

MATH 323 * OPERATIONS RESEARCH: DETERMINISTIC MODELS

Spring 2023

Welcome to Operations Research: Deterministic Models! I hope we all have a great time together, and that we all learn from each other this semester. Below you will find all the relevant information about this class and the assessment. While going through the rest of this document, note that everything written in maroon contains a link.

1 General Information

- Schedule: Monday, Wednesday and Friday 9:00-9:50 am
- Modality: In person
- Classroom: Jones Hall, room 306
- Instructor: Daniela Hurtado-Lange
- Office hours:
 - Monday, Wednesday and Friday 12:00-1:00 pm in person at my office
 - By appointment in my virtual office (Zoom meeting) or in person
 - If you want to meet virtually, please set up an appointment via email

2 Description

An introduction to operations research - how to use analytics to find the most efficient decision with available data. Focus is on quantitative modeling and formulation of optimization problems, which has been widely applied to management, engineering, and science. Model applications include machine learning, statistics, data science, sports analytics, supply chain, marketing, as well as other domains.

In this course we will use the mathematical tools you have learned in the past to solve and analyze real-life problems. One of the most important skills that you will learn is modeling problems as linear programs. Even though the lectures will focus more on solving and analyzing the solution of these problems, I will encourage you to keep practicing your modeling skills in the homework.

Prerequisites: Undergraduate level MATH 211 or Mathematics 211 Equivalent 1 or MATH 210.

3 Textbook

Optimization in Operations Research, Ronald L. Rardin, Pearson (2017)

* The textbook is available in hard and soft copies at this [link](#).

AMPL: A Modeling Language for Mathematical Programming, Robert Fourer, David M. Gay, and Brian W. Kernighan, Second edition, Thomson (2003).

* A free soft copy is available at this [link](#).

4 Learning Objectives

By the end of the semester you will be able to:

1. Understand the importance of linear programming
2. Construct linear programming (LP) and mixed integer programming (MIP) models that represent real-life situations

3. Understand the foundations of the Simplex method
4. Construct the dual of a linear program and use it for sensitivity analysis
5. Use AMPL to solve linear programs, interpret the output and develop sensitivity analysis
6. Understand the foundations of the most popular algorithms to solve Integer Programs

5 Assessment and Grading Structure

This is a letter-grade course, under the grading scale presented below:

Letter grade	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
Total score	> 94	> 90	> 87	> 83	> 80	> 77	> 73	> 70	> 67	> 63	> 60	≤ 60

I might curve the grades in your favor at the end of the semester.

There will be multiple opportunities for lower-stake assessment, with the goal of preparing you for the exams and the final. Some of these will be graded, and some will not. I encourage you to use all these opportunities to learn what you know well and what needs practice before the exam.

Below you will find a brief description of each graded assignment:

- **Workshops and participation (5%):** I will provide a list of problems, and you will have 50 minutes to work on them. You may work in groups of 2-3 people, discuss out loud, ask me questions, revise your notes, etc. At the end of the 50 minutes, you have to submit your work.
 - Grading: The workshops are graded by submission, that is, if you submit your work you get 100 points and if you do not, you get 0. So, don't worry if you do not finish all the problems. The goal is to get you working on some problems while I'm there to solve your questions.
 - Solutions: I will provide the solution to the problems after class.
 - Feedback: I will give back your papers one class after the workshop. As stated earlier, I won't grade them, but I may add some feedback.
 - Frequency/schedule and absence : We will have workshops every other Friday approx. I invite you to check Section 10 for a detailed schedule, and Section 7 to learn what to do if you miss a workshop.
- **Homework (average 20%):** Sets of problems to be solved individually. You will have 1 week to solve them, and they will be released biweekly (approx). The problems will be released on the same day of the workshops, and the deadline will be one week after. Collaboration is encouraged subject to the "empty hands policy", described in Section 6.
 - Where do I find the questions? They will be posted on Gradescope, and I will send an announcement to let you know when they are available.
 - Submission: You should submit your homework to Gradescope in a **single pdf** file and **mark in which page(s) you answered each question** using the Gradescope feature. Following these simple rules saves a lot of time in grading. Let's be empathetic! If you fail to follow these rules, you automatically lose 5 points on the corresponding homework.
 - Due dates: You will have until 11:59 pm of the due date to submit your homework, or you may use some "late days." I invite you to check Section 6 to learn what these are.
 - Grading: Each homework will be graded from 0 to 100 points. A subset of problems will be graded with a rubric, and the rest by completion.
 - Solutions: I will provide the solution to the problems after the days of lateness or after everybody submits (whichever happens first).
 - Optional homework: If a homework is labeled as optional, you may or may not submit. Your grade is only affected if you submit the homework and your score helps you. If you submit and get a low score, the optional homework doesn't count. Additionally, **you may not use late days** for optional homework.

