Large System Theory, Actor Network Theory, and Relations in Design

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Abstract:

Design methods relying solely on linear approaches based on analysis followed by synthesis to 'solve problems' need to be augmented by strategies that focus on ways to understand indeterminate, evolving relationships inherent in any complex system. Large Technical Systems– and Actor Network Theory may provide useful starting points for developing new metodologies.

Keywords:
Design method
Large Systems Theory
Actor network Theory

Introduction

Design approaches are often articulated in ways that explicitly or implicitly incorporate principles of input and output. Further, the approach is presented as a linear one with two phases: an analytic stage that leads to the definition of a problem followed by a synthetic stage in which the needs and restrictions are reconciled with each other.

This approach is attractive for a number of reasons: it is solution oriented; it is usually technocratic; it appears to be active, every stage is transformative; it is constructionist; it is perceived to be determinate; and it has a particular logical appeal. As well, it exerts an appeal as it also follows an inherently "classificational" and hierachical organizational principle.

However, all classification systems are arbitrary in that they are based on a constructed set of assumptions, e.g. the articulation of a design "problem" is usually not the result of any "real" understanding of actual circumstances, but rather, is based on a similar set of circumstances that have occurred in the past—this is rather like driving a car by only looking in the rearview mirror—and this past is often constructed as a straight-forward and determinate unfolding of events. A statistical analysis of past occurrences can then be used to make comforting predictions about an unknown future.

Problems identified in this way are artificial in their pretence to understanding given circumstances, and the unicursal methods used to solve them are self-reflexive, isolated, and limited because they ignore the interdependence of the procedural elements, and the interdependence of any process upon others outside itself. Such an approach insists that processes are simple, *determinate* sequences when in fact they are complex, unstable and *indeterminate* systems.

It would be of benefit to the design disciplines if design theoretical discussions took as their subject the latter—complex, unstable and *indeterminate* systems— with a view to developing new strategies to think about the potential of design as an investigative discipline. Two lines of inquiry may give insight: Theories of large technical systems (LTSs) and actor network theory (ANT) These offer promising starting points for revised design thinking.

Thomas Hughes has pioneered the idea of large technical systems. He used an explicitly sociological and historical approach to show how early entrepreneurs tried to impose cultural systemic qualities on their technological enterprises. Renate Mayntz, Jane Summerton, and Olivier Coutard, among others, have built on Hughes' work.

A second perspective rests on actor network theory (ANT); this is based on the writings of Michel Callon, Bruno Latour, John Law, John Hassard *et al*, and by extension on the work of those writing about cyborgs (Donna Haraway). These writers have examined how humans and specific social situations enroll technologies into actor networks over time and space. ANT does not draw exclusionary distinctions between the 'social' and the 'technological', rather it assumes that assemblies of actors or actants make up contemporary life.

Both approaches see meaning as lying in relationships, and therein lies the key to developing new design strategies.

Design process

As alluded to at the outset, it is a commonplace for many designers, when asked what it is that they do, to say that they are in the business of solving problems. If then asked how they do that, they are likely to say that there is a design process that can be applied to problem solving. There are numerous superficial variations of the process, but at root all of these adhere to the same model: a two-phase linear progression comprising an analytic stage that leads to the definition of a problem and the identification of needs and requirements followed by a synthetic stage in which the varied needs and requirements are reconciled with each other until a solution that can be implemented is identified. Although it is called the ‘design process’ in professional writings—with an implication of, if not uniqueness, then distinction—it is in its outline a ‘standard’ way of pursuing problems.

In essence, it is identical to the approach codified by John Dewey in a series of four essays entitled collectively “Thought and its Subject-Matter,” published in the volume *Studies in Logical Theory* (1903). In the essays, Dewey, with a view to elucidating the means by which we attain knowledge, gave a detailed analysis of the process of enquiry. He distinguished three phases of that process. It begins with the problematic situation, i.e. a practical, existential situation in which previous practices are no longer adequate for fulfilling needs and desires. In the second phase of the process, the problem, its parameters, and the goal are identified. The third phase involves reflection: hypothetical solutions— ideas, suppositions, theories, etc.—are “tried out” in the abstract. For Dewey this is the cognitive stage, one that provides provisional knowledge; this knowledge is contingent on its ability to provide understanding that can lead to action. The potential solutions are then tested in action and if one works, it is implemented. Dewey saw this process as the proper one for understanding how we become knowledgeable, no matter whether it is in a common-sense or scientific way.

