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Methods of Analysis
Systems Analysis

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However empirical and material, systems analysis relies on a metaphysical assertion: The whole is greater than the sum of the parts. The symmetrical is equally metaphysical: The whole is less than the sum of the parts. Much less debatable than this metaphysics or ontology is the epistemology or methodology of these assertions applying to systems. An implication here is that systems defy or exceed comprehensive analysis— analysts exhaust understanding through a sense of the parts and can never see or say enough about the whole. Hence, “the whole behaves in ways, and exhibits characteristics, which could not have been deduced from a study of the constituents taken in isolation” (*Mind*, 1935, p. 264). Definitions tend to reinforce these assertions and implications: A *system* is “a set of *entities* mutually interrelated and interdependent, themselves functioning together as an entity at some higher level of organization” (Caws, 1971, p. 1).

Systems analysis (SA) involves “the identification and, if possible, the quantification of the relationships between the different elements” (Hinterhuber, 1974, p. 86). Systems under analysis may be experienced and concrete (i.e., communications network, ecosystem) or imagined and abstract (i.e., model, simulation). These range from concrete artificial systems and natural systems to conceptual systems (Weingartner, 1979, p. 356). SA is effective for disclosing or demystifying the operations and workings of artificial, natural, and conceptual systems. Whether the purpose is description or modelling and optimization, this necessarily entails *what* the system includes (e.g., actors, energy, processes, resources, effects) and what disturbances or additional inputs may do, along with *how* or *why* it behaves, functions, or operates as a system. SA generally involves three stages: 1) Lexical: delimitation of system boundaries; 2) Parsing: definition of relationships between or among components; 3) Modelling: description or operationalization of the whole system (Ross, 1967).

Technical and sociotechnical systems, like ecosystems, are never isolated even though we treat them as such. Identifying a system involves locating where one system or subsystem ends and another begins. Analysts often distinguish between hard (clearly defined boundaries) and soft systems (loosely defined boundaries). Some components or elements are made perceptible or ‘visible’ while others are left ‘invisible’ or imperceptible. Still, the challenge is identifying the interconnections, interrelations, or interfaces of components (e.g., animal-object, human-machine, machine-machine, object-object relations).

Some analysts recommend focusing on *interrelationships* or *interactions* between and among components or organisms in a dynamic system, rather than on components themselves. For instance, in their analysis of a sociotechnical school system, Zhao and Frank (2003) focus on “the interactions of the parts with each other as well as their interactions with the whole" (p. 811). Concepts for ecosystems and sociotechnical systems differ yet are somewhat interchangeable, as Zhao and Frank demonstrate. The behavior, goal, or state of a particular *sociotechnical system* is coordination of *components* in some way. Components are *coproducers* of outcomes or states and have distinctive characteristics that must necessarily be respected or *variance* (unprogrammed events) is a result. When the *compatibility* of components is respected, the probability of variance is reduced. Making certain that components interact harmoniously requires that characteristics are respected and correlated in both initial *design* and in progressive *use*. SA tends to require knowledge of the way systems behave *and* the way animals, organisms, people, and groups behave or the way humans and nonhumans interact under various conditions.

Systems are often stereotyped as linear inputs and outputs with feedback loops (Figure 1). The counter stereotype is complex systems, with suggestively emergent properties and nonlinear processes (Figure 2). A complex system is commonly defined as "a many-bodied system of components that, through interactions at the local level, self-organize into structures that we can characterize as emergent of the system as a whole" (Davis, 2012, p. 107). Complex systems are often associated with Maturana and Varela's (1973) identification of self-organization or autopoiesis as an inherent property. However, conceptions of complex systems characterized by emergentism date to the nineteenth century. A system is "a collection of organized things;" *how* a system is organized or organizes is a challenge of SA.

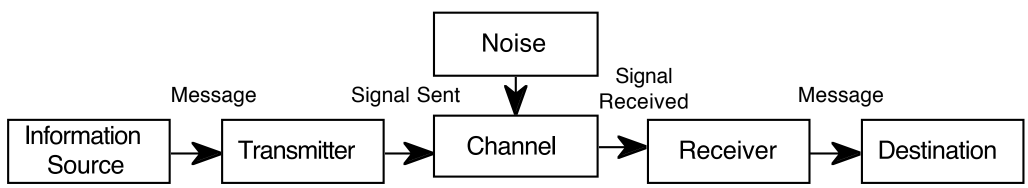


Figure 1. Shannon and Weaver's (1949, p. 7) Model of Communication.

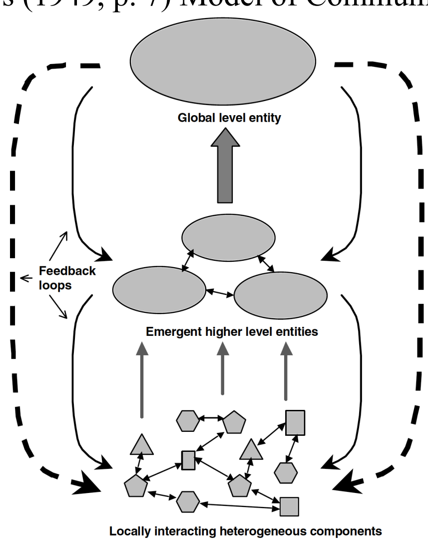
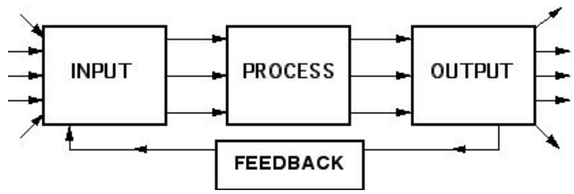


Figure 2. Complex system (Parrott, 2002, p. 2).

