Introduction

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Systems analysis has been with us for several decades now. Like many more or less consolidated domains of intellectual knowledge, it has many different roots, largely corresponding to different constituencies. One reason why systems thinking has become important is its many diverse fields of application for both research and practice. This, in turn, is due to the fundamental function of systems thinking as a widely used and flexible instrument for coping with complexity.

Senior readers will surely be familiar with the systems analytical tradition connected with the RAND corporation in the United States, which further developed the experiences gained during World War II in keeping track of a vast logistical system comprising myriads of items scattered all over the world. All these war-related procurement and logistic processes had to be organized in a firm and efficient way. In this connection the Operations Research line of strategic games was also developed. Here all movements of items were assessed together with issues concerning operational goals, dynamics and alternative paths. Many of the scenario approaches that later became strongly associated with systems analysis were developed in this context.

The large computerized models used in this line of analysis were later modified to meet civilian needs, like traffic planning or regional spatial development management. It is here that the notion of "applied" systems analysis arises. One example is the International Institute for Applied Systems Analysis (IIASA), the institute where such topics are studied. IIASA incorporated the word "Applied" in its name from the outset. The aim was to apply systems thinking in the analysis of real-world problems and the studies were conducted in order to achieve certain practical results. Thus, the linkage to the policy world has always been prominent in this tradition. There has always been a "decision maker" waiting somewhere around the corner for the "advice" of the analyst.

The advanced mathematical tools which are often used in systems analysis relate to another strand of systems theory. I refer to the strand of thought labeled *cybernetics,* where the theoretical issues related to the studied system were developed in mathematical form. There is a connection between the early aspirations in this branch of inquiry and more recent activities concerned with software architecture and artificial intelligence.

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Systems Approaches and Their Application: Examples from Sweden, xi–xvii.
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The interface between systems studies and the technical world has always been of central interest. Many systems analytical approaches have been employed in the production of complex machines. The development of aircraft (like the Swedish JAS fighter) needs the technological systems analysis strand not only for coping with the technical equipment itself, but also for coping with the difficult problems related to the man-machine interface. Handicap and robot technology offers examples in the same field. But we have also seen the emergence, almost as a separate field, of the "large technical systems" studies, incorporating the systems of telecommunications, railroads, etc.

The increasing interest in the environment during the last few decades has broadened the repertoire of systems objects to include the biological sphere, e. g., modeling of rain forest developments or lake eutrophication processes. In the environmental domain we have also seen the need to further relate the performance of ecosystems to the drivers of change in socioeconomic and cultural systems. In this way objects of "sustainable development" have been introduced that call for combinations of earlier disconnected types of logic and ways of approaching these "hybrid phenomena."

Another example of the broadening range of "interest objects" is the gradually increasing use of systems approaches for understanding the brain – lately even applied to human consciousness – which demonstrates lines of investigation with systems approaches as probing tools.

The Systems Approach and Its Varying Domains of Application

The many varying approaches and fields of application have given systems analysis many faces. The readers of this book will be confronted with a number of chapters describing systems analysis in different contexts and serving different purposes. However, the book will also discuss the systems approach in a *holistic perspective;* in terms of variations of a coherent whole. A great number of questions will be addressed in this connection. The following are three examples. "Where should a systems analysis begin?" "Which are the most important causal connections that we need to consider?" "How should system boundaries be defined to include broad features of the study object, while still providing some focus?" Such questions are basic for all types of systems approaches.

In this context "holistic" does not signify uniformity. A system, as it is distinguished in systems analysis, combines many different common basic features. We should, however, note that there is a great variation in the ambition to use formalized methods in the performance of a systems study. Such analyses may, or may not, be connected to varying levels of mathematically formalized techniques. The more "mathematized" approaches can often be characterized with reference to a "toolbox". The Swedish cases of systems thinking that are presented in this book demonstrate great variation in the application of such mathematical tools.

As mentioned above, the varying *styles* used in the application of systems thinking have their correspondence in varying *study objects.* The analysis may address a "natural" system (such as an ecosystem and the brain, etc.) or a "socio-economic" system, or, as is frequently the case nowadays, a combination of both. It may also address a "technical" system, e. g., a technically complex "machine," an infrastructure or computer software. Different study objects impose different demands on a systems analysis and this breeds variation with regard to the way the analysis is actually performed in a particular situation.

Likewise, the reasons for employing systems approaches vary greatly. One reason could be to enhance the "basic understanding" of a phenomenon or situation. This is the main driving force and characteristic feature of the "curiosity driven" research tradition of science. A typical example of such a problem area in systems analysis is "the brain, its functions and consciousness." Whatever knowledge might emerge from such studies it will have one feature in common: it attempts to shed light on inherently complex issues. However, the outcome of systems analyses seldom provides simple blueprints for immediate action.

