University of Southern California
School of Engineering
Daniel J. Epstein Department of Industrial and Systems Engineering

ISE 530: Introduction to Operations Research
Spring, 2002-03 (3 units)
Tuesday Evenings, 6:30-9:10 PM
OHE 100

Professor James Moore
KAP 224D
740-0595 (office)
jmoore@usc.edu

KAP Office Hours: Email is suggested as a first option. Answers to questions of sufficient breadth will be circulated back to the class. Appointments will also be taken.

A standing office hour for walk-ins and study groups will be established after the first week of class. Office hours might be set up in the period just prior to class if class members find this option convenient.

Teaching Assistant: Xumeit Tan xmeitan@usc.edu
GER 207 740-6664 (office)

Quantitative: (1) Expressed or capable of expression as a quantity. (2) Of, pertaining to, or susceptible to measurement. (3) Of, or pertaining to number or quantity.

Analysis: (1) The separation of an intellectual or substantial whole into constituents for individual study. (2) A statement of the results of such a study. (3) The method of proof in which a known truth is sought as a consequence of reasoning from the thing to be proved.

Operations research: Mathematical or scientific analysis of the systematic efficiency and performance of manpower, machinery, equipment, and policies used in a government, military, or commercial operation.

Objective:

This course is intended to provide a comprehensive overview of the principles and practice of operations research. **Part I** is a (very) brief introduction to the field, its history, and the role of models in the study operations. **Part II** focuses on smooth, deterministic models with an emphasis on linear and nonlinear programming algorithms. **Part III** focuses on combinatoric programming and discrete mathematics, including dynamic programming, and elements of control theory. **Part IV** focuses on stochastic models, including discrete time Markov processes and the theory of queues. Time-permitting, there will also be a summary discussion of continuous time Markov processes.

This course is appropriate for students in the MSEMT program, students in some MSSAE, and MSME options, MSISE students who are making up an undergraduate deficit in operations research education. MBA students interested in production and operations management, and graduate students in other areas of engineering, economics, business, policy and planning. The course is redundant for

PhD students in Industrial and Systems Engineering and for MS students in the Operations Research Engineering program. ISE PhD and MSORE aspirants who have not covered the material in ISE 530 should take separate courses in deterministic and stochastic methods.

SPPD students intending to use this course as a methodology course in the Urban Planning PhD program should see me, and expect register for an additional unit of PLUS 790 in addition to ISE 530.

Lectures:

Three hours of lecture will be offered each week. We have only a very limited amount of time, and routine attendance is strongly encouraged. If you do skip a class, the cost is yours, not mine.

This is a lecture-based course, but questions and informed discussions have an important role. Because this is a survey class treating a wide range of techniques, not all topics can be treated in the detail they merit. Questions concerning clarifications, extensions, and applications are welcome and always encouraged, but class members may sometimes find themselves asking reasonable, relevant questions that I will not take the time to answer during lecture. These questions can be pursued on the telephone, in email exchanges, or during office hours.

Requirements:

Ideal preparation for this special topics course includes calculus, Math 225 Linear Algebra, and a calculus-based course in probability or uncertainty, such ISE 220 Probability Concepts in Engineering. Students who feel that their mathematical backgrounds are suspect should discuss their situation with me. Students will likely find the course an uncomfortable experience without a working knowledge of matrix arithmetic and fundamental probability theory. Math programming assignments will routinely involve the use of LINDO (Linear INteractive Discrete Optimizer) or LINGO (Linear INteractive General Optimizer) optimization packages. LINDO's interface is user-friendly to the point of being user-obsequious. LINDO and LINGO have similar, windows-based interfaces, but LINGO addresses a larger class of problems. Our homework problems are all small enough to be solved on personal computers, and I have ordered the student versions of LINDO and LINGO for Intel platforms through the USC Bookstore. The software comes bundled with a third, package called What's*BEST!* that you may find useful, but will not be required to use in this course. What's*BEST!* adds optimization resources to spreadsheets.

