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2.2 Prologue to Autonomous Cooperation – the Idea of Self-Organisation as its Basic Concepts

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2.2.1 Introduction

Autonomous cooperation describes processes of decentralized decision-making in heterarchical structures. The implementation of autonomous co-operation aims at a flexible self-organizing system structure that is able to cope with dynamics and complexity while maintaining a stable status (Hülsmann and Windt 2005). The basic idea of the concept of autonomous cooperation derives from concepts of self-organisation, which analyze the emergence of ordered and robust structures in complex systems in general (Paslack 1991). The idea of self-organisation has its historical roots in different academic fields such as Physics, Biology and Chemistry and dates back to at least 500 BC of the pre-Socratic Heraclites and Aristotle who identified self-organized processes in natural phenomena (Paslack and Knost 1990; Paslack 1991). An increasing number of literature written by different scientists from different disciplines concern explicitly with self-organizing systems can be found from the 1970's, as for example in Cybernetics von Foerster (1960), in Chemistry Prigogine and Glansdorff (1971), in Physics Haken (1973) and in Biology Maturana and Varela (1980).

It does not seem feasible to apply a concept of natural sciences (the idea of self-organizing systems) cent per cent into social sciences, since there are essential differences between those systems in nature, constitution. There may exist attempts of its application to business, for instance to logistics in terms of autonomous cooperation which is believed to incorporate the self-organizing principles (Hülsmann and Windt 2005). Transferring the idea of self-organizing systems into the concept of autonomous cooperation a first step would be to understand the roots and principles of self-organisation.

The aim of this paper is to unlock via its primal foundation concepts the understanding of self-organisation and its different common characteristics underlying these concepts. This shall serve as a platform to get introduced into the working principles of self-organizing systems. These concepts are seen as the foundation for explaining the underlying principles as to how complex systems autonomously create ordered structures. It may be presumed that these concepts shall set the trajectory and common ground for understanding processes of autonomous order creation, which in turn forms the basis for autonomous cooperation.

Therefore, the core aspects of selected concepts of self-organisation are presented with a brief description of each in the subsequent section of this paper. Later to give a clear picture of the idea of self-organisation, the characteristics which form the basis of self-organizing systems out of the selected concepts shall be extracted and juxtaposed by means of the general criteria of system structure, system behavior and system abilities. Finally, a conclusion is drawn about the general understanding of the concept of self-organisation with emphasis on its potential application and further areas of research.

2.2.2 Concepts of self-organisation

In this section, the so called "primal concepts" of self-organisation out of which the main ideas of autonomous order creation have emerged are introduced. (Paslack and Knost 1990) mention the approaches Synergetic (Haken 1973), Dissipative Structures (Prigogine 1969), Autopoiesis (Maturana and Varela 1973), Cybernetics (von Foerster 1960), Ecosystems (e.g. Bick 1973) and Chaos Theory (e.g. Mandelbrot 1977 and Lorenz 1963) among those primal self-organisation concepts (see also Grapp et al. 2005).

