# Lecture 1: Introduction

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- Be punctual
- No Water and other breaks during the class
- No Murmurs and Chit-chat in the class
- Mobile Phones – switched off
- No Napping in the class

- Interactions Welcome
- Free/Open to Questions/Comments

## Course Structure

- Focus on Large and Complex Engineering Systems
- Mix of Lectures and Case Studies

- Grading
  - 1. Assignments (2) 10-20%
  - 2. Mini Project 25%
  - 3. Mid-term Exams (1) 25%
  - 4. End-Semester Exam (1) 40%

  Details will be announced during the course

## What is Engineering to you?

- Design & Building (Str.)
- Applns. of Sc Ideas & Principles
  eg: Heat engines
- Eff, Cost, Trade-offs

Eg:- Cycle →

## What does one mean by a System?

- Elements
- Interaction ↔ Processes
- Utility / Purpose

## What is a System ?

- a system is a dynamic and complex whole, interacting as a structured functional unit;
- energy, material and information flow among the different elements that compose the system;
- a system is a community situated within an environment;
- energy, material and information flow from and to the surrounding environment via semi-permeable membranes or boundaries;
- systems are often composed of entities seeking equilibrium but can exhibit oscillating, chaotic, or exponential behavior.
- A holistic system is any set (group) of interdependent or temporally interacting parts. *Parts* are generally systems themselves and are composed of other parts, just as systems are generally parts or *holons* of other systems.

# Categories of Systems

- **Hard systems** — involving simulations, often using computers and the techniques of operations research.
- **Soft systems** — For systems that cannot easily be quantified, especially those involving people holding multiple and conflicting frames of reference. Useful for understanding motivations, viewpoints, and interactions and addressing qualitative as well as quantitative dimensions of problem situations.
- **Evolutionary systems** —This technique integrates critical systems inquiry with soft systems methodologies. Evolutionary systems, similar to dynamic systems are understood as open, complex systems, but with the capacity to evolve over time.

# The systems approach

- Interdependence of objects and their attributes - independent elements can never constitute a system
- Holism - emergent properties not possible to detect by analysis should be possible to define by a holistic approach
- Goal seeking - systemic interaction must result in some goal or final state
- Inputs and Outputs - in a closed system inputs are determined once and constant; in an open system additional inputs are admitted from the environment
- Transformation of inputs into outputs - this is the process by which the goals are obtained
- Entropy - the amount of disorder or randomness present in any system
- Regulation - a method of feedback is necessary for the system to operate predictably
- Hierarchy - complex wholes are made up of smaller subsystems
- Differentiation - specialized units perform specialized functions
- Equifinality - alternative ways of attaining the same objectives (convergence)
- Multifinality - attaining alternative objectives from the same inputs (divergence)

# Example 1. Braking System

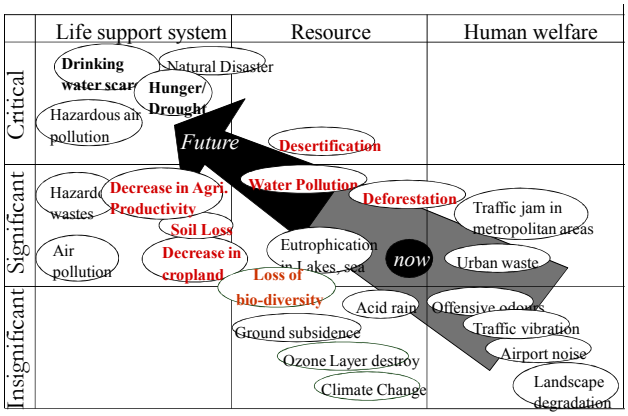
- Rather than trying to improve the braking system on a car by looking in great detail at the material composition of the brake pads (reductionist), the *boundary* of the braking system may be extended to include the interactions between the:
  - brake disks or drums
  - brake pedal sensors
  - hydraulics
  - driver reaction time
  - tires
  - road conditions
  - weather conditions
  - time of day

# Example 2. Supermarket as a System

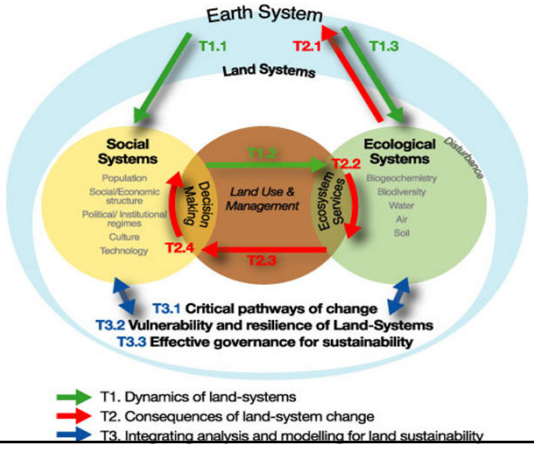
- Using the tenet of "Multifinality", a supermarket could be considered to be:
  - a "profit making system" from the perspective of management and owners
  - a "distribution system" from the perspective of the suppliers
  - an "employment system" from the perspective of employees
  - a "materials supply system" from the perspective of customers
  - an "entertainment system" from the perspective of loiterers
  - a "social system" from the perspective of local residents
  - a "dating system" from the perspective of single customers
- As a result of such thinking, new insights may be gained into how the supermarket works, why it has problems, how it can be improved or how changes made to one component of the system may impact the other components.

# Example 3. Environmental System

(ill-)Effects on the various systems and their magnitudes

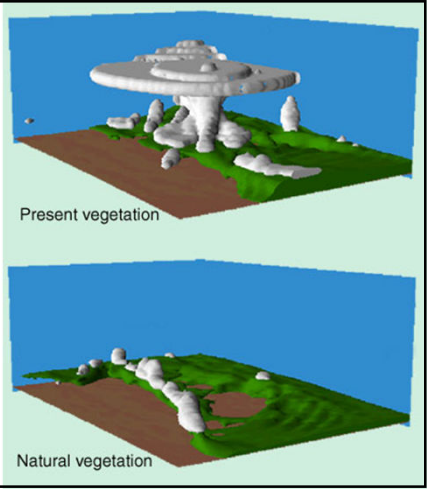



# GLOBAL LAND PROJECT: Analytical Structure



Changes in land use can dramatically alter weather patterns.

Models of cloud convection over the central USA show that storms can develop over current agricultural landscapes that would not have occurred over the original prairie land




*Source: IGBP slide series*