Chapter 2

Schools of Systems Thinking – Development Trends in Systems Methodology

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1 Introduction

> The ontology of the system paradigm differs from that of the science paradigm: whereas the latter sees the world in terms of closed, separable, and reducible analytical-mechanistic entities, the former advances the view that the world is rather made of open, nonseparable, and irreducible biological-behavioral wholes. Different ontological assumptions lead to different paradigms and methodologies. As a result, system science has been instrumental in stressing the need to design scientific methods suited to so-called soft-system domains, where the properties of systems are emergent as opposed to inherent, and where holism replaces reductionism.
>
> *John P. van Gigch (1991:27)*

In this chapter some characteristic traits of various systems theoretical "schools of thinking" are outlined. The outline is only a very partial one, merely focusing on some clearly discernible schools that have emerged in the fairly short (50 years) history of systems thinking. The important argument is that, while the basic systems concepts and ideas go back to the "founding fathers" of systems theory and have not changed very much over time, there has been a significant new development during the last 10–15 years in the epistemological "framing" of the established systems theoretical apparatus and this development constitutes a qualitative improvement of the systems approach in science.

Before having a closer look at some of the major schools of systems thinking it might be useful to pin down systems theory in the world of systems and sciences. To do so we will make use of a figure by John P. van Gigch (see Figure 2.1).

van Gigch (1991:65) is here using Boulding's distinction between frameworks, clockworks, and thermostats, where, according to Boulding, "'frameworks' are static structures, clockworks are 'simple dynamic systems with predetermined motions,' and 'ther-

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mostats' are 'control mechanisms or cybernetic systems.'" Moving to the right in the figure we encounter ever more complex sciences. The "life sciences," for instance, deal with open systems or "self-maintaining structures" (such as cells), with plants and animals. Commenting on the figure van Gigch (1991:67), however, adds:

> The taxonomy of sciences and systems presented here is not meant to be definitive. Many new sciences such as bioengineering straddle the separating lines outlined here. Our scheme is designed only as an aid in describing the scope of system thinking in the spectrum of knowledge. Placing system theory above the specialized sciences does not necessarily mean that the former is more important than the latter. Their relative position is representative only of the nature of the roles they play in the spectrum and of the differences among the types of systems that they treat.

The broadly defined schools of systems thinking that are surveyed in this chapter all represent organized efforts to establish a specific mode of (systems based) analysis of certain types of problems. However, it is not my intention to identify every "movement" in the systems arena.[1] The focus is rather on significant advances through which the systems approach has been made better equipped to deal with the problems one encounters when moving to the right in Figure 2.1, i. e., to problems studied in the behavioral and social sciences. It will be argued here that these advances mainly lie in the epistemological development of systems theory. However, this is not to say that there have been no advances in the systems methodology for the "hard" sciences. van Gigch has placed systems theory among the "general sciences," together with mathematics and philosophy, and the theory clearly plays into all of the sciences listed further down in the figure.

The following exposition of schools of systems thinking may be fairly comprehensive, but it is not particularly detailed. It should merely be seen as an attempt to structure a large and intricate theoretical development for the non-expert. The various schools are grouped under four main titles, *Developments directly related to* GST *and Cybernetics – Complexity,* OR *and Systems Engineering – working the "systems toolbox," Systems Analysis – applied* GST *in the social sciences,* and *From Soft Systems Methodology to Critical Systems Thinking.*

The order in which the various clusters of schools are discussed maps to some degree the theoretical development, starting with the "wide" GST school out of which cybernetics emerged (this might, however, be debated by cyberneticians). GST and cybernetics gave birth to OR. GST, cybernetics and OR eventually led to systems analysis. Finally, all of the above-mentioned schools played into the development of Soft Systems Methodology and Critical Systems Thinking. This view of the history of systems thinking might of course be contested. There is, for instance, no straightforward chro-

1 Overviews of the basics of systems theory and the development of systems approaches in science abound in the literature. A comprehensive and yet popularly written account of the topic has recently been published in Swedish by Prof. Lars Ingelstam (2002). An overview of various systems theories is given in Skyttner (2001). An impressive review of systems thinking comprised of seminal articles by prominent systems theorists was published by the beginning of 2003, just when this book was being prepared for publication. The review, presented in four volumes of all together more than 1,500 pages, was edited by Gerald Midgley. (See Midgley, 2003.)

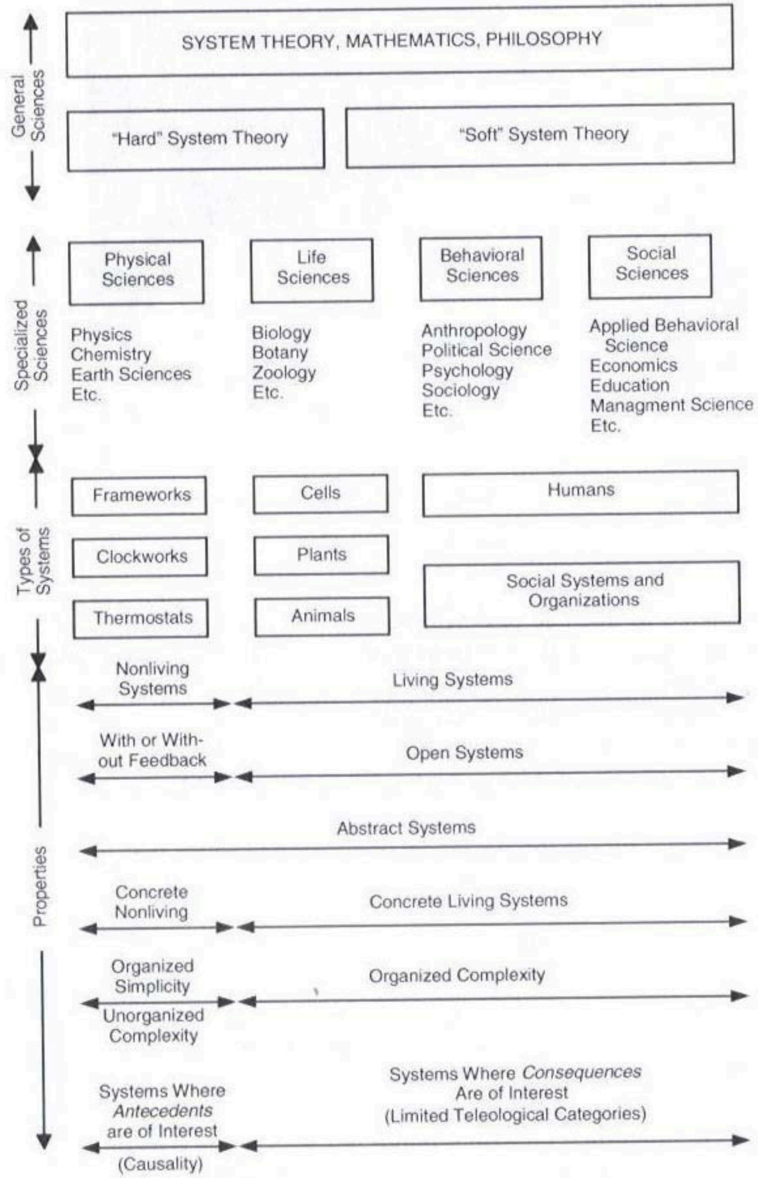

Figure 2.1: A taxonomy of sciences and systems. (Source: van Gigch, 1991:66)

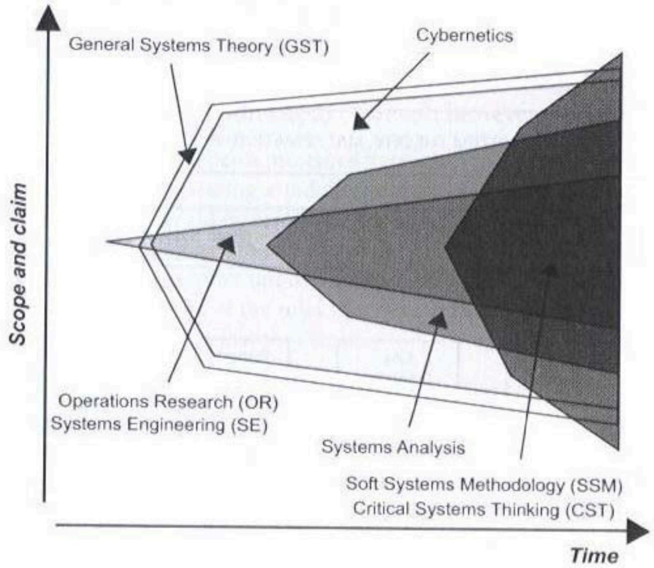

Figure 2.2: The relation between various "schools" of systems thinking discussed in this chapter.

nology displayed in this line of development. OR followers might rightly claim that OR was the first systems methodology to appear on the historical stage, while GST came later and, as would claim cyberneticians, in parallel with cybernetics. Furthermore, the schools discussed here are all still alive and thriving to this day. Finally, most analysts working with systems approaches would probably not much care to identify themselves as adherents to any one of the listed schools in particular. Many practical studies using a systems approach employ an eclectic variety of methods and methodologies with little or no concern for the specific school of thinking to which they might belong.

Figure 2.2 gives an indication of how the systems approaches discussed in this chapter are related.

The structuring attempted here is very tentative and rudimentary, but consciously so – others have come up with much more detailed and comprehensive classifications (see, e.g., Eriksson, 1998). In fact, it is probably not really correct to draw the lines between these schools of thinking as I have done. Nevertheless, in a popular overview like the one attempted here it seems necessary to make some rudimentary kind of distinction between (some of the) different types of systems approaches commonly used today. The question is on what grounds this structuring is made.

Overviews of systems thinking tend to include long listings of various systems schools or systems approaches. Just to give an impression of the existing variety of systems approaches in use today, in the advertising blurb for a recently published book by Michael Jackson (*Systems Approaches to Management*, Kluwer Academic/Plenum Publishers, 2000) the list of topics treated goes like this (the book, by the way, contains a broad overview of the systems movement structured along prominent social science perspectives):

> [The book] covers chaos and complexity theory, the learning organization, systems dynamics, living systems theory, soft systems methodology, interactive management, interactive planning, total systems intervention, autopoiesis, management cybernetics, the viable system model, operations research (hard and soft), systems analysis, systems engineering, general system theory, sociotechnical systems thinking, the fifth discipline, social systems design, team syntegrity, postmodern systems thinking, critical systems thinking, and much more. (*General Systems Bulletin*, Vol. XXX, 2001, p. 56)

This said to explain the drastic reduction in scope and complexity that it has been found necessary to make in the present narrative. After considering such a list it should be apparent that there must be a great deal of overlap between the various listed schools of thinking. Different attempts have been made to structure and categorize various schools in order to explain how they are related. However, finding an efficient and meaningful classification scheme is not so easy. Jackson and Keys (1984) have proposed a "system of systems methodologies" (SOSM) on the assumption that it is possible to "construct an ideal-type grid of problem contexts that can be used to classify systems methodologies according to their assumptions about problem situations." This classification identifies two types of system (simple, complex) and three types of relations (unitary, pluralist, coercive) between "participants" (those who can make decisions affecting the behavior of the system). This division leads to a two by six matrix into which various schools of thinking have been fitted.

This kind of fine division cannot be followed here. It is only mentioned as an example. Interested readers are referred to the writings of scholars like Michael Jackson (1992, 2000) (see also, e.g., Bausch, 2001). Together with Robert Flood, Jackson is the founder of a recent systems school labeled *Critical Systems Theory* or *Critical Systems Thinking*. Naturally, thinkers claiming a new and separate position for their systems ideas are eager to show in what way their thinking differs (is more advanced) than that represented by earlier schools. Flood and Jackson (1991) are the editors of a comprehensive volume of previously published papers by well-known proponents of the systems approach (incl. Churchman, Ackoff and Checkland) in which the basic lines in the development of the "systems movement" are reflected, ending up with an advocacy of what they label "critical systems theory and practice" that we will have a closer look at later in this chapter.

Another way of making various systems approaches "intelligible" – to try to establish a "heuristics" for evaluating systems approaches – has been tried by Darek Eriksson (1998), who distinguished four "discriminators" through which 15 different "systems approaches" were classified.[2] His choice of "discriminators" or "dimensions" along which to judge a particular school may be of some general interest: the theory-generation sources, the paradigmatic-historical development, the epistemological orientation and the decision making process.

2 Eriksson discusses the following fifteen "systems approaches" (the seemingly random order of the "schools" in the following listing is that found in Eriksson's paper): Operations Research & Management Science, Systems Analysis, Systems Engineering, Systems Dynamics, Cybernetics (both 1st and 2nd order), General Systems Theory, Living Systems Theory, Viable Systems Model, Autopoietic Systems Theory, Interactive Planning, Soft Systems Methodology, Critical Systems Heuristics, Living Social System Model, and Multimodal Soft Systems Methodology.

Since what I attempt to employ here to structure the narrative is similar to what Eriksson (1998) calls "the paradigmatic-historical development" it might be interesting to hear something about the more elaborate structure that comes out of his analysis. (A similar reasoning is also proposed by Mirijamsdotter, 1998.) Referring to the "systems community" and its "articulation" of various systems approaches in terms of paradigms, Eriksson identifies four such paradigms, "Hard Systems Thinking (HST)," "Soft Systems Thinking (SSM)," Critical Systems Thinking (CST)" and "Multimodal Systems Thinking (MST)," and he structures the various methodologies that belong to each one of these paradigms under three overarching "meta-paradigms," "Machine Thinking (MT)," "Biological Thinking (BT)," and "Social Thinking (ST)." Eriksson (1998:22) then concludes:

> Our studies have shown that Machine Thinking consists of Hard Systems Thinking – i. e. Operations Research & Management Science, Systems Analysis, Systems Engineering and Systems Dynamics – together with first order Cybernetics. Biological Thinking consists of General Systems Theory, Autopoietic Systems Theory, Living Systems Theory, Viable System Model, and first and second order Cybernetics. Finally, Social Thinking may be articulated in the paradigms of Soft Systems Thinking, Critical Systems Thinking and Multimodal Systems Thinking. Soft Systems Thinking, in turn, contains Soft Systems Methodology, Interactive Planning, and Strategic Assumptions Surfacing and Planning. The Critical Systems Thinking paradigm contains Critical Systems Heuristics, and the Multimodal Systems Thinking paradigm contains Living Social System model and Multimodal Soft Systems Methodology.