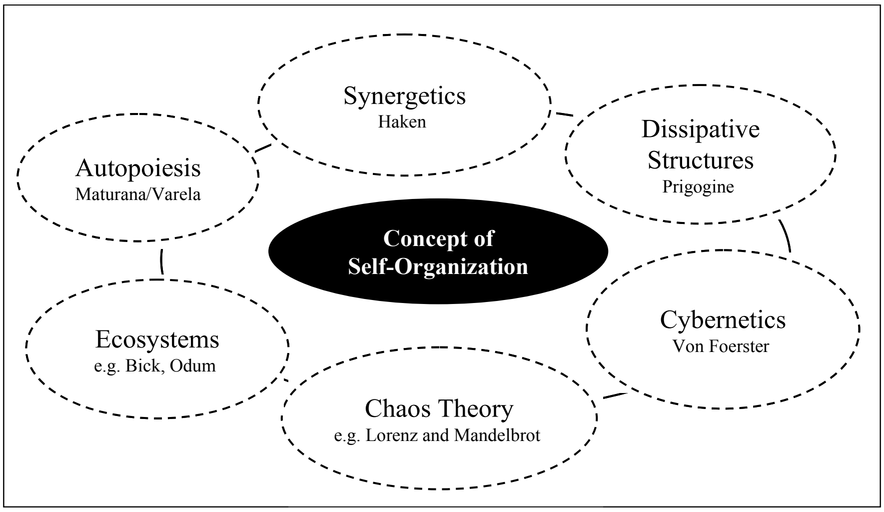

Fig. 2.1 Primal concepts of the idea of self-organisation

Synergetics

Self-organisation of systems has been the subject of central discussions of Synergetics in several research disciplines since its inception. The concept of Synergetics was invented by Haken in 1969 who for the first time saw this subarea of Physics as a new field of interdisciplinary research (Ulrich 1984). Though it originated from Physics (e.g. lasers, fluid instabilities, plasmas) it found applications not only in the natural sciences, such as Chemistry (e.g. chemical reactions resulting in pattern formation, including flames), Biology (e.g. morphogenesis, evolution theory), Meteorology, Neurobiology, Computer Sciences (e.g. synergetic computer), Movement Science, but also in the Humanities such as Sociology (e.g. city growth), Psychology and Psychiatry (including Gestalt Psychology). Several other authors who contributed to this field are Buckminster (1975), Ulrich (1984), Probst (1984), Kriz (1990), Tschacher (1992), Tschacher, Schiepek and Brunner (1992), Stadler and Kruse (1995), Dauwalder and Tschacher (1999), Malik (2000).

According to Buckminster, Synergetics can be applied to all aspects of human endeavor because it is capable of providing a method, a design and a philosophy for problem solving. It involves the integration of geometry and philosophy and accounts for both physical and metaphysical understanding of several methods and processes (Buckminster 1975).

Haken defines the core aspect of Synergetics as the cooperation of individual parts of a complex system that interact with each other and thereby autonomously produce macroscopic spatial, temporal or functional structures. The concept attempts to explain that these structures develop spontaneously in nature by virtue of self-organisation. In physical systems, Synergetics studies the nonlinear non-equilibrium process, where – after energy is being pumped into a system – macroscopic structures emerge from disorder in behavior of large number of microscopic particles. The functioning of a laser, for example, can be seen as such a synergetic process. A laser is a light source that produces light with properties, which vary from conventional lamps. For instance in the case of a gas discharge lamp, individual atoms are excited by means of electric current. Each excited atom then emits a light wave track making their transitions entirely independent from one another, i.e. the light emission is entirely irregular. On the contrary, in case of a laser a transformation of energy occurs where the random motion of electrons of electrical current is transformed into highly ordered energy of the light field, i.e. a beam of coherent light is emitted out of the chaotic movement of particles exhibiting harmony among them (Haken 1978).

The coherent process in Synergetics as described above exhibits a process of self-organisation. Seen from a thermodynamic point of view it seems to contradict with the second law of thermodynamics, which states that no system can convert energy from one form to another useful form with hundred percent efficiency and all systems tend towards disorder (Kuhn 1978). However this contradiction gets resolved by the fact that the laser is an open system through which permanently energy is pumped, while the thermodynamics second law deals with closed systems. As chaos turns into order, Synergetics makes use of probabilities (to describe uncertainty) and information (to describe approximation) and therefore deals with stochastic (chance) and deterministic (necessity) processes. This transition from disorder to order is found to be related with the concept of entropy (degree of disorder). But Synergetics has replaced the entropy principle by a dynamic principle which refers to open systems through which energy (and matter) can be pumped into the system (Haken 1981).

In this open system, competition sets in between different forms of collective modes. Those modes which win the competition slave the whole system (known as "slaving principle") and thus determine the macroscopic order (known as "order parameters"). Here, Haken (1981) states that neither the elements of the system nor the order parameters determine the state of order but rather that order parameters and elements determine each other. He further explains that despite the different nature of individual disciplines, the corresponding order parameters obey the same equations which describe logical processes. These logical processes can take place in different substrates or in different systems. More high ordered states can arise in different disciplines due to change in external conditions. In this way more and more complex structures arise in a self-organized way i.e. evolution of new structures internally and not from external sources (Haken 1981). These complex non-equilibrium systems are studied by Synergetics and self-organisation theory (Tschacher et al. 2003).

