94.867/12.768/19.867: Decision Analytics for Business and Policy
Spring 2019; 12 units

Instructor
Alexandre (Alex) Jacquillat: ajacquil@andrew.cmu.edu

Teaching Assistant
Rick Grahn: rgrahn@andrew.cmu.edu

Graders
Abdullah Al Arfaj: aarfaj@andrew.cmu.edu
Namratha Vishwanath: nbeksevi@andrew.cmu.edu

Meeting times and locations
Lecture: Mondays, Wednesdays 3:00 pm – 4:20 pm HBH 1204
Recitation: Fridays 3:00 pm – 4:20 pm HBH 1204
Office Hours (Alex): Thursdays, 11 am – 12 am HBH 2118J
Office Hours (Rick): Mondays 4:30pm – 5:30 pm HBH 2201

Recitations are optional. They will provide a review of the concepts covered in class, help with the computational implementations, and introduce additional problems.

Course Web Page

The course web page is available on Canvas. Class announcements, lecture notes, homework assignments and solutions will be posted online.

Course Content

This is a course on prescriptive analytics. It introduces modeling frameworks and computational tools to address complex, ill-defined, large-scale problems of decision-making that arise in policy and business. It covers advanced methods of decision-making under uncertainty in four main areas: large-scale optimization, stochastic optimization, stochastic modeling, and discrete-event simulation. This course is targeted to Master’s students who aim to engage in advanced quantitative analysis and modeling of complex problems and systems, as well as PhD students looking for an introduction to the field of Operations Research and Management Science.

Classes alternate between focusing on (i) modeling techniques, which introduce new techniques to address problems found in real-world instances, (ii) computational solutions, which focus on the implementation of the models to derive actionable solutions and insights, and (iii) implementation results and insights, drawn from case studies and research papers. You are expected to take “active learning” roles in class and in your homework assignments. First, the in-class discussions will benefit from your engagement on issues related to the implementation of the methods and examples from your domains of expertise. Second, you will implement the computational materials presented in
class using the R (or MATLAB) programming language and the CPLEX optimization solver (with the GAMS programming language). Eventually, you will have written pieces of code that you will be able to re-use for other problems in the future. Third, a term project will simulate professional situations where new solutions need to be developed, implemented and communicated.

Application examples will be drawn from a variety of business and policy domains such as transportation, energy, financial engineering, information systems, health care, supply chain management, etc. Such systems are typically characterized by complex decision-making problems and significant uncertainties, and can be substantially improved using a systematic approach to managerial and policy decision-making. Students will be encouraged to bring new problems from their domains of interest to the course.

The learning objectives of this course fall into the following categories
- **Methods**: learning advanced quantitative modeling and solution algorithms from the fields of Operations Research and Management Science (OR/MS)
- **Modeling**: applying OR/MS methods systematically to model complex decision-making problems faced in practice
- **Computations**: implementing simulation and optimization methods with large-scale datasets using state-of-the-art software
- **Analysis**: evaluating the challenges and trade-offs in quantitative modeling
- **Communication**: communicating technical models and results effectively based on the context and the audience

**Prerequisites**

The ideal prerequisites for this course include:

1. A course on applied probability and statistics (e.g., 90.711 Statistical Methods; 95.796 Statistics for IT Managers)

2. A course on optimization methods (e.g., 90.722 & 90.760 Management Science I & II; 95.760 Decision Making Under Uncertainty)

We will review these topics briefly. Programming experience is a plus, but not required. We understand you come from different backgrounds, so the requirements will be flexible. Please let me know if you are concerned about your background for the course.

**Readings**

Readings will be sampled from textbooks, academic papers and other sources. They will be posted on Canvas through the course of the Semester.

Readings will fall into two categories: *course readings* and *research readings*. Course readings aim to help you understand the course’s concepts, methods and algorithms. They will help you learn more effectively and will lead to more engaging discussions in class. It is highly recommended that you read the course readings before class. There will be 6 research readings assigned through the Semester. **For each research reading, you must read the paper before class, and write a (very) short synthesis summarizing the problem, the approach, the model, the solution, and the insights (roughly 150 words). The synthesis is due on Canvas by 5 pm the day before the discussion, and will factor in the participation grade.**

*95.760 Spring 2019 Syllabus*
Homework

HW 1: Deterministic optimization
Out: Wed, 01/16
Due: Wed, 02/06, 3 pm

HW 2: Deterministic optimization applications
Out: Wed, 02/06
Due: Wed, 02/20, 3 pm

HW 3: Stochastic optimization
Out: Wed, 02/20
Due: Wed, 03/06, 3 pm

HW 4: Stochastic modeling
Out: Wed, 03/20
Due: Wed, 04/03, 3 pm

HW 5: Stochastic simulation and optimization
Out: Wed, 04/03
Due: Wed, 05/01, 3 pm

Homework policies:
- Make sure to submit on time. 5 points (out of 100) will be taken out for each hour late.
- Please submit your homework in a single pdf report via Canvas. Make sure to communicate your approach, assumptions, implementation, results, and recommendations. If you need to draw a picture or write equations by hand, you can scan it into your report.
- Homework assignments must be submitted individually. You are allowed to work with one partner, in which case you are required to write the name of your partner in your submission. Partners are welcome to collaborate on the design of the overall approach and on setting up computer runs. However, your results and report should be the product of your own work.

Midterm exam: Wednesday, March 6 [in class]

The exam will be open book and closed computer.

Term project

You will work in groups of 4. The problem description will be deliberately broad, starting with little more than a request for proposals. Through the second half of the Semester, each group will go through several phases of a project, including: (i) writing a proposal, (ii) running an analysis and writing a full-length report, (iii) writing a memo synthesizing the results, and (iv) presenting their findings to a specific audience. You will need to model a complex problem of practical importance in a tractable way, develop your analysis and obtain results, and tailor the communication of your approach and your results to your audience. Details will follow.

