Civil and Environmental Engineering 483
Infrastructure Systems Analysis
Winter 2007

Instructor:	Pablo L. Durango-Cohen
	Office: Tech A335
	Office Hours: T 3–4, F 1–2, and by appointment.
	Phone: (847)491-4008
	Fax: (847)491-4011
	Email: `pdc@northwestern.edu`
Class Times and Locations:	T-Th 9:30-10:50 (TECH L158), F 10-10:50 (TECH MG28)
Class Website:	Northwestern Course Management System
	`http://courses.northwestern.edu`

Course Description

The course introduces students to the formulation and analysis of mathematical models to address tactical and strategic problems in the context of planning and managing civil infrastructure systems. The methodological tools are drawn from applied statistics, decision analysis, dynamic programming, Markov decision processes, and game theory. Applications and topics include: condition assessment and statistical performance modeling, shortest path problems, inventory management, capacity management, and maintenance optimization. The course integrates methodological tools with applications.

Intended Audience

1. Students who are interested in the issues and challenges (economic, technical, environmental, political, ...) involved in the planning and management of civil infrastructure systems, and the development of models to support such decisions.

2. Students who are interested in learning how to apply quantitative models to solve sequential decision-making problems. In particular, we will focus on tools often used in the management sciences, such as dynamic programming and game theory to develop insights about the structure of problems and policies.

Objectives

1. To encourage the development of a "systems perspective" necessary for the planning and management of large-scale civil and environmental engineering systems;

2. To introduce students to the formulation and analysis of prescriptive models for planning or management of (civil) infrastructure systems such as bridges, highway pavements, power-transmission and telecommunication networks, hospitals, hotels, factories, airports, etc. The methodological tools that will be covered are actually quite general and useful in many planning and management situations; and,

3. To expose students to recent research in the management of civil infrastructure systems.

Course Materials

The required reference materials for this course have been compiled in a course reader that is available at Quartet Copies (825 Clark Street, Evanston). The reader includes: (i) appendix G from *Dynamic Programming and Optimal Control* by Bertsekas; (ii) chapters 1, 2, 4, 9, 10, and 11 from *The Art and Theory of Dynamic Programming* by Dreyfus and Law; and (iii) research papers related to infrastructure planning and management to be presented in class. The reader for the current year has been modified, so I urge you to purchase your own copy. Additional required materials will be distributed in class as necessary. Other reference texts include:

1. Keeney, R.L. and Raiffa, H. (1993); *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*; Cambridge University Press.
2. Hirshleifer, J. and Riley, J. (1992); *The Analytics of Uncertainty and Information*; Cambridge University Press.
3. Hillier, F. and Lieberman, G. (1990); *Introduction to Operations Research*; Fifth Edition, McGraw-Hill.
4. deNeufville, R. (1990); *Applied Systems Analysis*; McGraw Hill.
5. Revelle, C.S., Whitlatch, E.E. and Wright, J.R. (2004); *Civil and Environmental Systems Engineering*; Prentice Hall.
6. Dreyfus, S. and Law, A. (1977); *The Art and Theory of Dynamic Programming*; Academic Press.
7. Bertsekas, D. (2000); *Dynamic Programming and Optimal Control*; Athena Scientific.
8. Bather, J. (2000); *Decision Theory: An Introduction to Dynamic Programming and Sequential Decisions*; John Wiley & Sons, Ltd.
9. Gibbons, R. (1992); *Game Theory for Applied Economists*; Princeton University Press.
10. Hudson, W.R., Haas, R. and Uddin, W. (1997); *Infrastructure Management*; McGraw Hill.

Reference 1 is a/THE comprehensive book about Decision Analysis. Reference 2 presents in-depth coverage of the economics of uncertainty and information. References 3, 4, and 5 are introductory texts that present coverage of the methodology that we will be studying. Reference 6 is an intermediate level text in Dynamic Programming. It focuses on the art of formulating sequential decision problems. The next two references are advanced references on Dynamic Programming and Optimal Control Theory. Reference 9 provides an intermediate level coverage of Game Theory. Finally, reference 10 provides an overview of Infrastructure Management. Many interesting and relevant articles can be found in the Journal of Infrastructure Systems available online through the ASCE website (`www.asce.org`).