According to Fuchs (2002), Haken's work infers self-organisation differently as Haken has tried to transfer the synergetic principle of slaving directly from Physics to Sociology. Moreover, Fuchs argues that the term 'slaving' does not seem to be proper wording in social contexts and he views slaving as a terminus technicus which has no ethical or other implication.

Cybernetics

The term "Cybernetics" is derived from the Greek word kybernetes which means steersman, governor, or pilot (Drosdowski 1990). The Oxford Dictionary defines 'Cybernetics' as "the science of communications and control in machines (e.g. computers) and living things (e.g. by the nervous system)" (Oxford Dictionary 2002). The term was first coined in 1948 by Wiener to address the study of "teleological mechanisms" (Wiener 1948). Cybernetics is an interdisciplinary field being studied in Philosophy, Biology and Medical Sciences, Engineering as well as in Business Studies. Authors who have made major contributions are McCulloch and Pitts (1943), Wiener (1948), von Foerster (1960) and others such as Ashby (1970), Pask (1979), Probst (1984), Walter (1996), Heylighen and Joslyn (2001).

Speaking in general terms, the influence of Cybernetics may be seen in several contemporary disciplines such as computer science, information theory, control theory, automata theory, artificial neural networks, cognitive science, dynamical systems, artificial intelligence and artificial life. The main feature of Cybernetics which differentiates between Cybernetics on the one hand and information theory and control theory is its emphasis on communication and control. Not only in artificial or engineered systems but also in evolved and natural systems, which behave by setting their own goals rather than being controlled by their creators (Heylighen a. Joslyn 2001). Cybernetics has extended its application in various concepts like self-organisation (von Foerster 1960; Ashby 1970), computer architectures, cellular automata, and game theory (Aspray 1990), autonomous robots (Braitenberg 1984), and artificial neural networks (McCulloch and Pitts 1943).

Referring to Probst, Cybernetics takes into account the research on the mechanisms of control in its broadest sense. Using cybernetic principles, it might be possible to help managers in finding other and perhaps more adequate solutions for design, control and development of purposeful social systems. This may be achieved by deriving rules of action or confirming or rejecting the prevailing and accepted managerial rules of action (Probst 1984).

The theory of observing design or discovery in general and the science of communication were seen as 'Cybernetics of the first order' by von Foerster (1979). Through considering the whole domain as a system, he found necessary requirements and functions for observing this system. He termed this understanding as 'Cybernetics of the second order' or 'Cybernetics of observing systems'. Second-order Cybernetics explores the construction of models of systems. It studies Cybernetics with an increased awareness that the observers are a part of the system as well, i.e. the examiner (the observer) and the examination are part of the system being observed. Von Foerster also referred to this as 'Cybernetics of Cybernetics' (von Foerster 1979). The proceedings of the Macy Conference edited by von Foerster found that Cybernetics manages itself based on the notion of circular causality (von Foerster 1960). Following this, two generalizations were drawn by von Foerster. First, recursion that is implicit in Cybernetics of Cybernetics and tends to stabilize at a particular value (or a self-function generating a self-value), which he thought was a manifestation of an object, and therefore presents a model for the appearance of stability. Second, since each one of us is our own observer, every individual has its own unique way of understanding and observing things, which might vary from observer to observer (von Foerster 1979). This is in conjunction with Pask's conversation theory, which provides common means of communication in case understanding of individuals vary (Pask 1979).

Each dynamical system that belongs to attractors (which may have any type of shape or dimension within the system) finally results in having one of the attractors, thereby losing its independence to visit any other system's state space. This is what Ashby (1970) referred to as the principle of self-organisation. He also pointed out that if the system is composed of several subsystems, then the constraint generated by self-organisation implies that the subsystems have either become mutually dependent or mutually adapted. For example, in case of magnetization, initially the assembly of magnetic spins point in random directions (maximum entropy), but later end up being aligned in the same direction (minimum entropy, or mutual adaptation) (Ashby 1962). Self-organisation according to von Foerster can be enhanced by stochastic perturbations ('noise') of the system's state, in which the descent of the system gains momentum and forces shallow attractors to exit the system. This is referred to as order from noise principle (von Foerster 1960).

Hence it can be seen that early work on Cybernetics focused on defining and applying principles through which systems may be controlled. However recent work has endeavored to understand how systems organize and control themselves. Cybernetics – though not developed as an individual discipline yet – has developed as an emerging concept among varied processes involving people as active organizers, sharing communicators, and as autonomous, responsible individuals (Umpleby 1999).

