THE ROLE OF SYSTEM DYNAMICS WITHIN THE SYSTEMS MOVEMENT

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Summary

Systems theory and pertinent methodologies respond to a need of our time, providing adequate responses to complexities manifest in many domains. Several approaches of the systems movement have developed a strong momentum. System dynamics (SD) has proven to be a particularly potent methodology for helping actors cope with complexities in different fields. Its strengths rest on a mature formalism for the modeling of dynamical systems, the generality of which makes it widely applicable. The availability of powerful simulation tools enhances ease of use, sensitivity analysis (See *Sensitivity Analysis*), and model validation (See *Model Validity, Validation and Testing*). Also, potential connectivity with many other tools and methodologies is possible, both conceptually and technically.

System dynamics exhibits a strong record of applications to organizational, societal, and ecological issues. Therefore, specific dimensions, which have often been labeled as "soft," have to be taken into account. These are related to the cultural, communicational, political, ethical, and esthetic dimensions of social systems, and the free will of their actors. Several systems approaches, which have emanated from the interpretive—namely the hermeneutic and phenomenological—traditions of scientific inquiry, have developed specific methodologies or methods to address these aspects.

In the past, the dialogue between the different streams of the systems movement was very limited. Recently, there has been increasing interest, from inside as well as from outside the system dynamics community, in leveraging the complementarities of system

dynamics (SD) and the “soft” systems approaches. The huge potential for mutual learning and reciprocal fertilization is outlined.

1. Introduction

The purpose of this article is to give an overview of the role of system dynamics in the context of the systems movement. “Systems movement”—often referred to briefly as “systemics”—is a broad term, which takes account of the fact that there is no one systems approach, but a range of different ones. Indeed, the evolution of system dynamics methodology, and the worldwide community that applies SD to the modeling and simulation of a multiplicity of realities and in the most different contexts, suggest it is a “systems approach” on its own. Nevertheless, taking “system dynamics” as the (one and only) synonym for “systemic thinking” would go too far, as there are other approaches to systemic thinking as well as a variety of systems theories and methodologies, which—to a certain extent—are complementary to SD. The purpose of this article implies working out the actual and potential relationships between system dynamics and the other strands of the systems movement.

2. The Emergence of the Systems Approach

The systems movement has many roots and facets, with some of its concepts going back as far as ancient Greece. What we call “the systems approach” today materialized in the first half of the twentieth century. At least, two important components should be mentioned, those proposed by von Bertalanffy and by Wiener. Ludwig von Bertalanffy, an American biologist of Austrian origin, developed the idea that organized wholes of any kind should be describable, and to a certain extent explainable, by means of the same categories, and ultimately by one and the same formal apparatus. His *General Systems Theory* triggered a whole movement, which has tried to identify invariant structures and mechanisms across different kinds of organized wholes (for example, hierarchy, teleology, purposefulness, differentiation, morphogenesis, stability, ultrastability, emergence, and evolution).

Norbert Wiener, an American mathematician at Massachusetts Institute of Technology, building on interdisciplinary work he accomplished in cooperation with Bigelow, an IBM engineer, and Rosenblueth, a physiologist, published his seminal book on *Cybernetics*. His work became the transdisciplinary foundation for a new science of capturing, as well as designing control and communication mechanisms in all kinds of dynamical systems. Cyberneticians have been interested in concepts such as information, communication, complexity, autonomy, interdependence, cooperation and conflict, self-production (“autopoiesis”), self-organization, (self-) control, self-reference, and (self-) transformation of complex dynamical systems.

Along the tradition leading to the evolution of general systems theory (Bertalannfy, Boulding, Gerard, Miller, Rapoport) and cybernetics (Wiener, McCulloch, Ashby, Powers, Pask, Beer), a number of roots can be identified, in particular:

- mathematics (for example, Newton, Poincaré, Lyapunov, Lotka, Volterra, Rashevsky);

- logic (for example, Epimenides, Leibniz, Boole, Russell and Whitehead, Goedel, Spencer-Brown);
- biology, including general physiology and neurophysiology (for example, Hippocrates, Cannon, Rosenblueth, McCulloch, Rosen);
- engineering, including its physical and mathematical foundations (for example, Heron, Kepler, Watt, Euler, Fourier, Maxwell, Hertz, Turing, Shannon and Weaver, von Neumann, Walsh); and
- social and human sciences, including economics (for example, Hume, Adam Smith, Ferguson, John Stuart Mill, Dewey, Bateson, Merton, Simon, Piaget).
- In this strand of the systems movement, one focus of inquiry is on the role of feedback in communication and control in (and between) organizations and society, as well as in technical systems. The other focal interest is on the multidimensional nature and the multilevel structures of complex systems. Specific theory building, methodological developments and pertinent applications have occurred at the following levels:
- individual and family levels (for example, systemic psychotherapy, family therapy, holistic medicine, cognitivist therapy, reality therapy);
- organizational and societal levels (for example, managerial cybernetics, organizational cybernetics, sociocybernetics, social systems design, social ecology, learning organizations); and
- the level of complex technical systems (systems engineering).

Furthermore, the notion of "sociotechnical systems" has become widely used in the context of the design of organized wholes involving interactions of people and technology (for instance, Linstone's multi-perspective-framework, known for the mnemonic TOP (*t*echnical, *o*rganizational, *p*ersonal/individual), or de Raadt's theoretical framework, known as MMST (multi-modal systems thinking); the latter brings technology and humanity together and builds on philosophical, ethical, and esthetic considerations). Finally, certain system-theoretical developments that are rooted in Eastern philosophy share the same purpose and, in many aspects, the same view as those coming from the West; for example, the WSR Framework by Gu and Zhu; the mnemonic refers to the Chinese concepts of *W*uli (matter), *S*hili (relations) and *R*enli (involvement).