Course Assessment

The course integrates methodological tools with applications. Lectures will be devoted to learning the tools and solving problems to reinforce the material. In addition there will be sessions dedicated to the presentation and discussion of recent, relevant research papers.

1. Homework assignments (20%). Homework is due in class according to the schedule provided in the following page. Solutions to the assignments will be provided on the day the assignment is due. Therefore, no late homework can be accepted. Only the best four of the five for-credit assignments will count toward the final homework score. You should start working on the homework early so that you have time to ask questions before the homework is due. Please feel free to work in groups or to ask for help from fellow students or the instructor. Each student must submit his/her own work unless otherwise stated.
   In addition to the required problems, the assignments may have some in-depth problems that will be labeled with "*" or "**". Star-labeled problems are appropriate for take-home exams or for PhD entrance exams. Double-star-problems are appropriate for research papers. You may earn extra-credit by trying these problems. Only careful solutions will be evaluated.

2. Presentation (20%). Lead discussion of a set of technical papers assigned by the instructor in groups of two (or three). This should not be a lecture; discussion leaders should ensure that the main points of the paper are clearly elicited. *The leaders must prepare an outline to be distributed to the class and have it approved by the instructor at least one week in advance of the discussion.*

3. Participation (10%). Students are expected to prepare for and actively participate in class discussion (of technical papers). This may involve asking relevant questions, answering questions that are raised, preparing an example and explaining it to the class, etc.

4. Type-setting lecture notes (10%). Each student will be required to edit/type-set the lecture notes for up to two classes using LaTeX. The lecture notes for a class must be turned in to the instructor up to two weeks after the class so that they can be reviewed and posted on the course website.

5. In-class examinations (20% each). The examinations will be open-book/notes and will be designed to test your understanding of the methodological material presented in class, in the homework assignments, and in the readings. The dates for the exams are printed in the class schedule.
   Special arrangements for the exams must be discussed with the instructor two weeks prior to the exam's scheduled date. Travel arrangements ARE NOT sufficient to warrant special accommodations.

COURSE SCHEDULE				
Date:	**Topics**	**Scribe**	**Hand-ins**	**Handouts**
01/04	Introduction & Organization Introduction to Infrastructure Systems Analysis			Syllabus
01/05				
01/09	Introduction to Decision Analysis			HW1
01/11	Value of Information and Options			
01/12				
01/16	Introduction to Dynamic Programming	Laurence		
01/18	Introduction to Dynamic Programming (cont.)	Laurence	HW1	Sol1, HW2
01/19	LaTeX tutorial session by James Chu			
01/23	Class canceled due to TRB Annual Meeting			
01/25	Class canceled due to TRB Annual Meeting			
01/26	Class canceled due to TRB Annual Meeting			
01/30	Deterministic Equipment Replacement	Elhousseine		
02/01	Shortest Path Problems			
02/02				
02/06	Stochastic Dynamic Programming	Elaine	HW2	Sol 2, HW3
02/08	Stochastic Dynamic Programming	Marshall		
02/09				
02/13	EXAM 1 (Decision Analysis and Deterministic Dynamic Programming – material covered through 02/01)			
02/15	Stochastic Equipment Replacement	Zitao		
02/16	Presentation 1			
02/20	Stochastic DPs with special structures Infinite planning horizons		HW3	Sol3, HW4
02/22	Adaptive Dynamic Programming	Xing		
02/23	James Chu: Infrastructure Performance Modeling			
02/27	Introduction to Game Theory Nash Equilibrium & Subgame perfect Nash Equilibrium		HW4	Sol4, HW5
03/01	Sequential and Simultaneous move games			
03/02	Presentation 2			
03/06	Credibility and SPNE Bargaining			
03/08	Presentation 3			
03/09	Wrap up and review		HW5	Sol5
03/14	FINAL EXAM: Time: 12-2; Location: TECH L158			