Dissipative structures

The term 'Dissipative Structures' was coined by the physicist Prigogine in order to explain the phenomena of non-equilibrium thermodynamics (Prigogine 1969). The application of the concept can be found not only in Physics and Chemistry but also in Biology and Sociology. Authors who work in cooperation with Prigogine on this subject are Glansdorff (Glansdorff and Prigogine 1971), Balescu (1975), Nicolis (Nicolis and Prigogine 1977), Lefever (1978), Stengers (Prigogine and Stengers 1984), Goldbeter (1997), and Herschkowitz (2001).

Prigogine was awarded the Nobel Prize for his contribution to non-equilibrium thermodynamics, which is seen as a source of order in a system, and particularly for the theory of dissipative structures, which results from dynamic states of matter caused by irreversible processes (Prigogine 1980). Prigogine describes the world as evolving from order to disorder, and considers thermodynamics as the science of 'becoming' from 'being' (Prigogine 1980). He has shown that the behavior of matter under non-equilibrium conditions can be radically different from its behavior at, or near equilibrium condition. This difference introduces different alternatives such as self-organisation and complex dynamics (Thore 1995).

Near equilibrium, the description of the temporal evolution of a system can be expressed by linear equations. Far from equilibrium one deals with nonlinear equations, which may result in bifurcations and the spontaneous appearance and evolution of organized states of matter of the so called Dissipative Structures. As an example of a dissipative structure consider a pan of liquid heated from below. When the temperature is low, heat passes through the liquid by conduction. As the heating is intensified, regular convection cells appear spontaneously. The liquid boils. Energy is transferred from thermal motion to convection currents. The boiling dissipative structure is radically different from the equilibrium structure of the liquid. However, the order can be maintained in this boiling dissipative structure far from equilibrium conditions only through a sufficient flow of energy. According to Prigogine, the world can be seen as subject to self-organisation and evolution. He views energy dissipation as the driving force of evolution. Despite the increase in organisation and complexity of living systems, the biological evolution has accelerated over a period of time. Each new step increasing the functional organisation has in itself the germs for further evolution. For instance, mathematical relations describing the evolution of thermodynamical systems can be adapted to understand the notion of survival of the fittest in predator and preys. On the one hand, the prey evolves as to exploit available resources more efficiently and tries to prevent itself from being caught by the predator. On the other hand, the predator evolves as to increase the frequency of capturing the prey and to decrease its death rate. The ratio of the biomass of predator to prey can be seen as gradually increasing with evolution (Prigogine 1969).

According to the second law of thermodynamics the world can be seen as evolving from order to disorder while biological evolution is about the complex emerging from the simple i.e. order arising from disorder (Scaruffi 2003). Though both views being contradictory show that irreversible processes and non-equilibrium states are an integral part of the real world. Nicolis and Prigogine stress the need for a system composed of independent units that interact with each other, in which flow of energy drives the system away from equilibrium and nonlinearity. This non-equilibrium and nonlinearity excels the spontaneous development of self-organizing systems of ordered structure and behavior in open systems regardless of the general increase in entropy by ejecting matter and energy in the environment (Nicolis a. Prigogine 1977).

Autopoiesis

The origin of the term "Autopoiesis" lies in its Greek meaning, wherein 'Auto' means self and 'poiesis' means creation or production (Drosdowski 1989). Put together, it means self-creation or self-production i.e. a process where an organisation produces itself (Maturana a. Pörksen 2002). The biologists Varela and Maturana introduced the concept of Autopoiesis in 1973, which is concerned with the question "What is life?" or more precisely what differentiates living systems from non-living systems

(Maturana a. Varela 1973). They explained Autopoiesis as follows: “An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network.” (Maturana a. Varela 1973). The main objective of Maturana and Varela is to explain the totality of living systems through an entire conceptual theory (Maturana a. Pörksen 2002). This concept has diffused into several other disciplines of study like Psychology (Walter 1996), Law (Teubner 1995; Teubner a. Willke 1984), Politics (Beyerle 1994) and social sciences (Luhmann 1984). Several other authors who have made contribution to the study of Autopoiesis are Uribe (Varela, Maturana a. Uribe 1974), Goguen (Goguen a. Varela 1979), Kauffman (Kauffman a. Varela 1980), Winograd and Flores (1986), Dyke (1988), Mingers (1989), Luisi (Luisi a. Varela 1989), Capra (1996).

