

***Strategy and Complex Systems***  
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“Today the network of relationships linking the human race to itself and to the rest of the biosphere is so complex that all aspects affect all others to an extraordinary degree. Someone should be studying the whole system, however crudely that has to be done, because no gluing together of partial studies of a complex nonlinear system can give a good idea of the behavior of the whole.”

---Murray Gell-Mann (1929–2019)

***Purpose:***

The primary purpose of this document is to explore the details of complexity in general, and complex systems, specifically, in the context of business strategy.

Some organizational ideas and pedagogical structure came from the following book:

Mitchell, M. (2011), *Complexity Science: A Guided Tour*, Oxford University Press.

To assist in further study, the definitions regarding complex systems were excerpted and adapted from the Wikipedia page on Complex Systems:

[https://en.wikipedia.org/wiki/Complex\\_system](https://en.wikipedia.org/wiki/Complex_system)

A gentle introduction for business students to some aspects of Complexity can be found in the following book:

Jolly, R. (2015), *Systems Thinking for Business: Capitalize Structures in Plain Sight*, Systems Solutions Press.

An in-depth examination of the role of systems thinking in the modern economy is:

Beinhocker, E. (2007), *The Origin of Wealth: The Radical Remaking of Economics and What it Means for Business and Society*, Harvard Business Review Press.

The specific goal of this document is to help student-professionals incorporate various aspects of complex systems into the formal and informal processes associated with strategic visioning and strategic execution, including all of the technical, detailed analyses that accompany both of those two strategy components.

Rigorous and relevant application of complex systems should help improve our modeling and judgment, both in a quantitative (numbers) sense and in a qualitative (words) sense. At worst, a working knowledge of complex systems helps us understand the limitations of our strategic modeling. At best, complex systems holds the potential to improve successes and mitigate against failures in a variety of organizational purposes and contexts.

### **Key Concepts of Complex Systems:**

A complex system must exhibit at least one of the following key concepts.

#### **Complexity:**

"Systems exhibit complexity" means that their behaviors cannot be easily inferred from their properties. Any modeling approach that ignores such difficulties or characterizes them as noise, then, will necessarily produce models that are neither accurate nor useful.

#### **Emergence (over scale):**

Another common feature of complex systems is the presence of emergent behaviors and properties: these are traits of a system that are not apparent from its components in isolation but which result from the interactions, dependencies, or relationships they form when placed together in a system.

#### **Self-Organization (over time):**

Self-organization, also called spontaneous order, is a process where some form of overall order arises from local interactions between parts of an initially disordered system. The process can be spontaneous when sufficient energy is available, not needing control by any external agent. It is often triggered by seemingly random fluctuations, amplified by positive feedback. The resulting organization is wholly decentralized, distributed over all the components of the system.

### **Key Dimensions of Complex Systems:**

Broadly, a complex system can be classified into one of the following seven (7) dimensions.

#### **Collective Behavior:**

The study of complex systems is an approach to science that investigates how relationships between a system's parts give rise to its collective behaviors and how the system interacts and forms relationships with its environment. The study of complex systems regards collective, or system-wide, behaviors as the fundamental object of study; for this reason, complex systems can be understood as an alternative paradigm to reductionism, which attempts to explain systems in terms of their constituent parts and the individual interactions between them.

### **Networks:**

The interacting components of a complex system form a network, which is a collection of discrete objects and relationships between them, usually depicted as a graph of vertices (objects) connected by edges (relationships). Networks often describe the sources of complexity in complex systems.

### **Evolution and Adaptation:**

Complex adaptive systems are special cases of complex systems that are adaptive in that they have the capacity to change and learn from experience. It is an ensemble composed of dynamic network interactions, but the behavior of the ensemble may not be predictable according to the behavior of the components. It is adaptive in that the individual and collective behavior mutate and self-organize corresponding to the change-initiating micro-event or collection of events. In the social sciences, learning from and integrating with its environment is also part of evolution and adaptation.

### **Pattern Formation:**

The science of pattern formation deals with the visible, statistically orderly outcomes of self-organization and the common principles behind similar patterns in nature. Some patterns exhibit symmetry. Chaos theory ranks as an essentially universal influence on patterns.

### **Systems Theory:**

Complex systems are chiefly concerned with the behaviors and properties of systems. A system, broadly defined, is a set of entities that, through their interactions, relationships, or dependencies, form a unified whole.

### **Nonlinear Dynamics:**

In linear systems, the effect is *always* directly proportional to cause. Complex systems often have nonlinear behavior, meaning they may respond in different ways to the same input depending on their state or context. In nonlinear systems, a small perturbation may cause a large effect, a proportional effect, or even no effect at all.

### **Game Theory:**

Game theory is the study of mathematical models of strategic interaction among rational decision-makers. For example, sensible decision-making is critical for the success of strategy. In strategic management, game theory is used to model the decision-making process of players, such as investors, project managers, contractors, sub-contractors, governments and customers. Quite often, these players have competing interests, and sometimes their interests are directly detrimental to other players, making strategic management scenarios well-suited to be modeled by game theory.

### **Key Features of Complex Systems:**

A complex system may have one or more, often many, of the following features.

**Cascading Results:**

Due to the strong coupling between components in complex systems, a failure (or success) in one or more components can lead to cascading failures (or successes) which may have catastrophic (or beneficial) consequences on the functioning of the system. Localized attack (or net gain) may lead to cascading failures (or increasing returns) and abrupt collapse (or growth) in spatial networks.

**Complex Systems May Be Open:**

Complex systems are usually open systems — that is, they exist in an environment from which they can both consume and dissipate energy. In other words, complex systems are frequently far from equilibrium.

**Complex Systems May Exhibit Strong Transitions:**

Critical transitions are abrupt shifts in the state of ecosystems that may occur when changing conditions pass a critical point, often called a bifurcation or “tipping” point.

**Complex Systems May Have a Memory:**

Recovery from a critical transition may require more than a simple return to the conditions at which a transition occurred. The history of a complex system may thus be important. Because complex systems are dynamical systems, they change over time, and prior states may have an influence on present states.

**Complex Systems May Be Nested:**

The components of a complex system may themselves be complex systems. For example, an economy is made up of organizations, which are made up of people, which are made up of cells - all of which are complex systems. This structure promotes a system's capacity to persist under increasingly harsh circumstances as well as the potential for large-scale systemic regime shifts.

**Dynamic Network of Multiplicity:**

As well as coupling rules, the dynamic network of a complex system is important. Small-world or scale-free networks which have many local interactions and a smaller number of inter-area connections are often employed. Natural complex systems often exhibit such topologies. In the human cortex for example, we see dense local connectivity and a few very long axon projections between regions inside the cortex and to other brain regions. Of course, the reverse could also be true in other sociological rather than biological examples.

**Relationships Contain Feedback Loops:**

Both negative (damping) and positive (amplifying) feedback are always found in complex systems. The effects of an element's behavior are fed back in such a way that the element itself is altered.