Improving Organizational Systems: Incorporating General Systems Theory and Design Principles

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ABSTRACT

A crucial factor for understanding system behavior is observing how the parts interact (Atwater & Pittman, 2006). However, the very act of analysis (defined as studying the parts in isolation) makes it impossible to understand a system and its underlying dynamics (Ackoff, 1981). This paper highlights the need to revamp our current approach to systems analysis and design and incorporate more systems thinking and system modeling into the development of organizational systems.

INTRODUCTION

The design of organizations and organizational information systems has been guided by the use of several underlying principles. These design principles are a result of an over-reliance on one mode of thinking – the application of analysis and functional decomposition, based on the *scientific method*. While the scientific method has been the cornerstone of the majority of advancements in our knowledge and the development of new technologies, an over-application and over-reliance on some of the modes of scientific thinking can actually be detrimental for the design of organizational systems.

Another mode of thinking – *systems thinking* or general systems theory, when used in combination with principles from the scientific method, may actually lead to greater insights, expanded viewpoints, and better designed organizational systems.

THE SCIENTIFIC METHOD AND ORGANIZATIONAL DESIGN

The industrial revolution ushered in the use of machines to increase worker productivity. Since machines could only be designed for very specific, repetitive tasks, it became necessary to redesign work and workflow in order to take advantage of specialized machines. Workers went from having multiple skills and general, wide-encompassing tasks to narrow, repetitive or specialized tasks. Adam Smith published the famous *Wealth of Nations* in 1776, where he described this new concept – *the division of labor*. The development of the machines that led to the industrial revolution could be directly linked to the accumulating scientific and engineering knowledge resulting from increased understanding provided by the application of the scientific method.

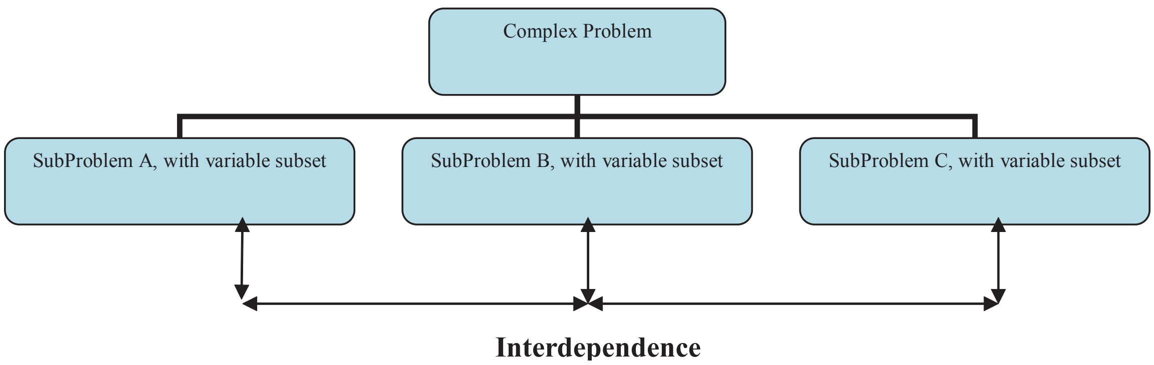
A basic principle from the scientific method is the notion of seeking truth and developing an understanding of nature or natural phenomena by breaking-down or decomposing complex systems into their elemental components. Thus, biologists are able to understand organisms by focusing on the parts (or subsystems) that make-up or compose them. An understanding of the parts helps in understanding the functioning of the whole.

The notions of understanding complex phenomena using this approach were then applied to the design of artificial, man-made systems, and organizational design. The primary organizing (design) principle from the scientific method is *functional decomposition*. Functional decomposition is a design principle whereby a complex problem is solved by breaking it down into smaller, more manageable and simpler sub-problems. This design principle, together with the use of machines and specialization of labor, led to the development of mechanistic or bureaucratic organization designs.

SIDE EFFECTS OF THE SINGLE PARADIGM

Problem solving based on the scientific paradigm can be thought of as composed of two primary parts: (1) Analysis and (2) Design. The analysis step of problem solving relies on understanding problems and phenomena by examining the individual parts in order to understand the functioning of the whole. After problems and phenomena are understood, the design step then seeks to design a solution by simplification via functional decomposition, or identification of sub-problems and specialization. This method limits the variables and complexity of the problem and, in the case where mathematical models may be applied, reduces the computational space. This has been the dominant, meta-model for isolating and solving management and organizational problems.

