SYSTEM SCIENCE TRADITIONS: DIFFERING PHILOSOPHICAL ASSUMPTIONS

by

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Abstract
It is in vogue to "take a systems approach," yet what exactly a *systems approach* is varies considerably depending upon the systems science tradition examined. Systems science traditions tend to share a set of underlying assumptions which are less common in other scientific fields. Still, philosophical assumptions are not common across systems science traditions. We examine six traditions within systems science -- cybernetics, general systems theory, organizational learning, operations research, total quality management, and system dynamics. We then consider seven underlying assumptions -- self-organization, observation, causality, reflexivity, predictability, environment, and relationships. Finally, we assess where each tradition stands with respect to each of the underlying assumptions.

[1]Currently, it is fashionable to take a "systems approach" to just about anything. In fact, taking a systems approach is considered the mark of someone who can understand the big picture - a policymaker who understands the interrelationships of all of the important variables, the executive who has an (intuitive) grasp of the complexities of a business. People who don't take a systems view are described as narrow-minded, limited in perspective, and linear-thinking. Since taking a systems approach seems so desirable, the question arises, what does it mean to take a systems approach? One clear distinction is that all systems approaches purport to take a holistic rather than a reductionist view (Jackson, 1991, p. 7). To judge by the frequency with which the word *systems* is used in everyday conversation, one might suppose that the terms *systems approach, systems thinking*, and *systems view* were commonly understood. This does not appear, however, to be the case. Many theorists, researchers, and practitioners are using these terms, but often with very different meanings. Umpleby and Dent (1999) provides an excellent historical overview of the same six traditions of systems science described below.

[1] This paper is the product of a body of research conducted jointly with Stuart A. Umpleby. His input and critique throughout the process have been invaluable.

We examine six schools or traditions within systems science: cybernetics, general systems theory, organizational learning, operations research, total quality management,[2] and system dynamics by selecting a relatively recent work in that tradition which is representative of the philosophy of that tradition[3]. We then consider seven underlying assumptions on which each field takes a position and which are important in defining differences among the various traditions. The seven underlying assumptions are: unit of analysis, environment, causality, reflexivity, predictability, observation, and self-organization. Because these systems thinking traditions focus more on practice than theory, systems theorists generally have not adequately explored the philosophical assumptions upon which their traditions stand (Jackson, 1991, pps. 3-4).

KEY UNDERLYING ASSUMPTIONS OF SYSTEMS APPROACHES

Unit of Analysis

Another underlying assumption shared by many systems traditions is that the unit of analysis should be relationships rather than entities. Entities only take on definition when they are in interaction with each other. It makes little sense to study a woman for example. The richness of her experience becomes much more apparent when she is studied in relationship to her husband, her sister, her subordinates, her friends, etc. A proponent of this assumption is

[2] Many do not consider TQM to be a systems science. We include it here because it seems to meet the criteria of a systems approach in practice, although not in language (as this paper will demonstrate).

[3] This paper does not address soft systems methodology, viable system model, social systems sciences, artificial intelligence, complexity theory, family therapy, or many other traditions which might have been included.

Gregory Bateson who argued that relationships should be used as a basis for all definitions, and that this should be taught to our children in elementary school (Bateson, 1979, p. 17). The alternative view is that the unit of analysis is an entity - the world is comprised of distinct entities which themselves are fruitful objects of study. It is especially useful to understand the basic building blocks of phenomena.

Environment

Another underlying assumption of several systems traditions is that the environment plays a role in the manifestation of the phenomenon (environment-full). The environment is central to understanding and explanation. Ackoff (1981) suggests that in situations which he refers to as producer-product, any principle or explanation offered must stipulate the conditions under which the principle applies. If the principle were to apply in all conditions, then the environmental conditions are not co-producers of the effect.

The alternative view is that the environment does not matter (environment-free). The laboratory and its rules often explicitly omit the environment. The second law of thermodynamics, for example, stipulates that it is operational only when entities are left to themselves. In the Law of Freely Falling Bodies, "freely" means "in a vacuum," which is in the absence of any environmental influences.

Causality

Assumptions about cause and effect, as well as those pertaining to observation and level of explanation (holism or reductionism) give the best indication of worldview (Dent, 1999). A concern with circular causality as opposed to linear causality was a key issue leading to the establishment of several systems science traditions. Most writers on the subject of cause and effect begin with David Hume who in 1748 suggested three requirements - association, direction of influence, and nonspuriousness - which he said are necessary (but not sufficient) to demonstrate causation (Singleton, Straits, and Straits, 1993).

