Chapter 1

Systems and Systems Theory

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1 Introduction

System is a word that is used more and more frequently in Swedish, as well as in many other languages. One reason seems to be that system may have different meanings and appear in many contexts. A system may refer to an "object." For example, an organism may be conceived of as a biological system. Sophisticated industrial products, for instance aircraft, are sometimes described as technological systems. A rapidly growing number of people are playing with software systems on computers. The word system may also represent an organization of activities, manifest or planned. When activities are *systematically* organized it may imply or explicitly include a guiding norm or an objective. Gamblers dream of inventing systems that will make it possible to win a fortune on horse-racing or roulette. A new coach often wants to introduce a new tactical system in order to make a football team more competitive. System may also be a key concept in an intellectual approach to problem solving, such as in *systems analysis.*

Given this large variation of interpretation it is not surprising that system has become a somewhat controversial concept, sometimes even considered to be almost meaningless due to its many uses. Nevertheless, it is possible to provide a general understanding of system that is acceptable to a large number of analysts.

The heart of a system is *interaction* between a number of systemic elements separated from an external environment. A system is typically linked to its external environment by a number of inputs and outputs. This conventional image of a system is represented in Figure 1.1.

Ultimately, the notion of a system provides a *mode of thinking* about complex problems. This book addresses different aspects of systems thinking: its theoretical foundations, its modes of operation, its tools and its various fields of application. Thus, it considers systems thinking in the context of scientific research in the natural as well as in the social sciences, in technological development, political planning and decision making.

One aim of the book is to present a broad overview of what systems thinking means; *what it is, what it does* and *what it achieves.*

M.-O. Olsson & G. Sjöstedt (Eds.),
Systems Approaches and Their Application: Examples from Sweden, 3–29.

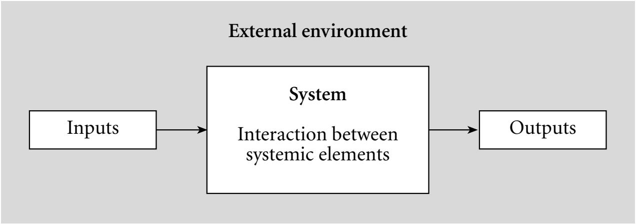

Figure 1.1: A conventional understanding of a system.

Another objective is to assess measures for developing systems thinking and to reflect on how to take advantage of the systems analytical approach more effectively. In this study Sweden is used as a reference case.

One set of questions addressed in the book concerns how, and to what extent, technological and societal developments have changed the conditions for using systems approaches in various scientific contexts and for different purposes. For example, what has the emergence of new information technologies and other communication tools meant for the applicability and significance of the systems approach? Or how has new learning and the accumulation of knowledge affected the use of systems approaches in science and policy making?

A second set of questions asks for what purposes and with what expectations systems thinking is used in science and how a systems approach is actually employed for different purposes and in different contexts.

A third round of questions focuses on the achievements of systems thinking. What kind of results does it produce in different contexts like research, teaching or decision support or with regard to different functions or purposes? What kind of benefits do these results represent?

The book turns to different audiences interested in keeping track of important developments in systems thinking, such as academic researchers in various fields, decision makers in research foundations, engineers and other individuals concerned with technological development, or policy makers and their advisors in public or private organizations at the regional, national or international level. The study is not framed to fit the terms of reference of any particular audience group. The project has been designed with the assumption that all parties using systems approaches, be they scientists or policy makers, have a common interest in following – and often supporting – the evolution of systems thinking for scientific or policy purposes. As will be demonstrated in this book, a systems approach in science may take on quite different forms depending on the circumstances – problem areas, actors involved, internal or external contexts, etc. Nevertheless, all parties relying on a systems approach have a special interest, and stake, in its use. For example, the systems approach might be regarded as an integrative "tool" facilitating the complex interaction between various professional cultures.

The book consists of three parts, where the two chapters belonging to the first part aim at giving a background to the field. The chapters give an overview of the basics of systems thinking and the history of its development. The second part consists of thirteen chapters in which a number of Swedish systems analysts describe their systems oriented research and reflect upon the use of the systems approach to solve the problems facing them. In the two chapters comprising the third and final part of the book an overview is given of some important perspectives motivating the use of a systems approach to solve complex problems in science as well as in the field of public policy.

The survey of systems thinking performed in this book is far from comprehensive since it includes only a limited number of cases. Nevertheless, the descriptions and discussions have been designed to cover a number of important dimensions. The selection of cases has been deemed to represent a sufficiently varied and large "sample" to permit the overview which is the purpose of the project. The systems analytical studies described were conducted within a variety of academic disciplines ranging from political science to the interdisciplinary study of the brain. The book also demonstrates the character of the "toolbox" used in systems studies and indicates the wide choice of systems methodologies available to the researcher today. The systems studies presented are assessed in a comparative spirit, the aim being to identify general properties representing opportunities as well as basic problems. The description, analysis and comparison of cases is couched in a common theoretical framework including basic concepts, philosophical and historical contexts and competing schools of thought.

The remainder of this chapter contains a presentation of the basic concepts of systems thinking and the early use of systems approaches in science. It also discusses the scientific claims of the approach and lists what are commonly seen as the opportunities of using systems thinking in trying to solve complex problems encountered in science as well as in the societal sphere. The chapter closes with an introduction to some generic problems involved in the systems approach in science and a brief overview of the contributed chapters making up Part II of the book.

2 Basic Concepts and the Early Use of the Systems Approach

> With special regard to systems thinking, what is the fundamental question to which systemic research and practice should respond? That is, if systems thinking is (part of) the answer, what is the question?
>
> In the search for this question it should be clear that systems thinking is of interest more as a means for promoting competence in various fields of study than as a field of study for its own sake. The primary concern is competence, not systems.
>
> *Werner Ulrich (2001)*

The intriguing question that Werner Ulrich poses above is of fundamental importance for this book and its discussion of systems approaches in science. The question explicitly moves us into the cognitive realm. What Ulrich implicitly states, however, is that the important thing to know is not whether the object of study does indeed constitute a system (or a part thereof) in the real world. The focus should rather be entirely on "systemic research and practice." And perhaps this is the only way we could think about a system. The question of whether or not reality constitutes a system (or a hierarchy of interlinked systems, which might be a more realistic notion) is not a thing that can be resolved by science, at least not by the science of today. Thus, the ontological issue must be left unresolved. Reality might well constitute a system (or a system of systems), but there is no way for us to identify this system with certainty. If we say that systems exist in reality we are simply making an assumption about the existence and the quality of reality, an ontological assumption.

However, as Ulrich argues, useful systems analysis does not require the existence of real systems. This is a book about "systems thinking" and "systems practice" as a set of principles – a scientific or investigative approach – that we may employ to gain a better understanding of reality, whether or not this reality itself constitutes a system. Thus, the epistemological issue is highly pertinent. How systems thinking can be employed – and how it actually has been employed in Sweden during the last twenty years or so – will be illustrated and discussed in this book. In this connection a number of fundamental questions are addressed: Why is systems thinking important? What are the motives for using a systems approach in science? What are the costs and benefits of systems analysis? How could society support and stimulate systems analytical research?

A special problem with an analytical approach based on the concept of system is that today the word "system" itself is used by everyone everywhere and probably often without much thought of its theoretical implications. The question is whether we thereby safely can assume that a common use of the word implies that people in general believe in the "interconnectedness" of different phenomena, whether it implies a general insight that "things are somehow connected," that phenomena rarely (if ever) can be viewed as totally independent of their context, independent of other, related phenomena.