Clearly, any structuring of the vast premises of systems thinking must be attempted for a specific purpose, and this purpose (implicitly or explicitly) affects (restricts) the actual structuring. In the present context I am not particularly interested in detail, preferring to focus on general trends and main lines of long-term development making the systems approach increasingly usable in the study of complex social systems (going to the right in Figure 2.1 above). The grouping here is also (even if it is only loosely) related to two other "dimensions" along which Eriksson is discussing his various "systems approaches," "the epistemological orientation" and "the decision making process." Specifically, I am interested in the relation between the system observed and the observer, and the degree to which observation (analysis) of a system is coupled to strategies for intervening to obtain specific, desirable systems outcomes.

The systems approach or systems inquiry, as it is sometimes called, incorporates three interrelated fields of study: systems theory, systems philosophy, and systems methodology. Some would also like to add systems practice to this list of interrelated fields (see, e. g., Ulrich, 1983; Jackson, 2000; Midgley, 2000). (Systems practice will be of prominent interest later in this chapter when we look at Soft Systems Methodology and Critical Systems Thinking.) Bela H. Banathy (2000), in the so-called "Primer project" of the International Society for the Systems Sciences (ISSS), has characterized these fields in the following way:[3]

3 The "Primer Project" is executed by the "Primer Group," which is a "special integration group" within the ISSS. The "Primer Project" was started in 1995 with the aim of producing a systems handbook. Today its goal is to produce "a primer equal to that task of educating the seasoned systems scientist as well as the naive elementary school pupil, or media person" (http://www.isss.org/primer/primer.htm).

> In contrast with the analytical, reductionist, and linear-causal paradigm of classical science, systems philosophy brings forth a reorientation of thought and world view, manifested by an expansionist, non-linear dynamic, and synthetic mode of thinking. The scientific exploration of the theories of systems standing for the various sciences have brought forth a general theory of systems, a set of interrelated concepts and principles, applying to all systems. Systems methodology provides us with a set of models, strategies, methods, and tools; that instrumentalize systems theory and philosophy in analysis, design, development, problem solving in – and the management of – complex systems.
>
> [...]
>
> The methodology of a discipline is clearly defined and is to be adhered to rigorously. It is the methodology which is the hallmark of a discipline. In systems inquiry, on the other hand, one selects methods and methodological tools or approaches that best fit the nature of the identified problem situation, the context, the content, and the type of system that is the domain of the investigation. The methodology is to be selected from a wide range of systems methods that are available to us.
>
> [...]
>
> Systems philosophy, systems theory, and systems methodology come to life as they are used and applied in the functional context of systems. It is in the context of use that they are confirmed, changed, modified, and reconfirmed. Systems philosophy presents us with the underlying assumptions that provide the perspectives that guide us in defining and organizing the concepts and principles that constitute systems theory. Systems theory and systems philosophy then guide us in developing, selecting, and organizing approaches, methods and tools into the scheme of systems methodology. Systems methodology then is used in the function context of systems. But this process is not linear or forward moving circular. It is recursive and multi-directional. One confirms or modifies the other. As theory is developed, it gets its confirmation from its underlying assumptions (philosophy) as well as from its application through methods in function contexts. Methodology is confirmed or changed by testing its relevance to its theoretical/philosophical foundations and by its use.

In the sequel we will see how developments in these fields of systems inquiry have influenced the evolution of systems thinking.

2 Developments Directly Related to GST and Cybernetics – Complexity

As was indicated in the previous chapter, systems thinking was largely "codified" through the works of Ludwig von Bertalanffy on "General System Theory" (GST) and of Norbert Wiener and W. Ross Ashby on Cybernetics. The work of the former was, in the parlance of Eriksson (1998), primarily devoted to "Biological Thinking," while the latter scientists primarily dealt with "Machine Thinking." Although both lines – or schools – of thinking have engaged themselves with the most varied topics it is probably fair to say that GST has primarily been occupied with the study of living systems, while Cybernetics, boosted especially by the speed and inventiveness that have characterized the development of computer technology (and computer science), has mainly been concerned with machines, man-machine relations, and information processing. This difference of focus seems to be what distinguishes (albeit rather vaguely) between these two huge and, in terms of topics of study, highly overlapping schools of systems thinking. Looking through and comparing the lists of contents of the "yearbooks" issued by general systems theory organizations and journals explicitly devoted to cybernetic research reveals largely identical fields of interest. Simply by reading the titles of published articles it would not often be possible to correctly guess to which of these two schools the article belongs.

While several new schools of thinking have been established and separated from GST and Cybernetics in the course of time, both these basic schools are still alive and highly active. Here I will only try to convey the major lines of development within the two schools.

It is not possible to give a fair representation of the multi-faceted development of GST and Cybernetics in a short overview. I see the scope of these two foundational schools of systems thinking as almost all-encompassing (cf. Figure 2.1). An account of the history of GST and Cybernetics might in fact incorporate practically all systems oriented research that has been performed in science till this day. A quick look at the names of the various so-called "special integration groups" of the International Society for Systems Sciences (ISSS)[4] can serve as an illustration of the broad spectrum of topics that the organization sees as established themes of systems research. (It may also be noted that there are virtually equivalent names for various "sub-disciplines" in the cybernetic movement. Thus, cybernetics deals with simulation models and artificial intelligence, with social system modeling, neurocybernetics, medical cybernetics, management cybernetics, industrial cybernetics, etc.) Obviously, today the use of the computer is prominent in all of these fields. However, cybernetics has always been closely related to computer use and developments in computer science.

James Grier Miller's "Living Systems Theory" (LST) could be seen as a direct outgrowth of GST – it has also (as can be seen from the above list) provided the topic for a "special integration group" in the ISSS. Miller's is an integrative effort combining biological and social systems, showing how these systems are organized and operate at seven hierarchical levels: cells, organs, organisms, groups, organizations, societies or nations, and supranational systems. Miller published his book on "Living Systems" in 1978 after preparing it for more than 25 years. The following data-rich citation concerning Miller's book conveys something of the huge task that the author had set himself and of the impact that the book made:[5]

> This book of 750,000 words contains evidence from more than 3,000 scientific articles to support its thesis that over more than 3 billion years there has been an evolution of seven levels of progressively more complex living systems. Each of these levels consists of input-

4 This is the primary GST organization, originally called the Society for the Advancement of General Systems Theory (cf. footnote 3 in Chapter 1).

5 The citation is from a biography of Miller by G. A. Swanson published on the Internet, as part of the ISSS "Primer Project" at URL: http://www.isss.org/lumJGM.htm.

Table 2.1: Special Integration Groups within the ISSS.

- Critical Systems Theory & Practice
- Designing Educational Systems
- Duality Theory
- Evolution and Complexity (Epic of Evolution Society)
- Evolutionary Learning Community (Syntony Quest)
- Futurism and Change
- Hierarchy Theory
- Human Systems Inquiry
- Information Systems Design and Information Technology
- Living Systems Analysis
- Medical and Health Systems
- Modeling and Metamodeling
- The ISSS Primer
- Processes and Human Processes
- Research Toward a General Theories of Systems
- Spirituality and Systems
- Survival of Evolving Systems
- Systems Application to Business and Industry
- Systems Modeling and Simulation
- Systems Philosophy and Systems Ethics
- Systems Psychology and Psychiatry
- Systems Studies of Climate Change
- Thermodynamics and Systems
- Women and Children in Community Systems

Source: ISSS web presentation. Retrieved on January, 28, 2002, from http://www.isss.org/sigslist.htm.

> output systems which process matter, energy, and information through 19 subsystems which are essential for them to survive. Living Systems received about forty reviews in journals of about twenty disciplines, and almost all of them were strongly positive or positive.

Living systems theory is concerned with inter-system generalizations, and many of the 173 testable cross-level hypotheses which appeared in Living Systems (many of which apply to all "levels," others to two or more "levels") have been tested empirically (Miller & Miller, 1992).

Early research in the social sciences that clearly was inspired by GST was, for example, the work of Talcott Parsons (1964; 1971) in sociology and of people like David Easton (1953; 1965a; 1965b) and Gabriel Almond and G. Bingham Powell, Jr. (1966) advocating systems approaches in political science. Later Russel Ackoff and Fred Emery added to this tradition in their book on "purposeful systems" (1972). In economics, which has always used a kind of limited or partial systems approach, a new approach named "comparative economic systems" emerged on the basis of the systems movement. This field of research naturally gained a special significance during the days of the Cold War, when interest was primarily focused on the performance of western capitalist systems compared to the systems of the "communist bloc."[6] But, as a proponent of the discipline asserts (Zimbalist, 1984:1):

> The scope of comparative economic systems as a field singularly offers the potential, inter alia: (a) to explore and challenge the assumptions and methods of traditional economic analysis, (b) to reinterpret conventional wisdom; (c) to understand the interplay of economic and noneconomic forces in different institutional contexts; and (d) to evaluate the desirability of alternative economic policies and structures.

Today, the tradition has attracted renewed interest through the systems changes in Eastern Europe and the transition of these societies from their earlier forms of socialism into market oriented systems. The rapid speed and broad scope of the East European transition have provided unique opportunities to study rapid and profound social system change.

Other prominent research performed in the GST "tradition" is that of Nicolis and Prigogine (1977) on non-linear thermodynamic models demonstrating the phenomenon of "self-organization," of Conrad (1983) who showed that adaptability is a general characteristic of biological systems, of Odum (1983) who constructed ecological models to describe systems in terms of energy and entropy, and of Forrester (1973) and Meadows *et al.* (1972) who developed global models incorporating population, food supply, industrial and agricultural production, and pollution.

It should be noted that several of the research themes just listed have themselves grown into prominent schools of systems thinking. But it might be claimed that they emanated more or less directly from GST.

2.1 Cybernetics

Let us now have a look at the cybernetics tradition, which I see as almost, but not entirely, overlapping GST, a view that receives support from many systems scientists today (cf. Klir, 2001).

Wiener defined cybernetics as "the science of control and communication, in the animal and the machine" and it has been said to constitute a "theory of machines," but rather than treating machines as mechanical things cybernetics focuses on "ways of behaving," asking not "what is this thing?" but rather "what does it do?" (Ashby, 1956). Thus, cybernetics focuses on function and behavior. As Ashby (1956:3–4) puts it:

> Cybernetics envisages a set of possibilities much wider than the actual, and then asks why the particular case should conform to its usual particular restriction. In this discussion, questions of energy play almost no part – the energy is simply taken for granted. Even whether the system is closed to energy or open is often irrelevant; what is important is the extent to which the system is subject to determining and controlling factors. So no information or signal or determining factor may pass from part to part without its being recorded as a significant event. Cybernetics might, in fact, be defined as *the study of systems that are open to energy but closed to information and control* – systems that are "information-tight."

6 See Eckstein (1971), Zimbalist (1984), Gottlieb (1984), Vining (1984), and Elliot (1985) for examples of studies in the field of "comparative economic systems."

Ashby's reasoning about the definition of the concept of system also clearly indicates that cybernetics envisages a system as defined by "a list of variables" selected by the analyst/ experimenter and varied until he finds a set of variables that gives the "transformations that are closed and single valued."

What distinguishes cybernetics more than anything else is the importance laid on the role of computers in science (Rudall, 2000). This comes as no surprise considering Ashby's definition of the school cited above. Cybernetic research, mostly with the help of mathematical modeling, is performed in many disparate fields, like social systems, fuzzy systems, artificial intelligence, economic systems and management, neuro- and biocybernetics, informatics and education, industrial cybernetics, systems and models (incl. environmental problems), and medical cybernetics (Rudall, 2000). Warwick (1994) discusses several methodological developments in cybernetics associated with computers, for instance cluster analysis, neural networks and artificial intelligence, robotics, genetic algorithms and learning systems, and fuzzy control.

A lively line of research – and one that has made a profound impact on real-world events – is that concerned with business management. The work of people like C. West Churchman and Stafford Beer emerged in the cybernetics tradition, but should perhaps rather be referred to the operations research or systems analysis field. We will briefly come back to the development of the "management cybernetics" field later in this chapter.

Cybernetics is also a well-organized movement, special departments of cybernetics exist at many universities, there are professional associations and special scientific journals, and the discipline is advocated on several Internet sites.[7]

2.2 Complexity

A relatively late new direction of research in the GST and cybernetics tradition is concerned with *complexity* or the study of *complex systems.* The concept of complexity is of course not new, but the discussion about the meaning of the term has acquired a special pertinence during the last two decades. Complexity is a tricky concept, limitations of space as well as the present author's limited knowledge prevent any deep diving into its "muddy waters." While complexity studies have already attracted a huge interest there seems not even to be any proper agreement on how the basic concept should be defined (Klir, 2001). W. Ross Ashby (as cited in Klir, 2001:136–137), for example, allows that a system's complexity is relative to a given observer, and that "this acceptance of complexity as something in the eye of the beholder is, in my opinion,

7 A good starting point for "browsing" cybernetics on the Internet is the website maintained by the "Principia Cybernetica Project" at URL: http://pespmc1.vub.ac.be/DEFAULT.html.

the only workable way of measuring complexity." Klir (2001) recognizes three different types of system complexity:

> According to the *first general principle*, the complexity of a system (of any type) should be proportional to the amount of information required to describe the system. Here, the term information is used solely in a syntactic sense; no semantic or pragmatic aspects of information are employed. One way of expressing this *descriptive complexity*, perhaps the simplest one, is to measure it by the number of entities involved in the system (variables, states, components) and the variety of relationship among the entities. (p. 137)
>
> Descriptive complexity can also be characterized in a universal way, independent of the nature of systems to which it is applied. In this sense, descriptive complexity of a system (of any type) is defined to be *the size of the shortest description of the system in some standard language* or, alternatively, the size of the smallest program in a standard language by which the system can be simulated on a canonical universal computer. (p. 138)
>
> According to the *second general principle*, systems complexity should be proportional to the amount of information needed to resolve any uncertainty associated with the system involved (predictive, retrodictive, prescriptive). Here, again, syntactic information is used, but information that is based on a *measure of uncertainty*. (p. 138)
>
> The two types of complexity introduced thus far, the descriptive complexity and the uncertainty-based complexity, pertain to systems. Yet another face of complexity exists, a complexity that pertains to systems problems. This complexity, which is usually referred to as *computational complexity*, is a characterization of the time or space (memory) requirements for solving a problem by a particular algorithm. (p. 143)

These are all "definitions" by way of a measure that will, if applied, indicate a *degree* of complexity. Klir (2001) goes deeper into the notion of computational complexity which is a field of study in the general theory of algorithms. A Dutch computer scientist, Cor van Dijkum (1997), notes that complexity entered science at the moment it was shown that simple deterministic systems could produce chaotic outcomes, so-called deterministic chaos. It at once became clear that not all effects of a set of interdependent variables could be predicted, unexpected behavior might emerge. Van Dijkum concludes (p. 731):[8]

> More important is that, in the science of complexity, the observer also plays an important role. The definition of complexity is connected to the subjectivity of the observer:
>
> How many inequivalent descriptions of N can our observer generate? The complexity of a system N as seen by an observer is directly proportional to the number of such descriptions (Casti, 1994).
>
> Also, in this way, there is a parallel between discussions within cybernetics of the second order and discussions within the science of complexity.