Maturana and Varela examined Autopoiesis or self-production as a key to understand biological phenomena, which express that the mechanism of self-production explains both the diversity and the uniqueness of living systems. Autopoiesis endows living systems with the property of being autonomous. A typical autopoietic system is a biological cell. For example, the eukaryotic cell, which is made of various biochemical components like proteins and nucleic acids, is organized into bounded structures such as the cell nucleus, a cell membrane and cytoskeleton. On the basis of external flow of molecules and energy these structures produce components which in turn continue to retain the organized bounded structure. Hence, it can be seen that the concept of Autopoiesis lays emphasis on reproduction, evolution, and cognitive aspects (Maturana and Varela 1980).

The process of Autopoiesis explains the dynamics of living systems. Dyke refers to it as the dynamics of non-equilibrium thermodynamic system, or organized states what may also be understood as dissipative structures, which remain stable despite the continuous flow of matter and energy through them (Dyke 1988).

Chaos theory

Chaos and complexity can be represented by a mathematical model of phenomena of emergence of order out of chaos. Lorenz was the one who – while making experiments for weather predictions – came up with a theory which is well known as Chaos Theory. Lorenz found that even small and minor changes in initial stages can lead to a severe change in the long term behavior of a system (Lorenz 1963). Poincaré advocated this theory as well much earlier as Lorenz's work (Poincaré 1890). This behavior of changes may be seen as masquerading with the flapping of the wings of a butterfly, also known as Butterfly Effect. This phenomenon may demonstrate the Chaos Theory as it has high sensitive dependence on initial conditions. For example, two variables in flipping of a coin may be seen as sensitive dependence on initial conditions. First, how high the coin flips, and second, when the coin will hit the ground (Lorenz 1963). Apart from Poincaré and Lorenz, Chaos Theory has been worked upon by other scholars. They are for example Birkhoff (1923), Cartwright (1965), Prigogine (1969), May (1976), Derrida (1976), Mandelbrot (1977), Gleick (1987), Littlewood (1988), Kolmogorov (1991), Ruelle (1991), Binnig and Feigenbaum (1995), Smale and Hirsch (2004).

The phenomenon of emergence shows how structure arises from the interaction of many independent units. In physical and mathematical terms, it can be described as nonlinear equations out of which unpredictable solutions emerge. Based on sensitivity to initial conditions as discussed above, every system follows its laws of motion and traces some trajectory in phase space. 'Phase Space' is the space in which all possible states of a system are represented, with each possible state of the system corresponding to one unique point in the phase space. The different shapes that chaotic systems produce in this phase space are known as "strange attractors" (Lorenz 1963). These strange attractors can occur in both discrete as well as in continuous dynamical systems. An example of continuous dynamical systems could be the equations used by Lorenz to make weather predictions, while an example for discrete dynamical systems could be the Hénon Map (Dickau 1992).

Chaos Theory can be said to be an interdisciplinary field of research. The application of this theory could be seen in ecology and biological population predictions. The changes in growth rates make it even more difficult to make such predictions. May (1976) found out that after a certain point in growth rate it becomes impossible to forecast the growth behavior using equations. However, with a closer look some order could be traced in form of white strips on the graph, wherein the equation passed through bifurcations before returning to chaos. It can be interpreted that the graph has an exact replica of itself within. This exhibits self-similarity (May 1976). Mandelbrot studied this self similarity by taking into account 100 years cotton price fluctuations. On examining the data he noticed the following fact: each particular price change was random and unpredictable. But the sequence of changes was independent on scale, where curves for daily price changes and monthly price changes matched perfectly (Mandelbrot 1977). These findings reflect a common thing which is self-organisation i.e. how interaction among independent parts produces structures.