However, the general dilution of the meaning of the concept of system in everyday language causes a special problem when one wants to properly explain what scientific inquiry based on a systems approach is all about. Few contemporary scientists are likely to deny that they study the behavior of some kind of a *system,* that is, that they view the phenomenon that they study as "interrelated with" or "dependent upon" a number of other phenomena. But the specific character of these interdependency relations, what other phenomena to take into account in this context, and what methods to use in the analysis of the phenomena are likely to vary. However, in an applied research situation the choices made to settle these issues automatically entail a number of (explicit or implicit) specifications through which the constructed system is simultaneously determined.

Thus, the popular acceptance of the idea of "systemicity" is not entirely unproblematic when a specific phenomenon and its mode of functioning is analyzed by scientists. Systemicity implies a mode of thinking according to which a phenomenon must be understood in its relation to the surrounding world, to its environment. The question is how such an understanding can be reached. The choices through which a studied system (a model) is specified must (ideally) be made under the explicit consideration of a number of restrictions of a theoretical as well as a practical nature.

Thus, the "systems approach" begs a number of rather difficult questions. Before looking more in depth at these questions a short overview of some basic systems concepts will be presented.

2.1 Basic Concepts in Systems Theory[1]

> It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general.
>
> In this way we postulate a new discipline called General System Theory. Its subject matter is the formulation and derivation of those principles which are valid for "systems" in general.
>
> *Ludwig von Bertalanffy (1968:32)*

A coherent set of interrelated systems concepts has emerged during the last 50 years. Ludwig von Bertalanffy (1901–1972), an Austrian theoretical biologist who emigrated to Canada in 1949, is generally regarded as "the father of General Systems Theory."[2] In articles appearing from the beginning of the 1940's von Bertalanffy developed his ideas about the general character of systems. In 1968, he published his *General System Theory: Foundations, Development, Applications,* a book that has become something of a bible for adherents of systems theory all over the world. The book is based on the author's numerous journal publications in the period 1940–1968 and it covers most aspects of systems theory, from its basics to its more advanced or even controversial issues. This is probably the single most influential text ever published advocating a systems approach in science (only rivalled perhaps by Norert Wiener's writings on cybernetics). Advocating a systems approach in science soon developed into a kind of "social movement" among scientists and in 1954 von Bertalanffy was among the founders of the Society for the Advancement of General Systems Theory.[3]

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1 Those who are already familiar with the basic systems theoretical concepts might want to proceed to the following section of the book.

2 Today the Russian scientist Alexander A. Bogdanov (1873–1928) is increasingly recognized as a forerunner of General Systems Theory and Cybernetics. Bogdanov outlined his ideas about *tektology* (the science of building, where "building" in a broad sense corresponds to "organization") in two volumes that were published in St. Petersburg as early as 1913 and 1927. The books early appeared in German translation (in 1926 and 1928 respectively), but the influence of Bogdanov was still limited to the Russian/Soviet scene. After Bogdanov's death (1928) the research program outlined in his two volumes on tektology was efficiently silenced by the criticism which Lenin had made and subsequently through Stalin's purges in the 1930's. In the Soviet Union Bogdanov's systems ideas were only "rehabilitated" in the late 1960's–early 1970's, some years after the "false science" ban on cybernetics from the late 1950's–early 1960's had finally been lifted. The importance of Bogdanov as an "Eastern" precursor of systems thinking was early noted by Susiluoto (1982) and Bogdanov's work has become the focus of an increasing interest in the last 10–15 years (cf., for instance, Capra, 1997; Biggart *et al.*, 1998).

3 Since its inception this society has been very active, organizing, for example, yearly conferences on general systems theory. Other well-known scientists among the founders were economist Kenneth Boulding, mathematician-biologist Anatol Rapoport, neurophysiologist Ralph Gerard, psychologist James Grier Miller and anthropologist Margaret Mead. In 1957, the society changed its name to "Society for General Systems Research" and later again to "International Society for the Systems Sciences" (ISSS). (More information about the society can be obtained from its Internet presentation at URL: http://www.isss.org/homepage.htm.)

Other schools of thought, similar to the one led by by von Bertalanffy, were emerging in parallel. A practical implementation of general systems theory even before it was formulated by von Bertalanffy became known as *Operations Research* (OR). In OR scientists helped solve man-machine problems and its first practical applications were designed to meet the demands of logistics and resource management of the British World War II effort. Another important parallel development became known as *cybernetics.* Originally it dealt with communication and control in animals and machines. The approach is connected with names like Norbert Wiener, W. Ross Ashby and, later, with a focus on self-reference, Heinz von Foerster. More will be said about these and other schools of thought in the next chapter.[4]

The seminal works of von Bertalanffy, Wiener, Ashby, von Foerster and others were followed by books and articles by many authors all over the world, giving rise to a huge literature on systems theory, a large part of which are summaries of basic systems theoretical concepts and principles in general terms advocating the adoption of a systems approach in science.

A reasonable first question with regard to the theory of systems is: what exactly is meant by the concept of "system"? How should a "system" be defined? Looking to the systems theoretical literature one finds numerous definitions of the concept of system. In the next chapter, when we look at different schools of thinking, some other definitions of the system concept will be reviewed, but here we will simply take our departure in the writings of von Bertalanffy on General Systems Theory.

von Bertalanffy (1968) himself does not give a very structured and clear-cut presentation of the basic ideas of his general systems theory. However, his seminal book enhances our understanding of the basic systems concepts that are of concern to us here. In the third chapter of the book, which is based on an article originally published in 1945, von Bertalanffy (1968:55–56) provides a strict definition of a system:

> A system can be defined as a complex of interacting elements. Interaction means that elements, p, stand in relations, R, so that the behavior of an element p in R is different from its behavior in another relation, R'. If the behaviors of R and R' are not different, there is no interaction, and the elements behave independently with respect to the relations R and R'.

The author then proceeds to give an equivalent, but formal mathematical definition of a system through a set of simultaneous differential equations.

What von Bertalanffy called the "elements" of the system have variously been labeled "agents" or "actors" by other authors and the relations between the elements have been named "interaction." Agents (or actors) and interaction are probably the most fundamental concepts of systems theory beside the notion of system "boundary." The *boundary problem* is especially pertinent in a social systems context, but it

4 In the first chapter, specially written for his 1968 book *General System Theory,* von Bertalanffy actually discusses a large number of emerging systems theoretical "trends." "Leaving aside approaches in applied systems research, such as systems engineering, operational research, linear and nonlinear programming, etc.," von Bertalanffy discusses "more important approaches" like set theory, graph theory, net theory, cybernetics, information theory, theory of automata, game theory, and decision theory.

is in principle a fundamental problem in any application of a systems approach. The critical question is what perceivable elements (agents/actors) should be considered to be a part of the system and what factors should be seen as belonging to its *environment.* Since we primarily see systems theory as a methodological approach to the study of little known and often complex structures it follows that systems, in our view, are *mental constructs* or *models* of a specified part of reality, models to assist in the production of knowledge about this part of reality. Obviously, the boundaries of such a system will necessarily be set in such a way that the system contains one of many possible sets of elements. Where the boundary lies between the system and its environment, what elements are seen as belonging to the system rather than to its environment, may, in fact, be decisive for the analysis of a system's behavior.

Another fundamental aspect of a system concerns the quality of its behavior, which depends on the interaction between the system's agents. Intrinsic to the approach is the idea that in displaying a certain behavior the system performs a specific function and produces some kind of impact. In fact, the systems approach is used to understand *emergence,* to explain emergent behavior. (This has a correspondence in the popular notion that the whole is larger, or something more, than the sum of its parts.)