Dewey’s process of enquiry has been reformulated into a step-by-step Standard Agenda comprising:

1. problem identification
2. problem analysis
3. goal determination.
4. solution generation.
5. solution evaluation and selection. (Measured against goals)
6. solution implementation.

The similarities between the design process and the Agenda are striking and immediately apparent. Their inherent assumptions are also the same. Both are or have been deemed suitable for most problem solving challenges. Both adhere to the principle of causality; i.e. Step 1 precedes Step 2, and Step 1 leads to Step 2 …; hence, if one process applied to any problem will resolve it, then one process applied to two problems that are identical will resolve each of them in the same way. Or, stated in another way, identical problems (causes) imposed on identical processes (systems) will produce the same effects (solutions) in a predictable, deterministic way.

Scientific method

As well, the Agenda and the design process stipulate problem analysis as a first stage of the process. Analysis is that form of critical evaluation whose method involves breaking a subject—in this case a problem—into its constituent parts, and then describing the parts, and their relationship to the whole.

As Lars Skyttner (10) has pointed out, one of the prerequisites of this kind of reductionist analytic method is freedom from any kind of environment; in fact, the environment is considered to be irrelevant. All scientific laboratories exclude the environment by standardizing it; in this way experimental variables can be introduced in an ordered way. (It is interesting that one still comes across the idea of a design lab from time to time.) Through this isolation, science can describe, control, and predict, while the scientist is presumed to remain outside the experiment: neutral, objective, and non-interventionist. Some designers still assume this stance.

This way of "doing" science—this rational procedure, based on the concepts of empiricism and determinism, for dealing with all kinds of problems—is summed up in The Scientific Method:

1. analysis (reduction of complexity)
2. development of hypotheses
3. experimentation and replication of same
4. deduction of results (rejection of hypotheses)

Empiricism; determinism; and monism, the belief in the inherent inseparability of body from mind: are often referred to as the Scientific Paradigm (Skyttner 11).

The preceding is familiar, historical territory, nevertheless, I have reiterated the elements of the three approaches to show their connections, and to show that the design process often taught in design schools and employed in almost formulaic ways is rooted in the scientism of an earlier age. Unfortunately, the method, although still very useful, is no longer adequate to deal with design challenges.

Indeterminism

Our worldview has changed radically over the course of the twentieth century, indeed, the process began in latter part of the nineteenth. Rudolph

Clausius William Kelvin, Ludwig Boltzmann and James Maxwell formulated the two main laws of thermodynamics. The first law or thermodynamics says: The total energy in the universe is constant and can thus be neither annihilated nor created. Energy can only be transformed into other forms. The second law or thermodynamics states that all energy in the universe degrades irreversibly, in short, entropy—disorder—increases continually. As a result of this discovery, indeterminacy and chaos entered our view of the universe.

As if that was not enough, Albert Einstein proved, with the Special Theory of Relativity that the concept of time is unimaginable without the concept space and vice-versa. Even before Einstein published his theory, Max Planck had formulated the outlines of Quantum Theory. Building on these ideas, Niels Bohr articulated the Complementarity Principle. This states that an experiment on one aspect of a system (of atomic dimensions) destroys the possibility of learning about a complementarity aspect of the same system. At the same time, Werner Heisenberg framed the Uncertainty Principle: It is impossible to define simultaneously the position and the velocity of a particle.

In short, not only was indeterminism a part of things, it became a fundamental principle of quantum mechanics (when it focuses on the atom). Quantum mechanics deals with probabilities, not certainties.

