

Sanders, T.I. (1998): *Strategic Thinking and the New Science: Planning in the Midst of Chaos, Complexity, and Change*. New York: The Free Press.

Sastry, M.A. (1997): Problems and Paradoxes in a Model of Punctuated Organizational Change. *Administrative Science Quarterly*, Vol. 42, p. 237-276.

Schein, E.H. (1985): *Organizational Culture and Leadership*. San Francisco, CA: Jossey-Bass.

Schumpeter, J.A. (1934): *The Theory of Economic Development*. Harvard University Press, Cambridge, MA.

Schumpeter, J.A. (1950): *Capitalism, Socialism, and Democracy* (3rd ed.). New York: Harper.

Scott, W.R. (1981): *Organizations: Rational, Natural, and Open Systems*. Prentice Hall, Inc., Englewood Cliffs.

Segev, E. (1976): Triggering the strategic decision-making process. *Management Decision, 14*, p. 229-238.

Senge, P.M. (1990): *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Doubleday Currency.

Shapira, Z. (1995): *Risk Taking: A Managerial Perspective*. New York: The Russel Sage Foundation.

Shapiro, C. (1989): The theory of business strategy. *RAND Journal of Economics*, 20, p. 125-137.

Sheppard, B.H. and D.M. Sherman (1998): The Grammars of Trust: A Model and General Implications. *Academy of Management Review*, Vol. 23, p. 422-437.

Simon, H.A. (1955): A Behavioral Model of Rational Choice. *Quarterly Journal of Economics*, *69*, p. 99-118.

Simon, H.A. (1956): Rational choice and the structure of the environment. *Psychological Review*, *63*, p. 129-138.

Simon, H.A. (1957a): *Administrative Behavior*. 2nd ed, New York: The Macmillan Company.

Simon, H.A. (1957b): *Models of Man, Social and Rational*, New York: John Wiley and Sons, Inc.

Simon, H.A. (1981): *The Science of the Artificial*. Cambridge, MA: MIT Press, 1969; 2nd ed., 1981.

Slovic, P. (1975): Choice between equally valued alternatives. *Journal of Experimental Psychology: Human Perception and Performance, 1*, p. 280-287.

Slovic, P., B. Fischhoff and S. Lichtenstein (1982a): Facts versus fears: Understanding perceived risk. In D. Kahneman, P. Slovic and A. Tversky (Eds.), *Judgement under uncertainty: Heuristics and biases*. Cambridge, England: Cambridge University Press.

Slovic, P., B. Fischhoff and S. Lichtenstein (1982b): Response mode, framing, and information-processing effects in risk assessment. In R.M. Hogarth (Eds.), *New directions for methodology of social and behavioral science: Questions framing and response consistency* (No. 11). San Francisco: Jossey-Bass.

Smith, T.B. (1973): The Policy Implementation Process. *Policy Science*, 4, p. 197-209.

Sorgar, L. (1997): *Konkurransestrategi: Eksempler på anvendt mikroøkonomi*. Bergen: Fagbokforlaget.

Sproull, L. (1981): Beliefs in organizations. In Nystrom, P. and W Starbuck (Eds.), *Handbook of Organizational Design*, Oxford University Press, Oxford, p. 203-225.

Stacey, R.D. (1995): The Science of Complexity: An Alternative Perspective for Strategic Change Processes. *Strategic Management Journal*, Vol. 16, p. 477-495.

Stacey, R.D. (2000*): Strategic Management and Organisational Dynamics: The Challenge of Complexity* (3rd ed.). Prentice Hall, Pearson Education Limited.

Stake, R. (1995): *The art of case study research*. Thousand Oaks, CA: Sage Publications.

Stutzer, M. (1980): Chaotic Dynamics and Bifurcations in a Macro Model. *Journal of Economic Dynamics and Control*, *2*, p. 353-376.