The emergent behavior of a system, or the emergent effect of the interaction between the agents belonging to a system, can be seen by the system observer as the "rationale," the "purpose" or the "goal" of the system. In fact, it cannot be seen in any other way. This is an inherent feature of the systems approach. Such teleological notions were, however, earlier banned from science. As von Bertalanffy (1968:45–46) puts it:

> Similarly, notions of teleology and directiveness appeared to be outside the scope of science and to be the playground of mysterious, supernatural or anthropomorphic agencies; or else, a pseudoproblem, intrinsically alien to science, and merely a misplaced projection of the observer's mind into a nature governed by purposeless laws. Nevertheless, these aspects exist, and you cannot conceive of a living organism, not to speak of behavior and human society, without taking into account what variously and rather loosely is called adaptiveness, purposiveness, goal-seeking and the like.
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> It is characteristic of the present view that these aspects are taken seriously as a legitimate problem for science; moreover, we can well indicate models simulating such behavior.

Speaking of organismic processes von Bertalanffy introduces the term *equifinality* to signify the fact that, in contrast to machine-like structures, which follow a fixed pathway reaching different final states with changes in the initial conditions, in organismic processes the same final state, or the same "goal," may be reached from different initial conditions and through different pathways.

The concept of *feedback* so frequently encountered in systems theory is a loan from information theory. The behavior of simple stimulus-response (input-output) systems becomes arbitrarily more "complex" when a "monitoring mechanism" is introduced allowing an assessment of the produced response (output) to influence the stimulus in the system's next "round of action." Evidently such a feedback mechanism might in itself be regarded as a highly complicated system. For example, it is through this kind of mechanism that organisms can "automatically" maintain a balance (*homeostasis*) of certain functions (like a specific body temperature) necessary for staying alive.

In some cases feedback mechanisms are responsible for keeping a system on the previous track in spite of changing initial conditions. The feedback mechanism may sometimes maintain the system in a certain state and this homeostasis may in fact be equifinal to the system (the "goal" of the system). But, in the face of a prevailing change in the initial conditions, it may instead perhaps maintain the system in its previous state for only a limited period of time (after which change occurs), thus introducing a special kind of "rigidity" in the system. Such a rigidity is called *hysteresis.* In modern social science this kind of rigidity sometimes goes under the name of "path dependency."

Another fundamental distinction is that between an *open* and a *closed* system. The distinction refers to the relation between the system and its environment. A closed system is totally sealed off from its environment, the interaction between the agents of the system is all that matters. This is the kind of system that traditionally has been studied in physics. (In his discussion of open systems von Bertalanffy (1968:39 ff.) grants that "in recent years" there has been an "expansion of physics to include open systems.") Open systems, on the other hand, are, as von Bertalanffy says (1968:39):

> … systems which by their very nature and definition are not closed systems. Every living organism is essentially an open system. It maintains itself in a continuous inflow and outflow, a building up and breaking down of components, never being, so long as it is alive, in a state of chemical and thermodynamic equilibrium but maintained in a so-called steady state which is distinct from the latter. This is the very essence of that fundamental phenomenon of life which is called metabolism, the chemical processes within living cells.

Consequently, equifinality can only be a property of an open system. The final state of a closed system is entirely determined by the initial conditions. In open systems, on the other hand, the same final state can be reached from different initial conditions and in different ways. Another corollary of the distinction between closed and open systems has to do with the second principle of thermodynamics, the general trend of events in physical nature toward states of maximum disorder (entropy). von Bertalanffy explains it thus (1968:41):

> Therefore, the change of entropy in closed systems is always positive; order is continually destroyed. In open systems, however, we have not only production of entropy due to irreversible processes, but also import of entropy which may well be negative. This is the case in the living organism which imports complex molecules high in free energy. Thus, living systems, maintaining themselves in a steady state, can avoid the increase of entropy, and may even develop towards states of increased order and organization.

Two structurally equivalent systems are said to be *isomorphic.* The idea of isomorphism is at the root of the claim of general systems theory to be a suitable vehicle for integrating various scientific disciplines (von Bertalanffy, 1968). Isomorphisms make loans of theories and models from one science to another possible.

This somewhat kaleidoscopic review of some basic systems theoretical concepts will be sufficient for our purpose. Evidently there are a lot of other systems concepts, but we will leave them for later, when we have a chance to view the concepts in a specific context, which will help explain their meaning and significance. This overview has said nothing either about the analytical techniques (the "toolbox") that are used in the application of systems theory for the solution of real-world problems. We will come back to this as well later in the book.

2.2 The Early Use of Systems Theory in Analysis

> As many probably already know, there is great confusion about what is and what is not systems theory, and how general systems theory differs from such special system theories as cybernetics, process control, system engineering, etc. Part of the problem stems from the fact that we, as advocates of the systems approach, have largely failed to develop a coherent statement of its properties.
>
> *John W. Sutherland (1973:viii)*

Before having a brief look at the early use of systems theory we should perhaps address the conceptual confusion that is still today afflicting the field. It seems that von Bertalanffy's concept of *General System Theory* (GST) must be seen as the label of a broad and basic theoretical approach, which is not a scientific theory in a strict sense. Some proponents (see, e. g., Sutherland, 1973) designate it as "a fundamentally new approach to scientific analysis." It subsumes a number of theoretical developments found in many different disciplines, such as set theory, graph theory, net theory, cybernetics, information theory, theory of automata, game theory, and decision theory. According to the "founding fathers" (cf. von Bertalanffy, 1968) GST should not be confused with "applied systems research," such as systems engineering, operations research, linear and non-linear programming. Clearly, all these specialized theories are based upon, or use, systems theoretical concepts. Thus, to us in the present context, all such more specialized theories represent aspects of the original GST, they adopt a *systems approach* or constitute outcomes of *systems thinking.* Since the 1950's a number of systems theoretical schools of thinking have emerged, all based upon, or related to, systems thinking in this wide sense. We will return to this development in the next chapter.

The systems concept has a long pre-history. References to "system" and "systemic" can already be found in the writings of Descartes, who in his "Discours de la Méthode" introduced a coordinated set of rules to be used to reach coherent certainty.[5] As pointed out by Francois (1999), practically all philosophers after Descartes constructed their own philosophical systems and at the end of the eighteenth century "the philosophical notion of system was firmly established as a constructed set of practices and methods usable to study the real world." Gradually, during the nineteenth century, the system concept was introduced in other scientific disciplines as well. Thus, by the mid 20th century, when systems thinking began to appear as a "discipline" in Europe and the United States, many of the concepts that are at the root of the approach had already been developed in various disciplines and contexts, even if they had not yet been merged into a coherent theoretical framework.

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5 Actually, the concept was used as long ago as in classical Greek literature. See, e. g., Francois (1999), who gives a broad overview of the history of systems thinking prior to the post-world-war-two period that we are mainly concerned with here.

The "codification" of the systems approach achieved by von Bertalanffy in his GST and almost in parallel by Wiener, Ashby and others in what came to be known as *cybernetics*, rapidly made an impact on society and the way public authorities attended to social problems.

The earliest and best-known implementation of systems thinking emerged in Great Britain in the late 1930's (Lilienfeld, 1978). What later came to be known as Operations Research (OR) was developed in the British preparation for World War II. The problem of making radar devices work in a coordinated way was the first task assigned to a group of people consisting of military officers, researchers and government officials.

> As time went on, operations research, in the form of application of statistical methods to military problems, spread from work on radar systems to the analysis of fighter losses in France, the analysis of aerial bombing raids, the evaluations of weapons and equipment, and to the analysis of specific tactical operations. [...]
>
> The operations research approach rapidly spread among British military and naval commands and was soon adopted among United States commands. (Lilienfeld, 1978:104)

In a (strongly critical) review of systems analysis, Ida Hoos (1972) traces the origins of the systems approach to solving social problems back to the military OR of the Second World War and the way this thinking (most often dealing with numerical analyses of the most cost-effective ways of achieving specific goals within a clearly defined "system") subsequently penetrated almost the entire public decision making process in the United States. This development was initiated in the 1960's and driven by President Kennedy and his Secretary of Defense, Robert S. McNamara, a former president of Ford Motor Company. McNamara and his newly recruited staff of former RAND corporation economists thoroughly reformed military planning and budgeting.[6] According to Hoos (1972:46–47) the impact of this changed planning methodology was indeed significant:

> Long before proof, or even adequate trial, could establish the validity of the military as model for further and wider application, the technique in its various forms became rigidified and entrenched as required procedure in agencies at all levels of government. It rationalized and became the staff of life of new bureaucratic structures; it acquired a constituency of and advocacy by professionals of all stripe. It attracted and commanded huge expenditures of public funds; and it gave further impetus to already flourishing government-by-contract activities. Above all, it deeply implanted the notion that what government affairs needed was better management, and the more "scientific," the better, at that.