Predictability

The assumption of indeterminism is that at times it is "inherently impossible to determine in advance which direction change will take" (Prigogine and Stengers, 1984, p. xv). The alternative view is that "conclusions can be precisely drawn from a set of known variables" (Dent, 1995, p. 13-5).

As noted by von Bertalanffy (1968), "[classical science is] essentially concerned with two-variable problems, linear causal trains, one cause and one effect, or with few variables at the most. The classical example is mechanics [in physics]" (p. 12). Postmodernists, also, have coined the term Fordism to connote the direct-causal mindset "characterized by the semi-automatic assembly line, organizing work into a straight forward linear flow of transformations applied to raw materials" (Clegg, 1990, p. 177).

Reflexivity

The primary question under the label of reflexivity is, Is the system composed of knowing subjects with characteristics such as the following: they are

able to generate new states in themselves (think new thoughts, do new things) that they never manifested before. Indeed, they are best thought of as continually *trying* to generate such new states... [They] have the property of being able to notice your attempts to theorize about them and model them, and they modify themselves according to their reaction to this information. (Vaill, 1996, p. 117)

The opposite assumption is that the system in question is not comprised of knowing subjects.

Observation

A key belief underlying classical science was that observations are independent of the characteristics of the observer. Objectivity was possible if one assumed that very different people looking at the same phenomenon in the same way would create similar descriptions. In recent years, due in part to studies of the nervous system, more attention has been paid to subjectivity and to including the observer within the domain of descriptions. According to this point of view observers have immediate access only to their experience, and a "reality" is constructed by each observer. Hence, there are constructivists, who emphasize perception, conversation and reality construction and there are realists who assume that descriptions can be accurate representations of an external world.

Self-organization

"Self-organization" occurs when the elements of a system change states largely independently of specific causes. The opposite assumption is that one or a small number of causes affect the elements of a system. Clemson (1984), for example, writes "Complex systems organize themselves; the characteristic structural and behavioral patterns in a complex system are primarily a result of the interactions among the system parts" (p. 26). Systems scientists claim that all systems self-organize, but some authors emphasize this phenomenon more than others.

Next we will explore a relatively recent work in the six traditions of systems science discussed in this paper. Each makes assumptions in the seven philosophical areas described above. Table 1. provides a gross reduction of the underlying assumptions across the six traditions.

Table 1. Major Philosophical Assumptions of Six Systems Science Traditions.

Assumptions	Systems Approaches Sources						
	Miser & Quade	**Joiner**	**Argyris & Schön**	**Maturana &Varela**	**Meadows & Robinson**	**Rapoport**	**TOTAL**
UNIT of ANALYSIS interaction/relationship (or an entity)	Yes	Yes	Yes	Yes	Yes	Yes	**6**
ENVIRONMENT environment-full (or environment-free)	Yes	Yes	Yes	Yes	Yes	Yes	**6**
CAUSALITY indirect, non-proportional, circular (or direct, proportional, linear)	Yes	Yes	Yes	Yes	Yes	Yes	**6**
REFLEXIVITY knowing subjects (or not-knowing)	Mostly, No	Yes	Yes	Yes	No	Yes	**4**
PREDICTABILITY probable or indeterminate (or predictable or determinate)	Yes	No	No	Yes	No	Mostly, Yes	**3**
OBSERVATION constructivism (or realism)	No	No	Yes	Yes	Mostly, No	Mostly, No	**2**
SELF-ORGANIZATION self-organizing (or expert-organizing)	No	No	No	Yes	No	No	**1**
	4	**4**	**5**	**7**	**3**	**5**	

PORTRAYAL of the UNDERLYING ASSUMPTIONS of SYSTEMS APPROACHES

Cybernetics

The Tree of Knowledge: The Biological Roots of Human Understanding (1987) by Humberto R. Maturana and Francisco J. Varela is representative of recent work in the area of cybernetics. Maturana and Varela claim to have written an “alternative view of the biological roots of understanding” (p. 9) which does not coincide with mainstream views on this subject. Their primary distinction is that they “propose a way of seeing cognition not as a representation of the world ‘out there,’ but rather as an ongoing bringing forth of a world through the process of living itself” (p. 9). Their primary thesis is “that evolution occurs as a phenomenon of structural drift under ongoing phylogenetic selection. In that phenomenon there is no program or optimization of the use of the individual, but only conservation of adaptation and autopoiesis. It is a process in which organism and individual remain in a continuous structural coupling” (p. 115).