Still, other distinctions between simple and complex systems have been suggested. The late Robert Rosen, a mathematical biologist of Dalhousie University, Canada, maintained that the fundamental difference between simple and complex systems is captured in the difference between mechanistic systems and organisms (living systems). The notion has a number of fundamental corollaries, such as the fact that physics, which focuses on "simple systems," is merely a "special case" of biology. Rosen has also suggested a mathematics for complex systems, which formally brings final (teleological) causality inside the domain of science. Rosen's radical ideas on this (and other) topics have of course been considered controversial and provocative and his thinking has been questioned by many of his colleagues in science.[9]

In a recent article, Steven Phelan (1999) has tried to sort out the correspondence between complexity and systems theory:

> As a complexity scientist, I was both surprised and embarrassed to find such an extensive body of literature virtually unacknowledged in the complexity literature. A common terminology suggests a high degree of commensurability between the two theories. However, on closer examination, although they share a common worldview, the two theories differ markedly in their research agenda and methodologies.

Comparing complexity theory with the recent developments in systems theory (SSM or "soft systems theory" and CST or "critical systems thinking"), Phelan finds that systems theory focuses on improvement and "problem solving." The emphasis on confirmatory analysis in systems theory is in sharp contrast with the exploratory nature of work in complexity theory. While systems theory relies on feedback (and feedforward) loops, complexity theory has been helped by techniques developed in artificial intelligence (neural nets) to focus on agent-based approaches, to "populate simulated worlds with multiple intelligent and *idiosyncratic* agents." Phelan also finds that, while both SSM and CST have moved away from the positivist epistemology of "hard" systems to a constructivist position in which a negotiated knowledge is the closest we can get to the ontological reality, most scientists still view complexity as a positivist theory. Phelan finds that even if "postpositivists" have looked upon chaos theory as an "attack from within" on the privileged position held by science there is not enough proof that chaos theory will have to leave the positivist realm. Phelan ends (p. 245):

> While complexity theory maintains a strongly positivistic stance, there is some evidence that a constructivist awareness may be just starting to emerge (Rocha, 1997). One of the strengths of agent-based modeling is its ability to model heterogeneous behavior among agents. It is conceivable that a model could be developed to allow agents to have different perceptions of an underlying ontological reality. These differences in perception would lead to divergent learning experiences and an inevitable variation in preferences and actions among agents. Agent-based methods may thus go some way toward operationalizing the constructivist worldview.

8 The citation from John Casti that van Dijkum uses here is taken from Casti, J. (1994). *Complexification*. New York, NY: HarperCollins.

9 Several of Rosen's papers are included in Klir (2001). Until his death in 1998 Rosen was a returning participant in the yearly workshops that the Swedish Committe for Systems Analysis and IIASA organized at the Abisko scientific station in the Swedish circumpolar north. The workshops, which started in 1983, have produced a series of volumes issued by international publishing houses. A recurring theme at these workshops has been problems related to the notion of complexity. (The series of Abisko workshops can be seen as an activity within the Swedish "systems movement" and, as such, it is of relevance to the study reported in this book. A list of publications from the series of Abisko workshops can be found in Appendix 1 to this chapter.) An excellent summary (in Swedish) of the "Abisko discussions" has been written by Prof. Anders Karlqvist, who was also the initiator of the workshop series (cf. Karlqvist, 1999).

In the context of GST, cybernetics and complexity I should, finally, also mention the very rich systems theoretical construct known as *autopoiesis theory* originally suggested by the two Chilean biologists Humberto Maturana and Francisco Varela.[10] The term "autopoietic" refers to the authors' notion of living systems as autonomous, self-referring and self-constructing closed systems. The theory was originally conceived on the basis of the definition of cognition as a biological phenomenon, claimed to be the very nature of all living systems (editors' preface to Maturana & Varela, 1980). Maturana and Varela's theory immediately generated a great interest not only on the part of biologists, but on the part of systems scientists as well. This interest was early manifested by the fact that "management cybernetician" Stafford Beer was invited to write a preface to "Autopoiesis: The Organization of the Living" originally published in Chile in 1972 (subsequently reprinted in Maturana & Varela, 1980). Beer's preface is extremely positive and he immediately engages in a dialogue with the authors, sensing that autopoiesis might be a useful construct for analyzing social systems. In the last decade there has been a lively debate on the applicability of autopoiesis in social science. For instance, the late German sociologist Niklas Luhmann took up Maturana and Varela's ideas and developed his own "theory of self-reference" in social systems (see, e. g., Bailey, 1997, for a comprehensive overview[11]). It seems that Luhmann's modification of biological autopoiesis for the study of social systems and the development and use of his ideas by an emerging school of social system autopoiesis is providing an interesting, even if complicated and (still) somewhat controversial, systems theoretical basis for the understanding of social systems.[12] In contrast to the "intervention" oriented systems approaches discussed later in this chapter, Luhmann's "autopoiesis of social systems" primarily aims at an understanding of the structure, functioning and reproduction of social systems.

So much about the development of the general systems approach. GST and cybernetics are tremendously large research areas and there is no way of doing the development justice on a few pages. Let us now instead turn to some more applied methods clearly using a systems approach to solve various problems encountered in society.

10 The theory was elaborated in the late 1960's and offered in a series of papers by Maturana during the 1970's. Two of the key articles (Maturana's "Biology of Cognition," and "Autopoiesis: The Organization of the Living" by Maturana & Varela) were reprinted in Maturana & Varela (1980). In 1987, Maturana & Varela published an overview of their autopoiesis theory for a broader audience in the book *The Tree of Knowledge*.

11 In Sweden, a careful review of Luhmann's sociological systems theory was reported in a PhD thesis by Jan Inge Jönhill (1997).

12 Maturana and Varela's theory has triggered a huge literature discussing challenges to the theory and describing applications. Mingers (1995) provides an accessible overview of the origins of the theory as well as its subsequent applications. On the Internet (at URL: http://www.enolagaia.com/AT.html) Dr. Randall Whitaker has compiled "The Observer Web: Autopoiesis and Enaction" dedicated to the theories of Maturana and Varela. The site contains useful materials for the more advanced student as well as for the beginner.

3 Operations Research and Systems Engineering – Working the "Systems Toolbox"

I have already mentioned the origins of Operations Research (OR) going back to the time of the Second World War, when the British war-waging authorities and the military recruited scientists and administrators to work on problems related to logistics and material supplies needed for sustaining the war effort.[13] OR clearly lies in the systems theoretical field and its development during the last half-century, which must be said to have been extremely successful, has been affected by the overall development of GST and cybernetics. After the war period, during which OR activities had been initiated in several of the allied countries, the OR advocates worked to establish a future in the civilian world (Cummings, 1997). The OR "movement" was rapidly organized all over the world. The first OR society in the world was established in Great Britain in 1948.[14] Today the International Federation of Operational Research Societies (IFORS), established in 1959, has national member organizations in 44 countries, among them 28 European countries united in EURO – the Association of European Operational Research Societies within IFORS. The Swedish Operations Research Association, established in 1959, is the Swedish member organization in EURO and IFORS.[15] The OR movement is also well provided with scientific journals and newsletters.[16]

What, then, is OR all about? What do operations researchers do when they do operations research? In an early paper W. Ross Ashby (1958:416) lists three characteristics of OR:

> Its first characteristic is that its ultimate aim is not understanding but the purely practical one of control. If a system is too complex to be understood, it may nevertheless still be controllable. For to achieve this, all that the controller wants to find is some action that gives an acceptable result; he is concerned only with what happens, not with why it happens. …

13 A review of the British OR experience has recently been published by Rau (2001).

14 The "Operational Research Club," as it was originally called, had a very limited membership. In 1952, the club was converted into a "society" and its membership grew. Since the early seventies the British Operational Research Society has had about 3,000 members. (More about the society can be found on its Internet website at URL: http:// www.orsoc.org.uk.)

15 Information about IFORS and EURO (and many other OR organizations) can be found at the organizations' Internet websites at URLS: http://www.ifors.org/ and http://www.euro-online.org/. Today, SOAF – the Swedish member organization of IFORS and EURO – has around 150 members. Information about SOAF can be found at URL: http://www.soaf.org/. See Kaijser & Tiberg (2000) for an historical overview of the establishment of operations research and the systems approach in Sweden.

16 For instance, IFORS publishes a journal (ITOR – *International Transactions in Operational Research*), a compilation of abstracts (IAOR – *International Abstracts in Operations Research*), a bulletin and newsletters. These publications cater for the needs of the international OR community. ITOR and IAOR are published and distributed by commercial publishers (cf. URLS: http://www.blackwellpublishers.co.uk/asp/journal.asp?ref= 0969-6016&src=sub and http://www.iaor-palgrave.com/content/html/index.htm, respectively). The bulletin and the newsletters are produced and distributed by IFORS itself. Some national OR societies publish their own journals. Today OR-related issues are discussed on a large number of Internet websites. For instance, on "Michael Trick's Operations Research Page" (at URL: http://mat.gsia. cmu.edu/) one can find a list of 35 OR journals (with websites) as well as 14 on-line OR journals.

A second characteristic of operational research is that it does not collect more information than is necessary for the job. It does not attempt to trace the whole chain of causes and effects in all its richness, but attempts only to relate controllable causes with ultimate effects. ...

A third characteristic is that it does not assume the system to be absolutely unchanging. The research solves the problems of today, and does not assume that its solutions are valid for all time.

In his comprehensive overview of systems science Klir (2001:51) briefly touches upon OR and characterizes it as "the study of possible activities or operations within a particular institutional and organizational framework (e. g., a firm, a military organization, or a government) for the purpose of determining an optimum plan for reaching a given goal." A systems methodology like OR, which primarily deals with man-made systems and how to improve their functioning, falls somewhat outside the scope of Klir's discussion that is primarily related to the analysis of general system properties. From these brief characterizations we understand that it is practical application rather than theoretical speculation that constitutes the core of OR.

We cannot either look to the official OR organizations for a formal definition of operations research. Nowadays, these organizations find it appropriate merely to maintain updated "summary descriptions" of the field (Cummings, 1997). The following summary can be found on the IFORS website:[17]

Operational Research can be described as a scientific approach to the solution of problems in the management of complex systems. In a rapidly changing environment an understanding is sought which will facilitate the choice of more effective solutions which, typically, may involve complicated interaction among people, materials, and money.

Operational Research has been used intensively in business, industry, and government. Many new analytical methods have evolved, such as mathematical programming, simulation, game theory, queuing theory, networks, decision analysis, multicriteria analysis, etc. which have powerful application to practical problems with the appropriate logical structure.

Operational Research in practice is a team effort, requiring the close cooperation among the decision makers, the skilled OR analysts, and the people who will be affected by management action.

The last paragraph of this description emphasizes a participatory approach to problem solving, which was absent in earlier definitions put forth by proponents of OR (Cummings, 1997). While the above citation gives a general indication of what OR is and what people do in OR, a somewhat more detailed impression can be obtained by looking at the themes of the working groups established within EURO:

To a certain extent these themes overlap with those of the "special integration groups" of the ISSS listed in the previous section dealing with GST and Cybernetics, but it is also clear that the topics for the EURO working groups are of a more "hands-on" character. In fact, one might see OR as GST "taken to the market." Looking at the history of OR and the listings of university departments where OR is performed, one can see

17 Retrieved on April 7, 2001, from http://www.ifors.org/or.html.

Table 2.2: EURO Working Groups.

- MCAD, Multicriteria aid for decisions
- EUROFUSE, Fuzzy sets
- ORAHS, OR applied to health services
- EUROBANKING, special interest group in banking
- EWGLA, Locational analysis
- ESIGMA, Special interest group on multicriteria analysis
- Project management and scheduling
- Financial modelling
- ECCO, European Chapter on combinatorial optimization
- Decision support systems
- Transportation
- Group decision and negotiation support
- MODEST, Modelling of economies and societies in transition
- WATT Working group on automated time tabling
- Environmental planning
- PAREO, Parallel processing in operation research
- DEAPM, Data envelopment analysis and performance measurement
- DDM, Distributed decision making
- Methodology for complex societal problems
- EUROPT, EURO Continuous Optimization
- HCP, Human Centered Processes
- E-CUBE, European Working Group on Experimental Economics
- EU/ME, European chapter on Metaheuristics
- PROMETHEUS, Euro Working Group on Ethics

Source: EURO Web presentation. Retrieved on May 26, 2002, from http://www.euro-online.org/display.php? page=working_groups&.

that Statistics probably is the academic discipline most closely affiliated with the OR movement. The focus of OR is on numerical modeling of logistical problems, a topic in which statisticians have frequently taken an interest. By scanning the topics dealt with in 85 special issues of the *European Journal of Operations Research* in the last 20 years it was found that in close to 70 percent of the cases the topic for a special issue belonged to one of the following four broad themes: management & planning, logistics & transportation, statistical methods (incl. optimization), and decision support. It can also be noted that the OR scientific journal articles most often deal with methodological developments, typically new uses (or refinements) of some mathematical modeling or statistical analytical techniques.

While the scientific journals are mainly devoted to the theory and methodology of OR, the work performed by the OR profession at large is mostly targeted towards solving specific problems in the real world. However, the reporting of such practically oriented projects is not nearly as well-developed and accessible as the research covered in scientific journals.

It is also obvious that the rapid development during the last 20–25 years of computer technology and computer science in general has had a tremendous impact on the development of OR. Today, in principle, the OR analyst can single-handedly manage very demanding "number crunching" tasks, something that was completely unthinkable ten or twenty years ago. A number of new computer-based methods of analysis have also been developed during this period and together these methods offer OR (and systems) analysts a large and very advanced "toolbox" ready to be applied to the most varied practical problems.

3.1 Systems Engineering

Systems engineering (SE) first appeared in the "systems arena" in the late 1950's–early 1960's. It was introduced through books by Goode and Machol (1957) and Hall (1962), in which various recently proposed "systems ideas" were brought to bear on the "problem of designing equipment." While Goode and Machol primarily set out to provide the engineer with "sufficient technical background" to make him a useful "member of a system-design team," Hall takes a more fundamental approach, aiming at establishing systems engineering as a separate discipline. He also tries to specify the difference between SE and OR, with which it is sometimes confused. Thus, he claims that, while OR is usually concerned with the operation of existing systems, often trying to optimize certain functions of a system, SE, in contrast, "emphasizes the planning and design of new systems to better perform existing operations, or to implement operations, functions or services never before performed" (Hall, 1962:18–19). With its "broadening goals" which include "the design of an enterprise," OR, notes Hall, has come increasingly closer to SE, to the point where, in several universities offering training in OR, course names have been changed to "Operations Research and Systems Engineering." Hall (1962:20) concludes,

> Whether systems engineering includes operations research, or vice versa, is not important. Partisan ideas only tend to mask the helpful relationship that can exist between the two fields. Fruitful contributions to systems engineering of the systems approach in operations research have been some new philosophy, a few new techniques and the promotion of still more. Some tools vigorously promoted by operations research, notably game theory and linear programming, have been useful but as yet not vital to systems engineering. In return, systems engineering has enriched operations research, notably through traffic theory, which was developed for systems design mainly by the telephone industry here and in Europe. On the other hand, tools like feedback theory and information theory have paid few dividends in operations research.