Figure 1. Detail complexity and dynamic complexity



However, this problem solving orientation reduces one type of complexity only to produce more of a different kind of complexity. Senge (1990) defines two types of complexity: *detail complexity and dynamic complexity*. Detail complexity involves situations where there are numerous variables, data, and although the relationships may be complex, they can often be modeled mathematically to achieve optimal solutions. Problems involving detail complexity are the focus of management science techniques and or techniques that require the use of computer-based solution. Dynamic complexity involves the interaction of the decision variables through time. While detail complexity is reduced through the application of functional decomposition and specialization or partitioning of the problem space, the very act of partitioning will result in an increase in the number of interacting components (partitions), and creates a complex web of interdependent components that share inputs and outputs (see Figure 1).

Thus, over-reliance on the problem solving methods based on the scientific approach has resulted in one type of complexity being traded-off for another. The problem-solving mindset of the scientific approach when decoupled from an understanding of system thinking, results in a limited understanding of organizational problems and problem solving. Specifically, managers often fail to realize: (1) cause and effect are often separated by time and space, (2) problem solutions that fix a problem in the short-run often create or exacerbate problems in the long-run, and (3) because of system effects (inter-dependent components) and system dynamics (multiple, non-linear feedback loops) short-term results may differ strongly from long-term results which then affects one's ability to learn from and correct past mistakes or decisions (Forrester (1971); Atwater & Pittman, (2006).

In order to understand these issues and understand how to deal with the two types of complexity, the next section discusses systems theory and systems thinking.

SYSTEMS THEORY AND ORGANIZATIONAL DESIGN

General Systems Theory (GST, or systems theory) was originally conceived by von Bertalanffy (1969) in 1945, and has been expanded, clarified, and applied to many different areas of science and thought. The concept of *systems thinking* refers to the set of cognitive strategies or systems related thinking strategies that may be applied to solve problems and or understand complex phenomena. Systems thinking behaviors are based on the original notion of general systems theory. An important area of study that arose out of general system theory (well to some extent, but mostly from engineering and computer technology) to aid in the understanding of complex systems is - *system dynamics*.

SYSTEMS DEFINED

A system may be defined as a set of interdependent components which is unified by design to accomplish one or more objectives (Kast & Rosenzweig, 1972). A system is thus an artificial creation, a way of thinking about and organizing complex phenomena. When defining or creating a system, a boundary is defined. The boundary separates the internal components from the system's external environment. A closed system does not interact with the environment, whereas an open system is one that shares information, energy or physical flows with the outer environment.

Although the system concept is very simple, its power as a problem-solving and design paradigm originates from its elegant simplicity, and this gives rise to the ability to create abstraction tools which then provide insight into problem structure and problem resolution. The systems approach thus provides a structure from which several modes of thinking are derived. *System thinking* is holistic thinking and includes notions of feedback, time delays, and dynamic interplay between components.

In essence systems thinking may be described as a paradigm or a "world view," where phenomena are viewed holistically and interconnected (Manni & Maharaj, 2004). Systems thinking may also be viewed from a more detailed and cognitive processing perspective. Richmond (1997) delineates the following cognitive processing or thinking skills or tracks that fully-define systems thinking: (1) Dynamic thinking, or examining or framing a problem or pattern of behavior over time, (2) System-as-cause thinking, or viewing the system's behavior as a result of the system itself, and thus under the control of decision makers. In essence, one must define the system boundaries in a meaningful way. (3) Forest thinking, or viewing the "big picture." This is the ability and skill to effectively see above the functional areas or silos and perceive the system of interrelationships and interdependencies that connect the component parts. This is a central feature of systems thinking and serves to strongly differentiate this mode of thinking from scientific thinking, which views and seeks to understand phenomena by understanding the parts first. (4) Operational thinking, or examining, in detail, the structure and nature of relationships; at *how* the variables affect one another, not simply that they affect one another. (5) Closed-loop thinking, is realizing that causality tends to follow a feedback loop whereby causality does not run in just one direction, but loops-back to change one or more causes and that causes can affect one another.

SYSTEM DYNAMICS

The area of system dynamics incorporates the systems thinking skills into a modeling framework that allows the problem solver to apply a systems approach to understand the complex system interactions.