From the fields of military applications OR spread to universities and private industry and in 1957 the International Federation of Operations Research Societies (IFORS) was founded in Oxford.

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6 The Rand corporation is a renowned American "think-tank" established as long ago as 1948. The organization is still very active. Its claimed purpose is to "improve policy and decisionmaking through research and analysis." More information about Rand can be found on the Internet at URL: http://www.rand.org/

The Swedish OR association (*Svenska operationsanalysföreningen,* SOAF) was founded in 1959. The association has always kept close ties with the national defense research organization (FOI).

Another "movement" inspired by systems thinking has become known as *systems analysis.*[7] It is hard to make a strict distinction between operations research and systems analysis. Lilienfeld (1978:111) claims that:

> … in its practical applications [as opposed to its "missionary" publications] operations research is focused and disciplined in its approaches by the specific requirement of an industrial process or a marketing problem. Under such circumstances it is highly specific, narrow, and technical.
>
> When the operations researcher turns his gaze to wider fields and becomes a "systems analyst," he begins to make social, political, economic, and bureaucratic claims.

Systems analysis was made the unifying theoretical concept on which, in October 1972, after six years of preparatory negotiations, the International Institute for Applied Systems Analysis (IIASA) was founded by representatives (in most cases) of academies of sciences in twelve countries. (Sweden joined the institute in 1976.) According to Howard Raiffa, IIASA's first director, who was very actively involved in the long negotiations leading to the establishment of the institute, the question of its name caused a lot of discussion. The name "institute for applied systems analysis" was invented by Raiffa "because nobody will know what it means."[8] Nevertheless, in these discussions it was obvious that the impact of OR as a new method of analyzing problems besetting modern societies played an important role. The establishment in the midst of the Cold War of an international research institute with East-West participation must be said to be a remarkable achievement. During its almost 30-year history IIASA, using an eclectic variety of systems methods, has engaged in a number of large interdisciplinary research projects studying complex problems that threaten or cause serious trouble for many countries in the world. The focus has not only been on "modern societies" – especially the last 10–15 years have seen an increase of the institute's work relating to developmental problems both in the South and, of late, in the East. The establishment of IIASA's original research agenda can be seen as a manifestation of widely spread general expectations of systems analysis in the early 1970's.[9]

2.3 Systems Analysis for Policy Making

Many of the main characteristics of systems analysis or systems thinking have a general significance regardless of the topic on the agenda, the actors involved, or, generally, the prevailing circumstances. For instance, systems analysis offers a holistic approach for

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7 Note that we are not (primarily) concerned here with the "systems analysis" that is a field in computer science.

8 Raiffa in a talk given at IIASA on September 23, 1992. Here Raiffa gives a vivid picture of IIASA's turbulent "creation process." (An edited version of Raiffa's talk can be found on the institute's web pages at URL: http://www.iiasa.ac.at/docs/IIASA_History.html.)

9 The history of the institute and its work are well documented on IIASA's web pages at URL: http://www.iiasa.ac.at.

both analysts and decision makers in public and private institutions. The difficulties involved in separating a system from its external environment and at the same time controlling the consequences of this analytical operation will in principle be the same for any user of systems analysis. Furthermore, the opportunities and problems of systems analysis experienced by scientists will be indirectly shared by policy makers relying on input from scientific investigations employing a systems approach.

Nevertheless, in practice, systems analysis tends to have a somewhat different meaning and usefulness for scientists and policy makers respectively. Although the divergences are likely to be of a relative rather than of an absolute nature, and of a comparatively modest magnitude, they are still important to note. A comparison of how systems analysis is assessed by different professional cultures – such as the ones in which scientists and policy makers live – will help to enrich the overall evaluation of the approach.

Systems analysis is useful to the scientist because it supports the performance of a research project in various ways. It does not have the role of a theory based on generalized empirical observations. Its function is rather to serve as a context for such theories. The systems perspective may, for instance, help an analyst or a research team to simplify the research effort by breaking it down into manageable components, such as systemic elements, systemic tasks or input flows.

One important outcome of this simplifying function is that it may be employed as a principle for the distribution of work within a research team. For example, the systems approach has recurrently served to support inter-disciplinary scientific cooperation. Such collaboration may typically be wanted when different aspects of a set of problems depend on different kinds of scientific information.

It is a reasonable assumption that this organizational function of systems analysis may be of particular significance for policy makers, especially when they work in a team whose members are recruited from more than one ministry or other kind of institution. The endogenous logic of the systems model may become a helpful guide for the organization of the work of a group commissioned to undertake the study of a complex problem situation. Firstly, the systems model may help identify the main components of the problem area addressed by the group. Secondly, the systems model may also give the necessary authority to a plan for the distribution of work among the participants of the study group, who may be representing rival institutions.

3 Scientific and “Political” Claims of Systems Theory and Systems Analysis

> A unitary conception of the world may be based, not upon the possibly futile and certainly farfetched hope finally to reduce all levels of reality to the level of physics, but rather on the isomorphy of laws in different fields. [. . .]
>
> We come, then, to a conception which in contrast to reductionism, we may call perceptivism. We cannot reduce the biological, behavioral, and social levels to the lowest level, that of the constructs and laws of physics. We can, however, find constructs and possibly laws within the individual levels. . . . The unifying principle is that we find organization at all levels.
>
> *Ludwig von Bertalanffy (1968:48–49)*

It seems that von Bertalanffy’s advanced claims for his General System Theory (GST) changed somewhat during the period before his 1968 book (Blauberg *et al.*, 1977). While he at first had seen GST as a “universal science” he later modified his claims to some extent under the influence of other systems approaches (like cybernetics) developed during the 1940’s and 1950’s. But, still, one can only say that von Bertalanffy’s claims for GST were indeed far reaching. He thought of it as a discipline or a science – indeed *the* science – for the study of universal systems properties. He stated (1968, p. 88) that “the future elaboration of general systems theory will prove to be a major step towards unification of science” and he added that GST “may be destined in the science of the future, to play a role similar to that of Aristotelian logic in the science of antiquity.” Add to this that he “automatically” includes, without any caveats or cautions, most other systems approaches, such as cybernetics, game theory, and set theory, as “subclasses” of GST. Expectedly, such far-reaching claims invited outspoken criticism. One such critical reviewer is Robert Lilienfeld (1978:3):

> Although some systems thinkers advocate caution in generalizing beyond the limits of their disciplines, they also write “missionary” articles and books for the general reader. The constantly recurring refrain of systems thinkers is that of the great new era that is dawning to replace the present malaise. But what they offer as a view of man in society is not at all new, and it precedes the emergence of their doctrines; for the most part, when the systems thinkers emerge from the discussion of specific technical problems and turn to a philosophy of humanity and society they echo the positivism of Auguste Comte, with a decoration of formal and mathematical terminology.

