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SYSTEMS, COMPLEXITY and CHAOS

a review of the literature

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A brief overview of the concepts of soft systems and complexity theory, as they apply to the management of organisations.

Soft Systems Methodology

One approach that facilitates the understanding of interactions between many factors has become known as *systems thinking*, which "makes use of the particular concept of wholeness captured in the word 'system', to order our thoughts" (Checkland, 1981). The examination of the elements of a complex topic - the technique known as decomposition or, in its broadest sense, as analysis - has great value as an aid to understanding, but risks overlooking those properties of the whole topic which only emerge and are only observable when the elements are conjoined.

> "Decomposition is a time honored way of dealing with complex problems, but it has big limitations in a world of tight couplings and nonlinear feedbacks. The defining characteristic of a system is that it *cannot* be understood as a function of its isolated components." (Kofman and Senge, 1993).

> "in spite of the fact that there are many definitions of the word system in the literature ... all take as given the notion of a set of elements mutually related such that the set constitutes a whole having properties as an entity." (Checkland and Scholes, 1990).

Checkland and his associates have been leading figures in the development of systems thinking and its application to management and organisation theory. He is especially concerned with understanding problem situations, which entails the recognition of

> "problems of two kinds - *structured* problems which can be explicitly stated in a language which implies that a theory concerning their solution is available [for example: how can we transport X from A to B at minimum cost?] and *unstructured* problems which are manifest in a feeling of

> unease but which cannot be explicitly stated without this appearing to oversimplify the situation [for example: What should we be doing about inner-city schools?]. ... It became clear that the present research was to be concerned not with problems as such but with *problem situations* in which there are felt to be *unstructured* problems, ones in which the designation of objectives is itself problematic." (Checkland, 1981).

Checkland further outlines some fundamentals of his "Soft Systems Methodology" in the following terms:

> "[Systems thinking] starts with an observer/describer of the world outside ourselves who for some reason of his own wishes to describe it 'holistically', that is to say in terms of whole entities linked in hierarchies with other wholes."
>
> "Systems thinking ... starts from noticing the unquestioned Cartesian assumption: namely, that a component part is the same when separated out as it is when part of a whole. ... Systems thinking is different because it is about the framework itself."
>
> "What distinguishes systems is that it is a subject which can talk about the other subjects. It is not a discipline to be put in the same set as the others, it is a meta-discipline whose subject matter can be applied within virtually any other discipline."
>
> (Checkland, 1981).

This approach allows consideration of complex situations whose very complexity is a salient feature of their demand for the attention of the researcher. It is especially applicable to human interactions - what Checkland characterises as "human activity systems" - when they are perceived to be problematical or difficult to manage. Jackson (1991) helps to put this in context:

> "The emphasis in soft systems thinking is on how to cope with ill-structured problems or messes. Rather than attempting to reduce the complexity of messes so they can be modelled mathematically or cybernetically, soft systems thinkers seek to explore them by working with the different perceptions of them that exist in people's minds. Systems are seen as the mental

> constructs of observers rather than as entities with a real, objective existence in the world. Multiple views of reality are admitted and their implications are examined. Values are included rather than excluded [in theory] from the methodological process."

Notwithstanding Jackson's remarks, the systems which are under discussion here are to be understood as *open* systems with a strong cybernetic aspect, in that they have import from and export to their environments, or "exchange of materials, energy and information [which involves] a set of processes in which there is *communication* of information for purposes of regulation or *control.*" They maintain a steady state, which is "thermodynamically unlikely, creating and/or maintaining a high degree of order." This is in contrast with closed systems, which have no interaction with the environment and have "no path to travel but that towards increasing disorder [high entropy]" (Checkland, 1981). The systems under consideration are also *natural* systems, in the sense that they occur as manifestations of the relationships between people within certain environments. Once again, the concept of systemic wholeness is important here:

> "In this systems typology I am claiming only that natural systems are the evolution-made, irreducible wholes which an observer can observe and describe as such, being made up of other entities having mutual relationships. They are 'irreducible' in the sense that meaningful statements can be made about them as wholes, and this remains true even if we can describe their components and the relationships between the components with some precision. Carbon dioxide is not reducible in this sense to carbon and oxygen, in that however much we know about interatomic distances and bond angles, carbon dioxide remains a higher level whole having properties of its own." (Checkland, 1981).