- **Midterm I and II (20% each):** Take-home exam to be solved individually in, at most, 48 hours. The dates and (tentative) contents are provided in Section 10. Observe they are scheduled on **Thursday and Friday**. There is no class whenever we have a Midterm. Instead, I will hold office hours.
 - Where do I find the questions? I will post them on Gradescope at 12 am of the corresponding Thursday.
 - What is allowed during the exam? You may use your notes, the textbook and everything posted on Blackboard, but **collaboration is not allowed**. Not even under the “empty hands” policy. I encourage you to prepare a couple of pages summarizing the contents to enhance your learning process and facilitate searching what you may need for the exam.
 - Submission rules: By Friday at 11.59 pm, you need to upload your exam to Gradescope, marking which page(s) correspond to each question.
 - Conflicts with schedule: If you have a schedule conflict with the exams, please let me know by **Friday, February 3rd** via email.
 - Grading: Each Midterm will be graded from 0 to 100 points. After the grades are released, you will have 1 week to request a regrade in case I made a mistake. The regrading requests must be submitted on Gradescope, and you should explain where and why you believe there is a mistake.
 - Opportunity for bonus points: After each Midterm, you will have 1 week to fill a survey with the following questions:
 1. What was easy in the Midterm?
 2. What was hard in the Midterm?
 3. What has the instructor done well so far?
 4. How can the instructor improve?
 5. What have I (as a student) done well so far?
 6. How can I improve for the next assessment?

I deeply care about the feedback you can provide, so I will give you 5 bonus points in the corresponding midterm for answering the survey (yes, you can end the semester with 105 points in each midterm if you answer these questions!). Please be as concrete as possible with your answers.

- **Final exam (35%):** Take-home exam at the end of the semester (dates available in Section 10). Topics may include every chapter covered in class. Except for the duration and the survey, the same rules of the Midterms apply.

How to compute my final grade?

The workshops can only improve your grade. In other words, if you do not participate in the workshops, your grade will not be affected. The final grade will be computed as follows:

$$\text{Grade} = \max \left\{ 0.05 \times \text{Workshops} + 0.2 \times \text{Homework} + 0.2 \times \text{Midterm I} + 0.2 \times \text{Midterm II} + 0.35 \times \text{Final} , \right. \\ \left. \frac{0.2 \times \text{Homework} + 0.2 \times \text{Midterm I} + 0.2 \times \text{Midterm II} + 0.35 \times \text{Final}}{0.95} \right\}$$

6 Some Ground Rules

- **Attendance to class and participation:** I highly encourage you to attend the lectures and participate to create an active learning environment. If you have to miss a class, no worries! I invite you to check Section 7 to see how we will handle it.
- **Collaboration:** Collaboration in solving the homework and preparing for the exams is encouraged, under the “empty hands policy” described below. The exams are individual, and no collaboration in solving them is allowed. I understand that you may use similar methods to solve the problems, but you must submit your own answers.
- **Empty hands policy¹:** Two or more students may enter a room (for example, a room with a whiteboard) and may together solve some or all of the problems on a homework assignment on the board. Each student must leave the room without any written or electronic materials describing these solutions. Students are to leave such a problem-solving session with only the solutions to the problems in their heads. Each student must perform their own individual write-up of the homework solutions sometime after the problem-solving session and submit their solutions individually.
- **Use of AI:** The use of AI-interactive software (such as ChatGPT) is allowed in homework and exams as long as you report it. You may include a screenshot of the answer(s) provided by the AI, and you must explain why you think it is correct (or not). This software is not fully tested for the topics we cover in this class and, hence, it may not give you correct answers.
- **Late work:** You will have 5 days of ‘lateness’ to use at your convenience when submitting your homework, to be spent in integer numbers. This means that you can submit your homework late by at most five days in the entire semester and your grade will not be affected. For any additional day of ‘lateness’ you will lose 5 points of the corresponding homework. For example, you may submit homework 1 two days late, homework 2 eight hours (hence, one day) late and homework 3 two days late and you qualify to the maximum grade. However, if you submit all three homeworks two days late, your third homework will have a maximum of 95 points.
- **Academic integrity:** I expect you to be familiar with the Honor Code and behave accordingly.
- **Student-faculty expectations:** I expect you to participate in class and ask questions during the lectures, via emails or in office hours. My job is to do my best to keep you interested in the class, transmit the content in the lectures and answer your questions. I know we all may work on weekends, but I will not reply to any email and I do not expect you to submit any work during weekends.
- **Accommodations for students with disabilities:** If you need any type of accommodation, please make an appointment with the Office of Disability Services to get an Accommodation Letter (steps in this [link](#)). I am happy to provide any accommodation, but you need to let me know as soon as possible (hopefully by the beginning of the semester).