“Early” critics of operations research and systems analysis (ORSA), like Hoos (1972) and Lilienfeld (1978), writing little more than 5–10 years after the wide adoption (around the mid 1960’s) of systems methods in the U.S. administration, today appear somewhat “ideological” in their rather loud attack. One has to remember that the use of computers in policy analysis was not yet as widespread as it is today. In retrospect one can perhaps say that the heavy focus on an unrestrained use of and belief in computer aided analytical techniques (mathematical modeling and statistical analysis) that seemed to be suggested by ORSA somehow “offended” the critics. And perhaps rightly so, since the early ORSA "enthusiasts" rarely seemed to care about the political implications of the fact that the modern analytical techniques of ORSA were only accessible to "experts" who imagined themselves – but were not in fact – value-free in their judgments of analytical techniques and options to assess. With the emergence of an easily accessible, widely used and increasingly powerful computer technology much of the criticism voiced by writers like Hoos and Lilienfeld has lost some of its thrust. Many of the techniques that were considered advanced and at the time could only be properly handled by computer specialists are now readily available for anyone having access to a PC. The dramatic technological development has undoubtedly played a significant role for our appreciation of systems analysis today. Many of the methods of analysis used by specialists some 30 years ago for making a one-time assessment of a situation are nowadays used on a continuous everyday basis by ordinary clerks as part of their normal routines. Moreover, while various shortcomings of methods and equipment earlier tended to be perceived as serious flaws in the advanced – and expensive – "scientific equipment," today it is common knowledge that computer based decision support tools have limitations, even defects. In fact, no one expects them to be the ultimate and perfect analytical tools.

Since the early days of von Bertalanffy and Wiener systems thinking should have had time to develop further. The technical innovations (mostly advances in mathematical modeling) that were elaborated by the "founders" of ORSA proved to be solid scientific progress with a great *potential* for improving the analysis of complex problems both in specialized scientific disciplines and in the world of the practitioner. The "embedding" and actual use of these technical advances for solving real-world problems have not been entirely unproblematic, a fact that has more to do with the epistemological framing of the problem-solving methods than with the methods themselves. In the next chapter we will develop the argument that significant advances in this respect have been made during the last 10–20 years.

While another early proponent of systems thinking, John W. Sutherland, in his 1973 book discussing a "general systems philosophy" for the social sciences, also adds to the claims of the systems approach, he simultaneously formulates a "credo" saying that the analyst has an obligation as a scientist to develop his science (Sutherland, 1973:vii):

> The general systems theorist, on the other hand, makes his primary mark by constantly questioning the methods and intentions of science. In effect, though he may belong formally to any of several dozen substantive disciplines, his first attention must be to the epistemological predicates of science in general. This is so because general systems theory is not really a theory at all – it is a fundamentally new approach to scientific analysis, an approach which stands in both logical and procedural opposition to more traditional schemas such as strict empiricism, positivism, intuitionalism, or phenomenology. True, it draws its precepts eclectically from all these, but in the process of selection becomes something very different than its components.

As we shall see in the next chapter, a number of scientists have jointly moved the "scientific frontier" of ORSA in the direction of making it less rigid and formalized but more able to attack real-world problems without losing sight of the restrictions imposed by the complexity of reality itself.

4 Adopting a Systems Approach in Science: Opportunities and Some Generic Problems

> When the process of metamodeling is discussed [. . .], we argue that, nowadays, certain scientific disciplines are failing to reach their research objectives because they overlook the importance of epistemology and do not consider the objectives of their research program from the perspective of an inquiring system at a sufficiently high level of abstraction.
>
> *John P. van Gigch (1991:24)*

The task that we have set ourselves in this book – to reflect on the theory and practice of systems studies in Sweden – can be seen as an activity that should be part of a continuously ongoing discourse concerning the validity and efficacy of any scientific approach. To illustrate what such a reflection might entail let us have a look at a figure constructed by John P. van Gigch outlining the framework for his so-called *Meta-Modeling Methodology* (M^3). van Gigch argues that a scientific approach should embrace three levels of inquiry. He actually considers these levels as three different but interrelated "inquiring systems" (cf. Figure 1.2).

The different levels of inquiry in Figure 1.2 have been given various labels (van Gigch, 1991; Ericsson, 1998):

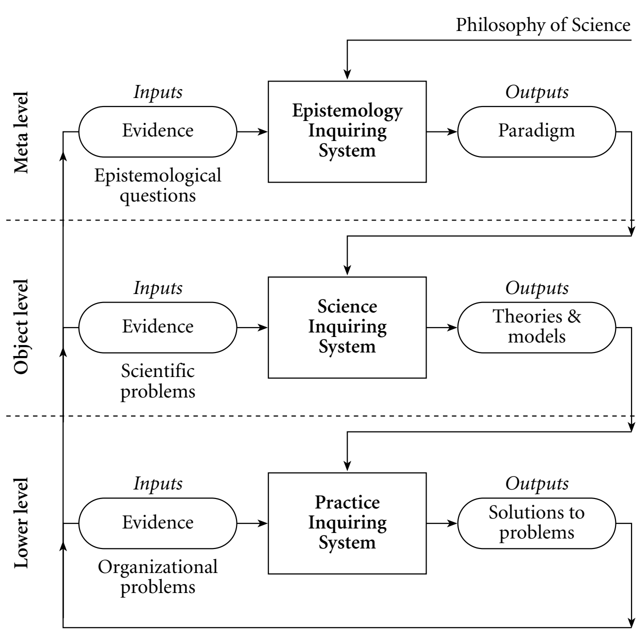

Figure 1.2: Illustration of van Gigch's "Meta-Modeling Methodology" (M^3) (Source: van Gigch, 1991:294)

Lower Level: The implementation level, the practice level, the operational level or the level of intervention

Object Level: The level of science, the tactical level, the object level, or the modeling level

Meta Level: The strategic level, the epistemological level, or the meta-modeling level

It is a sign of good science that there is an active and continuously ongoing discourse on all of these levels. While most of the projects that are presented and discussed in Part II of the present book deal with what van Gigch would refer to the "lower level" and the "object level" the aim of the entire book is to contribute to what van Gigch has assigned to the "meta level" and the interaction between the three levels.

4.1 Opportunities

What is the *purpose* of a systems approach in science? What opportunities does such an approach offer society in terms of better knowledge, better decisions and better designs?

The purpose of a scientific approach can be many different things depending on the context in which science is performed. But some general remarks might perhaps be ventured. Science works by way of researchers posing questions and looking for answers. So a first, very general, answer to the question of the purpose of using a systems approach in science would be that it is expected to improve the quality of both our scientific questions and the answers we can find to them. An underlying hypothesis motivating the interest in systems thinking in the first place is that the interesting knowledge that science is looking for can only be reached through the study of relations between various components of an imperfectly understood situation in life. In the systems approach relations are taken to mean "interaction" between "agents." In the selection of which specific interaction should be studied the researcher delineates, or identifies, a "system," the performance of which is then made the principal object of study. The hypothesis is that this kind of approach in science produces better knowledge than other, more particular approaches mainly focusing on the *properties* of – or "uni-directional cause and effect relationships" (Midgley, 2000:39) between – the phenomena or "objects" that are assumed to be associated with the problem requiring a solution.

The fundamental hypothesis is that the *holistic view* that the systems approach in science adopts might allow a better understanding of the questions that the scientist has posed for himself than the traditional, particularistic approach which has been entirely dominant in science right up to the mid 20th century. The *systems approach* has undoubtedly gained increasing ground during the last 40–50 years at the expense of the traditional *reductionistic approach.* The increasing significance of systems thinking depends on the fact that more and more scientists around the world in practically all scientific disciplines have come to believe that the phenomena (parts of reality) they study are characterized by interdependence and that the systemic properties of these phenomena therefore require attention if we are to be able to expand and deepen our knowledge of reality.

