

# MA416

## Operations Research I

### Linear Programming

## 1 Instructor

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## 2 Text

Linear Programming: Foundations and Extensions by Robert Vanderbei

The text is available online for online reading at Robert Vanderbei <http://www.princeton.edu/~rvdb/LPbook/>

I suggest you purchase a copy at an online bookstore such as Amazon. You can pick up a new copy for about \$63. You will also find a set of online lecture notes to go with the text at the above URL. I suggest you download these notes since I will follow them fairly closely.

There are many other sources online for notes on linear programming. Here are a few you might find useful.

- Vandenberghe Vandenberghe <http://www.ee.ucla.edu/ee236a/ee236a.html#lectures>
- AMPL , First Chapter. AMPL BOOK <http://www.ampl.com/BOOK/index.html>
- Linear Programming Wiki. Wiki [http://en.wikipedia.org/wiki/Linear\\_programming](http://en.wikipedia.org/wiki/Linear_programming)

I've also put some notes and ampl code online. You can find links here. [notes.xhtml](#)

## 3 Grading

Your grade for the course will be based on a midterm exam, a project, a final exam, and homework. Each of the four components will count toward 25% of your grade. I will post sample problems for the midterm and final exams.

Students who are taking the course for graduate credit will be expected to complete a more extensive project. In particular the project for graduate students will be at a beginning research level, and the writing style of the project description shall be at a level suitable for publication.

- Numerical Grading Scale: A 90-100, B 80-89, C 70-79, D 60-69, E below 60,
- Relative Value to Components: Midterm 25%, Problem Sets 25%, Project 25%, Final 25%.
- A midterm and a final letter grade will be assigned.

## 4 Software

### 4.1 AMPL

We will make extensive use on AMPL for solving linear programming problems. This software is available free (student version) from the AMPL website, AMPL <http://www.ampl.com/index.html>. You can download a version for either Windows or Linux. You should also download and install at least the two solvers Minos and CPLEX.

Here are a couple of links to files that contain sample AMPL model files and data files. You should start with the basic.mod file and then go to the general.mod file.

```
basic.mod ampl/basic.mod
basic.dat ampl/basic.dat
general.mod ampl/general.mod
general.dat ampl/general.dat
general.run ampl/general.run
ampl ampl/ampl_guide.pdf
```

### 4.2 Excel

Excel has a builtin solver and if you are familiar with Excel you might want to try using that solver as well. The solver that comes with Excel is rather limited in the size of the problem that it can deal with, so you should certainly get used to using AMPL. You will need it for working your project.

### 4.3 Pivot Tools

You will also need a matrix pivot tool for working some of the simplex exercises. You can find one on Vanderbei's website. It is written in Java and if you have the right version of Java linked to your html browser, you can use it. There is also an online pivot tool available at Online Pivot [http://people.hofstra.edu/faculty/Stefan\\_Waner/RealWorld/tutorialsf1/scriptpivot2.html](http://people.hofstra.edu/faculty/Stefan_Waner/RealWorld/tutorialsf1/scriptpivot2.html). This tool allows you to perform pivot operations on a matrix. In addition, some of the more sophisticated calculators have builtin pivot tools. You can download the pivot tool and use it with Excel.

You can also use the Java Script pivot tool found on Vanderbei's web site. You must have Java Runtime Environment installed on your computer.

## 5 Homework

We will use the online web homework system for weekly homework. Here is a link to the site.

```
mathclass http://www.mathclass.org
```

Information about using Webclass can be found here. [webclass\\_information.html](#)

You should have an account for the class. If you are in MA416 (CS416) your homework will be on the Webclass MA416 (CS416). The due dates for the assignments are indicated on each assignment.

## 6 Topics and Goals

We will cover Part I of Vanderbei's text as well as basic use of AMPL. In the course of learning to use the AMPL software we will cover several "real world" examples. The your goals for the course are

- Gain an understanding of the basic ideas of linear programming,
- Learn to formulate and solve moderately complicated practical optimization problems that can be approached using linear programming,
- Gain a basic working knowledge of the use of LP software such as AMPL.

Here is a list of the topics in the order that they will be covered. Each topic will take approximately one week.

- Introduction to LP: What is a typical problem that can be solved using linear programming?
- Simplex Method: Geometric and algebraic approach. Formalism of the simplex tableau and linear equations.
- AMPL: Setting up and solving some simple problems. Submitting problems to NEOS.