Checkland explains the use of the term "Soft Systems Methodology" in the following terms:

> "Within systems thinking there are two complementary

traditions. The 'hard' tradition takes the world to be systemic; the 'soft' tradition creates a process of enquiry as a system. ... SSM is a systemic process of enquiry which also happens to make use of systems models. It thus subsumes the hard approach, which is a special case of it, one arising when there is local agreement on some system to be engineered." (Checkland, 1981).

The properties that emerge from or are observable in a system, but not in the elements of the system when separated; "emergent properties," are fundamental to the soft systems approach.

"The concept of emergent properties itself implies a view of reality as existing in layers in a hierarchy [there being no connotations of authoritarianism in this technical use of the word]. In the biological hierarchy, for example, from atoms to molecules to cells to organs to organism, an observer can describe the emergent properties at each layer. In fact it is the ability to name emergent properties which defines the existence of a layer in hierarchy theory.

To complete the idea of 'a system' we need to add to emergence and hierarchy two further concepts which bring in the idea of *survival.* The hierarchically organized whole, having emergent properties, may in principle be able to survive in a changing environment if it has processes of *communication* and *control* which would enable it to adapt in response to shocks from the environment." (Checkland and Scholes, 1990).

The concept of hierarchy is further explained by Wilson (1984):

"a human activity system can be described as an interacting set of subsystems or an interacting set of activities. A subsystem is no different to a system except in terms of level of detail and hence a subsystem can be redefined as a system and modelled as a set of activities. Thus the term 'system' and 'activity' can be used interchangeably."

The precise definition of what constitutes a specific system depends, according to the Checkland view, upon the perspective of the observer:

"Even if there are no closely associated systems to emphasize the grouping of the activities, as in the example ... of 'the eating habits of the octogenarians of Basingstoke', it is difficult to deny the right of an observer to choose to view a set of activities as a system if he wishes to do so." (Checkland, 1981).

In fact, it is vital to the Checkland Soft Systems Methodology, as applied to the analysis of problem situations, that a variety of systems should be identified, each one from a different perspective. Checkland has adopted the philosophical term *weltanschauung*, or world-view[1], to indicate the specific individual perspective being employed in each definition of a system which "may be likened to a filter in the head of an observer which has been formed and is continually moulded by experience, personality, politics, society, and the situation." (Wilson, 1984). Checkland habitually abbreviates the word weltanschauung to a capital W. In the following extract the term *holon* is interchangeable with the term *system*; its specific meaning is, broadly, *a system or any element of a system which has in its own right the attributes of a system*.

"the description of any purposeful holon must be from some declared perspective or worldview. This stems from the special ability of human beings to interpret what they perceive. Moreover, the interpretation may, in principle, be unique to a particular observer. This means that multiple perspectives are always available. [The letter from the tax collector may seem to be unequivocally a message concerning your financial affairs, but no one can stop you perceiving it as a bookmark!]." (Checkland and Scholes, 1990).