Forrester (1961) first articulated notions of system dynamics and their proper modeling. Underlying the need for systems dynamics is the realization that many of today's problems in business, policy and human affairs are not only complex and difficult to solve but that many of our efforts aimed at solving these difficult problems result in "unintended side-effects." In fact, in many cases our solutions and decisions result in causing our problems. In other words, today's solutions become tomorrow's problems (Sterman, 2002).

The notion of "unintended side-effects," may actually be viewed from the standpoint of incomplete modeling. In other words, in an effort to apply scientific problem-solving methods, many problems are analyzed, decomposed to smaller subsets, and then solved by means of decision modeling, optimization, and other techniques. However, as stated previously, analysis and design of the problem domain may reduce detail complexity but when modeled from a system dynamic perspective, isolated subsystems and systems beyond the problem boundary may still interact – in other words, dynamic complexity has not been accounted for properly. Thus, notions of "unintended side-effects," may be viewed as "un-modeled interactions" from a system perspective.

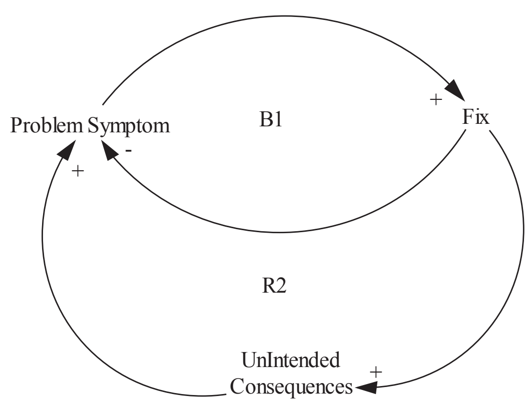
A primary tool used in system dynamics is the Causal Loop Diagram (CLD, shown in Figure 2). The CLD is an important modeling tool to help understand system dynamics, to facilitate holistic thinking, time delays, feedback loops, and all of the cognitive processing and systems thinking strategies.

System thinking is not always intuitive, commonly performed or easily understood, even by intelligent managers or educated individuals (Sterman, 2000). A number of empirical studies have confirmed this assertion (Sterman & Sweeney, 2000; Pala & Vennix, 2005). Many common mistakes by managers may be traced to incomplete understanding of system dynamics, and Senge (1990) has documented these common pitfalls using system archetypes, documented using CLDs, as in Figure 2.

BUILDING EFFECTIVE ORGANIZATIONAL SYSTEMS

A basic premise of this paper is that both paradigms are necessary to build effective organizational systems: System Thinking and Scientific Thinking. Organizational systems may be thought of as being composed of operational and decision

Figure 2. Causal loop diagram (CLD), "Fixes that Backfire"



making tasks performed by humans and machines (computers), within defined organizational structures, and that may interface across organizational boundaries and interact with other systems. Essentially, organizational systems may be designed in a myriad of ways, but are generically defined by tasks, structures, people, and machines.

Traditional information systems development techniques and methodologies have stressed functional decomposition. Thus, traditional analysis and design tools have tended to model information requirements, processes and tasks from a functionalist (scientific) viewpoint. As a result, two primary "un-anticipated side effects" have resulted: (1) information systems (that support the basic business system) have failed because of a failure to understand the human component of systems – the socio-technical system viewpoint, and (2) business systems have failed because an overemphasis on functional decomposition has led to business processes that are too fragmented, with too many information interfaces and "hand-offs" required to coordinate the entire business process (defined as the ability to provide a requisite value to an end customer). Both of these major failures are the result of a lack of system thinking, modeling and design.

