



International Council on Systems Engineering
A better world through a systems approach

Complexity and Adaptive Systems

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A Complex Systems WG View

- Not all Adaptive Systems are Complex;
- Not all Complex Systems are Adaptive;

Can AI help?

- LLM AI (ChatGTP4.o) Question: “Please search for types of systems that are non-complex and non-adaptive, complex and non-adaptive, non-complex and adaptive and complex and adaptive using this definition of a complex system: A complex system has elements, the relationship between the states of which are weaved together so that they are not fully comprehended, leading to insufficient certainty between cause and effect, and the definitions of adaptability in the attachment”. The attachment contained the SEBoK definition of Adaptability. Results are shown on the next four slides.

Non-Complex, Non-Adaptive

These systems have easily comprehensible relationships between elements, with fixed interactions and predictable outcomes. Examples might include simple machines (e.g., a basic conveyor belt) or straightforward algorithms where both operation and environment remain constant.

	Non-Adaptive	Adaptive
Non-Complex	<div> <div>①</div> <div>②</div> <div>③</div> </div>	
Complex		

- ① **Simple Machines:** Lever, pulley, or inclined plane systems with straightforward, predictable relationships.
- ② **Basic Electrical Circuits:** Simple on/off circuits where the relationship between components (like a battery and a light bulb) is easy to understand and predict.
- ③ **Standard Operating Procedures (SOPs):** Rigid processes in an organization with predictable steps and outcomes, unresponsive to changes in the environment.

Complex, Non-Adaptive

These systems have interwoven relationships among elements that are challenging to fully understand, making causality hard to predict, but they lack the capability to change in response to environmental shifts. An example could be a large, rigid mechanical system (e.g., an industrial assembly line with tightly coupled operations) that cannot alter its functionality if circumstances change.

	Non-Adaptive	Adaptive
Non-Complex		
Complex	<div> <div>①</div> <div>②</div> <div>③</div> </div>	

- ① **Traditional Banking Systems:** Highly interconnected financial systems with numerous rules and components but limited in their ability to adapt quickly to unexpected changes.
- ② **Older Power Grids:** Large grids that can be complex in structure and interdependencies but lack adaptability, especially under stress or environmental shifts.
- ③ **Traffic Control Systems (Non-Adaptive):** Dense networks of traffic signals and roadways in some cities where the fixed light timings create complex interactions but don't adapt to real-time traffic flow.

Non-Complex, Adaptive

These systems have straightforward and easily comprehended relationships but can adjust to changes in their environment. An example might include a thermostat-controlled heating system, which has a simple structure yet adapts to maintain desired temperatures.

	Non-Adaptive	Adaptive
Non-Complex		<div>①</div> <div>②</div> <div>③</div>
Complex		

- ① **Home Heating System with Thermostat:** Simple in structure but adjusts automatically to changes in temperature.
- ② **Self-Watering Plant System:** Basic system where sensors detect moisture levels and activate watering, adapting to plant needs without complex interrelations.
- ③ **Basic Inventory Control System:** Stock levels that trigger reorder points automatically, reacting to inventory changes in a straightforward manner without intricate dependencies.

Complex, Adaptive



These systems are both hard to fully understand due to complex interrelations among elements and capable of changing in response to their surroundings, demonstrating resilience and self-organization. Ecosystems and economies often exemplify complex adaptive systems, as do certain software networks that adjust based on user behavior(resilience and adaptability).

	Non-Adaptive	Adaptive
Non-Complex		
Complex		<div> <div>①</div> <div>②</div> <div>③</div> <div>④</div> </div>

- ① **Ecosystems:** Forests, coral reefs, and other natural ecosystems where species interact dynamically with each other and the environment, adjusting to changes in food availability, climate, etc.
- ② **Global Supply Chains:** Highly interconnected networks that adapt based on demand, availability of resources, and geopolitical factors.
- ③ **Social Media Platforms:** Platforms like Twitter or Facebook, where user interactions form complex networks, and algorithms adapt to user behavior, trends, and content preferences.
- ④ **Human Immune System:** An adaptive system with complex interactions among cells and proteins, responding to new pathogens by building immunity over time.

A Complex Systems WG View

- There are indicative characteristics to determine if you have a complex system (e.g. Emergence), but they aren't necessary or sufficient for many complex systems, so are problematic to use to define complex systems.
- We agree System Adaptability is a characteristic and a confounding factor.
- We agree it is difficult to model complex adaptive systems.
- It may be impossible, especially given the lack of direct cause-and-effect relationships for complex systems.
- Can AI help?
- How best to proceed with complex adaptive systems?
- Perhaps start with a consistent, agreed taxonomy framework?

A Gas Turbine Example

- Non-Complex: In a gas turbine, the relationship between Cause and Effect is clear, but is obscured by heavy coupling. Expected Emergence = Thrust, Vibration, Noise, Emissions.
- Complex: Relationship between Cause and Effect is not clear and Emergence is usually Unexpected.
- Organizations are typically complex.

	Non-Adaptive	Adaptive
Non-Complex	①	
Complex		② ③

- ① Gas turbine with traditional PID controller
- ② Gas turbine with Prognostic Health Monitoring and control algorithm tuning
- ③ System that designs the gas turbine and control system