System Theory

Ronald E. Giachetti, Ph.D.
Associate Professor
Industrial and Systems Engineering, FIU
Overview

- Describe how an enterprise fits the definition of a system
- Contrast reductionist thinking with systems thinking
- Apply systems thinking to understand and solve problems
- Create a causal loop diagram
- Create a stock & flow diagram
System Definition

GOAL or PURPOSE

Interacting Parts

Open = interacts with environment

Goal or Purpose

Boundary
Emergent Properties

Properties associated with the system as a whole that cannot be attributed to a single subsystem.

- Compressor: Number of Stages, Fan Diameter, Expansion Ratio
- Engine: Weight, Afterburner Weight, Thrust Reverser Weight
- Turbine: Blade Count, Efficiency, Number of Stages
- Inlet: Design Mach Number, Ramp Angle, Contraction Ratio, Aperture Aspect Ratio
- Wings: Area, Span, Aspect Ratio, Sweep, Taper Ratio, Thickness Ratio
- Nozzle: Noise Suppression, Acoustic Treatment Area, Average Exhaust Velocity
- Fuselage: Length, Cross Sectional Area, Maximum Width
- Performance
- Stability and Control
- Cost
- Aerodynamics

Ronald E. Giachetti
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Complexity

- Is complexity simply the large number of pieces a system has?

- What about emergent behavior that cannot be predicted from system components?

- Ability to understand?
Complexity

- **Complex Adaptive Systems** – a system composed of independent agents, each with separate goals, that interact and exhibit emergent group behavior
Dynamic

![Graph showing patient service rate and booked appointments over time.]

- **Patient Service Rate**: A line graph showing the service rate over time with peaks and troughs indicating changes in service levels.
- **Booked Appointments**: A line graph showing the number of booked appointments increasing over time, with a steady trend.

The graph illustrates the dynamic nature of patient service rates and appointment bookings over a period.
Dynamic

- System changes over time
- Open systems are self-regulating, they adjust to changes in their environment (human body maintains constant internal temperature regardless of outside temperature).
Equifinality

There are many combinations of inputs, outputs, transformation processes, and decisions that all lead to the same outcome
Reductionist Thinking

- The idea that by decomposing a system we can understand how it works
- Dominate form of thinking in engineering
Systems Thinking

- A way of thinking about enterprises that stresses the importance of relationships
- A paradigm for thinking about the world
- A language and set of definitions
- A set of tools to understand systems
Summary

- Define the enterprise boundaries that help best solve the problem.
- Understand the system structure, identify its subsystems & parts.
- Determine the stakeholders, their perspectives and their goals.
- Remember there are many ways to achieve the goals (equifinality).
- Understand the interaction with the environment (enterprises are open systems).
- The enterprise has behavior that can be observed only at the enterprise level and cannot be deduced by analyzing subsystems of the enterprise in isolation.
- To maintain stability in a changing environment the enterprise must adapt, which requires feedback loops from the environment.
- Enterprises are purposeful systems because it can both choose its goals and its means to attain those goals. Additionally, the people in the enterprise are purposeful.
- The enterprise is hierarchical, it is composed of lower-level subsystems, and the enterprise is part of higher-level systems (e.g., supply chains).
- There are multiple ways to define the subsystems depending on the observers views (e.g., organizational subsystems, process subsystems, etc.).
System Dynamics

- A theory and a set of tools to study systems
- Developed at MIT by Forrester
- Combines computer simulation, control theory, and decision-making with systems theory
- Two tools to support thinking:
  - Causal Loop Diagrams
  - Stock & Flow Diagrams with simulation
Causal Loop Diagrams

- Depicts system as interrelated system of variables
Feedback Loops

Heat loss is through windows, doors, etc.

Desired Room Temperature

Heat

Gap

Room Temperature

Loss of Heat to environment
Example Causal Loop

Nurses Available

Nurse Productivity +

Diagram showing the relationship between nurses available and nurse productivity in a causal loop.
Causal Loop Adv/Dis

- In a group, facilitates brainstorming and system understanding
- Uncover all possible relationships
- Uncover complexity

- No analytical capabilities (qualitative)
- Diagrams may not be valid – difficult to check
The short-comings of causal loop diagrams is the inability to analyze the diagram

Stock & Flow are continuous simulation (think water flow through pipes)
Stock & Flow illustrated

Flow
Variable

auxiliary relationship

Stock Variable

Appointment Requests

Booked Appointments

Service Rate
Stock & Flow Illustrated

\[
\text{Booked Appointments} = 300 + \int_0^t \text{Appointment Request}(t) \, dt - \int_0^t \text{Service Rate}(t) \, dt
\]
Simulation Results

![Graph of Patient Service Rate and Booked Appointments over Time (day)]