PhD students can use the term project to advance their own research.

Final Grades

The grades for this course will be computed as follows:
- Homework: 45% (10% for HW1, HW2, HW3 and HW5; 5% for HW4)
- Midterm: 20%
- Term project: 25%
- Participation: 10%

Pass/Fail and Auditing

Due to logistical constraints, the course cannot be taken Pass/Fail.

The course can be audited. The requirements include: (i) attending lectures, and (ii) submitting the synthesis of the “research readings” (see above) for the corresponding lectures.
Special needs

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will be happy to discuss your specific needs privately and to 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.

Communication

Please bring your questions to the weekly office hours. This is the time where the teaching staff is most available. You are also welcome to send your questions by email. You should address any email to the instructor and the TA. The Canvas system has an open forum for discussions. You are encouraged to use this for communications that might be of interest to others.

Communication Support

For assistance with the written or oral communication assignments in this class, visit the Global Communication Center (GCC). GCC tutors can provide instruction on a range of communication topics and can help you improve your papers and presentations. The GCC is a free service, open to all students, and located in Hunt library. You can make tutoring appointments directly on the GCC website: http://www.cmu.edu/gcc. You may also visit the GCC website to find out about communication workshops offered throughout the academic year.

Academic Integrity

Honesty and transparency are important features of good scholarship. The rules and the academic integrity standards outlined in your student handbook will be strictly enforced. Violations are considered a fundamental breach of trust and will result in failure of the course.

Homework computations and reports must be prepared individually, or with a partner following the guidelines detailed above. Demonstrated evidence of copying (same presentation, same pieces of code, same wording of sentences, etc.) will result in zeros for each paper with this evidence.

Take Care of Yourself!

Do your best to maintain a healthy lifestyle. In particular, make sure to get enough sleep and take time to relax. This will help you achieve your goals and cope with stress. All of us benefit from support during times of struggle. There are many helpful resources available on campus. Asking for support sooner rather than later is almost always helpful. 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 their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or a family member you trust for help getting connected to the support that can help.

If you have questions about this or your coursework, please let me know. Have a great semester!
Course Schedule

Week 1
Lecture 1: Introduction to decision-making modeling

*Introduction Reading* INFORMS (2014) OR - A Catalyst for Engineering Grand Challenges, A report to the National Science Foundation
Lecture 2: Large-scale Linear Programming—Modeling
Friday: Recitation [MATLAB and GAMS/CPLEX installation and use]
**HW1 OUT** Wednesday, Week 1—Deterministic optimization

Week 2
Lecture 3: Large-scale Linear Programming—Implementation and results

Friday: Recitation [Linear Programming]

Week 3
Lecture 4: Large-scale Integer Programming—Modeling
Lecture 5: Large-scale Integer Programming—Implementation and results

Friday: Recitation [Integer Programming]

Week 4
Lecture 6: Multi-objective optimization
Lecture 7: Multi-objective decision-making

**HW1 DUE** Wednesday, Week 4—Deterministic optimization
**HW2 OUT** Wednesday, Week 4—Deterministic optimization applications
Friday: Recitation [Multi-objective Optimization]

Week 5
Lecture 9: Application—Value of integration

Lecture 8: Duality and sensitivity analysis
Friday: Recitation [Review of probability]

Week 6
Lecture 10: Introduction to Decision-making under uncertainty

*Course Reading* Bertsimas, D. and Freund, R. *Data Models and Decisions*, Chapter 1
Lecture 11: Stochastic Programming—Modeling


Friday: Recitation [Stochastic Programming]

HW2 DUE Wednesday, Week 6—Deterministic optimization applications

HW3 OUT Wednesday, Week 6—Stochastic optimization

Week 7

Lecture 12: Stochastic Programming—Implementation and results
Lecture 13: Application – Risk Management


Friday: Recitation [Review]

Week 8

Lecture 14: Case study—Optimization in practice


Lecture 15: Midterm

HW3 DUE Wednesday, Week 8—Stochastic optimization

SPRING BREAK

Week 9

Lecture 16: Introduction to Markov chains


Lecture 17: Markov processes


Friday: Term project—Client Q&A

HW4 OUT Wednesday, Week 9—Stochastic modeling

Week 10

Lecture 18: Queuing theory—Overview of modeling and results


Lecture 19: Queuing theory—Discussion of advanced topics


Friday: Term project—Client meeting
Week 11
Lecture 20: Monte Carlo simulation—Principles of sampling and simulation
Lecture 21: Monte Carlo simulation—Implementation and results
Friday: Term project—Expert meeting
HW4 DUE Wednesday, Week 12—Stochastic modeling
HW5 OUT Wednesday, Week 12—Stochastic simulation and optimization

Week 12
Lecture 22: Monte Carlo simulation—Extensions and case studies
Lecture 23: Markov Decision Processes—Modeling
Friday: Recitation [Monte Carlo simulation]

Week 13
Lecture 24: Markov Decision Processes—Computational implementation
Lecture 25: Markov Decision Processes—Results and applications
Friday: Recitation [Markov Decision Processes]

Week 14
Lecture 26: Introduction to Computational Stochastic Optimization
Lecture 27: The Art of Decision Making
   Course Reading Kahneman, D. (2011), Thinking, Fast and Slow, Chapters 19-21

Week 15
Lecture 28: Term Project Presentations
Lecture 29: Term Project Presentations
HW5 DUE Wednesday, Week 14—Stochastic simulation and optimization