Underlying Assumptions of Cybernetics

Unit of Analysis - It is clear from many statements, such as, a "system is a unit of many interdependencies" (p. 166) that Maturana and Varela assume a relationship or interaction is a more fruitful unit of analysis than any single entity. Further support of their belief is found in the way they define language as "an ongoing process that only exists as languaging, not as isolated items of behavior" (p. 210).

Environment - Maturana and Varela assume the importance of the environment or context of any phenomenon. For example, they argue that "the evaluation of whether there is knowledge is made always in a relational context" (p. 174). Their book contains many other examples of differences in how certain species behave or develop depending on the environment.

Causality - Maturana and Varela demonstrate their focus on feedback loops when they remind the reader that there is always a circularity between action and experience (p. 26). They also provide evidence of their belief in the indirectness of phenomena. For example, they maintain that the knowledge generation process “does not consist of a linear explanation that begins with a solid starting point and develops to completion as everything becomes explained” (p. 244).

Maturana and Varela make mutually causal assumptions throughout their book. For example, they suggest that “what is distinctive about [living beings], however, is that their organization is such that their only product is themselves, with no separation between producer and product. The being and doing of an autopoietic unity is inseparable (pps. 48-49).

Reflexivity - Reflexivity is also an important topic for Maturana and Varela. This assumption pervades their writing probably more so than any of the other authors examined in this paper. Perhaps their belief is best captured in their statement, “maybe one of the reasons why we avoid tapping the roots of our knowledge is that it gives us a slightly dizzy sensation due to the circularity entailed in using the instrument of analysis to analyze the instrument of analysis” (p. 24).

Predictability - Maturana and Varela assume indeterminism. They present an internal paradox many people feel. People very much want to be able to predict things. They want to know, for example, that when they take medicine, the outcome will be predictable. Yet, at the same time, "we resist the idea that we are determined, explainable , and predictable[4] beings. We cherish our free will and want to be beyond determinism" (p. 122). The authors note that much of the analysis of the world and biological systems has been done assuming determinism. Maturana and Varela conclude that we as observers, live in a world in which we cannot develop deterministic equations for what will happen.

Observation - The topic of observation is an important one for Maturana and Varela. Their chapter one is entitled, "Knowing How We Know" and the largest part of chapter ten has the same heading. The distinction they draw about their assumptions concerning observation is what is described above as a defining difference between their work and mainstream biological theories. Their philosophical basis is clear in statements such as,

> Therefore, underlying everything we shall say is the constant awareness that the phenomena of knowing cannot be taken as though they were "facts" or objects out there that we grasp and store in our head (p. 25).

Self-organization - Perhaps because their subject matter is biological evolution, Maturana and Varela assume that systems are self-organizing. In fact, possibly in opposition to creationists, they frequently hint that an intelligent designer was not necessary for the evolution experienced in nature. An example of their assumption of self-organizing is their description of an autopoietic system which "pulls itself up by its own bootstraps and becomes distinct

[4] Maturana and Varela also make a distinction between determinism and predictability, which is beyond the purposes of this paper.

from its environment through its own dynamics, in such a way that both things are inseparable" (pps. 46-47).

General Systems Theory

General Systems Theory: Essential Concepts and Applications by Anatol Rapoport (1986) is representative of recent work in the area of general systems theory. A major goal of general systems theorists is to construct a unifying theory consisting of "integrating principles sufficiently general to apply to many different contexts: physical, biological, psychological, and social" (preface). The most important function of general systems theory is to make "thinking in terms of analogies, the basis of all searching for 'explanation' (probably a basic human need) sharper, broader, and above all, disciplined, as to satisfy the standards of scientific cognition" (p. 259). Rapoport's specific purpose in this book is to integrate the analytic and holistic perspectives, as well as the descriptive and normative perspectives (p. 7).

Rapoport places general systems theory within the confines of classical science (p. 220). At the same time, general system theorists "resort freely to non rigorous, even metaphorical, language when we feel that some understanding can be gained from such discourse" (p. 31). Their preference is for mathematical representation, rigor, analysis, and operational definitions while also valuing introspective inquiry. Consequently, the applications of general systems theory are somewhat different than the applications of classical science.