"Judging from their behaviour, all beavers, all cuckoos, all bees, have the same W, whereas man has available a

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1 In his *Notes on the Translation* of Schweitzer's (1923) "Civilization and Ethics," C T Campion offers the following explanation of this term as used by Schweitzer:

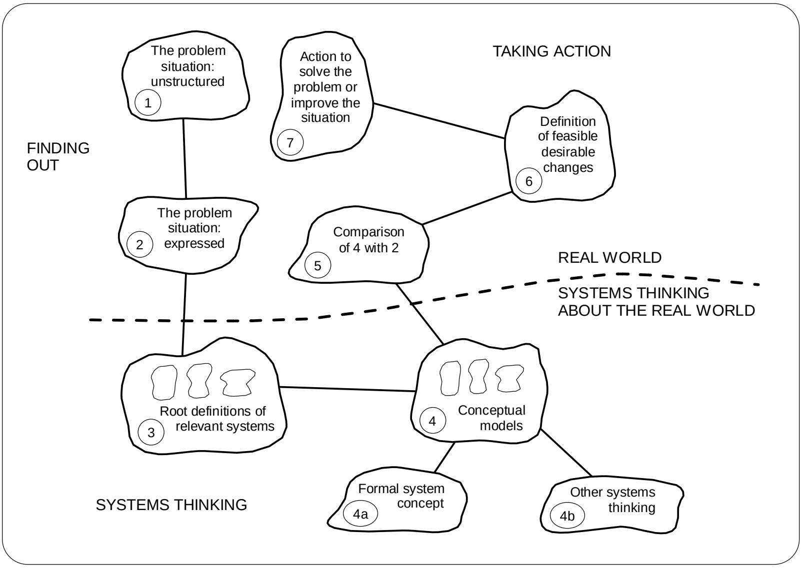
"*Weltanschauung*. This means literally view of the world, and it has been translated as 'world-view.' But it should be borne in mind that the German word *Welt* has also the wider meaning of 'universe.' Dr Schweitzer himself defines *Weltanschauung* as the sum-total of the thoughts which the community or the individual thinks about the nature and the purpose of the universe and about the place and destiny of mankind within the world."

range of Ws. The Ws of an individual man will in fact change through time as a result of his experiences. And the Ws of a group of men perceiving *the same thing* will also be different. It is because of these two facts that there will be no single description of a 'real' human activity system, only a set of descriptions which embody different Ws. ... In 'soft' systems methodology we are forced to work at the level at which Ws are questioned and debated, 'soft' problems being concerned with different perceptions deriving from different Ws." (Checkland, 1981).

Checkland illustrates the power of "Ws" in human thinking and perception by discussing the nature of jokes. Having given a number of examples he goes on:

"All these jokes are in fact the same joke, in the sense that they have the same structure. An image of the world is established, only to be shattered by a counter-image which turns the first upside down. ... In the language I am using, a W is established by implication and then suddenly is destroyed by a counter-W, the skill of the comedian lying in a careful pacing of the initial image-building, making it rich in association, so that the demolition, when it comes, comes as a sudden shock. Tension is released by the physical action of laughing, a remarkable response when we consider that it is triggered merely by the juxtaposition of two abstract images. It would seem that in-built Ws are very important to us." (Checkland, 1981).

In Checkland's early publications (for example, Checkland, 1981), he offers a fairly prescriptive model for the application of Soft Systems Methodology, as illustrated below:



Checkland's Soft Systems Methodology
adapted from Checkland (1981)

A root definition in this model is "a concise, tightly constructed description of a human activity system which states what the system is" (Checkland 1981). A conceptual model is defined as

> "a systemic account of a human activity system, built on the basis of that system's root definition, usually in the form of a structured set of verbs in the imperative mood. Such models should contain the minimum necessary activities for the system to be the one named in the root definition" (Checkland 1981).

Together with this model is offered an acronym: CATWOE, which can be used together with root definitions to check that essential elements are present in any system under consideration. The initials stand for:

Customer	"The beneficiary or victim of the system's activity"
Actor	"A person who carries out one or more of the activities in the system"
Transformation process	"The transformation of some input into some output"
Weltanschauung	"The [unquestioned] image or model of the world which makes this particular human activity system [with its particular transformation process] a meaningful one to consider"
Owner	"The person or persons who could modify or demolish the system"
Environment	"What lies outside the system boundary"

Source: Checkland (1981), Glossary

Checkland later expressed some concern that the seven-stage model "gives too much an impression that SSM is a seven-stage process to be followed in sequence" and advises that

> "The formal expression of SSM does not mean that it has to be used rigidly. It is there to help in the face of real-life's richness, not constrain." (Checkland and Scholes, 1990).

