Course Outline

CO370: Deterministic Operations Research Models

The professional society INFORMS answers the question "What is operations research?" as follows: "In a nutshell, operations research (O. R.) is the discipline of applying advanced analytical methods to help make better decisions." This course will serve as an introduction to the deterministic side of operations research, or OR for short. The term "deterministic" refers to the type of data that is presented: the data in our models is assumed to be fixed, like the distance between two points, rather than stochastic, such as the number of callers to a help center on a given day.

The emphasis throughout the course will be on practical techniques, preparing you to apply OR methods in a wide range of applied settings. A focus will be the development of modeling techniques in mixed-integer programming (MIP) models. These models add constraints that certain variables in linear programming (LP) models are required to take on integer values. The integrality constraints make the models more difficult to solve, but they allow us to capture important yes/no decisions that are beyond the reach of LP itself. Together with MIP modeling tools, we will discuss algorithmic techniques such as cutting planes and column generation, that allows us to handle problems with enormous numbers of constraints and variables.

The course will also cover practical solution techniques, such as branch-and-bound, local search, genetic algorithms, and simulated annealing, with application to many types of OR models.

It is expected that students have a good background in LP techniques, covered in CO250/255. We will start the course with a quick review of the LP topics we will need.

- William Cook
(Instructor), bico@uwaterloo.ca, http://www.math.uwaterloo.ca/~bico/
Office hours on Mondays and Wednesdays, 2:30 to 4:00 PM, Zoom Link: https://uwaterloo.zoom.us/j/96543354110?pwd=bjJWUzBzUXY2WVhwRUR5RnY5K3BIUT09 with passcode Model

- Teaching Assistants: Sean Kafer (skafer@uwaterloo.ca), Rian Neogi (rneogi@uwaterloo.ca), and Matheus Ota (mjota@uwaterloo.ca)

Course Textbooks

The main textbook for the course is H. Paul Williams book *Model Building in Mathematical Programming*. This is the go-to book for OR modelers. You will see it recommended by providers of optimization software such as Gurobi and CPLEX. The paperback edition of the book is reasonably priced, but be sure to get the 5th edition is you decide to order it. It is a great reference to have in your library if you are thinking about a career in OR or analytics. But my recommendation is take advantage of the UW library's etext service that allows you to freely download the book. Go UW!

We will also use a chapter from Robert Vanderbei's book *Linear Programming: Foundations and Extensions* (again the 5th edition). The entire book is also available for downloading at the UW library and can serve as a reference for general LP topics. The specific material we will use is Chapter 12: Data Science Applications.

The third text is my own popular-style book *In Pursuit of the Traveling Salesman: Mathematics at the Limits of Computation*. Also available as a free download at the UW library. This is for supplemental reading on solution methods, including heuristic search, cutting planes, and branch-and-bound, as well as modeling examples involving the traveling salesman problem.

Here are direct links to the three books. I recommend downloading all three right away, since it is not clear if the licensing conditions might change at a later point.

- **Model Building in Mathematical Programming (H. P. Williams)**
- LINK: https://ocul-wtl.primo.exlibrisgroup.com/permalink/01OCUL_WTL/pa2qcq/alma9999865
- ISBN : 9781118443330
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- **Linear Programming: Foundations and Extensions (R. J. Vanderbei)**
- LINK: https://ocul-wtl.primo.exlibrisgroup.com/permalink/01OCUL_WTL/pa2qcq/alma9999867
- ISBN : 9783030394141
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- **In Pursuit of the Traveling Salesman (W. Cook)**
- Link: https://ocul-wtl.primo.exlibrisgroup.com/permalink/01OCUL_WTL/3b6rcr/cdi_proquest_e
- ISBN : 9780691163529

An additional reference is Vašek Chvátal's classic book *Linear Programming*. It has been out of print for a number of years, but you can often spot used copies for under $10. It is a great place to review the LP methods we use in the course. I'll later post a chapter of the book (under the Fair Use copyright rule) that will be

Private: post a chapter of the book (under the Fair Use copyright rule) that will be the basis for our lecture on the cutting-stock problem.

Topics (tentative list)

Week 1

Operations research modeling and solution methods. Quick review of linear programming.

Reading: Williams Chapters 1 and 2. Extra reading: Vanderbei Chapter 1, TSP book Chapters 3 and 5.

Links: Amazon Last Mile Routing Research Challenge , Just Passing Through

Week 2

Building LP models.

Reading: Williams Chapters 3 and 4. Please read in detail Sections 3.2, 3.3, and 4.1. The remaining material can be quickly viewed. In particular, we will not be covering details of Dantzig-Wolfe decomposition (Section 4.3).

HW tip: The following MIT Tutorial on constraints with absolute values may be useful for HW#1, Q1.

Week 3

LP models in data science.

Reading: Vanderbei Sections 12.1-12.4 and 12.7. Extra reading: Williams Chapter 5.

Week 4

LP Sensitivity Analysis

Course notes: co370_week4.pdf. Nice set of similar notes from Brown University: Sensitivity Extra reading: Williams Chapter 6.

Week 5

Mixed-integer programming (MIP) models

Reading: Williams Chapters 8 and Sections 9.1, 9.2. A very good, compact reference is Jim Orlin's IP Reference Guide for Integer Programming Formulations.

Test #1

[Study guide](#) [Practice Test](#) [Test #1 Solutions](#)

Week 6

MIP models in discrete optimization

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Activity Details

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