> General systems theory represents an outlook or a direction rather than a scientific theory.... [Its applications] become relevant if 'application' is seen as a two-stage process. The first stage is the impact of a particular *way of thinking* on the development of knowledge. The second stage is the actual application of this *new form* of thinking (p. 220).

The Underlying Assumptions of General Systems Theory

Unit of Analysis - Rapoport suggests that systems seen holistically are defined as a network of relations (p. 79). Consistent with the most important function of general systems theory listed above, Rapoport notes "Analogy enters practically all explanations, since to explain something is to relate something not yet understood to something understood, which is done with the help of analogies" (p. 14). Analogy is defined as the perceived invariance of relationship. What is of greatest significance is the interactions of states rather than the states themselves.

Environment - Rapoport argues for the importance of the environment in the explication of fundamental principles. He suggests that this is only "common sense" (p. 10). Many people write A causes B, which causes C, etc. In real life, however, categorically necessary or categorically sufficient conditions are rare. Rapoport is also critical of the well-known model of communication in which there is a sender and receiver, with processes of encoding, transmitting, and decoding. The inadequacy of this model is that communication is primarily a matter of inference, and the inference involves knowing the receiver's previous experiences and inferences about events in the environment (pps. 141-142).

Causality - Rapoport is, likewise, critical of the classic cause and effect relationship. He suggests that the "fixation on unidirectionality" (p. 11) leads to endless fruitless debates such as whether mistrust instigates an arms race or an arms race generates mistrust. For Rapoport, "very few causes turn out to be either necessary or sufficient for particular effects. What is even more significant from the point of view of 'application' as conventionally conceived, very few manipulations produce *only* the expected or *only* the desired effects" (p. 221). Yet, Rapoport is equally critical of the "everything is related to everything else" viewpoint.

Reflexivity - The knowing subject is not a frequent topic of discussion for Rapoport. Still, whenever he addresses the topic, it is clear that he considers reflexivity. He provides the example of the second order adaptation of insects to pesticides. Resistance to the earliest chemical took over forty years to develop. The timeframe dropped to nine years for the second chemical, and subsequently, three years.

Predictability - Rapoport's writing seems somewhat ambivalent on the topic of predictability. He respects the prediction and control paradigm of classical science. Yet, he notes that "prediction and control are not the only rewards of scientific cognition. Equally important, in fact, even more important in some areas are understanding and emancipation" (p. 259). Predictability is not directly addressed by Rapoport, but implicit in his writing is the assumption of indeterminism.

Observation - Rapoport's assumption is very similar to Meadows and Robinson below. The only aspect of a realist ontology which Rapoport discusses differently is the values orientation of the observer. He contrasts objective observation with value-oriented observation, not constructivism (p. 34). He writes, for example, "Even the most rigourous application of the verifiability criteria of 'truth' leads, in the last analysis, to introspective verification" (p. 32).

Self-organization - Rapoport does not describe systems as self-organizing.

Organizational Learning

Organizational Learning II: Theory, Method, and Practice (1996) by Chris Argyris and Donald A. Schön is representative of recent work in the area of organizational learning. The field of organizational learning is, perhaps, the newest of the systems disciplines we consider in this paper. The term *organizational learning* may not have appeared in the literature until the late 1960s.

Argyris and Schön sketch the current state of work on the topic of organizational learning. They then reintroduce their concepts of single and double-loop learning(1974), and the espoused theory vs. the theory-in-use (1974), which are critical for their distinction between the organizational theories-in-use, model O-I and model O-II (The "O-" prefix designates an organizational theory-in-use rather than an individual one). Model I values: defining goals and trying to achieve them, maximizing winning and minimizing losing, minimizing generation or expression of negative feelings, and being rational. These values are operationalized in the following action strategies: design and manage the environment unilaterally, own and control the task, unilaterally protect yourself, and unilaterally protect others from being hurt (pp. 92-94).

Argyris and Schön offer that all of the organizations they have worked with exhibit Model I behavior (at least initially). Model I behaviors are self-reinforcing and self-sealing because they place people in double binds and because a feature of Model I is making actions that are threatening or potentially embarrassing undiscussable. Argyris and Schön maintain that Model

II is more productive for organizations because it leads to double loop learning. Important values in Model II are: valid information; free and informed choice; and internal commitment to the choice and constant monitoring of its implementation. Model II action strategies include: “design situations where participants can be origins of action and experience high personal causation, [the] task is jointly controlled, protection of self is a joint enterprise and oriented toward growth, and bilateral protection of others” (p. 118).