The holistic systems approach also entails a departure from the "objectivity" ideal of "High Science" (Toulmin, 1996), which was based on the assumption that a clear separation could be maintained between the object of study and the observer. In the systems approach impartial observation is replaced by the study of an identified system in order to enable intervention for the purpose of improving a problem situation. Coming to terms with this "subject/object dualism" means a fundamental change of outlook in science. The systems approach is clearly moving us in this direction. Gerald Midgley (2000:44) emphasizes that this is a fundamentally important development:

> The problem is that subject/object dualism is so ingrained in Western thought that it is very difficult to even identify in some instances, let alone challenge. However, the prize for doing so is great: rooting out naïve subject/object dualism will strengthen the critique of so-called value-free science (this critique has been gathering momentum for over one hundred years) so that the values flowing into observations can be made more visible. Ultimately, I believe that full acceptance of value-*full* science will take us beyond mere observation to an understanding that science, and indeed all activities which shape knowledge, is primarily concerned with *intervention*, not observation [...]

To summarize the argument so far, using a systems approach in science is always expected to enable better research questions as well as answers to those questions, and it also sometimes (when it is applied to social problems) aims to achieve changes, improvements through intervention, in the problem situations it studies. These features are intended and profound benefits of using a systems approach. They are, in fact, opportunities made available by this approach. However, these opportunities are not entirely unproblematic, they require consistent answers to a number of difficult and value-laden issues that should be openly and rationally dealt with. But before looking more closely at those problematic issues let us first list some more benefits and opportunities connected with the use of a systems approach in science.

One consequence of its holistic and action oriented, systems interventionist ambitions is that the systems approach *requires* legitimacy (trust) among everyone affected or taking part in the study/intervention. However, through its broad engagement of stakeholders the approach, properly handled, can also *create* legitimacy for the study process and its outcome. In this context the systems approach serves as a way of facilitating communication between various stakeholders. This is an important benefit of the approach.

The means that the systems approach offers for structured and efficient communication about a problem situation assumes a special significance when the study of such a situation requires participation by representatives of several different scientific disciplines (which is probably typical for non-trivial problems). In such situations the theoretical framework underlying the systems approach provides a convenient "language" of communication for joint interdisciplinary work.

Accepting the systemic interventionist practice as a key characteristic of systems approaches (which entails the dissolution of the subject/object dualism), the road has been paved for adopting a theoretical and methodological pluralism in research. Arguments for theoretical and methodological pluralism have been advanced by several proponents of modern schools of systems thinking. More will be said about this in the next chapter.[10]

4.2 … and Some Generic Problems

Several of the benefits or opportunities associated with a systems approach listed above are linked to the issues we are now going to raise. While there may be, in principle, many benefits to be gained by adopting a systems approach in science there are also a number of profound problems connected to such an approach. Here we will briefly list some of these "generic problems" and motivate their relevance.[11]

4.2.1 What kind of systems can we identify?

We hypothesized that the systems approach was used with the ultimate purpose of gaining better knowledge. But the systems approach must be applied to a problem and it is important to keep in mind – and reflect upon the consequences of – who it is that selects the problem to be studied, to ask oneself what is the *purpose* of a specific study. Is the study undertaken for purely scientific reasons, is it initiated by the researcher, or is it initiated by someone (person or organization) posing the question to be answered and providing the funding to pay for the search for an answer? If the study is to be undertaken by someone who believes in the merits of a systems approach in research (which may or may not have been anticipated by the funder of the study) the analyst will both pose his questions and look for the answers within the framework of a system of some kind. Our first problematic issue, or our first generic problem, then, is this: What characterizes the system that is going to be made the object of study? A first question concerns the ontological status of the system. Does the system exist in reality, is it something that the researcher has "found" out there in nature, or is it a system that he has identified based on his existing knowledge and/or intuitive thinking about the situation at hand. Already at the outset of this chapter we expressed sympathy with the view that, while systems *might* exist in reality, all we can actually *know* is what we can learn through our senses and through our mental operations. This might well lead us to "see" a system in nature, but we should acknowledge that the only thing there is for us to work with is our systems *model* of (a part of) reality. This view makes it difficult to say anything definite about the ontological status of systems. We may posit a system as an ontological fact, but this amounts to no more than an ontological assumption. Seeing systems as mental constructs is, on the other hand, quite legitimate, and is actually what is meant by applying a systems approach in science. The knowledge that we possess about systems has been gained through the study of such mental

10 A summary of these arguments can be found in a recent book by Gerald Midgley (2000) that also gives a broad and insightful overview of the systems movement in science, while at the same time advancing the theory of systemic intervention. Arguments for methodological pluralism in systems research are also presented in a volume of papers edited by Mingers and Gill (1997).

11 The problems listed below were given to the contributors to Part II of this volume to be discussed in the context of their respective presentations.

constructs. This view is compatible with what was said in the previous section concerning the opportunities offered by a systems approach in science. It represents a view of knowledge (epistemology) that has become known as *constructivism* (cf., for instance, von Glasersfeld, 1995). This issue will be further discussed in the next chapter.

Looking at systems as mental constructs we realize that the number of different systems that conceivably might be identified (specified, constructed) is unlimited. Since we cannot in this approach claim "objectivity" in the traditional sense of "High Science," the criterion by which to judge the results reached – the knowledge gained – through a systems approach to a problem must be related to how well it serves the purpose of the study, what use can be made of it and whether, and to what extent, the knowledge works. Constructivists call this the "viability" criterion. The value of the results of the study can be judged by the extent to which they are viable (von Glasersfeld, 1995).

4.2.2 System boundaries

With this frame of reference in place it seems natural next to focus on the issue of the system's extension, its limits or borders. We want to claim (in the good company of many prominent systems scientists) that the identification of the system, selecting what should belong to the system and what should be left out of consideration, i.e., what should be considered a part of the system's environment, is *the* crucial issue that always has to be initially dealt with in applying a systems approach in science. This has been called the *boundary problem.* Werner Ulrich (1983) is given the credit for drawing attention to the problem of system bounding (see, e. g., Midgley, 2000). Ulrich developed his ideas on "critical heuristics of social planning" while working for a period of several years in the late 1970's with C. West Churchman at the University of California, Berkeley. Churchman (1979) saw comprehensiveness as a highly desired quality in systems research. But since it is not, for practical reasons, possible to "sweep in" everything in a systems study, some things have to be excluded from consideration. Unlike the general system theorists, who seemed to assume that the boundaries of a system were "'given' by the structure of reality [...] Churchman made it clear that boundaries are social or personal constructs that define the limits of the knowledge that is to be taken as pertinent in an analysis" (Midgley, 2000:35). Evidently establishing the boundaries of a system to be studied can only be done through the discretion of the researcher. In the process the researcher makes use of his or her knowledge and earlier experience about similar problem situations. But the decision to draw the boundaries of the system in a specific way is also unavoidably influenced by the researcher's intuition, preferences and values. Moreover, in this process the researcher will also have to consider the restrictions on the choice of boundaries imposed by the situation itself, the time and resources available to perform the study, knowing that opting for a "wide" system boundary will make the study much more demanding of time and resources than if a "narrow" system boundary is specified instead.