The determinism of an earlier age has been replaced in a significant measure by indeterminacy, by chance and by randomness. Entropy, synergy, and evolution have become the hallmarks of our sense of the universe. As a consequence, analytic thinking is no longer sufficient to our needs. Skyttner (20) has pointed out that, „synthesis [rather than analysis] is a prerequisite for the systems thinking of our own time …. A system inasmuch as it is a whole, will lose its synergetic properties if it is decomposed; it cannot be understood through analysis.“

In practice, this means that we must reverse the analytical order when we approach problems. For instance, when we look at systemic problems, we must, in the first instance,

> identify the system of which the unit [or entity] in focus is a part, [then] explain the properties or behaviour of the system, [and] finally, explain the properties or behaviour of the unit [or entity] in focus as a part or function of the system.
> Synthesis does not create detailed knowledge of a system's structure. Instead, it creates knowledge of its function (in contrast to analysis).

> Therefore, synthesis must be considered as explaining while the scientific method must be considered as describing. The focus of the observer is expanded by system thinking, whereas analytical thinking reduces it. In other words, analysis looks into things, synthesis looks out of them (Skyttner 20-21).

Systems

Dealing with systems, particularly when they are large and complex, is a daunting task. For too long, unwanted interactions and effects have been ignored, often willfully; traditional manufacturing processes are a case in point. The system traditionally used and still-favoured for production is handled as if it is simple in nature. The process of making unfolds in a chain-like fashion. A product's life begins with raw-materials suppliers, moves on to materials processors, through manufacturers to assemblers, whence, once finished it moves onwards to the retail floor. After its purchase by the consumer and his or her disposal of it, the product then migrates into the realm of the waste management companies and disappears (or so it is hoped).

The process is one of input, transformation, output and finally, disposal. The analogy of a chain is an appropriate one; each step in the process is linked, but essentially separate from the others. In a sense, the individual links operate independently of each other. The process allows what are deemed to be undesirable issues—social costs, pollution, to name two—to be ignored, to be "thrown over the wall," or otherwise passed "downstream." Responsibility is passed along as well.

We can all think of numerous examples of similar miscalculations: environmental destruction; climate degradation; deforestation; desertification; nuclear radiation; water-, soil-, air-, water-, noise-, and light pollution, and so on.

Systems are complex, and understanding them is a daunting task. To see why, we only need to look at their makeup. Generically, complex systems:

- have a large number of elements
- have many interactions between the elements
- attributes of the elements are not predetermined
- interaction between elements is loosely organized
- are probabilistic in their behaviour
- evolve over time
- are subject to behavioural influences

- a have subsystems that are purposeful and generate their own goals
- are largely open to the environment

(Skyttner 66)

Further, General Systems Theory stipulates the following for systems (Ludvig von Bertalanffy; Joseph Litterer; summarized in Skytnner (33-34)

- Goal seeking (Systemic interaction must result in some goal or final state to he reached or some equilibrium point being approached.)
- Interrelationship and interdependence of objects and their attributes (Unrelated and independent elements can never constitute a system.)
- Holism (Holistic properties not possible to detect by analysis should be possible to define in the system.)
- Transformation process (All systems if they are to attain their goal must transform inputs into outputs. In living systems this transformation is mainly of a cyclical nature.)
- Inputs and outputs (In a closed system the inputs are determined once and for all; in an open system additional inputs are admitted from its environment.)
- Entropy
- Regulation (The interrelated objects constituting the system must be regulated in some fashion so that its goals can be realized. Regulation implies that necessary deviations will be detected and corrected. Feedback is therefore a requisite of effective control. Typical of surviving open systems is a stable state of dynamic equilibrium.)
- Hierarchy (Systems are generally complex wholes made up of smaller subsystems. This nesting of systems within other systems is what is implied by hierarchy.)
- Differentiation (In complex systems, specialized units perform specialized functions. This is a characteristic of all complex systems and may also be called specialization or division of labour.)
- Equifinality and multifinality (Open systems have equally valid alternative ways of obtaining the same objectives [divergence] or, from a given initial state, obtain different, and mutually exclusive, objectives [convergence].)