OR and SE have attracted comparatively little attention from systems thinkers mainly interested in system *properties* – in what Robert Rosen (1986) once called "systemhood" – rather than in the properties of the real-world phenomena ("thinghood") that analysts try to capture with the help of a systems approach. For instance, Klir (2001) in his broad overview of systems thinking does not devote much space to OR or SE. But both approaches have attracted substantial interest on the part of people in academia who want to see science applied to the solution of complex real-world problems as well as

on the part of people in private and public administration who are required to come up with suggestions for solving such problems.

SE, like OR, is well provided for in terms of organizational support. Special departments of SE early appeared at universities in both the U.S. and Europe for specialist training in SE methodology. In 1991, the National Council on Systems Engineering (subsequently renamed to International Council on Systems Engineering, INCOSE) was established in the United States. Today, the council has grown into an international professional society with about 4,000 members in 36 countries. The council has local organizations (so-called "chapters") in several countries (including Sweden). It also publishes two journals, *Insight* and the *Journal of Systems Engineering.*[18]

A working group inside INCOSE has compiled information about work performed by systems engineers in different fields. The summary listing of such fields presented in this compilation contains 26 "application domains" for SE. Even from this unspecified list (Table 2.2) it is clear that technical constructions are of greatest concern in SE[19].

Examples of such constructed systems are aircraft designs, flight navigation systems, decision support systems and computer-based administrative data systems for various applications, computer-based control systems in energy production, industrial and community waste management systems, systems for public and private facility provision, geographic information systems (GIS), computer-aided tomography and other technical solutions for health care systems, transportation network maintenance systems, information management systems for the public and private sector, computer hardware development, production management systems (material flow control, robot control, etc.), production of advanced technology (e. g., in medicine, biology, space, aviation, etc.), telecommunication systems, risk management tools, etc. (Mackey & Bauknight, 2000). In a recent article James Brill (1999) presents a retrospective view of the systems engineering field for the period 1950–1995, trying to identify "milestone" events in the development of SE. Brill finds that there are three themes that recur in the materials he has used for his retrospective, the first being that the engineering of systems requires "the application of a defined and disciplined process model." The second recurring theme is that SE defines the "problem" in terms of "requirements and/or functions, i. e., what the system must do." The third theme is that the practice of SE entails the design of "a management process (or management technology)."

In the 1960's–1970's OR and SE practitioners were very actively trying to influence social policy developments (Banathy, 2001). This was part of an emerging tendency in the industrialized world to try to use so-called "social engineering" to solve all sorts of problems appearing in society. The trend provoked much criticism among scientists as well as ordinary citizens, both because of the narrow principles on which the analysis

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18 More information about INCOSE can be found on the council's Internet website at URL: http://www.incose.org/. The academic training of SE personnel is supported by the recently (1999) established *International Systems Engineering Academic Alliance* (ISEAA) (cf. URL: http://www.seec.unisa.edu.au/international/iseaa.htm). The *Journal of Systems Engineering* can be accessed through URL: http://www.interscience.wiley.com/jpages/1098–1241/.

19 A comprehensive list of reports of projects in the respective "application domains" can be found in an appendix to Mackey & Bauknight (2000), pp. E–1 ff.

Table 2.3: Domains of systems engineering applications.

1. Agriculture
2. Commercial Aircraft
3. Commercial Avionics
4. Criminal Justice System and Legal Processes
5. Drug Abuse Prevention
6. Emergency Services
7. Energy Systems
8. Environment Restoration
9. Facilities Systems Engineering
10. Food Service
11. Geographic Information Systems
12. Health Care
13. Highway Transportation Systems
14. Housing and Building Systems
15. Information Systems
16. Manufacturing
17. Medical Devices
18. Motor Vehicles
19. Natural Resources Management
20. Political and Public Interest Applications
21. Service Industries
22. Space Systems
23. Telecommunications
24. Transportation
25. Urban Planning
26. Waste Management and Disposal

Source: Mackey & Bauknight (2000), p. 4–2.

was based and because of the meager results it produced. But for a while the reaction threatened the whole idea of applying systems approaches to try to find solutions to problems in the social sphere. However, the critique triggered a further development of systems thinking in the social sciences, leading to "redefinitions" of the roles of OR and SE (and also to a methodological development in social systems thinking, in the schools of soft systems methodology and critical systems thinking to be discussed below).

4 Systems Analysis – Applied GST in the Social Sciences

As already noted in Chapter 1, systems analysis (SA) might be regarded as a kind of further development of OR closer to the political domain. Like OR and SE, systems analysis adopts a systems approach – it does not do so, however, in order to discover new facts about systems, but to arrive at good results in the analysis of complex decision situations.

Klir (2001:51), for instance, who, as already noted, is primarily interested in the development of GST, says: "The aim of systems analysis is to use systems thinking and methodology (including methodological tools inherited from operations research) for analyzing complex problem situations that arise in private and public enterprises and organizations as a support for policy and decision making ...." In this context Klir refers to Hugh Miser's and Edward Quade's comprehensive *Handbook of Systems Analysis,* the first volume of which appeared in 1985.[20]

The introduction of systems approaches in management sciences is at the core of SA and one of the cornerstones in the establishment of institutes such as IIASA, the International Institute for Applied Systems Analysis. (This development also constitutes the basis for the schools of systems thinking that have emerged during the last 10–20 years. More will be said about that in the next section.) The early use of OR in the British World War II effort was to a large extent targeted on solving management problems. In 1957, Churchman, Ackoff and Arnoff published an introduction to Operations Research for "executive-type problems," i. e., problems relating to the effectiveness of organizations consisting of several functional units where the efficiency of the total organization was critically dependent upon how conflicting interests of the constituent units were balanced. The authors mention "systems analysis" as the label for the "application of science to the design of mechanical and man-machine systems," saying that "this is often equated with O.R." But, they continue, their book is "oriented toward human organizations since this has been the emphasis in the practice of O.R. in business and industry" (Churchman *et al.*, 1957:7). It seems that, to Churchman *et al.*, "systems analysis" rather signified the investigations on which decisions about the construction and use of new machinery were based. This might have had something to do with the fact that at the time the term "systems analysis" had a military connotation. Actually, in the United States the term "systems analysis" had been adopted as early as 1947 as a label distinguishing the U.S. Air Force research on future weapons systems from OR, which had a more narrow scope at that time (Miser & Quade, 1985:20 f.).[21] Systems analysis incorporated a broad assessment of long-term economic factors and considered interactions between means and objectives. However, as was also noted in the preceding section, OR later has broadened its scope to include much the same perspectives. In their "handbook" Miser and Quade (1985:21) conclude:

20 The subsequent two volumes were published much later, volume 2 in 1988 and volume 3 only in 1995. The project of writing the handbook was initiated as early as 1974 by the Soviet member organization of the International Institute for Applied Systems Analysis (IIASA), and it was actively supported by the institute at least until 1982.

21 See, e.g., Quade & Boucher (1968) for the use of SA in the U.S. defense sector.

In fact, systems analysis as it is characterized in this handbook, and operations research, as some define it broadly today, can be essentially the same. Cost-benefit analysis, systems engineering, and prescriptive modeling are also forms that systems analysis can take, but, as ordinarily practiced, they are more limited in scope. All these activities follow the same general approach to problem solving. Like systems analysis, they make use of many of the same disciplines, particularly economics, statistics, and probability theory; draw upon the same stockpile of tools (linear programming, queuing theory, and the computer, to name a few); and, when the need arises, employ procedures such as predictive modeling, sensitivity testing, optimization, and decision analysis. Hence where we speak of systems analysis in the following chapters, others might use a different name; in the United States it could be policy analysis, in the United Kingdom perhaps operational research.

Interest in the management of organizations and governments was also early expressed by proponents of cybernetics like Stafford Beer. In his *Cybernetics and Management* (1959) and in numerous later publications Beer discusses the basic cybernetic concepts and argues for their application in the study and development of industrial organization.[22] The point of departure here is the cybernetic notion of *control* and the crucial role that *information* plays in the operation of a system. The focus is on the principal possibilities of understanding and influencing the functioning of a particular kind of system, an organization.

While cybernetics dealt with problems relating to the *existence* of ways to achieve changes, OR and SE might be said to focus on what is "technically" required to actually make changes happen, on *how* to "produce" changes. Systems analysis, finally, widens the scope to study not only how changes could be achieved but also *why* changes are desirable. It investigates the rationale for trying to change a system from one state to another. This of course also requires knowledge about how the system works and how it can be changed.

In the first ten years or so after World War II the interest in organizational problems was combined with new developments of the scientific "toolbox" and an influx of new people into the post-war OR movement (Majone, 1985). New methods of analysis were elaborated, such as mathematical programming, whereby, for instance, limited resources could be efficiently allocated between various resource-using activities. The new recruits to the OR "profession" (often economists mastering the new analytical tools) gradually effected a shift in the focus of analysis. Majone (1985:43–44) claims that this reflected the

... traditional opposition between the economic viewpoint, which is concerned with finding the best allocation of given resources among competing ends, and the technical viewpoint, which is concerned with finding the best way of using given resources to achieve a single end. However, in a deeper sense what is at issue is the appropriate conceptualization of the system under investigation. The economist's recommendation for avoiding the pitfalls of suboptimization is the "golden rule" of allocative efficiency: scarce resources having alternative uses should be allocated so as to make each resource equally scarce (i. e., equally valuable at the margin) in all uses. But allocative efficiency can be achieved only if

22 A comprehensive overview of Stafford Beer's writings can be found in the article "Ten pints of Beer; The rationale of Stafford Beer's cybernetic books (1959–94)" in *Kybernetes*, Vol. 29, No. 5/6, 2000, pp. 558–572.

resources can be freely combined and substituted for each other according to their relative prices or scarcities [...]. In this logic, the internal organization of the system is irrelevant, if not positively misleading, since it tempts the analyst to make the scope of the analysis coincide with the boundaries of administrative units and decisionmaking authority.

Thus it is only a slight overstatement to say that the difference between the traditional operations researcher and the economist turned systems analyst is that the traditional operations researcher first establishes what the system to be studied is, and then inquires about the problems of that system, whereas the systems analyst first determines what the real problem is and only then inquires about the appropriate system or systems within which this problem must be considered if it is to be solved fruitfully. ... [I]n the period we are considering now (from the early 1950's to mid–1960s) the success of the economic paradigm in transforming early-vintage operations research into a more ambitious and intellectually, if not technically, more sophisticated systems analysis is almost complete.

However, in his chapter in the Miser and Quade "handbook," Majone (1985:51) also cautions that the evolution from "operations research" to "systems analysis" to "policy analysis," which is commonly perceived in English-speaking countries, may by no means be universally accepted or used. "In many countries a single label like 'operations research' applies to all three stages or forms of analysis that have been distinguished here. In such a case, 'operations research' assumes exactly the same meaning as 'systems analysis,' as the term is used in this handbook."

While people like C. West Churchman, Russel L. Ackoff and Stafford Beer introduced cybernetics (or systems approaches in general) to management sciences in the late 1950's – early 1960's, others, like Talcott Parsons, David Easton, and Gabriel Almond, introduced systems methods to political sciences. It is this eclectic methodological development that has eventually been brought together under the label of "systems analysis." This development gradually made an impact on academia in Sweden, where systems approaches started to be taught (or at least introduced) to students of business administration and political science towards the end of the 1960's and into the 1970's (cf., for example, Norrbom, 1973).

There seem to be no (or few) professional organizations or societies specifically devoted to the development and promotion of "systems analysis." Why this is so is of course difficult to know. It may be noted, however, that there are a number of societies and organizations devoted to the promotion of other "branches" of systems thinking, like GST, OR and SE, and since these schools of systems thinking seem to increasingly broaden their scope of interest "systems analysts" might well seek membership in the GST, OR or SE societies.

Looking for journals on "systems analysis" one finds that there is a plethora of journals devoted to the study of various aspects of systems, journals having the word "system" in their titles. Normally, however, "system" is accompanied by a qualifier indicating (in principle) the more specific topic of the journal (cf., for instance, journals like *System – An International Journal of Educational Technology and Applied Linguistics*, *Journal of Management Information Systems*, *Health Systems Review*, *Economic Systems*, *Decision Support Systems*, *Agricultural Systems*, etc.). Some journals seem to be more general in scope than others.[23] Many of these SA journals have large editorial boards and it seems, as Majone (1985) has suggested, that these boards in a way have taken the place of professional societies.

While there are quite a number of universities offering programs in "systems studies," "systems science," and "systems research," there are no (or few) programs explicitly focusing on "systems analysis." The situation seems to be similar when it comes to research institutes and centers. But here it is obvious that even if the names of the organizations themselves do not always contain "systems analysis" there are today many institutes in the world that use a systems approach in their research. The names of these institutes and centers do not always reveal this fact. Often enough, however, their names directly or indirectly contain reference to the "systems field." Thus, there is a large number of research institutes or centers around the world focusing on "operations research," "systems science," "systems studies," "system dynamics," "complex systems," etc.[24]

In his review of the genesis of systems analysis Majone (1985) found that the typical organization dealing with "fundamental, independent, multidisciplinary policy research" was nongovernmental and nonprofit. It would seem that universities should be well suited for such a task, but, due to their often rigid disciplinary structure and the incentive system favoring publication in specialized journals, universities cannot be said to provide a good environment for policy-relevant research. Since policy research often requires a long time horizon this type of research is not suitable either for private consulting firms that must show results within a relatively short period of time.

One of the earliest and probably most well-known systems analysis research institutes is the Rand Corporation, established as early as 1948 in Santa Monica, California.[25] While Rand researchers early on would probably have labeled themselves "operations researchers," today the research performed at the institute might be broadly characterized as "systems analytical." While still active in research of relevance for the military, Rand today conducts research on many topics from psychology to international affairs in various affiliated research centers around the world.