Hypercycles

Eigen, a German biophysicist and chemist, won the Nobel Prize in 1967 for his discovery that very short pulses of energy can induce extremely fast chemical reactions. Together with Schuster he came up with the model of "Hypercycles" (Eigen a. Schuster 1977). Hypercycles can be understood as self-replicating entities that integrate several autocatalytic elements into an organized unit by helping each other in a cyclic way. The main contributions to this concept were given by Eigen and Schuster (1979), but some other authors like Kuhn (1978), Smith (1979), Winkler (Eigen et al. 1981), Hofbauer and Sigmund (1988), Mallet-Paret (1993), Vespalcova, Holden and Brindley (1995) also contributed to this field of research. Theoretical and practical applications of hypercycles may be found in Biology, Chemistry, as well as in Physics, for example on hypercircuits in hypergraphs, molecular Biology, and in cellular automata.

Hypercycles are a network of cyclic reactions i.e. cyclic linkage of chemical reactions. This network gets formed with the help of combination of catalytic reactions. It stays in equilibrium when there is an adequate flow of energy and may contain closed loops known as catalytic cycles. A higher flow of energy drives the system far away from equilibrium, thereby influencing the combination of catalytic cycles to form closed loops of higher order, known as hypercycles. The production of enzymes within these hypercycles acts as a catalyst for its subsequent cycle in the loop turning each link in the loop into catalytic cycle of its own. Life is the product of a hierarchy of hypercycles in which basic catalytic cycles may get organized into an autocatalytic cycle i.e. a cycle which is capable of self-reproducing. A set of autocatalytic cycles in turn may get organized in a catalytic hypercycle. This catalytic hypercycle represents the basics of life (Eigen and Schuster 1979).

Eigen views hypercycles as a self-reproducing hypothetical stage of macromolecular evolution, which could follow quasispecies. Each specie acts as a catalyst for the replication of next either directly (ribozymes) or via intermediary enzymes (Hofbauer a. Sigmund 1988). The dual process of unity (due to the use of a universal genetic code) and diversity (due to the trial and error approach of natural selection) in evolution started even before the existence of life. Evolution of species may be seen as a precedent in parallel to process of molecular evolution. The difference between hypercycles and living systems may be seen in a way that hypercycles define no boundaries (boundary is understood as a container where chemical reaction takes place), while living organisms have a boundary as part of the living system, for example skin (Scaruffi 2003). In short it can be said that given a set of self-reproducing entities, which nourishes itself through common and limited resources like energy and material supply, natural selection is inevitable (Eigen 1971).

Ecosystems

The term "Ecology" was coined by the German zoologist Haeckel (1875). It has its origin in the Greek word oikos, which means "household" (Drosdowski 1990). Haeckel defines ecology as the science of relations between organisms and their environment. The concept of Ecosystems makes it possible to preserve, conserve, or protect both biotic and abiotic existing natural resources (Innis 1979).

Odum places energy as the central focus of his attention. He considers organisms and their physical environment as a single integral system and stresses that the flow of energy and nutrient cycling are rather more important than the entities that perform the function (Odum 1999). The fundamental goal of ecology, however, may be seen as identifying mechanisms that generate pattern. The spatial attributes of habitat, and individuals occupying habitat greatly influences the dynamics of biological systems, and thereby influences patterns in abundance, distribution, behavior, functioning, and evolution of organisms (Johnson 1997). The main authors contributing to the idea of ecosystems are Haeckel (1875), Bick (1973), and others like May (1976), Boerlijst and Hogeweg (1991), Camazine (1991), Nowak (1992), Karsai and Penzes (1993), Odum (1999).

A different approach to ecosystems is to study the dynamics of systems in which the spatial factor of interacting individuals or sub populations matter, wherein self-organisation which refers to the spontaneous emergence of global structure comes into play. The individuals or beings in the system are greatly influenced by their local environment. This biological phenomenon is as diverse as evolution of pre-biotic self-replicating molecules (Boerlijst a. Hogeweg 1991), evolution of cooperative behavior (Nowak and May 1992, 1993), co existence in fungal communities (Halley et al. 1994), and organisation in social insects (Camazine 1991; Karsai a. Penzes 1993). These models are equitable of the fact that spatial factors of individuals are crucial to the dynamics of system in terms of density, frequency, and population size. They affect the process which in turn affects the behavior of individuals. Hence, there can be seen a feedback between self-organizing behavior, system dynamics, and evolution of individuals within the system (Solé a. Bascompte 2006).

