國立臺北大學自然資源與環境管理研究所
九十七學年度第二學期
『環境系統分析』課程講義（一、二）

進度：課程簡介與線性規劃進階主題

- GOALS OF THE COURSE
  - □ Handout Download
    - ⇨ http://web.ntpu.edu.tw/~yml/yml/download/download.html
    - ⇨ http://sginrm.ntpu.edu.tw/yml/download/download.html (under maintenance!!)
  - □ Content ⇒ Systems Analysis Models and Applications Concerning the *Environment*
    - ⇨ Systems vs. Systems Analysis
    - ⇨ Systems Analysis vs. Operations Research (Operational Research)
    - ⇨ Systems Analysis vs. System Simulation
    - ⇨ Programming vs. Planning => Simulation and Optimization
    - ⇨ Conceptual models => Mathematical models => Simulation/Optimization models
  - □ Mathematical Models
    - ⇨ Classification: Prescriptive vs. Descriptive; Deterministic vs. Stochastic
    - ⇨ Solution Techniques: Symbolic/Graphical Interpretation; Analytical vs. Numerical
    - ⇨ Algorithms, Numerical Methods => Linearity, Convexity, and Complexity

- OPTIMIZATION AND SIMULATION SOFTWARE
  - □ Problems or Models
    - ⇨ Linear vs. nonlinear; constrained vs. unconstrained; continuous vs. discrete
  - □ Platform and Programming
    - ⇨ Command-line vs. Windows; Editor-oriented vs. Object-oriented
  - □ Programming Skill
    - ⇨ Solver package vs. Program coding => Compiling vs. Running of Program codes

- SOFTWARE TO BE COVERED
  - □ GAMS (General Algebraic Modeling System):
    "GAMS is a high-level modeling system for mathematical programming problems."
  - □ LINGO (LINDO System's Product):
    "LINGO is a comprehensive tool designed to make building and solving linear, nonlinear and integer optimization models faster, easier and more efficient."
  - □ What'sBest! (LINDO System's Product) lets you build linear, nonlinear, and integer models in Excel. Models are easy to build and understand using standard spreadsheet equations.
  - □ Vensim (Vensim from Ventana Systems): "Vensim is used for developing, analyzing, and packaging high quality dynamic feedback models."
  - □ ExpertChoice: A decision support software using Analytical Hierarchy Process (AHP)
  - □ EULER: "EULER is a numerical matrix system. It is not a MatLab clone, but very similar to that."
  - □ Other Software Packages?! – *What do you expect?*

- COMPONENTS OF AN OPTIMIZATION MODEL
  - □ Objective Function(s)
    - ⇨ Single vs. Multiple
    - ⇨ Linear vs. Nonlinear
    - ⇨ Convex (Concave) vs. Non-convex
  - □ Constraints
    - ⇨ Constrained vs. Un-constrained
    - ⇨ Linear vs. Nonlinear
    - ⇨ Convex vs. Non-convex Feasible Regions
  - □ Decision Variables
    - ⇨ Continuous vs. Discrete
    - ⇨ Deterministic vs. Stochastic
  - □ System Parameters (Coefficients)
    - ⇨ Deterministic vs. Stochastic
    - ⇨ Division into Sub-Models
  - □ Fuzzy Sets and Grey Information (Interval Variables)
    - ⇨ 'Probability,' 'Likelihood,' and 'Possibility'
    - ⇨ Uncertainties about Decision Variables and Parameters are Incorporated
    - ⇨ Division into Sub-Models

- PROPERTIES OF AN LP
  - □ Formulation: Standard Form, Algebraic Form, and Matrix Form
  - □ Proportionality, Additivity, Divisibility, Certainty , and Non-Negativity
  - □ Non-negative Decision Variables => What if negative values are needed?
  - □ A "Convex Programming" Model
  - □ Additional Terminology
    - ⇨ Feasible Region or Solution Space
    - ⇨ Vertex, Extreme Points or Corner Points
    - ⇨ Decision Space or Objective Space

- SOLUTION PROCEDURE OF AN LP
  - □ Pre-Optimal Analysis, Optimization (Solution) and Post-Optimization Analysis
  - □ Graphical, Simplex, Dual Simplex, Interior Point and Other Methods
  - □ Infeasible, Un-bounded and Degenerate Solutions
  - □ A "Convex Programming" Model: Feasible Region and Extreme Points
    - ⇨ Characteristics of Feasible Region for the LP: Convex, compact, and continuous
    - ⇨ Extreme Points (Corner Points) vs. Interior Points

- THE SIMPLEX METHOD
  - □ Augmented Form of the LP Models
    - ⇨ "Less-than-and-equal-to" Inequality constraints => Slack variables
    - ⇨ "Greater-than-and-equal-to" Inequality constraints => Surplus and Artificial Variables
    - ⇨ Equality constraints => Artificial variables => 'Big-M Treatment'
  - □ Terminology and Procedure of the Simplex Method
    - ⇨ Basic vs. non-basic variables

- ⇨ Feasible basic solution => "Adjacent"
- ⇨ Ratio test for Pivoting
- ⇨ "Optimality"

□ Simplex Tableaus and An Animated Presentation

- THE PROTOTYPE EXAMPLE: Glass Production at Wyndor Glass Co.
  - ⇨ Objective Function: Maximizing the profit
  - ⇨ Decision Variables: Production rate of the two types of products
  - ⇨ Constraints: Production time limits at the three plants

TABLE 3.1 Data for the Wyndor Glass Co. problem

	Production Time per Batch, Hours		
	Product		
Plant	1	2	Production Time Available per Week, Hours
1	1	0	4
2	0	2	12
3	3	2	18
Profit per batch	$3,000	$5,000	

$$\text{Maximize} \qquad Z = 3x_1 + 5x_2,$$

subject to the restrictions

$$\begin{aligned} x_1 &\le 4 \\ 2x_2 &\le 12 \\ 3x_1 + 2x_2 &\le 18 \end{aligned}$$

and

$$x_1 \ge 0, \qquad x_2 \ge 0.$$

- SENSITIVITY ANALYSIS
  - □ Overview and Post-Optimality Analysis
  - □ Sensitivity Analysis on RHS (Resource) Coefficients
    - ⇨ Shadow price, marginal value of a resource and economic interpretation
    - ⇨ Dual price (?)
  - □ Sensitivity Analysis on Objective Function Coefficients
  - □ Graphical Illustration
  - □ Outputs from Optimization Packages and Analytical Interpretation (?)
  - □ Parametric Programming

- DUALITY THEORY
  - □ Model Formulations
  - □ Dual-Primal Relationships
    - ⇨ Implementation from Production Problem
    - ⇨ Implementation from Resource Allocation Problem
  - □ Shadow Price
  - □ Primal-Dual Methods for Optimization (Lagrange Algorithms)

- HOMEWORK #1 (3/10/2009 Due): *Solve* the prototype example in Hillier and Lieberman's textbook (p.25) by using LONGO, What'sBest, and GAMS.