國立臺北大學自然資源與環境管理研究所
101 學年度第二學期『環境系統分析專題』

課程講義（六、七)：系統動力學簡介
Introduction to System Dynamics

System Dynamics Society (http://www.systemdynamics.org)
Vensim (Ventana Systems, http://www.vensim.com),
STELLA and iThink (isee Systems, http://www.iseesystems.com)
PowerSim (http://ww.powersim.com),

- INTRODUCTION TO SYSTEM DYNAMICS
  - □ Definition of System Dynamics: The Field of System Dynamics -- Overview

    System dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems — literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality.
  - □ History of System Dynamics (http://en.wikipedia.org/wiki/System_dynamics):

    System dynamics was created during the mid-1950s by Professor Jay Forrester of the Massachusetts Institute of Technology. In 1956, Forrester accepted a professorship in the newly-formed MIT School of Management. His initial goal was to determine how his background in science and engineering could be brought to bear, in some useful way, on the core issues that determine the success or failure of corporations. Forrester's insights into the common foundations that underlie engineering and management, which led to the creation of system dynamics, were triggered, to a large degree, by his involvement with managers at General Electric (GE) during the mid-1950s. At that time, the managers at GE were perplexed because employment at their appliance plants in Kentucky exhibited a significant three-year cycle. The business cycle was judged to be an insufficient explanation for the employment instability. From hand simulations (or calculations) of the stock-flow-feedback structure of the GE plants, which included the existing corporate decision-making structure for hiring and layoffs, Forrester was able to show how the instability in GE employment was due to the internal structure of the firm and not to an external force such as the business cycle. These hand simulations were the beginning of the field of system dynamics.

    During the late 1950s and early 1960s, Forrester and a team of graduate students moved the emerging field of system dynamics, in rapid fashion, from the hand-simulation stage to the formal computer modeling stage. Richard Bennett created the first system dynamics computer modeling language called SIMPLE (Simulation of Industrial Management Problems with Lots of Equations) in the spring of 1958. In 1959, Phyllis Fox and Alexander Pugh wrote the first version of DYNAMO (DYNAmic MOdels), an improved version of SIMPLE, and the system dynamics language that became the industry standard for over thirty years. Forrester published the first, and still classic, book in the field titled Industrial Dynamics in 1961.

    From the late 1950s to the late 1960s, system dynamics was applied almost exclusively to corporate/managerial problems. In 1968, however, an unexpected occurrence caused the field to broaden beyond corporate modeling. John Collins, the former mayor of Boston, was appointed a visiting professor of Urban Affairs at MIT. The result of the Collins-Forrester collaboration was a book titled Urban Dynamics. The Urban Dynamics model presented in the book was the first major non-corporate application of system dynamics.

    The second major noncorporate application of system dynamics came shortly after the first. In 1970, Jay Forrester was invited by the Club of Rome to a meeting in Bern, Switzerland. The Club of Rome is an organization devoted to solving what its members describe as the "predicament of mankind" -- that is, the global crisis that may appear sometime in the future, due to the demands being placed on the earth's carrying capacity (its sources of renewable and nonrenewable resources and its sinks for the disposal of pollutants) by the world's exponentially growing population. At the Bern meeting, Forrester was asked if system dynamics could be used to address the predicament of mankind. His answer, of course, was that it could. On the plane back from the Bern meeting, Forrester created the first draft of a system dynamics model of the world's socioeconomic system. He called this model WORLD1. Upon his return to the United States, Forrester refined WORLD1 in preparation for a visit to MIT by members of the Club of

Rome. Forrester called the refined version of the model WORLD2. Forrester published WORLD2 in a book titled World Dynamics.

- □ System Dynamics vs. System Thinking => Numerical vs. Diagrammatic
- □ Application Fields of System Dynamics: System dynamics has found application in a wide range of areas, for example population, ecological and economic systems, which usually interact strongly with each other.
  - ⇨ Generic Examples
    1. DO Sag Curve
    2. Populations of Foxes and Rabbits
    3. Modeling Sustainable Development: The T21 Model => A Brief Description of T21

- SYSTEM THINKING
  - □ Senge, Peter M., 1994. *The Fifth Discipline -- The Art and Practice of the Learning Organization*（彼得・聖吉，1994，《第五項修練》，天下文化）
    - ⇨ 五項修練：
      1. 自我超越（Personal Mastery）
      2. 改善心智模式（Improving Mental Models）
      3. 建立共同願景（Building Shared Vision）
      4. 團隊學習（Team Learning）
      5. 系統思考（System Thinking）=>「第五項修練」
    - ⇨ The 11 Laws of the Fifth Discipline:
      1. Today's problems come from yesterday's "solutions."
      2. The harder you push, the harder the system pushes back.
      3. Behavior grows better before it grows worse.
      4. The easy way out usually leads back in.
      5. The cure can be worse than the disease.
      6. Faster is slower.
      7. Cause and effect are not closely related in time and space.
      8. Small changes can produce big results...but the areas of highest leverage are often the least obvious.
      9. You can have your cake and eat it too ---but not all at once.
      10. Dividing an elephant in half does not produce two small elephants.
      11. There is no blame.
  - □ 系統基模（Systems Thinking Archetypes）(http://en.wikipedia.org/wiki/System_Archetypes)：
    - ⇨ 反應遲緩的調節環路 Balancing Loop with Time Delay
    - ⇨ 成長上限 Limits to Growth
    - ⇨ 捨本逐末 Shifting the Burden
    - ⇨ 目標侵蝕 Eroding Goals
    - ⇨ 惡性競爭 Escalation
    - ⇨ 富者愈富 Success to the Successful
    - ⇨ 共同的悲劇 Tragedy of the Commons
    - ⇨ 引酖止渴 Fixes and Fail
    - ⇨ 成長與投資不足 Growth and Underinvestment

- HOMEWORK #4 (2013/04/09 Due)：請建構氧垂曲線（Oxygen Sag Curve）系統動力學模型（系統動態模型），並設定模式參數值以求解、圖示該曲線之特性。