Suarez, F.F., H.A. Cusumano and C.H. Fine (1995): An empirical study of flexibility in manufacturing. *Sloan Management Review*, 37 (1), p. 25-32.

Thompson, J.D. (1967): *Organizations in Action*. New York: McGraw- Hill, Inc.

Thompson, J.D. and A. Tuden (1959): Strategies, Structures and Proesses of Organizational Decision. In Thompson, J.D. et al. (Eds.), *Comparative Studies in Administration*, Pittsburgh, Pa.: The University of Pittsburgh Press.

Trigeorgis, L. (1997): *Real Options: Managerial Flexibility and Strategy in Resource Allocation*. Boston: The MIT Press.

Tversky, A. (1972): Elimination by aspects: A theory of choice. *Psychological Review*, *79*, p. 281-299.

Van de Ven, A.H. and G.P. Huber (1990): Longitudinal Field Research Methods for Studying Processes of Organizational Change. *Organization Science*, Vol. 1(3), p. 213-219.

Volberda, H.W. (1996): Toward the flexible form: How to remain vital in hypercompetitive environments. *Organization Science*, 7, p. 359-373.

von Neumann, J. and O. Morgenstern (1947): *Theory of games and economic behavior*. Princeton, NJ: Princeton University Press.

Waldrop, M.M. (1992): *Complexity: The Emerging Science at the Edge of Chaos.* New York: Englewood Cliffs; Simon and Schuster.

Wax, R.H. (1968): Participant Observation. *International Encyclopedia of Social Sciences*. New York: Macmillan.

Weber, M. (1947): *The Theory of Social and Economic Organization*. Parson, T. (Eds.), New York: The Free Press of Glencoe.

Wheatley, M.J. (1992): *Leadership and the New Science: Learning about organization from an Orderly Universe*. San Francisco: Berrett-Koehler.

Williamson, O.E. (1975): *Markets and Hierarchies: Analysis and Antitrust Implications*. New York, The Free Press.

Williamson, O.E. (1979): Transaction-Cost Economics: The Governance of Contractual Relations. *The Journal of Law and Economics*, 22, p. 233-261.

Williamson, O.E. (1985): *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*. New York: The Free Press.

Williamson, O.E. (1991a): Strategizing, Economizing, and Economic Organization. *Strategic Management Journal*, 12, p. 75-79.

Williamson, O.E. (1991b): Comparative Economic Organization: The Analysis of Discrete Structural Alternatives. *Administrative Science Quarterly*, 36 (2), p. 269-296.

Williamson, O.E. (1991c): The Logic of Economic Organization. I Williamson, O.E., Winter, S.G: (red.), *The Nature of the Firm: Origins, Evolution and Developement*, p. 90-116, Oxford University Press, New York.

Winter, S. (1988): Knowledge and competence as strategic assets. In D. Teece (ed.): *The Competitive Challenge*. Cambridge: Ballinger, p. 159-184.

Winter, S.G. (1987). Knowledge and competence as strategic assets. In D. Teece (Ed.): *The competitive challenge: Strategies for industrial innovation and renewal*. Cambridge, MA: Ballinger.

Wright, W.F. and U. Anderson (1989): Effects of situation familiarity and financial incentives on use of the anchoring and adjustment heuristic for probability assessment. *Organizational Behavior and Human Decision Processes, 44*, p. 68-82.

Wyer, R.S. Jr. (1976): An investigation of the relations among probability estimates. *Organizational Behavior and Human Performance, 15*, p. 1-18.

Yin, R.K. (1989): Case Study Research: Design and Methods. *Applied Social Research Series*, Vol. 5, Sage Publications.

Yin, R.K. (1993): Application of Case Study Research*. Applied Social Research Series*, Vol. 34, Sage Publications.

Zimmermann, B.J. (1992): The inherent drive towards chaos. In P. Lorange, B. Chakravarty, A. Van de Ven and J. Roos (Eds.); *Implementing Strategic Processes: Change, Learning and Cooperation*. London: Blackwell.