Systems thinking has had some impact on the project management community, although it cannot be said to dominate thinking in this field. Yeo, writing in the *International Journal Of Project Management*, advocates the use of soft systems methodology in project management and comments:

> "Systems thinking has, over the past three decades, emerged as one of the most important intellectual disciplines, and it has provided a powerful mental frame of reference in understanding problem situations and in guiding day-to-day decision making." (Yeo, 1993).

Milosevic (1989) also advocates the use of SSM, especially in strategic project management, and illustrates his argument with a conceptual model utilising nouns. This produces a systems map which resembles an influence diagram, demonstrating the interaction of subsystems. Davies & Saunders (1988, Saunders, 1992) report the use of SSM in organising a small company for project management. They too suggest its wider use in project management, especially in unstructured problem situations, and again support their argument with a conceptual model which utilises nouns. Ramsay, Boardman and Cole (1996) develop the idea further, using models which they describe as “systemgrams.” They assert that "conceptual models of this type provide a valuable way of understanding and communicating the essence of the situation under observation."

Wilson - a close associate of Checkland in the mid-1980s - may be supposed to favour such developments of the methodology:

> "A model is the explicit interpretation of one's understanding of a situation, or merely of one's ideas about that situation. It can be expressed in mathematics, symbols or words, but it is essentially a description of entities, processes or attributes and the relationships between them. It may be prescriptive or illustrative, but above all, it must be useful." (Wilson, 1984).

"The concept of resolution level is crucial to the development of systems models. This is best described through the notion of *systems hierarchy*. This means that the boundary of the chosen system places the system at a particular level within a series of levels.

> “Thus a system is, at the same time, a subsystem of some wider system and is itself a wider system to its subsystems. What we define to be 'a system' is a choice of resolution level or the choice of level of detail at which we wish to describe the activities. It is a choice: there is no absolute definition of what is a

> system or what is a subsystem." (Wilson, 1984).

Similarly, the interactions between system components are shown in the model as simple lines of connectivity. It is improbable that the interactions will be as simplistic as this suggests. It is far more likely that multiple and complex interactions will be seen between subsystems. This makes the outcome of the interactions involved in even a small set of subsystems highly unpredictable, as recent developments in the field of complexity science, discussed below, help to explain.

Complexity and chaos

> "Acclaimed by its followers as the major intellectual revolution of recent times, 'chaos theory' [also known rather less catchily as 'complexity science' or 'non-linear dynamics'] uses mathematical techniques boosted by computer power to explore aspects of nature which have hitherto proved resistant to analysis. ... Its approach is not only multi-disciplinary but cross-disciplinary: biologists might draw on insights from engineering and physics, for example, while the study of stock-market prices might be related to weather records and other such apparently random phenomena." (van de Vliet, 1994).

Much of the literature relating to chaos theory is produced within narrow scientific disciplines and is fairly opaque to the non-specialist reader. However, a scientific journalist, James Gleick, has produced a readable but comprehensive overview (Gleick, 1987) which is relied on by many other writers seeking to apply the principles of chaos theory to human activity systems and, in particular, organisational behaviour and management (for example, van de Vliet, 1994; Wheatley, 1994; and especially Stacey, 1991, 1992).