2.2.3 Characteristics of self-organizing systems

At this point it may be seen that it is the organisation of systems which plays a major role in the patterns of interaction and overall behavior, structure and abilities. For example, if all organs of a living organism are put together, a body cannot be expected to become alive. A body must necessarily self-organize in order to function, sense, grow, develop, react or respond (Mishra 1994). Hence, it can be said that the importance of self-organizing systems focuses on the relationships of their components and not on the components itself. Interaction among the components of systems may be seen as a necessary condition for setting a path for its future courses of action.

Having introduced the primal concepts of self-organisation, the potent factors of self-organizing may be seen in the principles and conditions that govern those systems. In order to outline the major principles and conditions of self-organisation, the characteristics forming the base of self-organizing systems with reference to the selected foundation concepts shall be discussed below. Therefore, criteria like system structure, system behavior and system abilities shall be used. In using those criteria, from a system theoretical point of view (Bertalanffy 1951), it can be ensured that all necessary perspectives are taken into consideration to gain an overall and clear understanding of self-organisation.

Characteristics concerning the system structure

It may be seen that all introduced concepts deal with complex systems. Thereby, what is more central to the issue is not what kind of nature they are attributed to (e.g. living or non-living systems), but the extent of occurrence of existing interrelations between the elements of the system as well as between the system and its environment (Dörner 2001; Malik 2000). Probst and Gomez particularly emphasize the aspect of dynamics in their understanding of complex circumstances, which differentiates complex systems from complicated systems. Dynamics is described as the rate of modification of a system over a specific period of time. A system can be described as complicated if it features various internal elements and links as in a functional description of a major machine. Complexity is not reached until high dynamics between the system elements is identifiable

(Probst and Gomez 1989). This interaction of the system elements is one precondition for the process of self-organizing. Haken introduced in this context the term of emergence, which describes a result of self-organisation. Through the process of interaction of the individual elements new qualitative characteristics of the system arise – so called emergences – which cannot be related to individual system components, but result from the complex synergy effects of the interacting elements (Haken 1993).

Self-organizing systems are open systems that means that they are open to absorb information and resources. The more information and resources absorbed by the system, the more changes of its status are assumed thereby influencing the internal dynamics of the system. However, the system openness enables self-organizing systems to adapt to significant changes in the environment (Varela 1979; Malik 2000).

Characteristics concerning the system behavior

Self-organizing ordered structures do evolve autonomously from the interaction of individual elements. Haken's study of self-organisation by investigating laser light provides an instructive example of this. He observed individual light waves. After supplying them with a certain mass of energy, they autonomously arrange themselves through interactions from a chaotic system state to a profoundly structured state the laser (Haken 1987). Prigogine and Glansdorff (1971) could observe similar results when they fed a liquid with energy. It displayed autonomous patterns in the form of dissipative structures. The concept of self-organisation presumes that through interaction of the systems elements an ordered structure evolves autonomously, which enables the system to cope with complexity and dynamics.

This implies that self-organizing systems contain autonomous system elements. A system's or an individual's autonomy can be identified if they form, guide or develop themselves, meaning that their decisions, relations and interactions are not dependent on external instances (Probst 1987). In doing so, a complete independence of the system from other systems cannot be assumed however (Varela 1979; Malik 2000). Each system only represents a part of a wide-ranging total system (environment) which it is in some way dependent on and influenced by. Therefore, it has to be understood as a relative autonomy of the individual or the system in relation to certain criteria (Varela 1979; Probst 1987). Regarding autonomously cooperating processes within a company, these criteria are defined by the given scope of action and decision making of the autonomous subject. For this reason autonomy manifests itself in the company as a result of processes of decentralization and delegation (Kappler 1992). Additionally, the autonomously acting systems are operationally-closed, which is termed as self-reference. It implies that the system defines its actions and borders by itself (Luhmann 1984). The system only induces actions which are essential for further survivability.

The characteristic of non-linearity can be found in all self-organizing systems. Non-linearity could be understood as a non-deterministic behavior referring to a system whose behavior is not causally predetermined and hence not predictable (Haken 1987; Prigogine 1996). In social autonomously cooperating systems, a framework of general rules of decision-making is predetermined (Hülsmann a. Windt 2005) and the desired final state of the system may be predictable, but not the mode of achieving it. Based on the ability of autonomous decision-making and autonomous acting of the individual system elements, the system behavior is not casually predetermined and thus not predictable. However, an organisation's way of acting is not completely non-linear. In general, a reason may be found in corporate history. According to the theory of path dependency a grown system is always predetermined by its former decisions. Thus, the amount of acting alternatives is always limited by former irreversible decisions (Schreyögg, Sydow and Koch 2003).