Argyris and Schön see two major tasks for those assisting in organizational learning. The first step, described below, consists of surfacing the dysfunctional Model I behavior in the organization. The second step is to develop a strategy for short-circuiting the dysfunctional behaviors when they occur and establishing productive, Model II behaviors. Part of this second step is for any outside consultants to transfer the skills of this second step so that organizational members can perform them without assistance.

Underlying Assumptions of Organizational Learning

Unit of Analysis - Organizational learning theorists see organizational actions as their unit of analysis rather than employees of the organization, for example (p. 8). More specifically, they focus on the interactions between individuals, and the interactions between individual and organizational phenomena (p. 188).

Environment - The environment of these interactions is also of importance. Argyris and Schön suggest that “the very process of inquiring, individual or collective, is conditioned by membership in a social system that establishes an inquiry’s taken-for-granted assumptions” (p. 33). The assumptions vary depending on the context of the social system within which the inquiry takes place.

Causality - Argyris and Schön place a strong emphasis on the identification of feedback loops which are often implicit[5]. They provide some excellent examples of how typical actions taken by managers can result in an outcome which is the opposite of what was intended. For example, if an organization implements a pay-for-performance reward system, managers will learn to soften the criticism in their performance appraisals to avoid grievance actions, which will increase because the performance appraisal now has additional, important meaning. Thus, performance appraisals will be inflated, raising the cost of labor. The rising cost of labor will alert upper-level managers to implement other ways of reducing the cost of labor. Consequently, “the system of pay-for-performance, originally intended to improve productivity, turns out to have the cumulative effect of rewarding mediocre performance and increasing the cynicism of the supervisors” (p. 40).

Reflexivity - Argyris and Schön include 11 main features to their approach to organizations. Item eight in this list, “practitioners...capable of reflecting on their own inquiry (“inquiring into inquiry,” as Dewey put it.)” (p. xxiii) demonstrates their belief in the underlying assumption of

[5] In fact, the authors suggest that organizations often design ways for employees to be blind to causal feedback loops.

systems being composed of thinking entities. They also ascribe to the assumption that theories have an effect on the systems they describe. As an example, they provide their finding that when people create an organization map, the "participants are too easily willing to confirm a map if they believe the end result is only research knowledge" (p. 155), but they will show greater concern for the accuracy of the map if they know they will be involved with using it in the future.

Predictability - Argyris and Schön do not address indeterminism in any explicit or implicit way. Therefore, we assume they hold the assumption of the traditional worldview (Dent, 1999), determinism.

Observation - The topic of observation does not receive much attention in Argyris and Schön (1996). Nonetheless, a few statements suggest that Argyris and Schön assume a constructivist epistemology. For example, they write, "Each member of an organization constructs his own representation of the theory-in-use of the whole, but his picture is always incomplete" (p. 15). They also place themselves at odds with positivists in the goals of their research and the nature of the causal relationships they deem important.

> According to the normal-social-science model of causality, probabilistic covering laws may be inferred from data provided by either of two empirical methods: "contrived experiment" or "natural experiment." Researchers...avoid referring to their subjects' intentions, which they regard as subjective, idiosyncratic and qualitative -- unsuited to the generality, quantitativeness and context-independence that are essential to the normal-social-science model.... In everyday practice, on the contrary, organizational practitioners ... [connect] an actor's intention to the action he or she designs in order to realize that intention... to put the same idea in different terms, we describe the reasonings that led up to the action, not the reasoning by which the action might be justified after the fact. (p. 39)

Moreover, Argyris and Schön assume that "the act of inquiry influences the situation inquired into" (p. 49). They accept that the interview process -- by virtue of the questions, the interactions with the interviewer, the nonverbal communication -- has an effect on the way an interviewee will construct meaning, as well as whether the interviewee will choose to be honest and open in sharing his or her information.

Self-Organization - Likewise, Argyris and Schön do not mention self-organization in their work. Consequently, we conclude they do not hold this assumption.

Operations Research or Systems Analysis

Handbook of Systems Analysis (1985) edited by Hugh Miser, Jr. and Edward Quade is representative of recent work in the area of operations research. Miser and Quade date their discipline to the 1940s. The term *systems analysis* was adopted in 1947 to differentiate this body of work from *operations research.* Systems analysts also distinguish themselves from general systems theorists, whom they describe as "classifying systems or ... discovering properties common to systems.