Evaluation:

Objective measures include homework exercises (30%), one midterm (in class, 25%, tentatively scheduled for Tuesday, March 11), and a take home final exam (35%, Tuesday, May 6). These weights add up to 90%. An additional 10% will be added to the weight for that course component accounting for each student's best performance. There are many ways for a student to turn in a performance that reflects a state of information lower than his or her true state of information, but relatively few ways for a student to turn in a performance reflecting a better state of information than the he or she actually has. Consequently, I place a premium on the importance of each student's best score on the assumption that this score include less bias than his or her lower scores. There is nothing arbitrary about this procedure. The same rules apply to all students. Consider the following examples.

Student 1	Score (out of 100)	Weight	Contribution
Homework Average	82.	30.%	24.60
Midterm Examination	88.	25.%+ 10.%=35.%	30.80
Final Examination	73.	35.%	25.55
Course Total			80.95*

* This is probably some flavor of "B."

Student 2	Score (out of 100)	Weight	Contribution
Homework Average	93.	30.%+ 10.%=40.%	37.20
Midterm Examination	88.	25.%	22.00
Final Examination	85.	35.%	29.75
Course Total			88.95*

* This is probably some flavor of "A, " a low "A."

Makeup midterm examinations will not normally be given. Makeup final examinations can only be given if the terms of an incomplete grade are met. Homework assignments will be distributed approximately bi-weekly, and are always due in seven days. Class members should respect this schedule. Late work will normally be declined.

Homeworks are for instruction as well as evaluation. Our world class Teaching Assistant Xumei Tan and I am willing to discuss the homework assignments at any length during office hours. Anyone who wants a perfect score on any homework assignment can get one by asking the Teaching Assistant or me for assistance.

Academic Integrity:

Cooperation is often the least expensive means of overcoming difficulty. You are encouraged to execute homework assignments in teams of up to four members. Team members will receive identical grades on group assignments. If you have not contributed to the completion of a homework assignment, please do not ask your colleagues to fraudulently append your name to their work. This would be a violation of University Conduct Code § 11.15, 11.17, 11.21, and 11.31. See the 2002-03 edition of *SCampus*.

The Department of Industrial and Systems Engineering adheres to the University's policies and procedures governing academic integrity as described in *SCampus*. Students are expected to be aware of and to observe the academic integrity standards described in *SCampus*, and to expect those standards to be enforced in ISE 530. The Division of Student Affairs imposes penalties for academic fraud ranging from an "F" on the assignment involved to the termination of a USC enrollment. Academic integrity is serious business. The Dean of a local law school was fired for plagiarism in 2001.

Students with Disabilities:

Any Student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to the

TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m. - 5:00 p.m., Monday through Friday. The phone number for DSP is (213)740-0776.

Required Text:

Phillips, Ravindran, and Solberg. Operations Research: Principles and Practice, 2nd ed., New York: John Wiley & Sons, Inc., 1987 (USC book store).

Required Software:

Lindo Systems, Inc., "Solver Suite, the Premier Modeling Tools: LINDO, LINGO, and What's BEST!," Lindo Systems: Chicago, 1998 (USC book store).

Required Manual:

Lindo Systems, Inc., *LINDO Users manual*, Lindo Systems: Chicago, 1998 (USC book store).

There is also a LINGO manual available, but it is redundant with respect to the LINDO manual and the Solver Suite's online help function. If you want to order the LINGO manual, visit http://www.lindo.com to order.

Website:

The course websites are http://den.usc.edu/ and http://learn.usc.edu/. The DEN site is for students enrolled in the DEN version of the course, or who have otherwise purchased access to the DEN resources, and includes webcasts of the lectures. The LEARN site contains all of the static material available on the DEN site, but no webcasts. Any student may access the LEARN site.

