Decision Analytics for Business and Policy

94-867 (Heinz) / 19-867 (EPP) / 12-768 (CEE)

Fall 2024

Instructor:	Peter Zhang	**Lecture:**	M/W 3:30-4:50PM (A), 5-6:20PM (B)
Email:	pyzhang@cmu.edu	**Place:**	HBH 1204

Updated: August 20, 2024

Teaching Assistants:

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Instructor Office Hours: Drop-ins Mondays and Wednesdays (2118E)

Main References: There is no required text. You may find the following optional textbooks useful.

- Hillier and Lieberman, *Introduction to Operations Research*, McGraw-Hill, 2015.
- Abbott, *Applied Predictive Analytics: Principles and Techniques for the Professional Data Analyst*, Wiley, 2014.

Summary: Most courses under the name of "analytics" are about making predictions (*i.e.*, *data* analytics). However, predictions alone are not sufficient to solve problems. We need to produce *decisions*. This course focuses on the process of making good decisions.

This course assumes intermediate python experience and prior exposure to management science and operations research topics. It focuses on modeling frameworks and computational tools to address complex decision-making problems that arise in policy and business. The course is organized by technical topics, from contextual optimization, optimization under uncertainty, to dynamic learning and optimization. We motivate our technical discussions by a rich set of applications, such as logistics planning, resource allocation, and health care. Coding will be done in Python. Students will use a range of modern optimization and machine learning packages.

Prerequisites: (1) An introductory course in management science / operations research, (2) intermediate Python programming skills, (3) basic understanding of data and machine learning, and (4) mathematical maturity.

Assessment:

- Participation (15%)
- Assignments (15% = 5% × 3)
- Midterm Exam (20%)
- Quiz (10%)
- Project (40%)

Important Notes About Grading

- For each assignment, it is important to include both the mathematical formulations (with clear explanation) and code, you will not receive any points if either part is missing.
- Collaboration on assignments is encouraged, with no more than one partner. You have to indicate whom you have collaborated with in each submission, and submit your own version of the write up and code. Project is done in teams of 3 to 5 people. Other deliverables are individual.
- For late submissions of most deliverables (homework, project, reading synopsis, Learning & Question survey), 5% is deducted every hour, e.g., final score of a submission is $\max\{(s - 5x), 0\}$, where x is the number of hours late, and s is the score out of 100 if submitted on time. Quizzes are done during lecture times, and late submissions are not accepted.
- Final letter grades are calculated in a two-step process.
    1. We first convert percentages to letters by this mapping: A+ 97.00 – 100.00%; A 93.00 – 96.99%; A- 90.00 – 92.99%; B+ 87.00 – 89.99%; B 83.00 – 86.99%; B- 80.00 – 82.99%; C+ 77.00 – 79.99%; C 73.00 – 76.99%; C- 70.00 – 72.99%.
    2. If necessary, we then curve the letter grades upward until they match Heinz College standards. There is no downward curving. This usually means a distribution similar to or better than 50% A's and 50% B's.

Special Needs: If you have a disability and have an accommodations letter from the Disability Resources Office, please 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 Disability Resources Office, I encourage you to contact them at access@andrew.cmu.edu.

Academic Honesty: 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.

Your 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 their website at 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. If the situation is life threatening, call the police: CMU Police 412-268-2323, or 911.

Student Academic Success Center (SASC): SASC focuses on creating spaces for students to engage in their coursework and approach learning through a variety of group and individual options. They offer many opportunities for students to deepen your understanding of who you are as learners, communicators, and scholars. Their services and workshops are free to the CMU community and meet the needs of all disciplines and levels of study. SASC programs to support student learning include the following:

- Academic Coaching – This program provides holistic, one-on-one peer support and group workshops to help undergraduate and graduate students implement habits for success. Academic Coaching assists students with time management, productive learning and study habits, organization, stress management, and other skills.
- Peer Tutoring – Peer Tutoring is offered in two formats for students seeking support related to their coursework. Drop-In tutoring targets our highest demand courses through regularly scheduled open tutoring sessions during the fall and spring semesters. Tutoring by appointment consists of ongoing individualized and small group sessions. You can utilize tutoring to discuss course related content, clarify

and ask questions, and work through practice problems. Visit the webpage to see courses currently being supported by Peer Tutoring.