- Degeneracy: What can go wrong in the simplex method and how can it be fixed?
- Efficiency: Basic ideas of computational complexity.
- Duality: Economic and geometric interpretation. Setting up the dual.
- Matrix Notation: Write a linear programming problem and dual in matrix notation.
- Sensitivity: Modification of a problem. Getting more information from AMPL. Bounding constraints.
- General Form of an LP: Equality constraints, unbounded variables. Very easy in AMPL.
- Convex Analysis: Convex sets, hyperplane separation.
- Game Theory: Zero sum games. Mixed strategies. (Go rent the DVD "A Beautiful Mind")
- Regression: Economists make a living doing it. So do statisticians.

## 7 Projects

As part of your course grade you are to do a project that goes beyond the standard homework in complexity. Your project must be typed as a report and include information about any software you used. At a minimum you must include

- Statement of Problem
- Sources of data or information about the problem.
- Statement of methods
- Description of solution including software used.
- Set of references used (including online references).

I have included a list of project topics below. You can select one of these or come up with your own project. If you select your own project, you must discuss it with me first and give me a basic outline for approval.

### 7.1 Regression

Construct and solve an  $L_1$  regression model for your favorite statistic. For example, find a relationship between earnings of two or more different occupations. The Bureau of Labor Statistics is a good source of data on prices, wages, and employment.

### 7.2 Portfolio Optimization

Read the lecture notes of Vanderbie on portfolio optimization. Implement the AMPL program he describes to find an optimal portfolio.

### 7.3 Scheduling

Set up and solve a linear model for scheduling of instructors to courses and time slots. Allow each instructor to weight each course and time slot. Maximize the total reward of the instructors and cover all courses.

### 7.4 An interactive Simplex Solver

Write an interactive simplex solver in Perl. The user should be able to input a linear programming problem in augmented form (including slack, surplus variables). Input should be possible from STDIN or from a file. The user selects pivots and the program performs the pivot operations and tests for optimality. Display should include variable and constraint labels. Ideally, the program would be placed in a CGI script so that it could be used online.

### 7.5 Data estimation and suppression.

The Census Bureau and the Bureau of Labor Statistics both release huge amounts of data to the public. However, private data must be protected. The BLS uses linear programming to determine which data should be suppressed. As a project, set up and carry out an AMPL to determine data that must be suppressed in a three dimensional table.

## 8 Tentative Schedule

- Midterm shall be held during the 6th week of the course,
- Final shall be held during the time scheduled by the Registrar,
- Problem sets shall be assigned once per week and collected one week after they have been assigned,
- Project shall be turned in before the last day of class.

## 9 Additional Course Policies

- Course policy for attendance: Attendance will be recorded by calling on students to answer questions in class. If you are called upon but are not present your absence will be recorded. You are allowed four unexcused absences during the semester. For each unexcused absence in excess of four, two points will be deducted from your total course average that is used to determine your final letter grade. Excused absences will be given at instructor's discretion only with proof as defined by S.R. 5.2.4.2. For further information see <http://www.uky.edu/StudentAffairs/Code/part2.html>.
- Make-up opportunities: The instructor shall give the student an opportunity to make up the work and/or the exam missed during an excused absence...” implies the student shall not be penalized for the excused absence.
  - Verification of Absences: Students missing work due to an excused absence bear the responsibility of informing the instructor about their excused absence within one week following the period of the excused absence (except where prior notification is required), and of making up the missed work.
- Course policy for submission of assignments: Students shall return all assignments on the due date. No late assignments shall be accepted without an excused absence.
- Course policy on academic integrity: All assignments, projects, and exercises completed by students for this class should be the product of the personal efforts of the individual(s) whose name(s) appear on the corresponding assignment. Misrepresenting others' work as one's own in the form of cheating or plagiarism is unethical and will lead to those penalties outlined in the University Senate Rules (6.3.1 & 6.3.2) at the following website: [http://www.uky.edu/USC/New/rules\\_regulations/index.l](http://www.uky.edu/USC/New/rules_regulations/index.l). The Ombud site also has information on plagiarism found at <http://www.uky.edu/Ombud>.
- Course policy on classroom civility and decorum: The university, college and department has a commitment to respect the dignity of all and to value differences among members of our academic community. There exists the role of discussion and debate in academic discovery and the right of all to respectfully disagree from time-to-time. Students clearly have the right to take reasoned exception and to voice opinions contrary to those offered by the instructor and/or other students (S.R. 6.1.2). Equally, a faculty member has the right – and the responsibility – to ensure that all academic discourse occurs in a context characterized by respect and civility. Obviously, the accepted level of civility would not include attacks of a personal nature or statements denigrating another on the basis of race, sex, religion, sexual orientation, age, national/regional origin or other such irrelevant factors.

## 10 Additional Links

- INFORMS: The Operations Research Website. Informs <http://www.informs.org>
- Government Jobs in Operations Research Government Jobs. <http://www.usajobs.opm.gov/>. Search Operations Research.
- Math-Jobs.com Math-Jobs <http://www.math-jobs.com/>