The preceding lists make it very clear that we cannot hope to know any complex system completely in detail. Complex systems tend to become more complex over time. Any open system is always dependent on an environment with which it can exchange information, energy and matter. Open systems are also negentropic because, for a time, they can import energy from their environments. Thus an open system tends to develop a more elaborate structure over time. Once a system reaches a state of equilibrium, it is no longer capable of performing any work; complex systems are usually far from equilibrium. Despite the appearance of stability, there is constant change, which adds to the uncertainty of anyone—a designer—observing the system.

Actually, this disequilibrium is necessary to what is perhaps one of the key hallmarks of complex, open systems: emergence. As a result of the (inter)actions of its components, a system will develop new, coherent structures, properties and behaviours. Emergent properties can also develop between other emergent properties. These emergent properties cannot easily be predicted or deduced from the properties of the components whose interactions produced them. In short, complex systems can self-organize over time, without having to rely on simple cause and effect relationships between elements. Small changes in individual elements can have profound effects on future behaviours of the whole system.

At the same time, single elements in a complex system cannot "know" what is happening in the system as a whole. If they did, all the complexity would have to be present in that element. It also follows from this that no element in the system could hope to control the system.

The relationship between an open system and its environment is also not a simple one. We can define a system's immediate environment as the next higher system (without the system in question itself), and by extension, a given system's overall environment is every system that contains it. A system's environment can also be defined as that which is beyond its control and that which has an influence on it. Sometimes the environment can be seen as part of the system itself: a case in point is a designer "called in" to work for a client. Through constant interaction, a system and its environment are mutually affecting.

Further, it is usually difficult to determine the boundaries between a complex system and its environment. One indication is the nature of the various systemic interactions, those within a system are usually more intense than those that occur across its boundary, but these do occur, by definition, and in terms of emergence, add further complexity. As well, anything crossing into the system is usually transformed in some way.

Tools are being developed for understanding the dynamic behaviours of complex systems; in essence the approach recognizes that the relationships between the entities in the system are as important as the entities themselves. Systems thinking is an attempt to look at these linkages, processes, and interactions in a holistic (and reductionist) way, because it is accepted that the sum of a systems components does not sufficiently explain the properties of a system. Attempts to understand systems are, of course, not disinterested exercises; the goal is to be able to make systemic adjustments without being surprised—blindsided—by counterintuitive system responses. A designer working “on” a system is both in it and outside it, depending on the changing definitions of the system’s boundary. It is a challenge then to “know” the system whilst simultaneously being in two places (at least) as it were. Making decisions with a view to changing a system in directed ways is very much a series of leaps of faith.

Actor Network Theory

As we saw earlier, traditional decision-making tended to involve linear cause and effect relationships. Applied systems thinking, on the other hand, will reveal the complex of multi-directional interrelationships: processes, feedback loops, controls, as well as inputs and outputs. Nevertheless, the effects of the one on the others remain difficult to identify let alone predict. Bruno Latour (1986), Michel Callon (1980), John Law (1999), and others, in their work in the sociology of technology have developed an approach that is a useful tool for dealing with the interactions in complex systems; they have dubbed their approach Actor-Network Theory (ANT).

The central argument of actor-network theory is that technologies are more than simple artifacts. They also constitute and are constituted by networks of interacting humans, organizational entities, and other artifacts. Collectively these components are considered “actors.” New actor networks are continually created through evolving interactions and negotiations among elements within a system; these new actor networks may be unstable and temporary, however, some may endure to such a degree that they end up being taken for granted.

An essential part of Latour’s and Callon’s actor-network approach is their insistence that human and non-human actors should be treated equally and symmetrically. In hierarchical conceptions of complex systems, the human actors are usually privileged; in actor-network approaches non-human actors are just as effective.

For instance, as Langdon Winner (1980) has pointed out, technological systems are not neutral servants of the social order that chooses to adopt them. Their adoption often involves a reciprocal, engineered or designed change to parent social system. In short, artifacts—non-human actors—can have politics. A selective application of actor-network ideas to an investigation of a system, i.e. choosing to look at the system in a non-hierarchical way for a particular purpose is a useful strategy for designers to pursue.