Characteristics concerning the system abilities

Complex systems are defined as systems being in a state far from equilibrium (Prigogine a. Glansdorff 1971). This may be seen in a way that complex systems are permanently open to absorb information and resources that are essential for it to sustain and survive. The system openness results in an everlasting change of the system status, which forces the system to stabilize its ordered structure permanently. When two reversible processes occur at the same rate, it manifests a dynamic equilibrium. Equally, Maturana and Varela (1980) as well as Odum (1999) found that natural systems – unhindered by human interference – also seek stability and balance through the capability of self-control mechanism, e.g. ecosystems are able to restore stable status within its system until a certain degree if necessary (Odum 1999).

Within an autopoietic system, like a biological cell for example, the components of the system are permanently involved in the production of new system elements. The cell possesses the ability of self-replication. Processes of self-replication may play an important role in self-organizing systems. The cell for example produces its own borders through this process which distinguishes the cell from its environment.

Flexibility could be seen as a competence from a system viewpoint as it supports the system with the level of adaptiveness required for it to sustain and survive in a dynamic, complex and highly competitive environment (Hülsmann and Wycisk 2005). The ability of being flexible by the components of the system helps them in self-organizing and forming, communicating and establishing desired relationships. Being flexible also aides the process in how complex systems autonomously create ordered structures because of its ability to adapt flexibly to the demanding complex and dynamic situation. Moving from a self-management perspective to a more abstract level of system perspective, it can be said that self-organisation creates the ability within the elements of the system to organize itself autonomously i.e. the system determines its own goals, autonomously chooses its strategies and organisational structure and also raises the necessary resources itself (Manz and Sims 1980).

2.2.4 Conclusions

The aim of the paper as reflected throughout was to develop a general understanding of the basic principles underlying autonomous cooperation. Therefore, it is necessary to understand the sources of the basic idea, which lay in concepts of self-organisation. Having seen a glimpse above of the origin of primal foundation concepts of the idea of self-organisation, it may be realized that concepts like entropy, Synergetics, Cybernetics, dissipative structures, autopoiesis and chaos theory have made an imprint in academia. What can be seen as an area of core shift today is towards self-reference, self-similarity, self-organisation and autonomy. Autonomous systems derive their autonomy from their intrinsic self-organisation (Vernon and Furlong 1992). The multitude of the facets of self-organisation seems to span boundaries across the ability of systems and maintain its i-dentity and autonomy.

The phenomena of self-organisation may be considered to serve as explanations of the adaptive, intentional, and purposive functioning of many complex systems, especially of cognitive, biological, and social systems (Tschacher et al. 2003). As Bremermann puts it: “Self-organisation is creation without a creator attending to details” (Bremermann 1994), “Self” in this context may be seen as a result of internal mutual or reciprocal relations. Self-organisation may not only mean that it constitutes the idea of one science or idea of several sciences but the underlying basis or unifying substructure of various sciences (Zwierlein 1994). From the characteristics of self-organizing systems as discussed in Section 3 above, it can be said that the patterns of interaction among the elements of the system plays an important role in shaping the system's structure, behavior, and abilities. The concept of self-organisation may be recognized as a potential field capable of having its application in business processes as it increases the organisational ability and provides the flexibility to self-organize and cope with complex situations in a dynamic environment. There are attempts, however, to transfer and integrate the idea of self-organisation in autonomous co-operating logistics processes using modern technologies like RFID, sensors, etc.

Hence a general understanding of self-organisation that has been developed through this work is presumed to be helpful to management practice as a first step towards its application and transfer into autonomous cooperating business processes, for instance in logistics. However, the question that still persists is whether self-organisation is a sequel, progression or succession to autonomous cooperation. What remains to be answered in future research is to what extent the idea of self-organisation can be transferred to or used in the concept of autonomous cooperation and how they can be applied to obtain optimum performance in business processes.

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