As can be noted from these preliminaries, different kinds of system theory and methodology have evolved over time. One of these is Jay W. Forrester's theory of dynamical systems, which is a basis for the methodology of system dynamics. In SD, the main emphasis is on the role of structure, and its relationship with the dynamic behavior of systems, modeled as networks of informationally closed feedback loops between stock and flow variables (See *Historical Evolution of SD, its Present and Future, and Intellectual Roots* and *Philosophy of System Dynamics).*

Several other mathematical systems theories, for example, mathematical general systems theory (Pestel, Mesarovic, Takahara), as well as a whole stream of theoretical developments, which can be subsumed under the terms "dynamical systems theory" or "theories of non-linear dynamics," for example, catastrophe theory, chaos theory, complexity theory have been elaborated. Under the latter, branches such as the theory of fractals (Mandelbrot), geometry of behavior (Abraham) and self-organized criticality

(Bak) are subsumed. In this context, the term "sciences of complexity" has also been used.

In addition, a number of essentially mathematical theories, which can be called "system theories," have emerged in different application contexts, examples of which are discernible in such fields as:

- engineering, namely information and communication theory and technology (for example, Kalman filters, Walsh functions, hypercube architectures, automata, cellular automata, artificial intelligence, cybernetic machines, neural nets);
- operations research (for example, modeling theory and simulation methodologies, Markov chains, genetic algorithms, fuzzy control, orthogonal sets, rough sets);
- social sciences, economics in particular (for example, game theory, decision theory); and
- ecology (for example, H. Odum's systems ecology).
- Examples of essentially non-mathematical system theories can be found in many different areas of study, for example:
- economics, namely its institutional/evolutionist strand (Veblen, Myrdal, Boulding);
- sociology (for example, Luhmann's social systems theory, Hall's cultural systems theory);
- political sciences (for example, Easton, Deutsch, Wallerstein);
- anthropology (for example, Levi Strauss's structuralist-functionalist anthropology);
- semiotics (for example, general semantics (Korzybski, Hayakawa, Rapoport)); and
- psychology and psychotherapy (for example, systemic intervention (Bateson, Watzlawick, F. Simon), fractal affect logic (Ciompi)).

Several system-theoretic contributions have merged the quantitative and the qualitative in new ways. This is the case for example in Rapoport's works in game theory as well as general systems theory, Pask's conversation theory, von Foerster's cybernetics of cybernetics (second order cybernetics), and Stafford Beer's opus in managerial cybernetics. In all four cases, mathematical expression is virtuously connected to ethical, philosophical, and epistemological reflection. Further examples are Prigogine's theory of dissipative structures, Mandelbrot's theory of fractals, Kauffman's complexity theory, and Haken's synergetics, all of which combine mathematical analysis and a strong component of qualitative interpretation.

A large number of systems methodologies, with the pertinent threads of systems practice, have emanated from these theoretical developments. Many of them are expounded in detail, under a specific theme of this Encyclopedia, named *Systems Science and Cybernetics* (see *Systems Science and Cybernetics*). In this article, only some of these will be addressed explicitly, in order to shed light on the role of SD as part of the systems movement.

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Biographical Sketch

Markus Schwaninger (Prof. Dr.) is Professor of Management at the University of St. Gallen, Switzerland. He was born in Salzburg, Austria, and holds dual citizenship of Austria and Switzerland. His languages are German (native tongue), French, English, Portuguese, Spanish, Italian, and Latin.

His research focus includes: systems thinking, organizational cybernetics, and system dynamics applied to the study of complex social systems (for example, strategy and integrative management, organization design, management systems, organizational transformation and learning); and Inter- and transdisciplinary studies. He has undertaken research projects for the Swiss National Research Foundation and the EU, and been visiting scholar at universities in the United Kingdom (Aston), the United States (M.I.T.) and Canada (U.B.C.).

He has presented courses and undertaken consulting assignments on four continents. He has worked as a consultant to private firms and public organizations, including governmental institutions at federal and state levels, and has led seminars for executives in 12 countries. He has presented guest lectures and seminars at universities in Austria, Brazil, Canada, England, Germany, Hong Kong, Italy, Poland, Spain, Sweden, Switzerland, and the United States. He has undertaken **v**isiting professorships at: Fundação Getúlio Vargas/São Paulo School of Management, Brazil; Universidad de los Andes, Bogotá, Colombia; Universidad de Las Palmas de Gran Canaria, Spain; George Washington University, Washington DC, USA.

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Professor Schwaninger has authored approximately 150 publications in six languages, including books published by Wiley, Chichester; Campus, Frankfurt/New York; Haupt, Berne; and Duncker & Humblot, Berlin. Among his publications are: *Corporate Transformation and Learning: A Cybernetic Approach to Management*, Chichester: Wiley, 1996 (Co-authored with Espejo, Schuhmann, and Bilello); *To Be and Not to Be, that Is the System: A Tribute to Stafford Beer*, CD-ROM, Wiesbaden: Carl Auer-Systeme Verlag, 1998 (Co-edited with Raúl Espejo); and *Intelligente Organisationen*, Berlin: Duncker & Humblot, 1999.