One day soon, DEN will be using the software used to implement the LEARN site, and there will only be one course website for DEN courses. That day, however, is not today. All handouts will be distributed through the LEARN website. You may also view a private record of your scores on the LEARN website. Both sites are password protected. Log into the LEARN site using your USC unix user name and password.

Except for the NTU students, you all have a USC unix user name and email account, even if you have never used it. NTU students will log onto the LEARN website as guests. To log into the LEARN website as yourself rather than as a guest, you must execute the USC Information Services Division (ISD) first login procedure. This is web based. Go to

https://secweb.usc.edu/cgi-local/firstlogin/

You will see a screen like the one below. Follow instructions to activate your USC email account so that you can more easily access your http://learn.usc.edu/ account. You are part of the University Park campus (as opposed to the Health Sciences Campus). I will communicate with you at any email address you prefer. Send me a message at jmoore@usc.edu from your preferred account identifying yourself as a student in this course.

Welcome to the Information Services Division (ISD) Account Activation Page.

Computer accounts are automatically created for faculty, staff and students enrolled at USC. These pages allow you to determine your username and email address, activate your computer account, select an initial password, and learn about computer resources available at USC.

If you experience any problems while using this page please contact the ISD Customer Support Center located in Jefferson 150, via telephone at 213 740-5555, or through email to <consult@usc.edu>.

Fill in your first and last name and date of birth below.

First Name:

Last Name:

Date of Birth: January 1

Please check here if you are a student.

Please check here if you are a faculty/staff member at the University Park Campus.

Please check here if you are a faculty/staff member at the Health Sciences Campus or in the School of Dentistry.

Find Username | Clear Form

Anyone enrolled in the DEN version of the course has already visited the DEN website and set up a student profile. If not, do so now.

Additional references (available in Seaver Science Library):

Hillier and Lieberman, Introduction to Operations Research, 3rd ed., San Francisco: Holden-Day, Inc., 1980 (T57.6.H54 1986, the OR bible, a more recent edition is likely available).

Lipshutz, Schaum's Outline Series, Theory and Problems of Linear Algebra, New York: McGraw-Hill Book Co., 1968 (QA251.L54, more than anyone needs to know about linear algebra).

Tentative Course Outline and Reading List:

We will cover the materials below in the order indicated. The readings in the text are indicated in parentheses. The readings in the text are not optional. The remaining readings are located on the LEARN website, as are the lecture notes. Many of these additional readings are optional. I will indicate priorities as we proceed.

I. Introduction to Applied Mathematics Professional Practice and Modeling (1.1-1.4)

Grotschel, Krumke, Rambau, and Torres (2002) "Making the Yellow Angels Fly: Online Dispatching of Service Vehicles in Real Time," *SIAM News* (May) p 1.

Robinson, S. (2002) "Awaiting DMCA Clarification, Researchers Proceed Cautiously," *SIAM News* (February) p 1.

I tried to get these materials below loaded onto the LEARN website, but the cognizant editor is offering only limited cooperation. You will have to go the web for these materials. See the "External Links" section of the LEARN website. Lionheart Publishing is generally more supportive of students.

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Date: Mon, 09 Dec 2002 16:51:43 -0800
From: Peter Horner <horner@lionhrtpub.com>
To: Marnie Wrenn <mcwrenn@attbi.com>, "Jim Moore, Prof, CE/SPPD"
<jmoore@almaak.usc.edu>
Cc: patton@lionhrtpub.com
Subject: E-copies of ORMS Today articles

Dear Professor Moore,

Allow me to step in and make this process easier for all concerned. We are
pleased that you will be using OR/MS Today articles and surveys as part of
your teaching materials.

Instead of providing PDF files, I suggest your students simply access the
articles online at:
http://www.lionhrtpub.com/ORMS.shtml

I believe all of the articles you requested are available online.