The editors suggest that the term operations research is synonymous with their work, which they prefer to call *systems analysis*. The typical problems addressed by systems analysis are those "relatively easy to structure and in which some important aspect is dominated by technology" (p. xii). Only recently has systems analysis been applied to systems with a significant human component.

Miser and Quade see their expertise as lying at the nexus of issues affecting society, enterprises, and the environment. Such issues involve a number of variables and the system effects are widely distributed in both space and time. These systems analyses typically are performed by multi-disciplinary teams. Systems analysts commonly follow a nine-step approach, although the steps may occur in a different order (p. 16).

These analysts use the scientific method, but do not see their work as a separate science. They relate it to engineering, which can be characterized as an applied science. Such an applied science employs the methods of science, but also involves many aspects of a craft.

Systems analyses often include mathematical or computer model building, but the field is not limited to modeling.

Underlying Assumptions of Systems Analysis

Unit of Analysis - The assumption of "relationship as unit of analysis" is built into the foundation of systems analysis. The discipline was essentially created to focus on problems "arising from interactions among elements in society, enterprises and the environment" (Quade and Miser, 1985, p. 2). Systems analysts also display a strong appreciation for the interdependence of phenomena. They point out that the traditional form of sensitivity testing is often inadequate. This form varies a single parameter at a time. However, "it is almost always necessary to test the interactive variation by changing more than one factor at once." (Quade, 1985, p. 211).

Environment - Systems analysts display a strong belief in the assumption that the problems they work on are heavily determined by the environment. They accept the important distinction made by Schön:

> From the perspective of Technical Rationality, professional practice is a process of problem *solving*. Problems of choice or decision are solved through the selection, from available means, of the one best suited to established ends. But with this emphasis on problem solving, we ignore problem *setting,* the process by which we define the decision to be made, the ends to be achieved, the means which may be chosen. In real-world practice, problems do not present themselves to the practitioners as givens. They must be constructed from the materials of problematic situations that professionals are coming increasingly to see as central to their practice. (Schön, 1983, pp. 39-41, quoted in Miser, 1985, p. 288).

Causality - Systems analysis is imbued with an emphasis on identifying feedback loops. These analysts very much see their work as surfacing feedback loops which are present but are not apparent to the lay person. This identification of cause and effect relationships is one of the hallmarks of systems analysis. At the same time, there are many examples of a direct, sequential emphasis in this book. The systems analysis approach is listed as nine sequential steps[6] (Quade and Miser, 1985, p. 16). In the chapter, "The Methodology of Systems Analysis: An Introduction and Overview" by Wladyslaw Findeisen and Edward S. Quade, the authors provide a very linear framework for the discipline, including a flowchart which shows only direct, linearly causal links (pps. 122-123). Also, these researchers state a preference for linear models which simplify the mathematics (Quade, 1985, p. 206). Although a caution is provided that the linear model may represent an oversimplification of the situation, there is no real discussion of this caution, and no examples of alternative procedures are provided.

[6] The authors do hint that the steps may not always be taken in that order, but this hint is not given much attention thereafter.

Reflexivity - The topic of reflexivity does not appear in this book. The authors admit that only recently has systems analysis been applied to human systems, and that it is too early to include experiences with human systems in a handbook on systems analysis (p. xii). There is no stated recognition that ideas or actions on a system are internalized by a "knowing subject."

Predictability - Systems analysts make probabilistic rather than deterministic assumptions. They state, "We are well aware that the future can at best be determined only in a probabilistic way" (Findeisen and Quade, 1985, p. 138). Examples provided throughout the book employ this probabilistic assumption. Systems analysts also assume that their role is to predict, rather than to explain or to understand. As stated above, the discipline is very practical. Systems analysis is applied to specific projects and problems. Systems analysts are serving as experts who are expected to provide answers, which often means, accurate predictions.

Observation - Miser, Quade, and their chapter authors occasionally employ an epistemology in which the observations of inquirers are dependent on the characteristics of the inquirers. Checkland, for example, notes that the systems analysis process is one which "continually enriches the perception of problems" (Checkland, 1985, p. 152). He warns systems analysts that they should not be beholden to a single point of view. However, in general systems analysts hold a number of assumptions consistent with realism. Miser and Quade include a quotation which suggests that facts are the primary coin of science. Science must begin with facts and end with facts (Quade and Miser, 1985, p. 19).