For obvious reasons it is not possible here to dig very deeply into the many existing research institutes and their work. We can, however, once again briefly look at the International Institute for Applied Systems Analysis (IIASA).[26] IIASA is an international research institute with (by the beginning of 2003) eighteen member countries from both the "East" and the "West." The Rand Corporation clearly provided the model when IIASA was established in Laxenburg outside Vienna in 1972.[27] The institute was set up

23 Two journals that were of central interest for writing this chapter, for instance, were *Systems Research and Behavioral Science* (http://www.interscience.wiley.com/jpages/1092-7026/) and *Systemic Practice and Action Research*. (http://www.kluweronline.com/issn/1094-429X).

24 Links to a large number of systems societies, journals, academic programs, and research institutes or centers can be found on the *Principia Cybernetica* Project's website at URL: http://pespmc1.vub.ac.be/.

25 The Rand Corporation, its history and current mission is well documented on its Internet site at: http://www.rand.org/.

26 IIASA and its history was briefly introduced in Chapter 1 of the present volume. The structure and activities of the institute are presented in detail on its website at URL: http://www.iiasa.ac.at.

27 The RAND experience and its influence on the establishment of IIASA and the institute's early development has been reviewed in an article by IIASA's second director, Roger E. Levien (2000). The early history of the institute and two of its most successful projects are reviewed in Brooks and McDonald (2000).

as a formally nongovernmental, nonprofit, international organization, managed by a council composed of official representatives of the research communities in all member countries. Funding for the research conducted at the institute is provided by the member organizations (which typically are academies of sciences or other public research-funding organizations in the member countries) and to a lesser extent through grants generated by the institute itself from various research foundations. The institute was never very large in terms of employed scientists, but an extensive activity has always been developed, largely in collaboration with scientists and institutes around the globe engaging in network activities. Leaving further organizational details aside, let us instead just quickly glance at the type of research performed at IIASA over the years to illustrate what systems analysis has meant in this context.

Being largely a product of the 1960's and designed in the spirit of institutes like the Rand Corporation, IIASA started out by applying statistical and mathematical modeling, analyzing large amounts of data with the support of its (then) advanced mainframe computers to tackle problems related to the management of natural resources, the rapid population growth, the scarcity of food and the problems of agriculture, the provision of energy for further industrial growth, conflicts related to water management, etc. The track record of the institute is impressive, at least in terms of publications.[28] According to its charter the institute is supposed to "initiate and support collaborative and individual research in relation to problems of modern societies arising from scientific and technological development." Since the 1991 strategic plan for IIASA (*Agenda for the Third Decade*) the institute's strategic goal is said to be "to conduct scientific studies to provide timely and relevant information and options, addressing critical issues of global environmental, economic, and social change for the benefit of the public, the scientific community, national governments, and national and international institutions."[29] The importance of dissemination of the research results to policy makers was also emphasized in this connection.

Whether the results of the institute's research work have actually influenced decision makers in governments and the private sector and helped their efforts to remedy the problems studied is not quite as obvious. It seems that it is inherently difficult to conduct front-end research and simultaneously be able to impact policy making.

IIASA has always studied problems with wide and profound (often global) environmental and social impacts. While the research originally was largely "technical" in nature and very heavily data and model oriented (what is sometimes called "hard" systems analysis), one could in the course of the institute's practice discern a tendency, going back to the early 1980's but more pronounced during the last ten years or so, to

28 IIASA's main publications are books, Research Reports and Interim Reports (Working Papers). As of 1997 all Interim Reports can be downloaded from the Internet (http://www.iiasa.ac.at) free of charge. Browsing the IIASA Publications catalogue will display a large number of publications reporting on the research performed in the above-mentioned projects. Some of the early IIASA research topics were reviewed in Tomlinson & Kiss (1984) and in the Miser & Quade (1985) "handbook."

29 This formulation is from the IIASA (1999) strategic plan ("IIASA Enters the Twenty-First Century"). However, the wording was kept from the 1991 plan with only minor modifications.

broaden the scope of analysis accommodating "softer" aspects of the problems, an acknowledgement of the fact that workable solutions to complex social problems cannot be found unless people affected take part in elaborating their solution. This is not to say that the institute is now widely engaged in participatory policy making activities of various kinds. The development is rather reflected in a recognition that problems have to be tackled from different angles, not only from a purely technical side. This awareness makes IIASA researchers nowadays study a much more comprehensive set of issues relating to a problem situation than earlier. A seminar under the title "Rethinking the Process of Systems Analysis" organized at IIASA in August 1980 marked one stage in this development (cf. the seminar documentation in Tomlinson & Kiss, 1984). The continued development and its methodological consequences are reflected in the policy statements issued by the IIASA council, the first one in 1991 and the latest in 1999.

In Sweden, systems analysis was explicitly invoked in the late 1960's for the development of enterprise management (see, e. g., Langefors, 1968), and for the assessment of the situation in Swedish hospitals (Rhenman, 1969). Both applications belong to the domain of management SA or management cybernetics. Several examples of early Swedish experiences of systems approaches in research and public investigations are given in Molander (1981). A historical overview of the establishment and use of a systems approach in Swedish research until 1980 can be found in Kaijser and Tiberg (2000).[30]

Finally, what scientific and other claims are made by SA or systems analysts for their activity? Since there are no professional organizations or societies specifically working to promote SA (in the sense it has been given in this section) there are no commonly recognized "official" claims expressed. If we instead look at the position taken as early as the mid 1980's by Hugh Miser and Edward Quade, the editors of the earlier mentioned SA "handbook," the impression given is one of great ambitions for future applications of SA to help decision making, combined with a rather modest assessment of the results (both scientific and practical) obtained so far. They see SA primarily as a promising "craft" rather than as a scientific discipline or method (Miser & Quade, 1985:30):

> To date – although not without some criticism – systems analysis has found many applications, with results at least promising enough to generate a desire for more.
>
> Systems analysis, as we have argued, is not a method or technique, nor is it a fixed set of techniques; rather it is an approach, a way of looking at a problem and bringing scientific knowledge and thought to bear on it. That is, it is a way to investigate how to best aid a decision or policy maker faced with complex problems of choice under uncertainty, a practical philosophy for carrying out decision oriented multidisciplinary research, and a perspective on the proper use of the available tools.

Statements like these can be seen as a sign that practitioners in the SA field want to distance themselves from, and take a more realistic stance than, some of the earlier

30 In a small report called "Sverige och IIASA" (Sweden and IIASA) published by the Swedish IIASA member organization (FRN) in 1981, a number of Swedish researchers who were at the time (or had recently been) employed by IIASA gave an account of their work and their experiences of the institute. The articles were based on presentations at a small conference in Stockholm on 10–11 December 1980 marking the five year anniversary of the Swedish IIASA membership (cf. FRN 1981).

proponents of "general systems theory" who made rather grand claims for the systems approach in science.

Let us now turn to an overview of the widening of the scope of SA that has mainly happened during the last ten years or so.

5 From Soft Systems Methodology to Critical Systems Thinking

In this section will be traced the line of development that systems approaches in science has followed during the last 10–20 years. As noted earlier, what is described is not a strictly chronological development, it is rather a kind of "genealogical" evolution. A brief account will be offered of the movement, from traditional Operations Research via Systems Analysis to the "soft systems methodology," the best-known proponent of which is Peter Checkland, and further to "critical systems thinking" developed mainly during the last ten years or so by people like Werner Ulrich, Robert Flood and Michael Jackson.

In a recent article Peter Checkland (2000) traces the ideas that have come to be known as "Soft Systems Methodology" (SSM) back to the end of the 1960's. The author is of course aware that the representation of the methodology made in a thirty-year retrospect is different from what it might have been if done at some earlier stage. In fact, SSM has continuously developed over the years, explicitly starting off as a refinement of systems engineering, from the time when Checkland was first employed at Lancaster University in 1969, through a long study series of managerial practice, ending up in modern conceptions of action research in the late 1990's. The first publications from this study program appeared in an article by Checkland in 1972, but it was not until 1983 that the crucial "innovation" of SSM was explicitly stated (Checkland, 2000). This innovation lies in the perception of the system and it is precisely this specific perception that differentiates "soft" from "hard" systems science, or, in Checkland's own words (2000:S17):

> In the thinking embodied in SSM the taken-as-given assumptions are quite different. The world is taken to be very complex, problematical, mysterious. However, our coping with it, the process of inquiry into it, it is assumed, can itself be organized as a learning system. Thus the use of the word 'system' is no longer applied to the world, it is instead applied to the process of our dealing with the world. It is this shift of systemicity (or 'systemness') from the world to the process of inquiry into the world which is the crucial intellectual distinction between the two fundamental forms of systems thinking, 'hard' and 'soft'.

This fundamental shift in the perception of systems was clearly stated only *after* the publication of Checkland's famous first comprehensive book on SSM (*Systems Thinking, Systems Practice*, 1981).[31]

31 Checkland has subsequently elaborated his SSM further, first in *Soft Systems Methodology in Action* co-authored with Jim Scholes and published in 1990, then in *Information, Systems and Information Systems* written together with Susan Holwell (Checkland & Holwell, 1998). Recently, Checkland has published new and revised "30-year retrospects" of his *Systems Thinking, Systems Practice* (see Checkland, 1998) and *Soft Systems Methodology* (see Checkland & Scholes, 1999). Susan Holwell wrote her PhD dissertation on *Soft Sys-*

While Checkland should be acknowledged as the "father" of the SSM school it should be noted that the divergence between the "theory" of OR as taught in academic institutions and the practice of OR as performed in enterprises had grown during the 1960's. As pointed out by Checkland himself (see, e. g., his article from 1983), this had been noted and demonstrated at an early stage by many writers, not least by the "founding fathers" of OR themselves, C. West Churchman and Russel L. Ackoff.

Apart from the notion of the "learning system" the most characteristic feature of SSM is perhaps that it is deals with what are called "human activity systems" and that it is basically driven by practice.[32] As Jackson (2000) has put it:

> It is possible to see three intellectual breakthroughs as crucial to the emergence of SSM. The first was the delineation of the notion of 'human activity system' for exploring human affairs. Previous systems thinkers had sought to model physical systems, designed systems and even social systems, but they had not treated purposeful human activity systemically. A human activity system is a systems model of the activities people need to undertake in order to pursue a particular purpose. Second, it was realized that the models employed in SSM could not be attempts to model the real world, rather they needed to be epistemological devices used to find out about the real world. [...] Third, while the models produced in hard systems thinking are blueprints for design, human activity system models are contributions to a debate about possible change. They explicitly set out what activities are necessary to achieve a purpose meaningful from a particular point of view. On the basis of such models participants in the problem situation, aided by a facilitator if necessary, are able to learn their way to what changes are systemically desirable and culturally feasible given the meanings and relationships that currently pertain in the situation. Thus SSM is a learning system.
>
> These three breakthroughs allowed Checkland to propose a fully developed soft systems methodology premised on a fundamental shift of 'systemicity from the world to the process of enquiry into the world' (Checkland, 1989).

As pointed out both by Checkland himself and by other commentators, SSM developed over many years, and in retrospect one can discern three main development stages, the first of which ended with the publication of *Systems Thinking, Systems Practice* (1981), which is still the most well-known and widely used book presenting the "seven-stage" SSM mode of analysis (cf. Figure 2.3[33]).

In the next major publication, *Soft Systems Methodology in Action* (with Jim Scholes, 1990), the "seven-stage" representation of SSM was replaced by a "two-streams" model, a "cultural" and a "logic-based" stream of analysis (cf. Figure 2.4). Here the distinction is also made between SSM in *Mode 1* and *Mode 2* – the former designating an SSM used for prescriptive purposes, for explicitly methodology driven interventions, and Mode 2 focusing on situation driven interactions to help understand what is going on without explicitly invoking SSM. "In Mode 1, SSM is external and dominates proceedings. In

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tems Methodology and Its Role in Information Systems (1997). According to Checkland (2000:S38) Holwell's study is "the most cogent exegesis of SSM carried out so far."

32 Checkland (1985) vigorously argues for a "rational intervention in human affairs" as an important ingredient in what he perceives as useful and needed for the 1990's.

33 The figures also illustrate the author's "informal" style of presentation.

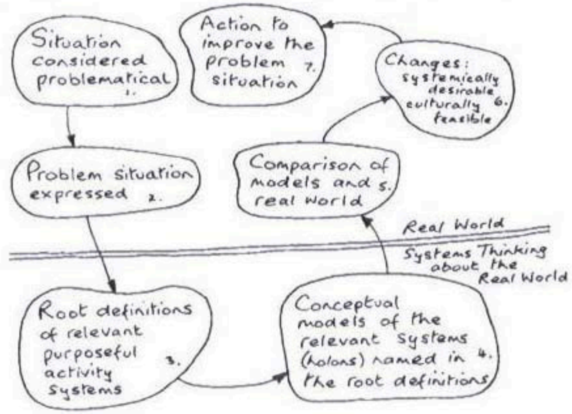

Figure 2.3: Checkland's illustration of SSM from 1981 (Jackson, 2000b:S6).

Mode 2 it is internalized and only occasionally breaks the surface of ongoing events" (Jackson, 2000:S8). Another useful feature of the 1990 book – and the same is true of Checkland's subsequent book (with Sue Holwell) from 1998 on SSM and information systems – is that the authors present a number of case studies where SSM has been put to practical use.

Even the picture of SSM in action found in Figure 2.4 was felt to "carry a more formal air than mature practice was now suggesting characterized SSM use, at least by those who had internalized it." (Checkland, 2000:S21). The 1990 book, therefore, also contained the authors' "four-activities model," in which the cultural stream is subsumed in all activities. The current representation of the still valid "four-activities model" from 1990 is shown in Figure 2.5.

