Room/Time: We are in Tech L221. For the first week, we’ll meet twice on Wed 09/20: once from 2:30 to 4:00 in Tech A110 and once from 4:00 to 5:20 (normal time) in Tech L221. After that, we’ll meet Mon and Wed (4:00-5:20) in Tech L221.

Co-Instructors: Michael Watson

Ehsan Khodabandeh

E-mail: [m-watson2@northwestern.edu](mailto:m-watson2@northwestern.edu) and [ehsan.khodabandeh@northwestern.edu](mailto:ehsan.khodabandeh@northwestern.edu)

Office Hours: By appointment

Lab Monday 1:00 to 2:00 pm in Padula classroom in the MEC led by the TA:   
Ruiqi Wang<[RuiqiWang2025@u.northwestern.edu](mailto:RuiqiWang2025@u.northwestern.edu)>

Communication: We will set up Slack for the class and use that to help with communication.

Main Texts: 1. Article: *The Allocation of Resources by Linear Programming*. Robert G. Bland. *Scientific American,* June, 1981, Vol 244, No. 6 (I’ll post it)

2. Book: *Supply Chain Network Design.* Michael Watson, Sara Lewis, Peter Cacioppi, and Jay Jayaraman. FT Press 2012. The online version is the cost of an HBR case study

3. Other material posted on the Canvas from time to time

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**Course Description:**

Optimization technology is an important part of analytics. Optimization allows you to mathematically “narrow your choices the very best when there are virtually innumerable feasible options and comparing them is difficult.” It is often a great compliment to a predictive model.

In practice, optimization technology allows firms to save millions if not hundreds of millions of dollars by helping make better decisions faster. It is a general technology that has been applied in manufacturing, retail, services, transportation, finance and banking, marketing, telecoms, energy, military, and a host of other industries.

When managers and organizations talk about optimization, they are usually referring to linear and integer programming. Understand these and you will be able to understand other types of optimization too.

This course will cover linear and integer programming. Our focus will be on how this works in practice, how you apply it to industrial-sized problems, and how you get results. We will cover what linear and integer programming is. We will cover how to translate a real-world problem into a mathematical optimization problem. We will cover how to write and organize industrial-strength optimization code. We will cover how to present the results of an optimization model to the decision makers—not a trivial task and important for the success of these projects.

At the end of the course, you should have a better understanding of how optimization works, the types of problems it can solve, and how to present the results. Throughout the course, we will use some open-source tools and solvers as well as a commercial-grade solver, Gurobi. Companies will value the fact that you know these tools.

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**Teaching Method:** Classes will be a mix of lectures, group discussions, and interactive computer exercises. The concepts will be reinforced with the text, case studies, additional readings, and homework assignments.

**Laptop Policy:** When we are in class, we ask that you use laptops only for taking notes. It can be very distracting for us (it is easy to tell when you are watching it) and your classmates around you.

**Prerequisites:** You will need a strong working knowledge of Excel and PC’s in general. Python knowledge is needed in this course. You should have access to Excel or Python for the homework assignments and case studies. We will tell you whether to use Excel or Python for solving each homework but if not mentioned specifically, Python is preferred.

**Evaluation:** Grades will be based on homework and case study write-ups (70%), a final exam (20%), and class participation (10%). The homework assignments will be a mix of group and individual- this will be announced during the class.

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| --- | --- | --- | --- |
| **Date** | **Topics Covered** | **Reading Prior to Class and In-Class Exercises** | **Home-work Due** |
| 9/20  Part 1 | Introduction to Optimization with case studies and discussion | Bland’s *Scientific American* article.  If you get the SCND book, read page 24-26 (in paperback version), it is Chapter 1, section called “Solving the Quantifiable Aspects of the Problem using Optimization.” | HW0 (intros!) |
| 9/20  Part 2 | Linear Programming Intro; Review of an LP model and solution from Bland’s Article; Learning to solve LP’s with OpenSolver in Excel both gurobipy and PuLP (technical overview) | You’ll need to have OpenSolver installed with Excel and have Jupyter Notebook with PuLP and Gurobipy installed |  |
| 9/25 | Linear Programming deeper dive through homework discussion; Algebraic Modeling Notation; Piecewise Linear Formulations. Dual Model and Sensitivity Analysis | Student review of models from homework; Excel Exercise with OpenSolver | HW1a |
| 9/27 | Linear Programming deeper dive through homework discussion; Algebraic Modeling Notation; Piecewise Linear Formulations. Dual Model and Sensitivity Analysis | Student review of models from homework; Excel Exercises with OpenSolver | HW1b |
| 10/2 | Integer Programming: What it is? Sample Applications; Why it is harder (P vs NP) Branch and Bound Example | SCND: Sidebar on 44-48;  Branch and Bound Exercise | HW2 |
| 10/4 | Introduction to supply chain network modeling. This is an example of a large-scale practical use of integer programming. This lecture will give you a sense of how this gets applied in business. | Optional for this class (but you will have to read it eventually- read if you want to get s sense of the problem before the lecture) SCND: Chapter 1, 2, and 3 (especially pages 48-52) and Chapter 4 |  |
| 10/9 | Deep dive into network design (facility location. Review HMWK #3 | SCND – Chapter 3, 4 | HW3 |
| 10/11 | Deep dive into network design (facility location. Review HMWK #3 | SCND 5, 6, 7 |  |
| 10/16 | Traveling Salesman and Vehicle Routing Problems. Deep dive into different optimization and heuristic approaches. Review HW #4; |  | HW4 |
| 10/18 | Traveling Salesman and Vehicle Routing Problems. Deep dive into different optimization and heuristic approaches. Review HW #4; |  |  |
| 10/23 | Traveling Salesman and Vehicle Routing Problems. Deep dive into different optimization and heuristic approaches. |  | HW 5 |
| 10/25 | Advanced Integer Programming: Industrial scale models- sparsity and run time, multi-objective optimization; Modeling Service Levels flexibility and metric variables; using integer variables- Electricity market example |  |  |
| 10/30 | Revenue Management- Introduction to Topic | In class simulation to teach the concept | HW 6 |
| 11/1 | Revenue Management- Models and Applications (review of mathematical models) | In-class models |  |
| 11/6 | Stochastic Optimization (and a review of Yield Management Model) |  | HW7 |
| 11/8 | IP Modeling and Troubleshooting models |  |  |
| 11/13 | Piecewise modeling; possible district modeling |  |  |
| 11/15 | Auction Models | Reading TBD | HW8 |
| 11/20  11/22 | No Class this week—Thanksgiving (we made up the Monday class by having 2 classes in Week 1 |  |  |
| 11/27 | Sports and Large Scale Scheduling (a mix of several techniques) |  | HW9 |
| 11/29 | Optimization Wrap-up | Coca-Cola article (very short BusinessWeek article) |  |
| 12/5 | Final exam is due. Most likely it will be a take-home exam done on your own. If so, it will be given out at the last class. If it is in-person, it will be a bit easier but you’ll have less time. |  |  |