Self-organization

As with reflexivity, the topic of self-organizing systems is not discussed in the *Handbook of Systems Analysis*.

Total Quality Management

Fourth Generation Management by Brian Joiner (1994) is representative of recent work in the area of total quality management (TQM). Joiner's book is a very practical, hands-on text written for practicing managers. The book references only other books that are also written for practitioners. He extends the field of TQM by maintaining that a new system of management is required, not just a focus on quality. Joiner refers to the new system as the Joiner Triangle (p. 11) which consists of three primary components.

1. Quality - Quality is defined by the customer and is the shared responsibility of every employee.
2. Scientific Approach - "Learning to manage the organization as a system, developing process thinking, basing decisions on data, and understanding variation" (p. 11).
3. All One Team - Fostering dignity, trust, and respect throughout the organization and working toward win-win solutions with all stakeholders.

Joiner and his mentor, W. Edwards Deming, were trained as statisticians. Consequently, the largest part of the book is the section on "Managing in a Variable World." Joiner raises the important distinction between sources of variation which come from special causes and those that come from common causes. This idea is foundational in fourth generation management. The job of managers is to develop processes which identify errors, determine whether those errors are special causes or common causes, and take appropriate corrective actions. These actions must take place in a dignifying environment.

Underlying Assumptions of Total Quality Management

Unit of Analysis - On the question of unit of analysis, Joiner writes, "to manage our organizations more effectively, we must begin to think more in terms of relationships than of independent components," (p. 25).

Environment - Joiner does not explicitly point out any particular significance to the environment, or to the context of his approach. Yet, one of the great contributions of Deming was to get executives to see their organizations not as the “black box” to be managed, but sited within an environment which includes suppliers, customers, and other external factors.

Causality - Joiner makes no reference to the possibility of circular causal phenomena. In fact, most of the tools he writes about (control charts, bar charts, etc.) are not able to portray circular causal phenomena. Joiner does not address what are commonly known as the “Seven Helpful Charts used in TQM. However, he does ally himself with people who have written extensively about them, such as Deming and Ishikawa (Joiner, 1994, p. 5). The seven charts - cause-and-effect (or fishbone diagrams), flow charts, Pareto charts, run charts, histograms, control charts, and scatter diagrams - are all based upon direct, sequential assumptions. They cannot be used to surface indirect causal chains. A cause-and-effect diagram, for example, cannot be drawn if there are loops in the causal chain or if there are mutually causal phenomena. The 7-step improvement method that Joiner advocates is also sequential, with little or no recognition of any non-linearities in the improvement process.

The direct causal assumption of these tools seems surprising because *Fourth Generation*

Management is otherwise very clear about the complexity of causality. Joiner writes, “The interdependencies within any system are often exceedingly complex and widely separated in time and space” (p. 30).

Reflexivity - Joiner includes in his book many prescriptions which are reflexive in nature. Perhaps the most prominent example is the inclusion of an entire chapter, “Improving our Ability to Improve.” In this chapter, he suggests that improvement efforts in an organization should themselves be viewed as a system which should be improved using the same philosophy and techniques of fourth generation management. This chapter includes several examples of Joiner’s belief that theories do have an effect on the systems they describe.

Predictability - *Fourth Generation Management* contains little or no discussion about assumptions of indeterminism vs. determinism or understanding vs. prediction. The most important clue to this assumption is the strongly worded statement, “A fundamental tenet of 4^{th} Generation Management is that nothing happens in a predictable, sustained way unless you build mechanisms that *cause* it to happen in a predictable, sustained way” (p. 79). As mentioned earlier, we will infer from the absence of discussion about an underlying assumption that the assumption held is the conventional one. In this case, it appears that Joiner assumes determinism, and seeks prediction as the outcome of his approach to systems.

Observation - Joiner states that individuals create their own mental models of the world. He provides examples of how people “see” only what their mental model allows them to see. Since the book is practical in nature, there is little or no discussion of epistemological issues.

Yet, it seems clear that Joiner is not a constructivist. An underlying theme of the book is that by understanding variation, managers can discover what is "really" happening in the world.

Self-Organization - Joiner does not discuss self-organizing systems.