SSM was early on "defined" through a set of "constitutive rules." These were originally suggested as early as 1977 by John Naughton and used in his teaching of SSM at the Open University. These rules, which were deduced from the early "seven-stages model" of SSM, were subsequently endorsed by Checkland in his *Systems Thinking, Systems Practice* (1981). The rules were revised in the 1990 book where the "seven-stages model" was replaced by the "four-activities model." In her PhD dissertation, Susan Holwell (1997) critically reviews the SSM development. She finds the constitutive rules to be "silent on some basic assumptions which SSM always takes as given" (Checkland, 2000:S38). She therefore suggests that SSM be defined on three levels (Holwell, 1997 as cited in Checkland, 2000:S38):

> ... there are three necessary statements of principle or assumption:
> (a) you must accept and act according to the assumption that social reality is socially constructed, continuously;
> (b) you must use explicit intellectual devices consciously to explore, understand and act in the situation in question; and
> (c) you must include in the intellectual devices 'holons' in the form of systems models of purposeful activity built on the basis of declared worldviews.
>
> Then there are the necessary elements of process. The activity models ... are used

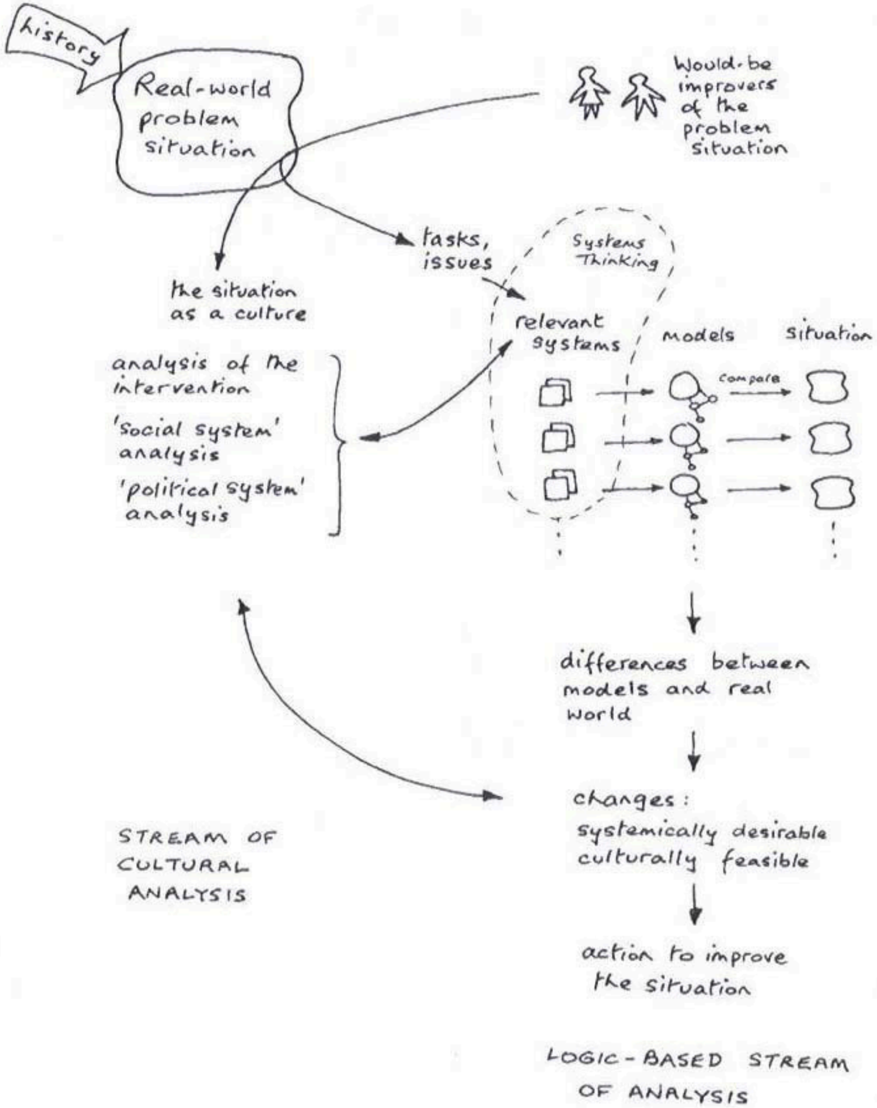

Figure 2.4: Checkland's illustration of SSM from 1990 (Jackson, 2000b:S7).

in a process informed by an understanding of the history of the situation, the cultural, social and political dimensions of it … (the process being) about learning a way, through discourse and debate, to accommodations in the light of which either 'action to improve' or 'sense making' is possible. Such a process is necessarily cyclical and iterative. Finally, while not limited to this pool … a selection from Rich Picture, Root Definition, CATWOE … etc. may be used in the process.

Peter Checkland's SSM has made a profound impact on modern systems based social science research. The Lancaster department where Checkland worked for many years has itself been engaged in numerous case studies using SSM and the methodology has

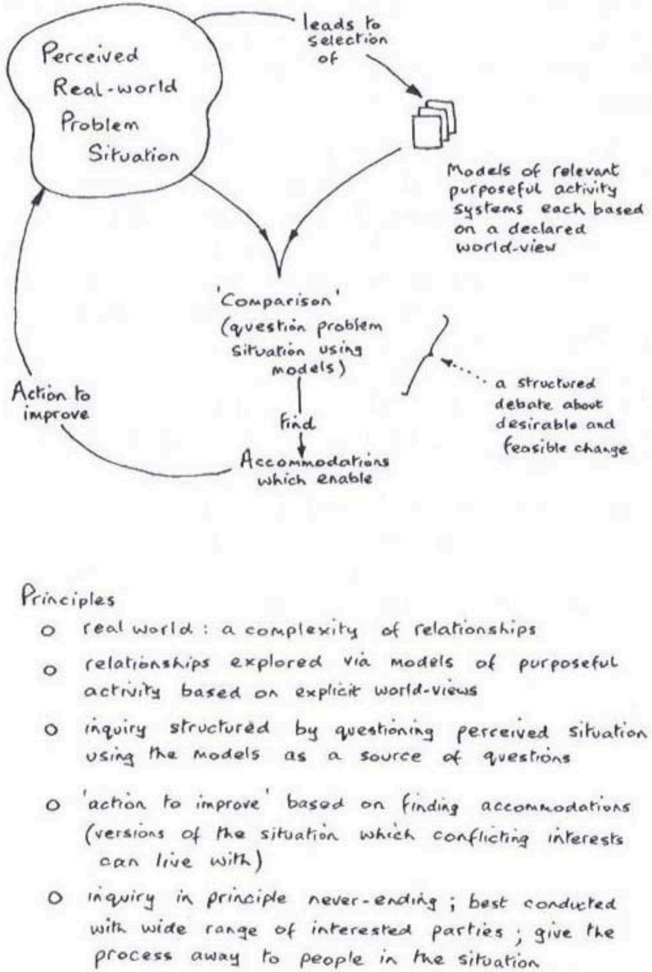

Figure 2.5: The current representation of the "four-activities model" originally introduced in the Soft Systems Methodology in Action. (Checkland, 2000:S16).

been extensively used in many parts of the world. The best way of learning more about SSM is perhaps by looking at the accounts of such case studies.[34]

In contrast to those made by some of his followers, the claims for SSM made by the "originator" himself are quite modest. In his main article in the special issue of the journal *Systems Science and Behavioral Research* (Vol. 17, Issue S1, 2000) Checkland cautions us thus (p. S45):

> We should be rigorous in thinking but circumspect in action. We should remember that many people painfully find their way unconsciously to world-views which enable them to be comfortable in their perceived world. Coming along with a process which challenges world-views and shifts previously taken-as-given assumptions, we should remember that this can hurt. So what right do we have to cause such pain? None at all unless we do it with respect and in the right spirit: no lofty hauteur. And we must remember, feet on ground, that all we can do with our 'natural' but intellectually sophisticated process of inquiry is learn our way to improved purposeful action, which is a ubiquitous part of human life but only a limited part of it, not the whole.

Critical Systems Thinking (CST) started to emerge in the 1980's and has since developed into a prominent and highly interesting school of systems thinking. The original conception of CST was suggested by Swiss practical philosopher Werner Ulrich in his 1983 book *Critical Heuristics of Social Planning; A New Approach to Practical Philosophy*[35] written during the late 1970's mainly while Ulrich worked with C. West Churchman at the Graduate School of Business Administration, University of California, Berkeley. However, the main work to establish CST as a new school of systems thinking has been performed by researchers affiliated with the Centre for Systems Studies at the University of Hull. Today, the most well-known proponents of CST, apart from Ulrich, are people like Robert L. Flood, Michael C. Jackson and Gerald Midgley. Flood and Jackson are probably the ones who have published most on CST. Some key contributions on the topic are Flood's book from 1990 (*Liberating Systems Theory*) and a series of books on "Contemporary Systems Thinking" published by Plenum Press (with Flood as series editor). A good overview of the development in systems approaches in science leading up to CST is given in *Critical System Thinking; Directed Readings* edited by Flood and Jackson and published in 1991. Here a number of "classical" papers from the earlier stages of the "systems movement" illustrate how OR and SE, via SSM (and related approaches), stimulated the conception of CST. These books were followed by numerous journal articles and books (cf., for example, Jackson, 1992, 2000; Flood & Romm, 1996; Midgley, 2000).

34 A number of such accounts are listed among Peter Checkland's published works, a compilation of which can be found in the special issue of *Systems Research and Behavioral Science* (Vol. 17, Issue S1, 2000, pp. S85–S89) celebrating his 70th birthday. Several case studies are discussed in Checkland & Scholes (1990), and in Checkland & Holwell (1998). Mingers (2000) lists a number of case studies using SSM with references to the papers where they were reported. Mingers & Taylor (1992) investigated the extent to which SSM has been used in practice and Ledington & Donaldson (1997) made a similar study among SSM users in Australia. An assessment of SSM as a "social science research tool" can be found in Rose (1997).

35 The book was originally published by Verlag Paul Haupt, Bern and Stuttgart. A paperback reprint was published by John Wiley & Sons in 1994.

Space does not allow of going into any detail regarding CST, but an attempt can at least be made to convey the distinguishing features of this new and advanced systems school. It is obvious that CST emerged as some kind of reaction to, and extension of, SSM and earlier "hard" systems schools.

To remind ourselves of the differences between the "hard" and "soft" systems tradition and at the same time see the basis on which CST launched its critique of earlier systems science, let us consider the following citation from Checkland (1985):

> The nature of the "hard" tradition can be summarized as follows: it seeks to make possible the efficient achievement of goals and objectives, taking goal-seeking to be an adequate model of human behaviour; it assumes that the world contains systems which can be "engineered," hence that models of those systems can be made; it talks the language of "problems" and "solutions" which eliminate problems.
>
> The "soft" tradition does not regard goal seeking as an adequate model for much of what goes on in human affairs; it does not assume that the rich complexity of the world can be captured in systemic models, and hence regards systems models produced within the "hard" tradition not as "models of X" but only as "models of the logic of X." Hence the "soft" tradition regards system models as models relevant to arguing about the world, not models of the world; this leads to "learning" replacing "optimizing" or "satisficing"; this tradition talks the language of "issues" and "accommodations" rather than "solutions." [...]
>
> Thus, using the example of SSM, we see that "soft" systems thinking is the general case of which "hard" systems thinking is the occasional special case, ...

The crucial criticism aimed at SSM concerned the role of value judgements in the analysis of practical situations. While SSM did have an interpretive approach focusing on the system as a way of looking upon the world and gaining knowledge to be used for purposeful intervention (this approach makes ample use of value judgements), it did not – in the eyes of the critics – sufficiently consider *whose* value judgments it incorporated. In situations characterized by an uneven (decision making or political) power distribution SSM tended to work smoothly in the service of those with dominating influence (in business interventions, for instance, SSM tended to favor the management rather than the workers or society at large). This was found to be the case, despite what the proponents of SSM and earlier systems approaches had stated to the contrary, as was early noted by some critics (cf., for example, Thomas & Martin, 1979, and Jackson, 1985).

At the bottom of this critique – and this is Werner Ulrich's perhaps most important contribution to CST and to the "systems movement" at large – lies the recognition of the importance of specifying (selecting) the boundary of a system, i.e., selecting what (agents and interaction) should be included in the system specification and what should be left out. Ulrich's early elaboration of a system "boundary critique" turned out to be of decisive importance for the further development of CST. Ulrich (1987:104[36]) emphasizes the importance of "justification break-offs" in any line of reasoning. "In other words, every chain of argumentation starts and ends with some judgements the

36 Page references are to the reprinted version of Ulrich's paper in Flood & Jackson (1991). The paper highlights some important points discussed at greater length in Ulrich (1983).

rational justification of which must remain an open question." His "critical heuristics" purports to help "the applied scientist" to be transparent to himself and others as to the "justification break-offs flowing into his designs" (*ibid.*, p. 105). Applied to systems science Ulrich's notion of "justification break-off" is relevant to making "boundary judgments" which ought to be crucial in any study using a systems approach. However, still in the mid 1980's, as Ulrich (1987) claims, the problem of boundary judgments was largely ignored in the systems literature. Arguing that system boundaries should not depend on modeling requirements such as the availability of data or modeling techniques (as typically happens), Ulrich maintains that the studied system should in fact not only consider (include) questions of what "is" (or "will be") but also of what "ought" to be. Ulrich (1987:108) then provides a "checklist" of twelve questions (all asking what function something "ought to" have in the system), the answers to which should "inevitably flow as normative premises into any concrete systems design."

The next issue that Ulrich takes up concerns by whom (and how) the concepts that he has introduced (through the list of "ought to" questions) should be debated and decided. He first dismisses the role of the "expert," who should not be allowed to exert any decisive influence simply on account of being an "expert," since "no amount of expertise or theoretical knowledge is ever sufficient for the expert to justify all the judgments on which his recommendations depend" (Ulrich, 1987:111). The answer that Ulrich provides to the question how ordinary citizens should be able to participate in settling the boundary problem invokes Kant's "polemical employment of reason" (pp. 112–113):

> How can ordinary citizens without any special expertise or "communicative competence" (as required by the ideal models of rational discourse) accomplish this apparent squaring of the circle? My answer is: by means of *the polemical employment of boundary judgments*. [...]
>
> Thus the polemical employment of boundary judgments enables ordinary people to expose the dogmatic character of the expert's "objective necessities" *through their own subjective arguments*, without even having to pretend to be objective or to be able to establish a true counterposition against the expert. Therein, I believe, lies the enormous significance of Kant's concept of the polemical employment of reason for a critically-heuristic approach to planning, an approach that would actually mediate between the conflicting demands of democratic participation (of all affected citizens) and those of rational, cogent argumentation (on the part of the involved planners and experts).