Still, systems analysis is often strongly oriented towards decision support. Many of the cases that are described in this book illustrate this fact. The objects of such decision oriented studies are often characterized by a natural-scientific issue set in a decision making or planning context. In these cases the ultimate aim of the analysis has typically been to clarify policy choices. In Sweden the practical employment of systems analysis started in areas like defense, energy and transportation, but the fields of application have expanded considerably over time and the variation of analytical approaches in a given policy area has increased.

An important element of such studies has been to design and establish appropriate mechanisms for the communication between science and decision making. Systems analysis will probably continue to support studies performed by governmental commissions in Sweden. The growing need for the government to develop positions in complex international negotiations also calls for similar efforts, as does the underlying complexity of an increasingly integrated global socioeconomic system. The demand for instruments to cope with complexity in decision processes will increase. Without such instruments there is a risk that decision makers will deal with the challenges of complexity simply by chopping the Gordian Knot rather than actually trying to disentangle it, which would require access to a variety of applied systems analytical tools of use for analyzing different problem contexts.

So the question about the future need for the services that the systems analysis tradition can offer is easy to answer. How the systems methodology should be applied to effectively address the large variety of challenging topics is, however, a more difficult question. Issues related to deep uncertainty constitute a pertinent example of this problem. These are issues where it is not possible to eliminate uncertainty, i. e., where it is intrinsic to the system that is being studied.

The study of "technical systems" represents still another field of application of systems analysis where knowledge has been both consolidated and further developed. Examples of foci in this realm are feedbacks in complex engineering practice, different modeling strategies related to non-linear systems, and stabilization challenges.[1] Issues of learning are central in modern applications of systems thinking in hardcore technology areas like ship propulsion systems, thermal systems, vibration control in high-rise buildings, helicopter or satellite controls. It can be expected that high-tech oriented nations like Sweden will continue to draw from systems knowledge in order to keep their industrial competitiveness. Systems thinking facilitates the coupling of technological progress with new societal developments in an increasingly globalized world. Such challenges may represent incentives to shape alliances within the European Union with its similar societal perspectives and administrative/legal traditions.

Continuous Theoretical Development

The future use of systems analysis in various fields of application depends on the advancement of its "scientific core." Some observers might argue that since the initial developments of the theoretical foundations of systems thinking there has been a sort of saturation or even stagnation, both in the general systems approach of von Bertalanffy and his followers and in later game theoretical approaches. We should, however, also take stock of the more recent dynamic theoretical developments, such as various advances in economics associated with seemingly different intellectual traditions covering, e. g., resilience issues in analyses of bio- and eco-systems. Today the increasingly integrated theoretical efforts to understand the "Earth system" – including its natural science as well as its "human dimensions" aspects – is a strong driver for theoretical innovation. The control-theoretical approaches to technology design constitute another example drawn from the area of industrial development. It is clearly premature to consider systems theory as being in a state of general stagnation.

For example, the theories of complexity have fed in new elements, new theoretical structures and new enthusiasm into the field of systems thinking. It is not just by chance that a number of new approaches in climate studies connecting natural science approaches with societal responses, present highly interesting illustrations of this development. New ways of handling resilience in the environmental field or, more generally, the "sustainability domain," are other good examples. The gains in our understanding of the brain that have been made during the last ten years or so are also starting to provide hints concerning the broader issue of the nature of consciousness. These advances have also been conditioned by new developments in systems theory, especially in the junctions between physics, biology, and mathematics. Advances in non-linear economic theory can also be mentioned in this context. We also see entirely new combinations of approaches that will be tried out, e. g., in the conflux of studies of ecosystems, on "carrying capacities", natural resources management regimes, eco-oriented economics, institutional design, and historical (including archeological) resource management based approaches to grand issues like the rise and fall of civilizations.

A workshop arranged in 1984 by the United Nations University in Montpellier,

1 See e. g. Åström, Karl J *et al.*, Eds. (2001). *Control of Complex Systems.* London: Springer Verlag.

France, summarized the main challenges facing systems thinking as follows:[2]

- How could complex systems be approached in terms of simplifications?
- How could data be turned into knowledge? And what is the relation to meaning?
- How could the many facets and varying understandings of complexity be probed?
- What is the relationship to self-organization issues?
- What is the relation to different schemes of causality?
- What does complexity mean in terms of understanding e. g. living systems and consciousness?
- What could be understood by further probing the hierarchization of systems in various forms?

These questions have not yet been fully answered. However, progress has been achieved with regard to the underlying issues. New concepts have been introduced. Developments in core mathematics have been absorbed into systems thinking, e. g., concerning non-linearities and chaotic behavior. Cross-over approaches borrowing from one field for application in another have become more frequent. The merging of bio-/eco-analytical approaches with social science is now standard practice. Today systems analysis can be characterized as a field where novel approaches and methods are unfolding in new areas harmoniously coexisting with more consolidated models used for a wide variety of practical applications.