Stacey (1991) provides a summary of the concept of chaos:

> "In its scientific sense, chaos does not mean utter confusion or a complete lack of any form. It means that systems driven by certain types of perfectly orderly laws are capable of behaving in a manner which is random and therefore inherently

unpredictable over the long term, at a specific level. But that behaviour also has a 'hidden' pattern at an overall level. We do not know what the weather will be like next month, in specific terms; but we do know that there will be familiar patterns of sunshine or rain. We do not know how the stock market will perform next month, but we do know that it will display characteristic patterns of rise and fall. Scientific chaos explains why we observe recognizable patterns of overall behaviour, or categories, within which no two individuals or events are ever exactly the same. No two fern leaves are exactly the same, but they are all nevertheless fern leaves. No two business organizations in the electronics market are ever exactly the same, but they are clearly electronics businesses. Chaos is creative individual variety within an overall pattern of similarity."

Gleick (1987) stresses that chaos is not the same as instability. A chaotic system can be unstable if "its particular brand of irregularity persist[s] in the face of small disturbances." He gives the example of a marble in a bowl - "locally unpredictable, globally stable." This precise application of a commonplace term has the potential to cause confusion and misunderstanding, which most writers seek to avoid by early explanations of meaning.

"the use of the shorthand term 'chaos' to cover the whole science of complexity or non-linear dynamics is unfortunate: in scientific terms, 'chaos' refers not to the word's popular meaning of utter muddle and confusion, but to the behaviour of a system - like the weather, for example - which is governed by simple physical laws but is so unpredictable as to appear random. (van de Vliet, 1994).

Stacey (1992) is concerned to make it clear that chaos occurs when the equilibrium, or stability, of a system is very finely balanced, so that the potential for very small changes in one or more of its elements to cause major changes in the whole system is very great.

"The first feature of scientific chaos is that simple feedback control loops produce amazingly complex patterns of behaviour, some of which are inherently random" (Stacey, 1992).

"as the sensitivity of a nonlinear feedback system is increased it moves from stable equilibrium patterns of behaviour [which may be highly complex], through a phase of bounded instability, before it becomes explosively unstable. That phase of bounded instability has been named chaos. Chaotic behaviour is random and hence unpredictable at the specific or individual level. The particular behaviour that emerges is highly sensitive to small changes and hence depends to some extent upon chance. But this is not explosive instability because it is constrained. And because it is constrained it always displays a pattern of category features, a kind of qualitative family resemblance. In this state the system uses positive feedback, albeit in a constrained manner" (Stacey, 1992).

"This unpredictability arises because of the system's extreme sensitivity to initial conditions: tiny variations are amplified with ultimately huge consequences. Whereas in a linear relationship, a given cause has one and only one effect, in non-linear relationships , a single action can have a host of different effects; and the interactions become so complex that the links between 'cause' and 'effect' disappear." (van de Vliet, 1994).

"The second feature uncovered by scientists is this. It takes only tiny changes in the control parameter, tiny changes in the sensitivity of the feedback mechanisms, to move behaviour over time from perfectly predictable cycles to random patterns. The changes are so tiny, for example a difference to the thousandth decimal place, that we would have to be able to measure the parameter with absolute exactness if we are anywhere near the chaos area and wish to secure a particular pattern of behaviour." (Stacey, 1992).

Feedback, positive or negative, is key to an understanding of chaos. Negative feedback acts to suppress trends, as in the example of a control unit in a domestic heating system; as the ambient temperature rises the system reacts negatively, turning off the heating and thus halting the trend towards high temperature. When the ambient temperature drops the control again functions negatively, switching on the heating and thus halting the trend towards low temperature. Positive feedback acts with opposite effect; for example, in human interactions praise or reward for good work may act to reinforce behaviour patterns and so lead to even better performance. Positive feedback enhances and accelerates trends. Within an open system, feedback provided by or through system elements may be highly complex and contradictory, and may produce reactions which may be positive or negative in character and range in their impact from very weak to very strong.

This sensitivity of finely-balanced complex systems to small changes affecting, initially, only one or a few of their component elements is what makes prediction, and therefore planning and forecasting, so uncertain. Fortunately, however, chaos theory holds that the instability of systems is "bounded." Stacey (1991) explains:

> "The third feature of non-linear dynamic systems which scientists have uncovered is this: there is order within disorder. Because it takes time for small differences to escalate into major changes of behaviour, the specific short-term behaviour of a chaotic system is predictable. Although we can never predict long-term weather patterns, we can predict the weather to a reasonable degree of accuracy over the next few days."