Discussing the necessity of stakeholders' participative engagement in establishing "criteria of validation," Jackson (1985) draws upon Habermas' theory of "communicative competence." Both Ulrich's and Jackson's discussion of how the boundary problem could be democratically settled illustrates the *emancipatory ambitions* of CST. The objective of CST is to effect improvement in problem situations through *systemic intervention* performed by stakeholders, including groups that are not normally able to influence the situation but are dependent upon or affected by the changes. On the basis of the fundamental principles laid down by Ulrich (briefly outlined above) a number of authors have later developed CST further, emphasizing for instance the importance of adopting an eclectic attitude to methodology manifesting itself in CST's declared support of *theoretical and methodological pluralism* (Jackson & Kays, 1984; Flood & Ulrich, 1990; Schecter, 1991; Jackson, 1999).[37]

In their 1991 book *Creative Problem Solving: Total Systems Intervention* Michael Jackson and Robert Flood outlined a meta-methodology to serve as a guide for practical systems interventions and for matching systems methodologies to problem situations. The methodology, commonly known by its acronym TSI, may be seen as an operationalization of CST (Jackson, 2000).[38] TSI suggests a three-phase structure of an intervention for the purpose of improving the efficiency and effectiveness of organizations. These phases are labeled *creativity, choice,* and *implementation.* The TSI literature discusses how in the creativity phase stakeholders are engaged under the "guidance" of a facilitator in identifying a set of crucial issues and concerns of importance for the improvement of the organization and how, in the subsequent choice phase, they select appropriate systems-based methodologies (in a pluralist approach) to suit the characteristics of the problem situation identified in the creativity phase. (Here Jackson and Keys' (1984) "system of system methodologies" is used to match methodologies to problem situations.) In the last phase – implementation – the chosen systems methodologies are used to select and implement specific measures intended to improve the problem situation. TSI and its use during the 1990's in practical systems interventions (mainly) by people affiliated with the Centre for Systems Studies (CSS) at Hull University aroused a lot of interest in the systems community. Work is going on to further develop CST (and TSI) at CSS and elsewhere. Results of this work are continuously being published. A major recent publication is Jackson (2000), in which the whole systems development is laid out and CST is given a critical review a decade after the original launching of the school. Midgley (2000) has published another major and highly praised book, in which the philosophy, methodology and practice of systems intervention are comprehensively discussed.

The proponents of CST have explicitly made rather advanced claims for the new school of thinking, as illustrated by the following citation from the introduction to the "directed readings" published by Flood and Jackson (1991:1–2) with the aim of "launching" CST as the new "dominant paradigm":

> Critical systems thinking is an important and substantial development in the management and systems sciences. It shares the soft systems thinkers' critique of the hard approaches, but is able to reflect more fully upon the circumstances in which such approaches can properly be employed. It recognises the unique contribution of organisational cybernetics, in terms of both its strengths in organisation design but limitations in handling cultural and political phenomena, and is able to incorporate cybernetics back into a reformulated conception of the nature of systems work (which soft systems thinking singularly failed to do). Fundamentally, critical systems thinking locates major short-

37 Without explicit reference to CST John Mingers (cf. Mingers & Brocklesby, 1997; Mingers, 2000) strongly argues for the use of what he calls a "multimethodology." He maintains (1997) that "it is desirable to go beyond using a single [...] methodology to generally combining several methodologies, in whole or in part, and possibly from different paradigms."

38 TSI was summarized and further discussed in Flood & Jackson (1991a), and Jackson (1991: Chapt. 11). Further discussion of TSI and examples of interventions can be found in Flood & Romm, 1996.

> comings in the soft systems paradigm, particularly its failure to question its own theoretical underpinnings and to be reflective about the social context in which it is employed. In seeking to establish itself as the new dominant paradigm, therefore, critical systems thinking demonstrates that earlier systems approaches are all special cases with limited domains of application. The valid and successful use of the earlier approaches for systems intervention depends upon the broader understanding of them provided by critical systems theory.

That claims for the CST school remain advanced is clearly demonstrated in Jackson (2000).

As was the case for SA and SSM, there seem to be no specialized professional associations working for the promotion of CST. This probably has to do with the fact that CST is built upon the whole earlier systems tradition and wants to be seen (and is obviously accepted) as making important further contributions to all of systems science.[39] Consequently, many proponents of the CST school have been well received in established systems organizations like IFSR (International Federation for Systems Research[40]). Michael Jackson is the former president of IFSR as well as editor-in-chief of the Federation's journal *Systems Research and Behavioral Science* published by John Wiley & Sons.[41] As of July 2001 Michael Jackson is also President-elect of the most "prestigious" systems association, the International Society for the Systems Sciences (ISSS), formed in 1954 (cf. above). Robert Flood is the editor of *Systemic Practice and Action Research* (before 1998 called *Systems Practice*), a journal devoted to the promotion of CST published by Kluwer Academic/Plenum Publishers.[42] The foremost academic "home" of CST is, as already noted, CSS, the Centre for Systems Studies of the University of Hull Business School.[43] Michael Jackson is Director of the Business School, and its Centre for Systems Studies is headed by Gerald Midgley, with people like Norma Romm, Paul Keys, and Peter Murray on its staff. Earlier both Robert Flood and Werner Ulrich have been affiliated with the center.

39 This is also exemplified by the fact that prominent advocates of CST (e.g., Gerald Midgley) have a long record of practical work in the sphere of "community OR."

40 Members of IFSR are systems societies and organizations from various countries around the world.

41 Robert Flood is associate editor and Werner Ulrich is a member of the journal's editorial board.

42 Michael Jackson is Associate Editor, and on the "international advisory board" we find names like Raul Espejo, Ramsès Fuenmayor, Gerald Midgley, Norma R. A. Romm, and Werner Ulrich, all prominent in the CST school.

43 Information about CSS can be obtained from the centre's website at: http://www.hull.ac.uk/hubs/research/groups/css/index.htm.

6 Concluding Remarks

> The conclusion is that the social (and indeed natural) world is inherently unknowable, at least to the human mind. The message that follows is that the human race would do well to wake up to this conclusion and respond to it, before current ways irredeemably damage our planet and our deeper relationship with this world in which we find ourselves.
>
> *Robert L. Flood (1999)*

In this chapter an attempt has been made to pin down the main lines of development of the systems approach in science. As should be apparent from this overview, the development has been multi-faceted and never-resting, as might be expected in the case of a comparatively new scientific approach. Since World War II a large number of systems schools have emerged, many of them growing into prominent scientific disciplines. In the limited space available here it has merely been possible to briefly outline the main traits of the schools that I believe have made the most profound contribution to the systems approach in science.

In so doing I have, furthermore, been especially looking for developments demonstrating the possibilities and usefulness of a systems approach in social science, in research aimed at improving problem situations and for developing better public policies. The perspective striven for has been informed by van Gigch's reminder of the importance of reflecting on all of the three levels of inquiry that are part of a comprehensive systems approach, the meta (or epistemological) level, the object (science or modeling) level and the level of practice or intervention (cf. Figure 1.1 in Chapter 1 above).

The overview laid out in this chapter – while seeking to discern a kind of "genealogical" development of the systems approach in science – ends up in tracing the development of the systems approach in action oriented research, in systems oriented efforts to intervene in order to improve problem situations. The trace followed can be seen as a movement from left to right in Figure 2.1 above. Basically, it has meant a shift of attention from "hard" systems sciences to "soft" approaches, where "the system" is no longer seen as a feature of the real world but as a feature of the mind – a theoretical construct – with the help of which the "systems analyst" seeks to gain useful knowledge about a problem situation.

The picture of the development of systems approaches in science painted here might of course be contested. With the main focus of attention on, for instance, more strictly physical or biological scientific problems the story might have come out differently. However, it seems clear that the development indicated in this chapter is (also) real and the important thing about it is that it has meant a revitalization of "applied systems approaches," systems approaches in social science contexts, dealing with decision and policy making in the public as well as in the private sphere. The basis for this important development is a significant change in the epistemological underpinning of the systems approach in science, increasingly favoring a *radical constructivism* promoted by people like Ernst von Glasersfeld (1990; 1995).

The development of systems approaches in science has of course not only been affected by the evolution of epistemology. There has also been significant progress in the systems scientific "toolbox," i. e., in the methods and techniques (mainly computer-based) that have become available to the systems analyst. This technological progress has undoubtedly affected the development and use of systems approaches in science. Some of the chapters in Part II of this book bear witness of this very interesting and challenging development.

Finally, what does the outlined development of systems approaches in science signify? What does this development mean for science and for our life on earth? A cautious, but reasonable, answer to this question today – remembering that history will probably change any such answer – might be based on an acknowledgment of the fact that our social and natural world is "inherently unknowable" (Flood, 1999), that there is no way for us to obtain complete and certain knowledge about the parts and wholes that constitute our world. Systems approaches in science might then be valuable in helping us to become aware of what we do know (with some limited certainty) and what we don't (yet) know. That is – in a sort of "minimalist" perspective – the systems approach in science might be able to help science if not to do good, to improve our situation (which it might of course also be able to do), at least *to avoid doing bad*. This seems important in a world where "development," be it technological or economic or indeed of any sort, often is "blindly" promoted, without much considering if progress, or what seems like progress, in one area means progress in general, or if it perhaps (which often seems to be the case) on balance really means "regress" when negative consequences in another area are taken into account.

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Appendix 1: The Series of Abisko Workshops on Mathematical Modelling and Complexity

In the period since 1983 the Swedish Council for Planning and Coordination of Research (FRN), which was also (until December 2000) the Swedish member organization of the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, has organized a series of workshops on mathematical modelling and complexity. As of January 2001, the Swedish IIASA membership was taken over by a newly established research council called The Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning (Formas). The location of these workshops has always been the Research Station in Abisko belonging to the Royal Swedish Academy of Sciences. Abisko is a small village in the northernmost part of Sweden close to the Norwegian border. The place is famous for its spectacular scenery and the midnight sun which is almost visible on clear nights in May.

List of Themes and Publications from the Abisko Workshops

1983: Dynamical Systems Theory Karlqvist, Anders, ed. (1984). *Dynamiska system; Rapport från ett seminarium i Abisko, maj 1983*, (Dynamical Systems; Report from a Seminar in Abisko, May 1983). Umeå: Cerum, Umeå University. (Report based on previously published material with an introduction (in Swedish) by Prof. Anders Karlqvist.)

1984: Structure and Evolution of Systems: Mathematical Approaches Casti, John L and Anders Karlqvist, eds. (1986). *Complexity, Language and Life: Mathematical Approaches*, Vol. 16 of the Springer series on Biomathematics. Berlin, Heidelberg, New York, Tokyo: Springer-Verlag.

1986: Brain Research, Artificial Intelligence, and Cognitive Science: at the Systems Interface Casti, John L. and Anders Karlqvist, eds. (1987). *Real Brains – Artificial Minds*, New York, Amsterdam, London: North Holland.

1987: Processes, Function, and Form Casti, John L. and Anders Karlqvist, eds (1989). *Newton to Aristotle; Toward a Theory of Models for Living Systems*. Boston, Basel, Berlin: Birkhäuser.

1988: Managing Complexity, the Issue of a Sustainable Societal Use of the Natural Environment No publication.

1989: Prediction and Explanation Casti, John L. and Anders Karlqvist, eds. (1991). *Beyond Belief: Randomness, Prediction and Explanation in Science*. Boca Raton, Florida: CRC Press.

1990: The Machine as Metaphor and Tool Haken, Hermann, Anders Karlqvist and Uno Svedin, eds. (1993). *The Machine as Metaphor and Tool*. Berlin, Heidelberg, New York, Tokyo: Springer Verlag.

1991: Global Environment-Development Policy – Pragmatism and Effective Policymaking A report based on the presentations at the workshop was prepared by IIASA, the International Institute for Applied Systems Analysis, Laxenburg, Austria. This report (together with others from IIASA) was presented to the UN Conference of the Environment and Development (UNCED).

1992: Cooperation and Competition in Evolutionary Processes Casti, John L. and Anders Karlqvist, eds (1994). *Cooperation and Conflict in General Evolutionary Processes*. New York: John Wiley & Sons.

1993: Matter Matters: on the Material Basis of the Cognitive Ability of the Brain Århem, Peter, Hans Liljenström and Uno Svedin, eds. (1997). *Matter Matters?: on the Material Basis of the Cognitive Activity of Mind*. Berlin: Springer-Verlag.

1994: Language and Reality No publication.

1995: Limits to Scientific Knowledge Casti, John L. and Anders Karlqvist, eds. (1996). *Boundaries and Barriers: on the Limits to Scientific Knowledge*. Reading, Mass.: Addison-Wesley.

1996: Technological Systems Change and Economic Theory Odhnoff, Jan and Uno Svedin, eds. (1998). *Technological Systemic Changes and Economic Theories*, Report 98:5. Stockholm: Swedish Council for Planning and Coordination of Research (FRN).

1997: Stories of Science and the Science of Stories Casti, John L. and Anders Karlqvist, eds. (1999). *Mission to Abisko: Stories and Myths in the Creation of Scientific 'Truth'*. Reading, Mass.: Perseus.

1998 (1st workshop): Sustainability Paths – Are They Possible? No publication.

1998 (2nd workshop): Art and Complexity Casti, John L. and Anders Karlqvist, eds. (2003). *Art and Complexity*. Amsterdam: North-Holland.

1999 (1st workshop): Knowing and Believing No publication.

1999 (2nd workshop): Emerging Importance of the Meso-scale in Addressing Issues of Systems Complexity A joint publication from the workshops in 1999 and 2000 is forthcoming in 2003. Cf. below!

In 1999, Prof. Anders Karlqvist published a popularly held overview (in Swedish) of the series of Abisko workshops until 1998: Karlqvist, Anders (1999). *På tvärs i vetenskapen; Kommentarer från seminarier i Abisko kring matematik, fysik och andra forskningsområden* (Traversing Science; Comments from the Abisko Seminars on Mathematics, Physics and Other Research Disciplines). Stockholm/Stehag: Brutus Östlings Bokförlag Symposion.

2000: Systems Shocks – Systems Resilience Liljenström, Hans and Uno Svedin, eds. (2002). *Micro-Meso-Macro: Addressing Complex System Couplings.* Singapore:World Scientific Publishing Co., Inc. (forthcoming). (This is a joint publication from the workshops in 1999 and 2000.)

2001: Emergence, Transformation, and Decay in Socio-Natural Systems Publication pending.

2003: Science as Art

References

Ackoff, R. L. & Emery, F. E. (1972). *On Purposeful Systems.* London: Tavistock Publications.

Almond, G. A. & Powell, G. B. Jr. (1966). *Comparative Politics; A Developmental Approach.* Boston: Little, Brown and Company.

Ashby, W. R. (1956). *An Introduction to Cybernetics.* London: Methuen.

Ashby, W. R. (1958). Requisite Variety and Its Implications for the Control of Complex Systems, *Cybernetica, 1* (83). (The article is reprinted in Klir, 2001.)

Banathy, B. H. (2001). *The Evolution of Systems Inquiry,* Part 1 & Part 2. Retrieved on October 26, 2001, from http.//www. isss.org/primer/003evsys.htm and http.//www.isss.org/primer/004evsys.htm.

Beer, S. (1959). *Cybernetics and Management.* London: The English Universities Press LTD.

Beer, S. (1966). *Decision and Control; The Meaning of Operational Research and Management Cybernetics.* London, New York, Sydney: John Wiley & Sons.

Brill, J. H. (1998). Systems Engineering – A Retrospective View. *Systems Engineering, 1* (4), 258–266.