Clearly, the manner in which the boundaries of a system to be studied are established is crucial for the study process as well as for the results – obviously it might even

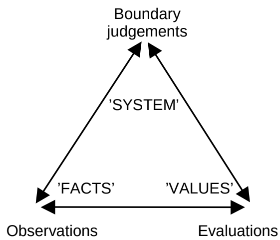

Figure 1.3: The interdependence of boundary judgements, observations, and evaluations. The facts we observe, and the way we evaluate them, depend on how we bound the system of concern. Different value judgements can make us change boundary judgements, which in turn makes the facts look different. Knowledge of new facts can equally make us change boundary judgements, which in turn makes previous evaluations look different, etc. (Source: Ulrich, 2000).

limit the "outcome space," i.e., prevent the study from obtaining all the results which it is in principle *possible* to obtain and that might help improve a problem situation. Thus, an interesting issue is whether it is at all possible to bring decisions concerning the system boundary problem within the domain of rational collective choice. Especially in the systems interventionist framework we discussed above it seems that it would be a good idea, both from a basic, democratic point of view and from an efficiency point of view, if decisions concerning the boundaries of the system to study were made under the explicit consideration of stakeholders' views. An effort to handle this set of problems goes under the name of *boundary critique* (Midgley, 2000). Werner Ulrich has discussed this ever since his comprehensive 1983 study of "critical heuristics." Ulrich (2000) has phrased the general problem thus:

> As a rule, our assessment of the merits and defects of a proposition depends on both observations of fact and judgments of value. What *facts* we observe (e. g. regarding the consequences and possible side effects of a proposed action), and equally what *values* we judge appropriate (e. g. regarding purposes and people to be served), in turn depends on our reference system. The moment we change our *boundary judgements* as to what belongs to the system of concern and what falls outside its boundaries, the relevant facts and values change, too. For example, if we expand the system boundaries, new facts come into the picture. Conversely, new facts can make us change our boundary judgements. For example, if we learn of previously unknown long-term effects of a proposed action, we may want to extend the time horizon we consider. Changing boundary judgements in turn may compel us to adjust our value judgements, which then may make the facts look different, and so on. Thus the boundary judgements strongly influence the way we "see" a situation.

Ulrich illustrates this interdependence in a figure (cf. Figure 1.3). He indicates that it might be possible to "practice systematic boundary critique." He suggests the use of "critical systems heuristics" in "reflective practice." Ulrich's suggestions have been further elaborated by other proponents of a systems "school" labeled "Critical Systems Thinking" (see, e. g., Midgley, 2000). The main thrust of "critical systems heuristics" has been summarized by Ulrich (2001) in the following way:

> An adequate approach to critical systems thinking should provide both a philosophical foundation and a practical operationalization of the critical employment of boundary judgements. Critical Systems Heuristics tries to accomplish precisely this
>
> [...] we must make it clear to ourselves and to all others concerned in what way we (or they) may fail to be comprehensive, by undertaking a systematic effort to identify and challenge the boundary judgements at work. This is what the process of systematic boundary critique is all about. In order to facilitate this process, Critical Heuristics offers a conceptual framework that includes, among other tools, 12 basic boundary concepts and a checklist of corresponding boundary questions. [...]
>
> For me this critical effort of disclosing and questioning boundary judgements serves a purpose that is relevant both ethically and theoretically. It is relevant theoretically because it compels us to consider new 'facts' that we might not consider otherwise; it is relevant ethically because these new facts are likely to affect not only our previous notion of what is empirically true but also our view of what is morally legitimate, that is, our '*values*' or '*norms*'.

Ulrich is also very explicit about the consequences of this position for the notion of knowledge (2001):

> The question of what counts as knowledge, then, is no longer a question of the quality of empirical observations and underpinning theoretical assumptions only; it is now also a question of the 'proper' bounding of the domain of observation and thus of the underpinning value judgements as to what *ought to be* considered the 'relevant' situation of concern. What counts as knowledge is always at the same time a question of *what ought to* count as knowledge. We can no longer ignore the practical-normative dimension of research or relegate it to a non-rational status.

Other authors (e. g. Midgley, 2000; Yolles, 2000) have proposed partly different positions and approaches, but it seems that their opinions have been much influenced by Ulrich.

To end this short overview of the boundary problem, we also want to draw attention to the fact that the position indicated above intentionally serves to *emancipate* the stakeholders in a systemic intervention. The emancipatory goal has been emphasized by the Critical Systems Thinking school further described in the next chapter.

Having looked at the two most fundamental generic problems involved in using a systems approach in science, we conclude this section by listing rather briefly five other types of problem that are also pertinent in most practical systems studies.

4.2.3 The linkage between different kinds of systems

Sometimes different kinds of systems are linked together in the analysis, such as systems models of society and models of the environment, physical-social-cultural systems, etc. The linkage between these different kinds of systems has caused substantial problems in many practical applications. (It is often the inclusion of people's behavior – the human aspects – that has caused most problems in large systems analytical projects.[12]) The question is if any kind of system really *can* be meaningfully linked to any other kind of system and what, in such a case, these linkages of different kinds of systems might look like.

4.2.4 The treatment of general systems properties and its consequences in analysis

There are also a number of "internal" scientific issues that are likely to affect the design and performance of an applied systems study. Various generic system properties are normally discussed, some such properties are considered more problematic and/or important (or interesting) than others. The implications of these properties are also taken into account in various ways in applied analyses, depending on a number of factors, such as which "research technology" (computer power, types of model, etc.) is available in the project, or how "extra-scientific restrictions" (like the knowledge and values of the researcher and other stakeholders, the demands from the funders of the study, etc.) influence the study. Examples of such systems properties are "resilience," "redundancy," "adaptiveness," "dynamics," and "path dependence." Such properties constitute restrictions on the "behavior" of a system, but there is likely to be variation in how the researcher allows these restrictions to affect his analysis, to what extent he is able or willing to analyze and take the implications of these restrictions into account.

4.2.5 The analytical "toolbox" and its effect on the performance of systems studies

To what extent and in what way (if at all) have systems analytical approaches become more interesting with the development of "research technology," i.e., with the growth and increased availability of theoretical knowledge (e. g., in mathematics and modeling), much of which is related to the fast development of computer technology? What is the essence of the interesting "technical" progress affecting the actual conduct of systems studies and the way such studies might be conducted?

4.2.6 Problems related to actors, participants, stakeholders

In which problem situations, which contexts, is a systems approach meaningfully used in science, under what circumstances *can* and *should* it be used? Who decides if a systems approach shall be used? Why is a systems approach chosen? How is the problem formulation affected by various actors/stakeholders? These questions are not only relevant for studies of "social systems" where (normally) a number of actors are involved in the study and affected by its outcome, they are also very relevant for the analysis of "natural systems." The "actor problem" is related to the means that the systems approach offers in terms of communication. The systems theoretical framework provides a "language" that might facilitate communicative clarity and thereby increase

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12 For a discussion and illustration of such linkages, see Anderberg *et al.* (2000:9 ff.). Anderberg, who is also a contributor to the present volume, is here reporting, together with his colleagues, on his experiences from a large research project at the International Institute for Applied Systems Analysis (IIASA) dealing with heavy metal pollution and environmental transition in Central Europe. The authors consider precisely the linkage between different kinds of systems (societal activities, resource use, and pollution) as a great challenge to research.

the trust between analysts and other stakeholders. (Obviously, the problem of trust is also closely related to the "toolbox issue" mentioned above, basically to various actors' competence and their willingness to make use of available competence.)

4.2.7 The implementation problem

It is possible to distinguish two types of implementation problems. One type concerns the way a study of an issue is affected (in its design and performance) by available funding and the accessibility of methods of analysis (including models and computer power). The systems approach (its realism, complexity, etc.) is likely to be affected by the contents of the analytical "toolbox" that is available for use by the analyst. Thus, the framing of the research issue is liable to become dependent on which methods of analysis happen to be known and available. This means that the implementation problem might concern the realization of the research project itself.

There is, however, another, and perhaps more common, interpretation of the implementation problem that has to do with the utilization of the research results. This seems especially relevant for social science research and research where the results are to be used as a basis for changing the performance of the studied system (i.e., the kind of interventionist approaches that are of primary interest in this book). Here we find a number of issues that are closely related to the "actor problem," i.e., the question of who is ordering the research, who is performing the research and how is it performed (to what extent there is communication/collaboration between users and other stakeholders). How should the study be designed and performed in order to make systems intervention possible? In real-world applications, however, one might sometimes suspect that the implementation issue is "reversed" so that the study is designed (and, thus, indirectly the results determined) beforehand in accordance with users' (or funders') expectations of support for measures proposed as a result of the research. That is, study results might be decided beforehand with a view to making them more palatable for stakeholders, thus increasing the chances of successful implementation. To what extent is the research affected by how the research process develops? Again we can clearly see the connection to the "the actor problem," and also to the problem of "trust."