Or, as van de Vliet (1994) puts it, "there are recognisable patterns or categories of behaviour; and within these there is endless individual variety." These patterns have been tested over time:

> "these patterns of behaviour are not confined to natural forms: the French mathematician Benoît Mandelbrot discovered, for example, when he fed cotton-price data covering 60 years into the computers that although each particular price change was random and unpredictable, the curves for daily and monthly price changes matched perfectly." (van de Vliet, 1994).

Van de Vliet argues that "there is, as yet, no homogeneous body of writing which could be labelled 'chaos economic and management theory' " but suggests that there is, however, "a pervasive spirit" which emphasises "adaptability, intuition, paradox and entrepreneurial creativity in the face of an unpredictable, indeed inherently unknowable, future." This is consistent with observations of managers' roles which suggest that managers typically work with incomplete information to make the best judgements they can whilst accepting that more or better information might lead to different decisions (eg, Mintzberg, 1973 or Karasek and Theorell, 1990). Simon's (1976) term for this is "bounded rationality."

Kauffman, originally a molecular biologist now exploring complexity in organisations with a consortium including Nortel, Unilever and the United States Marine Corps, argues that systems, including organisations, operate at their most robust and efficient level at the interface between stability and disorder; "the edge of chaos." He attributes this to the richness of interfaces and exchange of information which occurs across these interfaces (Kauffman, 1995). Mariotti (1996) also believes that organisations parallel the natural world and obey natural laws, describing these similarities as "adjacent possibilities." He supports Kauffman's arguments, claiming that an "optimal transition zone" exists between complexity and chaos where change and development occur at the maximum speed without being thrown into chaos by trivial events.

Stacey (1992) clarifies the criteria for recognising "bounded instability" in organisations:

> "It should be stressed, at this point, that we would describe the dynamics of a particular business as chaotic if we could point to behaviour on the part of its managers that has amplifying, self-reinforcing, unpredictable effects over the long term. We would not describe the dynamics as chaotic if we observe simply

> that there is no order at all; if we observe that managers are running from one short-term crisis to another, failing to deliver product on time to the right quality, at the right cost. We would not describe the dynamics as chaotic by simply observing that there is no clear hierarchy, no clear job definitions, everyone doing anything that came into their heads. That would be total confusion, a complete mess, which is not what we mean by chaos in its scientific sense."

Stacey points to certain assumptions frequently observed, or inferred by observers, to be held by managers.

> "[It is assumed that] clear cause and effect relationships exist. That is, business systems, and the market systems they operate in, are driven by laws in which a given cause always produces a given effect. But when the dynamic is chaotic, then it will often be impossible to ascribe an effect we observe to some clear set of causes. The effect may well be the result of many small, chance disturbances which have escalated. Looking back it will be almost impossible to say what caused what."

> "[It is assumed that] the environment is a given reality outside the business and independent of it. ... But when the dynamic is chaotic, the business itself will partly be creating its own environment through creative interactions with other organisations and people in that environment. We would have to know, in advance, the detail of what each business and its competitors, suppliers and customers would do before we could say what some future environment would look like." (Stacey, 1992).

These assumptions may be seen to correspond to Checkland's concept of weltanschauung, or W.

> "How we select events and build up explanations depends very heavily on our frame of reference, on what we are conditioned to look for in the first place, on very basic assumptions submerged below the level of awareness and therefore rarely questioned." (Stacey, 1991).