In one sense, SA is as ancient as the conception of systems. Zeno observed around 440 BCE that every *technê* (art, craft, technology) is a system (πᾶσα τέχνη ἐστὶ σύστημα [*sústema*]). In the *Theaetetus*, Plato's (ca. 360 BCE, 204b-206b) analysis of parts and wholes is very insightful. SA as described above dates to environmental analysis in the early 1900s, economic analysis in the 1930s, and cybernetic or technological analysis in the 1940s and 1950s (i.e., Bertalanffy, 1950, 1968). At that point critics such as Ellul (1968) asserted that technological macrosystems exceed human comprehension. Microsystems are often similarly opaque or inexplicable black boxes.

1. What is a System?
    a. Cybernetic system, depiction dating to the 1940s and 1950s:



    b. Watt, *Systems Analysis in Ecology* (1966): an interlocking complex of processes characterized by many reciprocal cause-effect pathways.
        i. SA is a body of techniques and theories for analysing such complexes.
    c. Clarke (1968, p. 669): An intercommunicating network of attributes or entities complex whole. An ensemble of attributes.
    d. Hartley (1969, p. 515): A *system* consists of two or more parts and their relations which together form a single identifiable entity. Analysis provides glimpses into the parts and operations of the system.
    e. Caws (1971, p. 1): a set of *entities* mutually interrelated and interdependent, themselves functioning together as an entity at some higher level of organization.
    f. Bertalanffy (1972, p. 417): a set of elements standing in interrelation among themselves and with the environment.
    g. Rapoport (1970, p. 15): portion of the world which at a given time can be characterized by a given state, together with a set of rules that permit the deduction of the state from partial information.
    h. Rapoport (1984, p. 8): entity which can maintain some organization in the face of change from within or without.
    i. Johnson (2006, p. 244): There are many definitions of "system ". Most assume that there are sets of "things" and that there are "relationships" between the things. Some of these relations reflect the idea of combining elements into wholes with emergent properties.
        i. In general, one can make three kinds of observation. The first and most fundamental is the *existence* of something. The second is the existence of *relationships* between things. The third is associating *numbers* with things. Our definition of system is based on this: Definition: A *system* is a class of sets with a class of relationships between their elements.
    j. Bronfenbrenner, "Ecological Systems Theory" of human development (1989, pp. 227-228):
        i. Microsystem: a pattern of activities, roles, and interpersonal relations experienced by the developing person in a given face-to-face with particular physical and material features
        ii. Mesosystem: the linkages and processes taking place two or more settings containing the developing person (e.g., the relations home and school, school and workplace etc.), in other words, a mesosystem system of microsystems.
        iii. Exosystem: the linkages and processes taking place between or more settings, at least one of which does not ordinarily contain the developing person, but in which events occur that influence processes within the immediate setting that does contain that person.

        iv. Macrosystem: consists of the overarching pattern of micro, exosystems characteristic of a given culture, subculture, or other broader context, with particular reference to the developmentally instigative systems, resources, hazards of life styles, opportunity structures, life options, and patterns of social interchange that are embedded in each systems.

2. What is Systems Analysis?
    a. Tansley (1935, pp. 299-300): The whole method of science, as H. Levy ('32) has most convincingly pointed out, is to isolate systems mentally for the purposes of study, so that the series of *isolates* we make become the actual objects of our study, whether the isolate be a solar system, a planet, a climatic region, a plant or animal community, an individual organism, an organic molecule or an atom. Actually the systems we isolate mentally are not only included as parts of larger ones, but they also overlap, interlock and interact with one another. The isolation is partly artificial, but is the only possible way in which we can proceed.
    b. Machol (1965, p. 14): the study of a system which does not yet exist in an attempt to elucidate its effectiveness or performance.
    c. Hinterhuber (1974, p. 86): the identification and, if possible, the quantification of the relationships between the different elements.
    d. Riggler-Peters (1995, p. 97): Reductionism v Holism: The proper approach to the study of complex phenomena, like life, is to decompose this complexity to simple components. In many cases, these components can then be shown to be instances of general physical and chemical laws. [versus] Complex systems must be treated as whole systems, because the process of analysis inherent in reductionism destroys the basis of their integrity.
3. Classification of systems: Weingartner (1979, p. 356) [adapted from Bunge, 1973, p. 124]:
    a. Natural systems (natural objects) such as hydrogen atoms, planets, cells, human beings, societies etc.
    b. Concrete artificial systems such as houses, railways, computers, individual linguistic expressions etc.
    c. Conceptual systems such as concepts, propositions, hypotheses, arguments, theories etc.
4. Procedures of Systems Analysis
    a. SA generally involves three stages (Ross, 1967): 1) Lexical: delimitation of system boundaries; 2) Parsing: definition of relationships between or among components; 3) Modelling: description or operationalization of the whole system .
    b. Walker (1986, p. 389): Although the analyses of different problems often show little similarity, they almost always involve performing the same set of logical steps. By now these steps are so well known and so well documented in the literature that they are referred to as "the classic steps of systems analysis."
        i. Problem identification
        ii. Definition of objectives
        iii. Choice of measures
        iv. Identification of alternative solutions
        v. Analysis of alternatives
        vi. Choice of solution

vii. Implementation
viii. Monitoring and evaluation of results

c. Petrina (2007):
    i. Identify the system
    ii. Conceptually or physically locate and isolate components and sub-systems
    iii. Identify inputs and outputs
    iv. Identify feedback mechanisms
    v. Identify or deduce processes
    vi. Analyze, troubleshoot, maintain or redesign system