System Dynamics

The Electronic Oracle by Donella Meadows and Jenny Robinson (1985) is representative of recent work in the area of system dynamics. Meadows and Robinson present an overview of system dynamics and compare and contrast it with econometrics, input-output analysis, and optimization. Much of the book is then devoted to exploring several highly-regarded models from each of these disciplines. System dynamics is a tradition of modeling which originated at Massachusetts Institute of Technology with the work of Jay Forrester. It consists of ideas brought together from control engineering, cybernetics, and organization theory (p. 27). System dynamicists create models which are closed, feedback-dominated, non-linear, and time-delayed (p. 38) and apply them to situations which seem to match these characteristics - economic development, global pollution, agricultural sustainability, population growth and so forth.

<u>The Underlying Assumptions of System Dynamics</u>

Unit of Analysis - System dynamicists are "purists" about the relationship as the appropriate unit of analysis. In fact, they have been criticized (p. 76) for their heavy emphasis on seeing analogies between various systems and having less concern for the particular elements of a given system. Within system dynamics, a body of archetypes has been built up, including such analogies as the "tragedy of the commons" in which each individual's incentive is to overuse a common resource.

Environment - Meadows and Robinson make environment-full assumptions. They suggest that system dynamicists are taught to be aware of and include explicitly environmental factors, desires, expectations, perceptions, goals, and assumptions (p. 38). The models they create allow for producer-product causal chains.

Causality - Meadows and Robinson assert circular causality. In their definition of causality they also note that causal relationships can go in both directions (p. 11). Moreover, their models allow for simultaneous causal relationships in which "elements respond to each other fully within a time period so short as to be insignificant for purposes of the model" (p. 23).

Reflexivity - Reflexivity is not a topic addressed by Meadows and Robinson. Such modelers do try to include all kinds of intangible factors, but they do not allow for the system components to change by virtue of their being modeled.

Predictability - Meadows and Robinson make deterministic assumptions. Their perspective is nicely captured in their statement,

> They assume that human actions and purposes as well as the operations of the physical universe can be categorized, quantified, and represented by mathematical equations. This postulate does not necessarily imply, as many non-modelers believe it does, a belief that human beings or the systems they create are totally predictable. It does require a belief that they are predictable in the aggregate and on the average, however (p. 21).

Essentially, they allow for localized instances of indeterminism, but within a broad framework of determinism.

Observation - For the most part, Meadows and Robinson espouse a realist ontology with one major exception. They are clear that modeling is value-laden and constructed from a given perspective. They write, for example, “Even supposedly objective modeling techniques and scientific disciplines endow their practitioners with subjective preferences and prejudices about how science should be carried out and how policy should be made. Like anyone who writes about these matters, we have biases” (p. 13). They suggest that everyone doing such work is obligated to state their biases, as well as they know them. None of the models, however, allow for a multiplicity of perspectives, which would require a diversity of models.

Self-organization - System dynamic models are not self-organizing in the sense that is generally modeled with a cellular approach. However, during the course of a particular simulation run, the values of the variables do “organize themselves.”

SUMMARY

Systems science is generally recognized to have emerged during and after World War II, although there were precursors to the basic ideas. The people who created each school of thought were working largely independently, although many of them knew each other. They came from different disciplines, they were working on different problems, they formulated different variations of the principles of systems and cybernetics, and they often chose to affiliate with different academic societies. Consequently, these separate traditions have grown up making different philosophical assumptions. Several authors (Dooley, 1997; Dent, 1999;

Slife and Williams, 1995; Schwartz and Ogilvy, 1979) have suggested that Western society should develop an emerging worldview which includes the assumptions listed first for each construct in Table 1. (the "Yes" designation).

Each of the traditions we reviewed also made assumptions of relationship as unit of analysis, environment-full, and circular causality, although to varying degrees. Maturana and Varela (1987) and Argyris and Schön (1996), for example, make several statements in which they assume mutual causality. That emphasis, though does not appear in Miser and Quade (1985), for example.

The assumption of constructivist observation is made by only two of the strands discussed, organizational learning and cybernetics. Only cybernetics explicitly makes the assumption of self-organization. Consequently, the cybernetics tradition makes the most number of assumptions consistent with the emerging worldview. System dynamics makes the least of the traditions explored here.

As this paper has shown, the systems sciences are making philosophical assumptions which depart from those of the classical sciences. Yet, not all assumptions are shared across these systems traditions. We join Jackson (1991, p. vii) in suggesting that perhaps an integration and synthesis of the field will occur if the different traditions coalesce around a shared set of underlying assumptions.

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