The readings listed for each week should be completed prior to the class. The homework assignments are due at the beginning of the class. No homework assignments or case study write-ups will be accepted late.

The homework assignments will be a mix of problems, case studies, and write-ups. The point total (and therefore their relative importance) will vary from week to week. More details will be available closer to the course start date and due date of the homework.

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* Last Updated on August 28, 2023 and subject to change.
* The most recent syllabus will be posted on the class web site

**All Northwestern Guidelines Apply to this class:**

**Academic Integrity**

Students in this course are required to comply with the policies found in the booklet, "Academic Integrity at Northwestern University: A Basic Guide". All papers submitted for credit in this course must be submitted electronically unless otherwise instructed by the professor. Your written work may be tested for plagiarized content. For details regarding academic integrity at Northwestern or to download the guide, visit: <https://www.northwestern.edu/provost/policies-procedures/academic-integrity/index.html>

**Accessibility**

Northwestern University is committed to providing the most accessible learning environment as possible for students with disabilities. Should you anticipate or experience disability-related barriers in the academic setting, please contact AccessibleNU to move forward with the university’s established accommodation process (e: [accessiblenu@northwestern.edu](mailto:accessiblenu@northwestern.edu); p: 847-467-5530). If you already have established accommodations with AccessibleNU, please let me know as soon as possible, preferably within the first two weeks of the term, so we can work together to implement your disability accommodations. Disability information, including academic accommodations, is confidential under the Family Educational Rights and Privacy Act.

**Exceptions to Class Modality**

Class sessions for this course will occur in person. Individual students will not be granted permission to attend remotely except as the result of an Americans with Disabilities Act (ADA) accommodation as determined by AccessibleNU.

Maintaining the health of the community remains our priority.  If you are experiencing any symptoms of COVID do not attend class. Follow the steps outlined on this site for testing, isolation and reporting a positive case. Next, contact your instructor as soon as possible to arrange to complete coursework.

Students who experience other personal emergencies should contact the instructor as soon as possible to arrange to complete coursework.

Should public health recommendations prevent in-person class from being held on a given day, the instructor or the university will notify students.

**Diversity, Equity, and Inclusion**

This course strives to be an inclusive learning community, respecting those of differing backgrounds and beliefs. As a community, we aim to be respectful to all students in this class, regardless of race, ethnicity, socio-economic status, religion, gender identity or sexual orientation.

**Prohibition of Recording of Class Sessions by Students**

Unauthorized student recording of classroom or other academic activities (including advising sessions or office hours) is prohibited. Unauthorized recording is unethical and may also be a violation of University policy and state law. Students requesting the use of assistive technology as an accommodation should contact [AccessibleNU](https://www.northwestern.edu/accessiblenu/" \t "_blank). Unauthorized use of classroom recordings – including distributing or posting them – is also prohibited. Under the University’s [Copyright Policy](https://www.invo.northwestern.edu/invention-disclosure/policies-forms/copyright-policy/), faculty own the copyright to instructional materials – including those resources created specifically for the purposes of instruction, such as syllabi, lectures and lecture notes, and presentations. Students cannot copy, reproduce, display, or distribute these materials. Students who engage in unauthorized recording, unauthorized use of a recording, or unauthorized distribution of instructional materials will be referred to the appropriate University office for follow-up.

**Support for Wellness and Mental Health**

Northwestern University is committed to supporting the wellness of our students. Student Affairs has multiple resources to support student wellness and mental health.  If you are feeling distressed or overwhelmed, please reach out for help. Students can access confidential resources through the Counseling and Psychological Services (CAPS), Religious and Spiritual Life (RSL) and the Center for Awareness, Response and Education (CARE). Additional information on all of the resources mentioned above can be found here:

<https://www.northwestern.edu/counseling/>

<https://www.northwestern.edu/religious-life/>

<https://www.northwestern.edu/care/>