THE SOCIO-TECHNICAL SYSTEM FAILURE

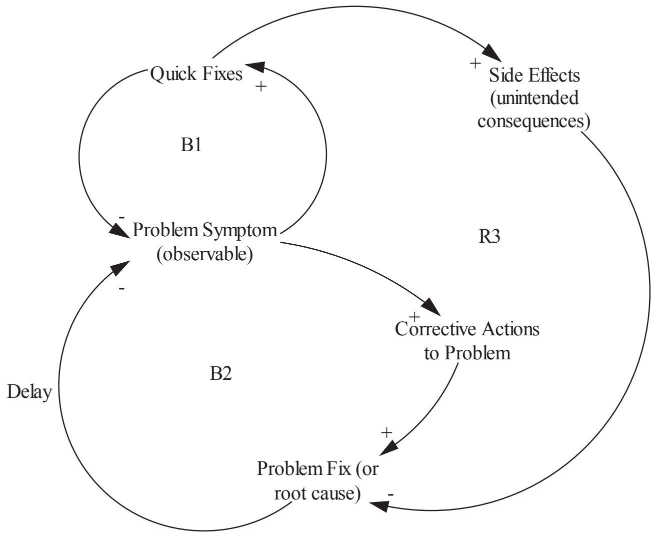
A hypothetical company is faced with the problem of making better product positioning and advertising decisions based on market research data. The hypothetical company scenario involves a product manager (who reports to the division manager), a market analyst (market research department) and a division manager (responsible for budgeting, deploying a sales force, etc.). The major problem symptom is that the product manager does not always have the best information on which to base his decisions. Based on an incomplete understanding of the situation, management decides to build a decision support system to help supply important sales, market, and demand information. The new DSS employs built-in decision models that more than provides advice, but actually "restricts" the range of possible outcome or decisions that are possible. This is done to reduce variability in product positioning decisions across the corporation, thereby providing a way for more centralized control. The DSS provides normative models based on complex mathematical principles to optimize certain relationships and outcome variables.

The result: the product managers feel completely constrained by the new system. Basically, the product managers feel: (1) a *loss of control* over their decisions, which increases their stress level since they are still held responsible for their decisions; (2) they feel their jobs have reduced their ability to have a *creative intellectual outlet*; (3) because of the use of the new system their jobs have become more *routine and repetitive*, (4) they now have *fewer interactions* with market analysts because the data collected has been standardized across the corporation for increased consistency and to aid in market comparisons at the corporate level, (5) they also have *fewer interactions and communications* with the actual sales personnel (which used to be an important and *informal way of gathering rich data*) because the DSS demands greater amounts of their time and because the inputs required by the DSS do not allow for considering their old, informal, rules of thumb that typically went into their positioning decisions. Figure 3 shows a Causal Loop Diagram of the new situation.

Basically, a lack of system thinking at the start caused management to focus on a problem symptom – the lack of good information for product managers. If a more systemic approach had been used, for example, use of *forest thinking* would have enabled management to see the bigger picture and include the human component in their view of this system (i.e., this is basically the socio-technical system viewpoint that considers the human component of the system, including humans personal goals). A more in-depth consideration of the human component would reveal that product managers did not have enough information because they also did not have enough *control* in their jobs. Lack of control meant that they did not have the ability to alter or influence the data gathered by the market research department, they did not have the bargaining power to influence the division managers to elicit time and cooperation from the sales force to gather important, rich and meaningful information.

The management decision to implement the DSS was a quick fix based on an inadequate understanding of the system dynamics. An unintended side effect of this approach was an increase in the lack of control by the product managers. This effect actually looped back and added to the underlying problem (Figure 3). In addition, all of the side effects, including a *loss of control*, reduced *creative intellectual outlets,* their jobs have become more *routine and repetitive, and*

Figure 3. Causal loop diagram of the STS situation (Shifting the burden archetype)



fewer interactions and communications all resulted in a lower Quality of Work Life of the product managers. A lower Quality of Work Life can have even more, long-term effects on the company as personnel may have greater turnover, higher absenteeism, and lower productivity.

Proper systems thinking would also have highlighted that good product management decision making depends on both access to the proper information (via databases, models, informal information gathered by interactions with employees and salesmen), and a motivated product manager (human component of the system). Reducing product managers' Quality of Work Life also reduces this last factor.

The actual problem or root cause in this system situation was that the *business system* was improperly designed. The next section explains the failure from the business system or business process perspective.

BUSINESS PROCESS DESIGN FAILURE

Business process design failures may be thought of as the over-application of reductionism or functional decomposition (stemming from the scientific viewpoint). In an effort to reduce detail complexity and to define work in its most basic form, managers have created work environments with many sub-processes, organizational units, and subsequently, narrowly defined jobs. The result of defining too many sub-processes is that the sub-processes require a great deal of coordination and information flow because the sub-processes are part of a set of interdependent tasks that make up the larger process or larger system. In essence, over-design leads to a reduction in detail complexity but an increase in system or dynamic complexity. Lack of coordination between sub-processes is often described as "increasing the hand-offs" or information flows required to "piece back the fragmented processes" (Hammer & Champy, 1993). The end result is less efficient organizations and decreased customer responsiveness.