To make it even easier, the survey articles are grouped together at:
http://www.lionhrtpub.com/orms/ormssurveys.html
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If you need hard copies, consider this e-mail permission for you to make 10
copies of each article and distribute them to your students for educational
purposes as outlined in your proposal.


Best,
Peter Horner
editor, OR/MS Today
horner@lionhrtpub.com
770-587-3172
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Horner (2002) "History in the Making," *OR/MS Today* 29 (5) pp 30-39.

Grossman (2002) "Software Survey: Spreadsheet Add Ons," *OR/MS Today* 29 (4) pp 46-52.

Dutta (2002) "System Dynamics," *OR/MS Today* 29 (3) pp 30-35.

Maxwell (2002) "Software Survey: Decision Analysis," *OR/MS Today* 29 (3) pp 44-51.

Hall, R. (2002) "Software Survey: Change of Direction," *OR/MS Today* 29 (1) pp 38-47.

Keeney, R. (2001) "Forum: Countering Terrorism," *OR/MS Today* 28 (6) pp 20-22.

Swain (2001) "Software Survey: Looking for Meaning," *OR/MS Today* 28 (5) pp 48-57.

Grossman (2001) "Education: Reversing Tradition," *OR/MS Today* 28 (4) pp 22-25.

Fourer, R. (2001) "Software Survey: Linear Programming," *OR/MS Today* 28 (4).

Swain (2001) "Software Survey: Simulation," *OR/MS Today* 28 (1) pp 52-63.

Koch, T. (1999) "GIS: Mapping the OR/MS World," *OR/MS Today* 26 (4) pp 26-30.

Cipra, B. (1999) "Massive Graphs Pose Big Problems," *Society for Industrial and Applied Mathematics (SIAM) News*, April, pp 1 and 12-13.

Davis, P. (1994) "Airline Ties Profitability to Yield Management," *Society for Industrial and Applied Mathematics (SIAM) News*, May/June, pp 12 and 18.

Pinchback, R. M. (1993) "Out of the Dark Ages: Once Obscure Computational Algebra Grows in Popularity," *OR/MS Today*, June, pp 38-40.

Trefthen, L. N. (1992) "Commentary: The Definition of Numerical Analysis," *Society for Industrial and Applied Mathematics (SIAM) News*, November, pp 6 and 22.

Kolata, G. (1991) "Computers Still Can't Do Beautiful Mathematics," *New York Times*, July 14.

Wallich, P. (1991) "Fortran Forever," *Scientific American*, July, pp 112.

II. Smooth Deterministic Models

A. (A quick) Review of Matrix Methods and Definition of Terms (A.2-A.3, lecture notes)

B. Linear Programming (LP)

1. Production Problem (2.1-2.2, lecture notes)

2. Simplex Algorithm - Phase II
- **a.** Geometric interpretation (2.3, lecture notes)
- **b.** Algebraic interpretation (2.4-2.6, 2.7-2.8 only lightly, the tableau procedure is not very useful in practice, 4.1 revised simplex is much more useful, lecture notes)

3. Transportation Problem, Assignment Problem, Other Standard Formulations (3.1-3.3 lightly, lecture notes)

4. Simplex Algorithm - Phase I and the Big-M Method (2.9, 4.1, lecture notes)

5. Duality Theory (4.2, lecture notes)
- **a.** Symmetric and asymmetric duals
- **b.** Shadow prices
- **c.** Complementary slackness

6. LP Extensions and Recent Developments (qualitative, lecture notes)
- **a.** Sparsity, speed, and special structure
- **b.** Interior point methods
- **b.** Connectionist paradigms

Brill, Downey E. (1979) "The Use of Optimization Models in Public Sector Planning," *Management Science*, **25** (5), pp 413-422.

Tovey, C. (1988) "Teaching Karmarkar's Algorithm," *OR/MS Today*, April, pp 18-19.

Wilson, R., and Sharda, R. (1992) "Neural Networks," *OR/MS Today*, August, pp 36-42.