Stacey believes that these assumptions on the part of managers are dangerous because they lead to reliance on planning and strategy based on "visions of the future" which are, in fact, fallacies:

> "the evidence that visions of the future have anything to do with business success is anecdotal and conditioned by interpretive bias. What we find is a number of case studies and examples that recount particular business successes in terms of some originating vision. These case studies and examples go back in time to look for a vision that might be said to have started the whole venture off and the ensuing sequence of events is then described in terms of vision realisation. When we do this, we first of all ignore 'visions' that failed. Furthermore we ignore other 'visions' that may have existed at the same time, but that were simply dropped as time passed by."

> "The key point is this. When the system is chaotic the long-term consequences of actions past, present and future are open-ended, where that means that they are unknowable. They are not simply currently unknown: it is totally impossible to know what they will be ... If the future is simply unknown there is the possibility that we will be able to identify it, if we gather enough information, conduct enough research and perform enough analysis. If it is unknowable then these things are a waste of time and we need to focus on different ways of doing things." (Stacey, 1992).

The complexity of situations facing managers and requiring administrative decisions is the theme of several chapters by Simon, writing before chaos concepts were widely available to a general readership (Simon, 1976, and earlier editions). He comments:

> "Discussions ... often bog down on the question: 'who *really* makes the decisions?' Such a question is meaningless - a complex decision is like a great river, drawing from its many tributaries the innumerable component premises of which it is constituted. Many individuals and organization units contribute to every large decision, and the problem of centralization and decentralization is a problem of arranging this complex system into an effective scheme."

> "Decision-making in organizations does not go on in isolated human heads.. Instead, one member's

> outputs become the inputs of another. Because of this interrelatedness, supported by a rich network of partially formalized communications, decision-making is an organized system of relations, and organizing is a problem of system design." Simon (1976)

The possibility of coming to "rational" decisions in the organisational context is dismissed by Simon (1976) on the grounds of complexity, the inadequacy of available data and the impossibility for individual minds of processing such data even if it were available:

> "It has already been remarked that the subject, in order to perform with perfect rationality ... would have to have a complete description of the consequences following from each alternative strategy and would have to compare these consequences. He would have to know in every single respect how the world would be changed by his behaving in one way instead of another, and he would have to follow the consequences of behavior through unlimited stretches of time, unlimited reaches of space, and unlimited sets of values. Under such conditions even an approach to rationality in real behavior would be inconceivable."

Decisions may be adequate for practical purposes, however, because

> "Fortunately, the problem of choice is usually greatly simplified by the tendency of the empirical laws that describe the regularities of nature to arrange themselves in relatively isolated subsets. Two behavior alternatives, when compared, are often found to have consequences that differ in only a few respects and for the rest are identical. That is, the differential consequences of one behavior as against an alternative behavior may occur only within a brief span of time and within a limited area of description. If it were too often true that for want of a nail the kingdom was lost, the consequence chains encountered in practical life would be of such complexity that rational behavior would be virtually impossible." (Simon, 1976).

Simon describes the process by which decisions are actually made in organisations as a series of eliminating steps, in each of which the perceived broad alternatives are compared and the least attractive discarded. Those remaining are then refined to a lower level of detail, and the process repeated. "The planning procedure is a compromise, whereby only the most 'plausible' alternatives are worked out in detail." - At every step there is the possibility that the optimum choice will be "eliminated without complete analysis."

Simon's term for this pragmatic utilisation of such information as is available, or can be perceived, is "bounded rationality"

Implications

Clearly, the tenets of chaos theory depend on systems concepts to a considerable extent. These related concepts are taken to apply to the behaviour of people, and specifically in this instance to project managers, in the context of their working lives. Systems models provide a useful metaphorical framework within which distinct identifiable elements may be examined individually but without losing sight of their status as parts of a conceptual whole.

Chaos theory suggests that the complexity of the interactions between these elements, which are themselves composed of lower-level elements, will make it impossible to predict outcomes mechanistically. However, the theory of bounded instability gives rise to optimism that patterns may be discernible in relationships between sources of perceived threat, individual personal responses, and work performance

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