- Communication Support – Communication Support offers free one-on-one communication consulting as well as group workshops to support strong written, oral, and visual communication in texts including IMRaD and thesis-driven essays, data-driven reports, oral presentations, posters and visual design, advanced research, application materials, grant proposals, business and public policy documents, data visualization, and team projects. Appointments are available to undergraduate and graduate students from any discipline at CMU. Schedule an appointment (in-person or video), attend a workshop, or consult handouts or videos to strengthen communication skills.

- Language and Cross-Cultural Support – This program supports students seeking help with language and cross-cultural skills for academic and professional success through individual and group sessions. Students can get assistance with writing academic emails, learning expectations and strategies for clear academic writing, pronunciation, grammar, fluency, and more.

- Supplemental Instruction (SI) – This program offers a non-remedial approach to learning in historically difficult courses at CMU. It utilizes a peer-led group study approach to help students succeed and is facilitated by an SI leader, a CMU student who has successfully completed the course. SI offers a way to connect with other students studying the same course, a guaranteed weekly study time that reinforces learning and retention of information, as well as a place to learn and integrate study tools and exam techniques specific to a course.

About Generative AI Tools. In this course, you are encouraged to explore the use of generative artificial intelligence (GenAI) tools, such as ChatGPT. From time to time we may explicitly ask you to explore ChatGPT and analyze its output for certain problems. In any case, the use of GenAI tools must be appropriately acknowledged and cited, including the specific version of the tool used. Submitted work should include the exact prompt used to generate the content as well as the AI's full response in an Appendix. Because AI generated content is not necessarily accurate or appropriate, it is each student's responsibility to assess the validity and applicability of any generative AI output that is submitted. You may not earn full credit if inaccurate, invalid, or inappropriate information is found in your work. Deviations from these guidelines will be considered violations of CMU's academic integrity policy. Note that expectations for "plagiarism, cheating, and acceptable assistance" on student work may vary across your courses and instructors. Please email me if you have questions regarding what is permissible and not for a particular course or assignment.

We hope you have a productive and safe semester!

Tentative Course Plan, Mini 1:

Week	Topic	Due
1	LP Review. Data-to-Decision Pipelines. Modern Solvers. *1M: Linear programming review.* *1W: Introduction to data-to-decision pipelines.* *1R: Introduction to modern solvers.*	
2	Data to Information via Parameterization. *2M: Labor Day no class.* *2W: Data-to-information theoretical framework.* *2R: TBD*	A1 (SIR fit) release
3	D2I Examples *3M: Flexible D2I function example: neural networks.* *3W: Mechanistic D2I function example: SIR model.* *3R: Epidemic spread coding.*	
4	Data to Decisions: Contextual Optimization *4M: D2D theoretical framework.* *4W: D2D practice: optimal admission decisions.* *4R: D2D practice.*	A1 due; A2 (Markowitz++) release
5	Decision Making with Generative AI. *5M: TBD.* *5W: Decision under uncertainty: Markowitz Portfolio.* *5R: Convex optimization solver cvxpy.*	
6	Decision Under Uncertainty *6M: Markowitz Model implementation.* *6W: Two-stage optimization theory.* *6R: TBD*	A2 due
7	Decision Under Uncertainty *7M: Two-stage model implementation (airline).* *7W:* ***Midterm Exam****.* *7R: No recitation.* · · · · · · · · · · · · · · · · · Fall Break · · · · · · · · · · · · · · ·	In-class exam on Wednesday

Tentative Course Plan, Mini 2:

Week	Topic	Due
8	(Conference Week) *8M: No class.* *8W: No class. Self guided project team formation.* *8R: No class.*	Project release
9	Deterministic Dynamic Decision Making. *9M: Dynamic programming theory.* *9W: Backward induction implementation.* *9R: TBD.*	A3 (hospital) release
10	Exploration versus Exploitation. *10M: Multiarmed bandit theory.* *10W: Multiarmed bandit implementation (pricing).* *10R: TBD.*	
11	Reinforcement Learning. *11M: Q-learning.* *11W: Q-learning implementation.* *11R: TBD.*	A3 due
12	Modern General Framework for RL. *12M: Offline training and online play theory.* *12W: TBD.* *12R: TBD.*	
13	Quiz *13M: Quiz.* *13W: Thanksgiving no class.* *13R: Thanksgiving no class.*	
14	Project Presentations *14M: Presentation day 1.* *14W: Presentation day 2.* *14R: No class.*	Report due