Brooks, H. & McDonald, A. (2000). The International Institute for Applied Systems Analysis, the TAP Project and the RAINS model. In A. C. Hughes & T. P. Hughes (Eds.), *Systems, Experts, and Computers; The Systems Approach in Management and Engineering, World War II and After* (pp. 413–431). Cambridge, Mass. and London: The MIT Press.

Checkland, P. (1981). *Systems Thinking, Systems Practice.* Chichester: John Wiley & Sons.

Checkland, P. (1983). O. R. and the Systems Movement: Mappings and Conflicts. *Journal of the Operational Research Society, 34,* (8), 661–675.

Checkland, P. (1985). From Optimizing to Learning: A Development of Systems Thinking for the 1990's. *Journal of the Operational Research Society, 36.* (The article is reprinted in Flood & Jackson, 1991).

Checkland, P. (1998). *Systems Thinking, Systems Practice; Soft Systems Methodology: a 30-Year Retrospective.* Chichester: John Wiley & Sons.

Checkland, P. (2000). Soft Systems Methodology: A Thirty Year Retrospective. *Systems Research and Behavioral Science, 17* (S1), S11–S58 (Reprinted from Checkland & Scholes, 1999).

Checkland, P. & Scholes, J. (1990). *Soft Systems Methodology in Action.* Chichester: John Wiley & Sons.

Checkland, P. & Scholes, J. (1999). *Soft Systems Methodology: a 30-Year Retrospective.* Chichester: John Wiley & Sons.

Checkland, P. & Holwell, S. (1998). *Information, Systems and Information Systems.* Chichester: John Wiley & Sons.

Churchman, C. W., Ackoff, R. L., & Arnoff, E. L. (1957). *Introduction to Operations Research.* New York, London, Sydney: John Wiley & Sons.

Conrad, M. (1983). *Adaptability.* New York: Plenum Press.

Cummings, N. (1997). *About* OR. Retrieved on November 1, 2001, from http://www.orsoc.org.uk/about/topic/news/orclub.htm. (The article was first published in the British Operational Research Society's OR *Newsletter* in April 1997.)

Dijkum, C. van (1997). From Cybernetics to the Science of Complexity. *Kybernetes, 26* (6/7), 725–737.

Easton, D. (1953). *The Political System; An Inquiry into the State of Political Science.* New York: Alfred A. Knopf.

Easton, D. (1965a). *A Framework for Political Analysis.* New York: Prentice-Hall.

Easton, David (1965b). *A Systems Analysis of Political Life.* New York: John Wiley & Sons.

Eckstein, A. (1971). *Comparison of Economic Systems.* Berkeley: Univ. of California Press.

Elliot, J. E. (1985). *Comparative Economic Systems* (2nd ed.). Belmont, California: Wadsworth Publishing Company.

Eriksson, D. M. (1998). *Managing Problems of Postmodernity: Some Heuristics for Evaluation of Systems Approaches.* IIASA Interim Report (IR–98–060). Laxenburg, Austria: International Institute for Applied Systems Analysis (IIASA).

Flood, R. L. (1990). *Liberating Systems Theory.* New York and London: Plenum Press.

Flood, R. L. & Jackson, M. C. (Eds.) (1991). *Critical Systems Thinking; Directed Readings.* Chichester: John Wiley & Sons.

Flood, R. L. & Jackson, M. C. (1991). *Creative Problem Solving; Total Systems Intervention.* Chichester: John Wiley & Sons.

Flood, R. L. & Romm, N. R. A. (Eds.) (1996). *Critical Systems Thinking: Current Research and Practice.* New York and London: Plenum Press.

Flood, R. L. & Ulrich, W. (1990). Testament to Conversations on Critical Systems Thinking Between Two Systems Practitioners. *Systems Practice, 3* (Reprinted in Flood & Jackson, 1991).

Flood, R. L. (1999). Knowing of the Unknowable. *Systemic Practice and Action Research, 12* (3), 247–256.

Forrester, J. W (1973). *World dynamics* (2nd ed.). Cambridge, MA: Wright-Allen Press.

FRN (1981). *Sverige och IIASA; rapport från en konferens i Stockholm 10–11 december 1980* (Sweden and IIASA; report from a conference in Stockholm on 10–11 December 1980). Rapport nr 40-D, December. Stockholm: Forskningsrådsnämnden.

Gigch, J. P. van (1991). *System Design Modeling and Metamodeling.* New York and London: Plenum Press.

Glasersfeld, E. von (1990). An Exposition of Constructivism: Why Some Like it Radical. In R. B. Davis, C. A. Maher, & N. Noddings (Eds.), *Constructivist Views on the Teaching and Learning of Mathematics,* Journal for Research in Mathematics Education, Monograph Number 4. Reston, Virginia: National Council of Teachers of Mathematics (Reprinted in Klir, 2000, pp. 279–288).

Glasersfeld, E. von (1995). *Radical Constructivism: A Way of Knowing and Learning.* London, Washington, D. C.: The Falmer Press.
Goode, H. H. & R. E. Machol (1957). *System Engineering; An Introduction to the Design of Large-scale Systems.* New York, Toronto, London: McGraw-Hill Book Company, Inc.
Gottlieb, M. (1984). *A Theory of Economic Systems.* Orlando: Academic Press, Inc.
Hall, A. D. (1962). *A Methodology For Systems Engineering.* Princeton: D. Van Nostrand Company, Inc.
Holwell, S. E. (1997). *Soft Systems Methodology and It Role in Information Systems.* Ph. D. Dissertation, Lancaster University.
IIASA (1999). *IIASA Enters the Twenty-first Century; Long-term Plan Prepared by the IIASA Council.* IIASA, Laxenburg. Retrieved on November 1, 2002, from http://www.iiasa.ac.at/Admin/DI/docs/papers/ iiasa21.pdf.
Ingelstam, L. (2002). *System – Tankar över samhälle och teknik* (System – Thoughts on Society and Technology). Eskilstuna: Energimyndigheten.
Jackson, M. C. (1985). Social Systems Theory and Practice: The Need for a Critical Approach. *International Journal of General Systems, 10.* (Reprinted in Flood & Jackson (Eds.), 1991).
Jackson, M. C. (1992). *Systems Methodology for the Management Sciences.* New York: Plenum Press.
Jackson, M. C. (1999). Towards coherent pluralism in management science. *Journal of the Operational Research Society, 50*, 12–22.
Jackson, M. C. (2000). *Systems Approaches to Management.* New York: Kluwer Academic/Plenum.
Jackson, M. C. & Keys, P. (1984). Towards a System of Systems Methodologies. *Journal of the Operational Research Society, 35.* (Reprinted in Flood & Jackson, 1991).
Jackson, M. C. (2000b). Checkland, Peter Bernard (1930–). *Systems Research and Behavioral Science, 17* (S1), S3–S10.
Jönhill, J. I. (1997). *Samhället som system och dess ekologiska omvärld; En studie i Niklas Luhmanns sociologiska systemteori* (Society as System and Its Ecological Environment; A Study in the Sociological Systems Theory of Niklas Luhmann). Lund Dissertations in Sociology 17. Lund: Lund University, Dept. of Sociology.
Kaijser, A. & Tiberg, J. (2000). From Operations Research to Future Studies: The Establishment, Diffusion, and Transformation of the Systems Approach in Sweden, 1945–1980. In A. C. Hughes & T. P. Hughes (Eds), *Systems, Experts, and Computers; The Systems Approach in Management and Engineering, World War II and After* (pp. 385–412). Cambridge, Mass. and London: The MIT Press.
Karlqvist, A. (1999). *På tvärs i vetenskapen; Kommentarer från seminarier i Abisko kring matematik, fysik och andra forskningsområden.* Stockholm/Stehag: Brutus Östlings Bokförlag Symposion.
Klir, G. J. (2001). *Facets of Systems Science.* Second Edition. New York, Boston, Dordrecht, London, Moscow: Kluwer Academic/Plenum Publishers.
Langefors, B. (1968). *System för företagsstyrning* (Systems for Enterprise Management). Lund: Studentlitteratur.
Ledington, P. & Donaldson, J. (1997). Soft OR and management practice: a study of the adoption and use of Soft Systems Methodology. *Journal of the Operational Research Society, 48*, 229–240.
Levien, R. E. (2000). RAND, IIASA, and the Conduct of Systems Analysis. In A. C. Hughes & T. P. Hughes (Eds.), *Systems, Experts, and Computers; The Systems Approach in Management and Engineering, World War II and After* (pp. 433–461). Cambridge, Mass. and London: The MIT Press.

Mackey, W. F. & Bauknight, J. (2000). *Systems Engineering Applications Profiles,* Version 3.0, July, Commercial and Public Interest Working Group, INCOSE. Retrieved on November 1, 2001, from http://www.incose.org/seatc/seap3.pdf.
Maturana, H. R. & F. J. Varela (1980). *Autopoiesis and Cognition: The Realization of the Living.* Dordrecht, Boston, London: D. Reidel Publishing Company.
Meadows, D. H., Meadows, D. L. Randers, J., & Behrens III, W. W. (1972). *The Limits to Growth.* New York: Universe Books.
Midgley, G. (2000). *Systemic Intervention; Philosophy, Methodology, and Practice.* New York: Kluwer Academic/Plenum Publishers.
Midgley, G. (Ed.) (2003). *Systems Thinking. [Vol. 1]: General systems Theory, Cybernetics and Complexity; [Vol. 2]: Systems Theories and Modelling; [Vol. 3]: Second Order Cybernetics, Systemic Therapy and Soft Systems Thinking; [Vol. 4]: Critical Systems Thinking and Systemic Perspectives on Ethics, Power and Pluralism.* London, Thousand Oaks, New Dehli: SAGE Publications.
Miller, J. G. & Miller, J. L. (1992). Applications of Living Systems Theory. In R. L. Levine & H. E. Fitzgerald (Eds.), *Dynamic Psychological Systems, Vol. 2: Methods and Applications.* New York: Plenum Press. (Adaptation published on the Internet. Retrieved on November 1, 2001, from http://www.newciv.org/ISSS_Primer/asem05jm.html.)
Mingers, J. (2000). Variety is the spice of life: combining soft and hard OR/MS methods. *International Transactions in Operational Research, 7*, 673–691.
Mingers, J. & Brocklesby, J. (1997). Multimethodology: Towards a Framework for Mixing Methodologies. Omega, *International Journal of Management Science, 25* (5), 489–509.
Mingers, J. & Taylor, S. (1992). The Use of Soft Systems Methodology in Practice. *Journal of the Operational Research Society, 43* (4), 321–332.
Mirijamsdotter, A. (1998). *A Multi-Modal Systems Extension to Soft Systems Methodology.* Luleå: Department of Informatics and Systems Science, Luleå University of Technology (Doctoral Thesis). April.
Miser, H. J. & Quade, E. S. (Eds.) (1985). *Handbook of Systems Analysis [Vol. 1]: Overview of Uses, Procedures, Applications, and Practice.* Chichester, New York, Brisbane, Toronto, Singapore: John Wiley & Sons.
Miser, H. J. & Quade, E. S. (Eds.) (1988). *Handbook of Systems Analysis [Vol. 2]: Craft Issues and Procedural Choices.* Chichester, New York, Brisbane, Toronto, Singapore: John Wiley & Sons.
Miser, H. J. (Ed.) (1995). *Handbook of Systems Analysis [Vol. 3]: Cases.* Chichester, New York, Brisbane, Toronto, Singapore: John Wiley & Sons.
Nicolis, G., & Prigogine, I. (1977). *Self-Organization in Non-Equilibrium Systems: From Dissipative Structures to Order through Fluctuations.* New York: John Wiley & Sons.
Norrbom, C. (1973). *Systemteori – en introduktion* (Systems Theory – an Introduction). Stockholm: M & B fackboksförlaget ab.
Odum, H. T. (1983). *Systems Ecology.* New York: John Wiley & Sons.
Parsons, T. (1964). *The Social System.* New York: The Free Press.
Parsons, T. (1971). *The System of Modern Societies.* Englewood Cliffs, N. J.: Prentice Hall.
Phelan, S. E. (1999). A Note on the Correspondence Between Complexity and Systems Theory, *Systemic Practice and Action Research, 12* (3), 237–246.
Quade, E. S. & Boucher, W. I. (Eds.) (1968). *Systems Analysis and Policy Planning; Applications in Defense.* New York: American Elsevier Publishing Company, Inc.
Rau, E. P. (2001). Technological Systems, Expertise, and Policy Making: The British Origins of Operational Research. In M. T. Allen & G. Hecht (Eds.), *Technologies of Power; Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (pp. 215–252). Cambridge, Mass., London: The MIT Press.

Rhenman, E. (1969). *Centrallasarettet; Systemanalys av ett svenskt sjukhus* (The Central Hospital; Systems Analysis of a Swedish Hospital). SIAR and SPRI: Studentlitteratur.
Rose, J. (1997). Soft Systems Methodology as a Social Science Research Tool. *Systems Research and Behavioral Science, 14* (4), 249–258.
Rosen, R. (1986). Some Comments on Systems and Systems Theory. *International Journal of General Systems, 13* (1). (Reprinted in Klir, 2001, pp. 241–243).
Rudall, B. H. (1997). Contemporary systems and cybernetics. *Kybernetes, 26* (1), 5–17.
Rudall, B. H. (2000). Cybernetics and systems in the 1980's. *Kybernetes, 29* (5/6), 595–611.
Schecter, D. (1991). Critical Systems Thinking in the 1980's: A Connective Summary. In Flood & Jackson, 1991.
Skyttner, L. (2001). *General Systems Theory: Ideas and Applications.* Singapore, New Jersey, London, Hong Kong: World Scientific Publishing Co. Pte. Ltd.
Thomas, A. R. & Lockett, M. (1979). Marxism and Systems Research: Values in Practical Action. *Proceedings of the 23rd Annual Conference of the International Society for General Systems Research.* (Reprinted in Flood & Jackson, 1991).
Tomlinson, R. & Kiss, I (Eds.) (1984). *Rethinking the Process of Operational Research and Systems Analysis.* Oxford, New York, Toronto, Sydney, Paris, Frankfurt: Pergamon Press.
Ulrich, W. (1983). *Critical Heuristics of Social Planning; A New Approach to Practical Philosophy.* Bern, Stuttgart: Verlag Paul Haupt.
Vining, R. (1984). *On Appraising the Performance of an Economic System.* Cambridge, London, New York: Cambridge Univ. Press.
Warwick, Kevin (1994). Cybernetics – The Modern Science of Systems. *Kybernetes, 23* (6/7), 76–85.
Zimbalist, A. (Ed.) (1984). *Comparative Economic Systems: An Assessment of Knowledge, Theory and Method.* Boston, The Hague, Dordrecht, Lancaster: Kluwer-Nijhoff Publishing.

Part II

Systems Analysis in Sweden – Examples of Projects Using a Systems Approach