HUMANS ARE NOT MACHINES

A secondary effect of poorly-defined or over-designed processes is less satisfied workers (Hammer, 1996). When designing computer-based systems, researchers from the socio-technical design perspective stress the importance of including an assessment of the human component of systems since workers attitudes and well-being can strongly influence successful organizations. Sherman, Garrity, & Sanders (2002) developed an IS success instrument, based on Garrity & Sanders (1998) model, to measure workers' quality of work life (QWL). The measure examines items such as: (1) control over work, (2) a worker's ability to schedule or manage tasks, (3) degree of autonomy, and (4) the amount of routine in work.

As work is defined and processes and work systems designed, it is vital to take the human component into account. However, a differing amount of functional decomposition is necessary for the application of management science models and computer software than is necessary for human defined work. Hammer & Champy (1993) provide a number of examples where work can be performed more effectively by a single worker with the aid of information provided by computer support (DSS and database technology for example), than by the over-design of processes into many fragmented, sub-processes. Over-design of work leads to over-specialization and lower quality of work life. Thus, a critical task is to design systems effectively that match the quality of work life needs of the human component of systems with the design considerations and reduction in detail complexity required for software systems.

RETHINKING SYSTEMS ANALYSIS AND DESIGN

Current systems analysis and design methods fail to produce system designs that account for the wider system view which includes consideration of the business process design (i.e., tasks, structures, and processes), the human element (with corresponding socio-technical concerns), and the technical design. We recommend the following changes to produce better system designs: (1) Emphasize the co-design of business process, socio-technical and information systems; (2) Emphasize modeling of both detail complexity and dynamic complexity by incorporating the use of system dynamic modeling using causal loop diagramming (CLD) in addition to traditional analysis and design tools (e.g., data flow diagrams, hierarchy charts and decomposition diagrams); (3) Emphasize the use of prototyping and multi-dimensional measurement to obtain feedback on the impacts of designs on the human and business process components of systems (Garrity, 2001); (4) Educate systems analysts and managers on systems thinking and system dynamics.

CO-DESIGN OF BUSINESS SYSTEM AND INFORMATION SYSTEM

A critical emphasis must be placed on the *co-design* of business systems (e.g., work design, organizational structures, and task definitions) and information technology systems. This is critical because the needs of the human component, as is often stressed by the socio-technical school of thought, are vital for the success of the entire system.

A balance must be forged between the needs of the human element and the requirements of the technical system component. This is because the two components are interdependent parts of a dynamic system. The nature of the interdependence (and conflict) is best understood by modeling the two types of complexity that must be accounted for in the overall system design. The use of analytical tools and modeling (e.g., data flow diagrams) is necessary to understand the detail complexity and to design aspects of the technical design. However, the use of systems thinking and dynamic modeling is also necessary to understand and design the entire business process and socio-technical system. Thus, a fundamental shift in thinking must take place in order to achieve the level of design sophistication necessary to achieve success in this wider system context.

SYSTEMS EDUCATION

System researchers have been advocating teaching system concepts and system dynamics in business schools (Atwater & Pittman, 2006; Sterman, 2000), and while this is necessary it may not be sufficient for the design of effective organizational systems. Traditional textbooks and courses on systems analysis and design continue to stress the importance of considering users and their socio-technical concerns, but these textbooks have not included tools for the modeling of interdependent components and system dynamics.

Although organizations are complex systems, the scientific viewpoint and scientific methods have dominated research and education in business schools. This can be viewed as problematic since a crucial factor for understanding system behavior is observing how the parts interact (Atwater & Pittman, 2006). However, the very act of analysis (defined as studying the parts in isolation) makes it impossible to understand a system and its underlying dynamics (Ackoff, 1981).

SUMMARY AND CONCLUSIONS

An over-reliance on the use of analysis and design techniques such as functional decomposition or reductionism strategies, have resulted in overly complex, interdependent organizational systems. Interdependent subsystems and systems often interact with each other using multiple, non-linear, feedback loops. The complex flow of interactions often creates counterintuitive behavior resulting in unintended consequences or sub-optimal results (Sterman, 2002). This paper advocates a fundamental re-thinking of systems analysis and design that incorporates a general systems theory orientation, system dynamics modeling and the use of prototyping to produce a better understanding of and to aid in the design of organizational systems.

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