Kalaba, R., M. Kim, M. & J. E. Moore II (1990) "Linear Programming and Simple Associative Memories," *Applied Mathematics and Computation* **40**, pp 203-214.

Moore II, J. E., M. Kim, J.-G. Seo, Y. Wu & R. Kalaba (1991) "Linear Programming, Recurrent Associative Memories, and Feed-Forward Neural Networks," *Computers, Mathematics, and Applications* **22**, pp 71-90.

C. Mixed Integer Programming (MIP, 4.6, lecture notes)

1. Relaxation

2. Implicit Enumeration

3. Land and Doig's Facility Location Problem

4. Maximum Covering (MC) and Maximum Expected Covering (MEC) Problems (lecture notes)

Salkin, H. M. & W. L. Balinsky (1973) "Integer Programming Models and Codes in the Urban Environment," *Socio-Economic Planning Science* **7**, pp 739-753.

Church, R. & C. ReVelle (1974) "The Maximal Covering Location Problem," *Papers of the Regional Science Association* **32**, pp 101-118.

Sacks, Stephen R., and Shirley Grief (1994) "Orlando Magic," *OR/MS Today*, February, pp 30-32.

__________ (1987) "Computer Science's Holy Grail," *The Economist*, August 29, pp 77-80.

Samuelson, D. A. "The Explorer's Parable," *OR/MS Today* **14** (1).

Robinson, S. (2002) "Computer Scientist Find Unexpected Depths in Airfare Search Problem," *SIAM News*, July/August, pp 1, 10.

D. Heuristic Algorithms (lecture notes)

1. Maranzana's Facility Location Procedure
2. Other Greedy Adding (GA) and Greedy Adding and Substitution (GAS) Algorithms

Maranzana F. E. (1964) "On the Location of Supply Points to Minimize Transport Costs," *Operational Research Quarterly* **15**, pp 261-270.

Kirkpatrick, S., Gelatt Jr., C. D., and Veechi, M. P. (1983) "Optimization by Simulated Annealing," *Science* **220**, pp 671-680.

Brandeau M. L. & S. Chu (1989) "An Overview of Representative Problems in Location Research," Management Science **35**, pp 645-675.

Nygard, K. E., Ficek R. K., and Sharda, R. (1992) "Genetic Algorithms," *OR/MS Today*, August, pp 28-34.

E. Nonlinear Programming

1. Transportation Problem Revisited (3.1-3.3 revisited, lecture notes)
2. Equilibrium Flows in Congested Networks (lecture notes)
3. Solution Characteristics (LINDO Systems 19, 11.1, lecture notes)

Eash, R. W., B. N. Janson, & D. E. Boyce (1979) Equilibrium Trip Assignment: Advantages and Implications for Practice, paper presented at the 58th Annual Meeting of the Transportation Research Board.

Summary of Chang, A. (1984) "Nonlinear Programming, Chapter 21 in *Fundamentals of Mathematical Economics*, 3rd ed., New York: Mc-Graw-Hill Book Co., pp 716-755.

Chang, A. (1984) "Nonlinear Programming, Chapter 21 in *Fundamentals of Mathematical Economics*, 3rd ed., New York: Mc-Graw-Hill Book Co., pp 716-755.

Gill, P. E., Murray, W., Saunders, M. A., and Wright, M. (1985) Model Building and Practical Aspects of Nonlinear Programming. Techncial Report SOL 85-2, Systems Optimization Laboratory, Stanford University, Stanford CA 94305, pp 1-9.

Dembo, R. S., Mulvey, J. M. & Zenzios (1989) "Large-Scale Nonlinear Network Models and Their Application," *Operations Research* **37**, pp 353-373.

