CARNEGIE MELLON UNIVERSITY

70-460 Mathematical Models for Consulting

COURSE SYLLABUS

Information

Time:	Mon/Wed 12:30-1:50PM
Location:	*Class* Tepper 2702 *Office Hours* Tepper 2703
Instructor:	Lin An, linan@andrew.cmu.edu
Office Hours:	Mon 2:30-3:30PM or Zoom by appointment
Course Webpage:	https://canvas.cmu.edu/courses/42175
Prerequisites:	Optimization: 70-257 or 21-257 or 21-292

Course Objective

In your prerequisite course, you learned the basics of optimization: you saw the (hopefully life-changing!) way in which we can capture nearly all decision-making using mathematical *optimization models* — recall that these models consist of three components: what exactly is being decided (variables), a list of underlying restrictions (constraints), and a goal (objective). You learned that depending on the nature of these three components, the resulting optimization model can have different flavors: linear programs, integer programs, nonlinear programs, etc. And you learned how to solve these models in Excel.

The goal of this course is to learn how optimization is actually used in *practice*. We'll see how individuals, companies, and governments use the same optimization models you learned to make complex decisions such as:

- determining locations for new airports, fire-stations, or distribution centers
- routing delivery trucks, school buses, flights
- improving radiation therapy for lung cancer
- personalizing content recommendations, prices, and user experiences
- scheduling each season's games in every major sport
- nearly all of machine learning and artificial intelligence

To get there, we'll need to learn a bit of optimization at a more *advanced* level. *Advanced optimization* is precisely what this course is about. It consists of three components, all of which we will cover in depth:

1. *Modeling*: In real-world problems, unlike homework exercises, there is almost never a single best optimization model (often there is not even a clear problem!). Good modeling requires creativity, a few strategies for dealing with large problems (i.e. many variables and constraints), and some useful tricks.
2. *Software*: Much of the progress in optimization speed happens behind the scenes, driven by academic research (including faculty at CMU), which leads to "smarter" algorithms that are then implemented in modern solvers. We will move beyond Excel's Solver, and learn to use the fastest solver today. This will require a programming-based (rather than spreadsheet-based) approach. *No prior programming experience is necessary*.
3. *Applications*: As alluded to above, there are many "success stories" of optimization driving massive increases in profit or efficiency, and for the student, there are insights to be gleaned from these past successes.

By the end of this course, you will be able to

- Give examples of real-world domains in which optimization can be applied
- Build mathematical models from problem statements using your understanding of the conceptual basics of a rich set of optimization tools
- Solve mathematical models using state-of-the-art optimization software
- Develop an "eye" for spotting real-world decisions that can be formulated and solved as optimization models

Course Material

The course materials include:

- Slides/notes that will be uploaded to Canvas following each lecture
- Additional readings, also uploaded to Canvas
- Textbooks: the following is an **optional** book for students interested in additional resources

  Bradley, Hax and Magnanti. *Applied Mathematical Programming*, Addison-Wesley, 1977. Available online at http://web.mit.edu/15.053/www/AMP.htm
- Software: We will begin the course by reviewing the built-in *Solver* in *Microsoft Excel*, and then transition to using *Gurobi* (the incumbent fastest solver, available to students for free) and *Python* (which we use to "speak" to Gurobi)

Course Schedule (Tentative)

Date	#	Topic	Assignment Due
26-Aug	1	Course Overview	
28-Aug	2	Linear Programming — review	
02-Sep		NO CLASS — Labor Day	
04-Sep	3	Linear Programming — sensitivity analysis	HW1
09-Sep	4	Linear Programming — column generation	
11-Sep	5	Linear Programming — column generation	HW2
16-Sep		NO CLASS	
18-Sep	6	Linear Programming — duality	HW3
23-Sep	7	Robust Optimization	
25-Sep	8	Robust Optimization	HW4
30-Sep	9	Robust Optimization	
02-Oct	10	Integer Programming — facility location	HW5
07-Oct	11	Integer Programming — facility location	
09-Oct	12	Midterm Exam Review	HW6
21-Oct		NO CLASS	
23-Oct		Midterm Exam	
28-Oct	13	Advance Solver — Gurobi	
30-Oct	14	Advance Solver — Gurobi	
04-Nov	15	Integer Programming — branch and bound	
06-Nov	16	Integer Programming — cuts	Project Proposal
11-Nov	17	Applications — scheduling	
13-Nov	18	Applications — scheduling	HW7
18-Nov	19	Applications — routing	
20-Nov	20	Online Optimization	HW8
25-Nov		NO CLASS — Thanksgiving Break	
27-Nov		NO CLASS — Thanksgiving Break	
02-Dec	21	Project Presentation	
04-Dec	22	Project Presentation, Course Wrap-up	Project
TBD		~~Final Exam~~	

Grading and Assignments

The grading of 70-460 will be based on the weights below.

Homework (team)	30%
Midterm and ~~Final Exam~~ (individual)	25% ~~+ 20%~~
Project (team)	30%
Class Participation (individual)	10% +5%(L5)

Students may form teams of up to **three** to complete homework assignments and the project. In team assignments, students are allowed to discuss the assignment only with their teammates.

Homework (team)

A total of **ten** homeworks will be assigned throughout the semester. These are due before the start of class on Wednesdays, and should be uploaded to Canvas. Your lowest score will not count toward your grade.

Late Policy: Any homework assignment may be submitted up to 48 hours late for half credit. Assignments will not be accepted more than 48 hours late.

Midterm ~~and Final Exam~~ (individual)

There will be a midterm and a final exam covering lectures and homework from the first and second halves of the course, respectively. In particular, the final exam is not "comprehensive," though the material tested does naturally build on concepts from the course's first half. There will be a review session before each exam.

Project (team)

You will be given a description of a problem based on an actual real-world case. Your task will be to formulate and solve an optimization model, and unlike the problems you will see throughout the course's lectures, homeworks, and exams, there will not be a single "best" optimization model to represent the problem. Further details will be provided in a separate document.

Class Participation (individual)

Full credit for class participation is, in principle, easy to achieve. You begin the semester with full credit, and can only lose points for disruptive behavior, such as inappropriate remarks or misuse of electronic devices. I reserve the right to impose harsher penalties (i.e. more than 10% of your final grade) for behavior that is disrespectful to your fellow classmates.

Student Support

The UBA Program Office is available to support all students in the fall semester. Students are encouraged to contact their UBA academic advisor or uba@andrew.cmu.edu to contact the program staff while the physical office remains closed in the fall semester.

Accommodations for Students with Disabilities

If you have a disability and are registered with the Office of Disability Resources, I encourage you to use their online system to notify me of your accommodations and discuss your needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

Health & Well-being

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.