Institutional Conditions

Systems analysis in Sweden is dependent on a fairly scattered institutional support. Sometimes it has been harbored in research institutions that already provide a degree of "inter-disciplinary breadth," such as often is the case in Technical Universities. In other cases special platforms – for instance in the form of "centers" – have had to be constructed inside universities or within or adjunct to some industrial organization. In the preparation of new environmental policies, or in regional planning, projects using a systems approach have often been set up for a limited period of time (a few years) with a specific decision point in mind (e. g., a Parliamentary decision on a particular topic).

The fact that the "institutional home" of systems analysis varies is a natural consequence of the wide diversity in its use for research, decision making and technology development. The dissimilar purposes and degrees of difference in approaches when it comes to systems analysis usually correspond to factual differences between separate policy areas. A good systems analysis praxis responds to the needs of a particular task and the conditions embodied in the problem context. There is a broad set of tools from which a particular study may select its own combination of analytical instruments.

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2 Aida, Shuhei, Ed. (1985). *The Science and Praxis of Complexity: Contributions to the Symposium Held at Montpellier, France, 9–11 May, 1984.* Tokyo: United Nations University Press.

Nevertheless, the beneficial methodological and institutional pluralism needs to be combined with a national effort to explore common traditions and tools for the purpose of facilitating participation in international efforts to develop systems analytical methods and new fields of application. This is a challenge that requires the attention of systems oriented researchers as well as decision makers in their capacity as users of the results of systems analyses and, ultimately, individual citizens. To meet such a challenge requires the allocation of increased means and efforts in the academic world, the establishment of platforms that might be instrumental in furthering an exchange between the worlds of science and industry, and measures facilitating cooperation between national policy makers and the international world of science.

However, the institutional framework supporting systems approaches in science should be constantly open to reforms. The organizational solutions have not always been sufficiently effective in the past. For example, the capacity of Swedish universities and research centers has often been insufficient for coping with the interdisciplinary challenges that are typical for systems thinking.

The fact that systems analysis is employed in so many and greatly diversified fields of application has led to a situation where the recruitment of new analysts usually occurs within a particular academic discipline. This might lead to a situation where the accumulated wealth of systems analytical knowledge, tools and processes cannot be fully taken advantage of. Thus the challenges for institutional innovation in the area of systems thinking and its analytical applications are considerable.

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Some twenty years ago Per Molander made a stock-taking assessment of systems analysis in Sweden.[3] The present book aims at making a similar overview of the current Swedish situation, although employing a different approach. An initial overview of the situation indicates that there is a *substantial continuity* from the 1980's until now, both with regard to the systems approaches employed by scientists and with regard to the categories of individuals and organizations who use systems analysis. The *capacity to address complexity issues* has increased considerably, e. g., in terms of computer power and the theoretical understanding of issues included in the analysis. The connection between micro and macro analysis is just one example of this. The new design approaches to software architecture are another. Complexity as a topic on its own has gained recognition and also become more consolidated.

Systems thinking will certainly continue to be needed for many purposes, which means that there will continue to be a great variation between individual studies. In this respect significant dimensions are:

- The degree to which there is an *applied* aim directly driving the analysis;

3 Molander, Per (1981). *Systemanalys i Sverige* (Systems Analysis in Sweden), Rapport nr 42-D, oktober 1981. Stockholm: Forskningsrådsnämnden, Delegationen för systemanalys.

- The tension between designing the process in order to get *immediate operational answers* under certain policy boundary conditions, and letting the study process evolve in order to gain deeper *insights* into the system under study;
- The *degree to which mathematics is used* in the approach. Many systems approaches have a strong mathematical core, while others only lightly allude to some type of mathematical formalism;
- The *degree of comprehensiveness* in the approach. This may differ considerably. In some lines of study the *didactic* element may be highlighted by suppressing the aim of every single connected item to be found in the model;
- The nature of the *object of study* may differ: it may be a technological object, a socioeconomic object, a sociotechnical object, a biological object, a geophysical-environmental object or a socioeconomic-ecological object;
- The *degree to which decision making is made an internal or an external part* of the systems analytical effort. This leads to profound differences in the design of the approach.

These broad dimensions in which Swedish systems analysis, or indeed systems thinking in general, can be characterized, have made it necessary in this book to highlight the development in two steps. First, a general presentation is needed of basic ideas of systems thinking as well as of its more elaborated approaches and methods. Second, descriptions of actual cases will be provided where a systems approach has been used for research, decision making and technical development. These cases are intended to illuminate how systems thinking is used in modern applications, what it produces and what the value of these efforts can be for society. These are also the main elements elaborated upon in this book assessing the current use of systems thinking and analysis in Sweden.

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