In fact, this strategy has inspired a design approach usually known as Values in Design. The approach begins with the idea that systems embody social, political, and ethical values. As a consequence, it behooves designers to design systems that embody those values that the society in which the system is embedded subscribes to.

“Knowing”

Even when actor-network thinking is added to systems thinking, it is still impossible to “know” systems, nevertheless, changes in “knowing” are a prerequisite for amending the design process in ways that will allow it to retain its utility when applied to systems. David Hakken (2003:40-42) s distinguishes between two knowledge discourses, he calls one modernist and the second post-modernist.

According to Hakken, the standard “modernist” account of knowledge acquisition in Western culture begins with and progresses from data. Data are empirically apprehendable and they can be separated from their context without difficulty. When these data are rearranged in a new frame, they are transformed into information. Further manipulation—verification, justification, etc.—transforms the information into knowledge. The transition from information to knowledge has been a particular focus of “sociology of scientific knowledge” studies, particularly the social aspects that underlie the creation of knowledge.

Hakken’s second “post-modern” model begins with knowledge rather than data and moves backwards from there through information to data. In this model, knowledge is situated, even “embodied” in the elements of a system. (Michael Polyani’s (1983) investigations into “tacit” knowledge, i.e. knowledge that is not easy to pass on except ostensively are an illustration in point.) Transforming this knowledge into information decontextulizes it perforce and reframes it artificially; the same process creates data. To quote Hakken (2003:41-42),

> In a postmodern account, data so regressed are never "raw." Because data are understood as always "cooked," the relevance of [science and technology studies] insights into the role of sociocultural processes in constructing knowledge is much more obvious in a postrmodern account. The postmodernist knowledge regression may strike the reader as odd, somewhat forced. Because the acts of decontextualization on which it focuses are themselves deeply dependent upon the specifics of context, its steps are certainly more difficult to automate than those of the modernist progression. Yet its insights are an important general caution to the simplistics of the typical modernist conception …. In such accounts, knowledge is too unproblematically quantifiable, packagable, and objectifiab!e, its creation too simply planned and predicted; it is too easily bought and sold. Far from being reducible to simple common elements like money value, knowledge, from the postmodern perspective is generally localized and difficult to describe, let alone quantify.

We can quickly sense the congruencies between the approaches to complex systems, and the approaches to ideas of knowledge; both can and should be approached holistically. The traditional design process must incorporate a different idea of knowledge, one that recognizes its social dimensions and focuses on them. We must think of different kinds of knowledge(s) nested in systems or networks from which it—they—cannot easily be separated.

Unfortunately, knowing how to approach systems does not automatically help with the practicalities of problem solving within them.

Planning

The solutions to problems are usually arrived at through planning. The solution—the goal—is identified and then a plan is laid out for reaching that goal. Planning is thinking through a series of conditions, actions and consequences that will achieve the goal; planning is thinking in terms of cause and effect. However, in complex systems, as we have discovered, neither cause nor effect is always easily identified, so planning in situations like that must allow for uncertainty and surprise; a plan must be flexible and resilient.

Over-planning, often the product of insecurity, can become self-defeating; on the other hand, too crude a plan can be equally dangerous. The former often leads to a too-narrow focus, the latter to one that is too broad. We have seen how a small change, a change that has no discernible immediate effect, can have tremendous consequences over time: the “butterfly effect” cited in accounts of chaos theory is a prime example. Crude planning would have missed the flapping of the butterfly's wings, or considered it insignificant. Over-planning can be just as detrimental; its extreme focus can lead to the "laboratory effect" of removing an object under consideration from its environment. At its worst, over-planning can lead to a blind "methodism": the unthinking application of a method or process in an attempt to reach a goal by repeating previous tactics (Dörner 170)

Nevertheless, a close view is important: the specific individual configurations—the small actor networks—must be studied, but this must be tempered by a wider view. Actions should be planned on the basis of both views, and surprise should be expected. As Napoleon is reported to have said: "On s'engage, et puis on voit!"

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