5 Overview of Part II of the Book – A Reader's Guide

The following chapter in this book (Chapter 2) contains an overview of the development of systems thinking and systems theoretical schools. A highly simplified picture of the lines of development is distinguished, the purpose being to illustrate the continuity and also the advancement of systems thinking in scientific analysis.

After the broad overview of systems thinking and the "systems movement" given in the first part of the book we find, in Part II, thirteen chapters, in which a number of Swedish research projects using a systems approach are presented and discussed. The chapters comprising this part of the book have been ordered into three main groups depending on their subject and goals. Thus, the first group of chapters contains descriptions of projects where a systems approach has been used with the primary aim of generating new or better theory (knowledge). This research does not at all, or not primarily, aim at systemic intervention at the societal level. We have brought these chapters together under the label "A Systems Approach for Better Theory."

A second group of chapters appears under the heading of "Systems Analysis for Better Practice." The group is composed of descriptions of research primarily aiming to improve (public and private) decision making. This is the "classical" systems analytical approach tackling "messy" real-world problems in a systematic way for the purpose of effecting changes (improvements) in a problem situation.

A third group of chapters, finally, illustrates research primarily aiming at improving the quality and efficiency of technical systems design and construction. This group is labeled "Systems Thinking for Better Design and Construction." The systems approach to the design and construction of human artifacts actually raises fundamental questions about the relation (and the view and understanding of this relation) between human beings in a social context, their use of theory (and methods of analysis) and the construction of (often complex) "systems" for facilitating or improving life on earth.

The division of the contributions to this volume into three broad categories might seem comprehensive (even complete), but, as we shall presently see, assigning the various contributions to only one of these categories has necessarily been done in a more or less *ad hoc* fashion. Typically, the contributed chapters could not be unambiguously classified in the way suggested by the three identified categories. Each one of the three categories has been assigned some chapters describing research that might well have been appropriately assigned to one or both of the other categories. But still, by and large, the division between the categories makes intuitive sense and, furthermore, the critical discussion of the chapters belonging to the respective categories requires in each case its own focus and approach.

All thirteen chapters to be found in Part II were written especially for this volume. The authors were asked to briefly account for their research, primarily its design and methodology, and also to reflect upon the "generic issues" outlined above that always intervene in the design and performance of any application of a systems approach in science. Evidently, thirteen chapters cannot represent the full spectrum of systems studies performed in Sweden during the last couple of decades. Nevertheless, we do claim that the chapters selected for this volume give a good picture of the kind of work currently performed by systems theorists in Sweden. There is one important area, however, that is not represented in the volume, viz., the well-established systems analytical research in Sweden on transportation systems. This line of research can be found, for instance, at the Royal Institute of Technology in Stockholm and (to some extent) at the Swedish National Road and Transport Institute (VTI) in Linköping.

Let us now turn to a brief overview of the contributions to Part II of the book.

Under the heading of "A Systems Approach for Better Theory" we find four chapters discussing complex issues in different scientific fields. In Chapter 3, Stefan Anderberg reviews the history of systems thinking in human geography and especially the use of systems approaches in environmental geography. The author argues for the use of systems approaches in geography, and indeed claims to have noted a recent increased interest in such approaches in the discipline. Despite serious earlier criticism the development of the global society calls for integrated approaches to solve, for instance, complex problems of socio-economic and environmental planning. Moreover, human geographers using systems approaches today adopt a modest and realistic attitude in their research.

In Chapter 4, computer scientist Magnus Boman and human geographer Einar Holm discuss two different approaches to agent based modeling. This modeling has taken on different forms in computer science as compared with human geography and other social sciences. The authors argue that both sides have a lot to gain from learning and even merging the two approaches.

The authors of Chapter 5, Hans Liljenström and Peter Århem, account for a systems approach in the study of the human brain. The project represents a joint effort of informatics and neurology. The example discussed deals with the olfactory function of the brain. The chapter illustrates how a systems approach can further theoretical development in the study of a very complex organ such as the brain.

In Chapter 6, Harald Sverdrup and Mats Svensson use a systems approach to initiate a structured discussion about methods to make the sustainability concept operationally workable. The authors argue that sustainability has three aspects and thus must be defined along three dimensions: natural, social and economic sustainability. With an example from forestry they discuss some fundamental problems with a methodology for making an integrated assessment of sustainability.

The contribution by E. Anders Eriksson (Chapter 7) starts off the set of chapters dealing with "Systems Analysis for Better Practice." Eriksson brings us right into an ongoing discussion on the principles guiding Swedish defense planning. The issue here – which degree of flexibility could and should efficiently be maintained in military planning in a world where uncertainties have changed in the context of the post-Cold War security environment and the emerging network economy – is discussed within a systems theoretical framework. The author argues that the new real-world qualities require a new type of planning oriented towards broad exploration of possible futures through challenging scenarios and the creation of a wide range of options to enable rapid future adaptation to change.

Chapter 8 by Anita Linell describes a systems analytical study of Sweden's future environmental policy performed during the second half of the 1990's by a large team of researchers and practitioners representing various sectors of Swedish society. The whole project design and the work process were largely guided by systems thinking. The author reflects on the merits of such an approach and notes some problems related to actors and implementation.

As a part of Sweden's current environmental policy the socio-economic effects of environmental pollution are to be assessed in so-called "green national accounts." In Chapter 9, Sofia Ahlroth discusses some of the problems encountered when the traditional national accounts were complemented with physical and monetary environmental accounts.

Anna Björklund (Chapter 10) and Göran Finnveden, Tomas Ekvall and Åsa Moberg (Chapter 11) discuss systems principles underlying methods for assessing environmental impacts resulting from different types of systems and activities in society. The two chapters illustrate how a systems approach can be used to construct frameworks and tools for quantitative assessments of environmental problems.

In Chapter 12, Semida Silveira argues for the use of a systems approach in the study of development problems and for the definition of development strategies. Systems thinking can help us reach a better understanding of the mechanisms constraining the socio-economic development of nations and also allow us to construct aid schemes that are more appropriate for the current technological revolution than conventional programs in operation today.

In Chapter 13, Gunnar Sjöstedt discusses the benefits of a systems approach in the analysis and implementation of international negotiation schemes. The author exemplifies with the negotiations concerning membership of the World Trade Organization (WTO). In particular it is emphasized that a systems approach may be of great value when a holistic view of a complex socio-economic problem situation is essential. It is also argued that the systems approach may be of great value for bridging "communication gaps" between policy analysts and decision makers.

The two final chapters in Part II of the book illustrate the application of systems thinking in the design and construction of modern complex artifacts for enhancing people's quality of life. In Chapter 14, Rune Gustavsson and Martin Fredriksson show how the systems approach can be used in the study of modern integrated technical information systems, which are all highly dependent on viable computer models and reliable real-time data about the situation that the systems are designed to control. A number of fundamental problems related to the construction and use of such systems are discussed. An example provided concerns "e-health," i.e., computer supported systems designed to keep automatic control over the health situation of people afflicted with a chronic disease but residing in their homes.

In Chapter 15, Lena Ewertsson and Lars Ingelstam discuss the relation between society and technology. With perspectives and concepts developed within the field of the history and sociology of science and technology, their focus is on large technical systems (LTS), such as telephone and radio communications networks and transport systems. The authors take their departure in Thomas P. Hughes' writings on LTS. They place the study of LTS clearly in the "systems domain" and they argue for viewing LTS as socio-technical systems, whose heterogeneous technological, social, political, economic, and cultural elements cannot be separated but interact to form complex larger wholes.

Part III of the book contains one chapter. In Chapter 16 Mats-Olov Olsson and Gunnar Sjöstedt discuss and compare the various contributions to Part II.

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