III. Combinatorial Optimization

A. Minimum Path Problem (3.5, lecture notes)

1. Bellman's equations and the equivalent LP problem: no cycles

2. Dijkstra's algorithm: no negative arcs

3. Bellman-Ford extension: no negative cycles

4. PERT/CPM procedures (3.7)

B. Dynamic Programming (10.1-10.9)

1. Machine replacement and other investment problems

2. Extensions to control theory

C. Maximum Flow and the Equivalent LP Problem (3.4)

1. Ford and Fulkersons' maximum flow / minimum cut theorem

2. Flow augmenting paths and the max flow algorithm (also see lecture notes)

D. Efficiency of Polynomial Time Algorithms (2.10, lecture notes)

1. Polynomial time comparisons

2. Traveling salesman and other difficult problems

Erisman, A., and R. Grimes (1989) "Sparse Matrices Today," *SIAM News*, May, pp 16.

Bellman R. & R. Kalaba (1965) "Multistage Decision Processes," Chapter II, Parts 5 and 20 in *Dynamic Programming and Modern Control Theory*, New York: Academic Press, pp 35, & 50-56.

Bellman R. & R. Kalaba (1965) "Computational Aspects," Chapter III, Part 10 in *Dynamic Programming and Modern Control Theory*, New York: Academic Press, pp 73-76.

Bellman R. & R. Kalaba (1965) "Analytic Results in Control and Communication Theory," Chapter IV, Parts 1-4 in *Dynamic Programming and Modern Control Theory*, New York: Academic Press, pp 66-72.

Bellman, R. (1958) "On a Routing Problem," *Quarterly Journal of Applied Mathematics* **16**, pp 87-90.

Bellman R. & R. Kalaba (1960) "On kth Best Policies," *Journal of the Society for Industrial and Applied Mathematics* **8**, pp 582-588.

Bishop, J. E. (1991) "Mathematicians Find New Key to Old Puzzle" *The Wall Street Journal*, Section B, February 15, pp 5.

Machol, R. E. (1991) "Interesting Work," Letter to the Editor of *OR/MS Today*, December, pp 13.

Cipra, B. A. (1993) "Engineers Look to Kalman Filitering for Guidance," *SIAM News*, August, pp 8-9.

Kobayashi, Mei, et. al. (1994) "The Traveling Salesman Problem: PCBs, Punch Presses, ... and Pachinko," *SIAM News*, December, pp 4, 6

IV. Stochastic Models in Operations Research

A. Review of Probability Theory (B.1-B.20, on your own time)

B. Definition of Terms (6.1-6.4)

C. Discrete Time Markov Processes

1. Chapman-Kolmogorov Equations (6.5-6.6, lecture notes)
2. First Passage Times (6.7, lecture notes)
3. Classification of States (6.8, lecture notes)
4. Ergodicity (6.9, lecture notes)
5. Absorption (6.10, lecture notes)

D. Markovian and Generalized Queues (7.1-7.3, lecture notes)

1. Performance Measures (7.4-7.5, lecture notes)
2. Balance Equations (7.6, lecture notes)
3. M/M/1 Results (7.7-7.8, lecture notes)
4. M/M/s Results (7.9-7.10, lecture notes)

E. Important Generalizations

1. Other arrival and service distributions (7.11, 7.13)
2. Continuous time chains (6.11-6.17)
3. Simulation (9.1-9.3)

Swain, J. J. (1992) "Telecommunications," *OR/MS Today*, February, pp 18-24.

Thesen, A., and L. Travis (1988) "Introduction to Simulation," pp 7-14.

This schedule is optimistic, but it has been met before. Hopefully, you will find these procedures useful in many ways. In any event, this schedule is not a contract, and will probably be subject to revision.

Assigned readings are important and will contribute significantly to your understanding of the lecture material. Fortunately, both the required text and the lecture notes are very clear. The first-best strategy is to skim the assigned material before class, attend lecture and listen carefully, and then read the text assignments with discrimination.

The Key to Success in This Class:

Don't fall behind. If you do fall behind, catch up. If you can't catch up, drop the class.