7 Absence to class, workshops or exams

- **To class (students):** If you are ill, please do not come to class. I will post all the lecture notes, so you will know exactly what I did in class. Additionally, I encourage you to ask as many questions as you need to in office hours, or setting up an appointment. Remember that “can you explain this section to me?” is a perfectly valid question.
- **To class (instructor):** If I need to miss an in-person class, I will post videos with the contents. I understand that videos are not interactive, and you cannot ask questions during the class, but we always have office hours. If I am ill, I will let you know and the office hours will be held virtually.
- **To workshops:** Workshops are not mandatory, and the grade only reflects attendance and participation. I understand that if you are ill you may want to join the workshop, but you won’t be able to. If that’s the case, **send me an email before the workshop ends** and I can excuse your absence. You may use this resource at most **once** in the semester.

¹Based on policy created by Prof. Steve Park

- **To exams:** If you need to miss an exam (including the midterms and the final), please let me know as soon as you know you will miss it. You will have 48 hours after the exam to email me explaining what happened, and we will find another time for a make-up exam. If you fail to contacting me withing 48 hours, you will get a 0 in the corresponding exam.

8 Software

In this class we will use AMPL to complement the technical knowledge. To download and install the software, please follow the instructions below.

- **Download:** Go to Blackboard and you will find a link to the files to download on the left-hand side menu. Please download the file corresponding to your OS.
- **Install:** Follow the instructions at this [link](#). If you installed the software correctly, you will see a folder with lots of files as shown in the following screenshot. If you do not see such folder, and you have only a few files instead, you installed AMPL incorrectly. Delete everything you downloaded and start over. This happens very frequently. If you run into trouble, you may come to office hours.

Name	Date Modified	Size	Kind
ampl	Aug 4, 2022 at 4:34 PM	1.3 MB	Document
ampl.ENV	Aug 4, 2022 at 4:34 PM	207 bytes	Document
ampl.lic	Aug 4, 2022 at 4:34 PM	583 bytes	Document
amplgs.dll	Aug 4, 2022 at 4:34 PM	1.8 MB	Microso...k libran
amplide	May 11, 2022 at 12:06 PM	--	Folder
amplkey	Aug 4, 2022 at 4:34 PM	9.6 MB	Document
amplxl.dll	Aug 4, 2022 at 4:34 PM	1.1 MB	Microso...k libran
baron	Aug 4, 2022 at 4:34 PM	534 KB	Document
bonmin	Aug 4, 2022 at 4:34 PM	15.8 MB	Document
cbc	Aug 4, 2022 at 4:34 PM	9.6 MB	Document
coin-license.txt	Aug 4, 2022 at 4:34 PM	11 KB	Plain Text
coin-versions.txt	Aug 4, 2022 at 4:34 PM	394 bytes	Plain Text
conopt	Aug 4, 2022 at 4:34 PM	1.9 MB	Document
copt	Aug 4, 2022 at 4:34 PM	3.3 MB	Document
couenne	Aug 4, 2022 at 4:34 PM	18.6 MB	Document
cplex	Aug 4, 2022 at 4:34 PM	548 KB	Document
docs	May 11, 2022 at 11:06 AM	--	Folder
fingerprint	Aug 4, 2022 at 4:34 PM	24 KB	Document
gsl-version.txt	Aug 4, 2022 at 4:34 PM	40 bytes	Plain Text
gsl.ampl	Aug 4, 2022 at 4:34 PM	12 KB	Document
gurobi	Aug 4, 2022 at 4:34 PM	427 KB	Document
ipopt	Aug 4, 2022 at 4:34 PM	6.8 MB	Document
kestrel	Aug 4, 2022 at 4:35 PM	7.9 MB	Document
knitro	Aug 4, 2022 at 4:34 PM	168 MB	Document
leasefingerprint	Aug 4, 2022 at 4:34 PM	42 KB	Document
libbaron-lin64.so	Aug 4, 2022 at 4:34 PM	38.1 MB	Document
libcilkrts.so.5	Aug 4, 2022 at 4:34 PM	325 KB	Document
libconopt464.so	Aug 4, 2022 at 4:34 PM	2.4 MB	Document
libconsob3.so	Aug 4, 2022 at 4:34 PM	1.5 MB	Document
libcopt.so	Aug 4, 2022 at 4:34 PM	19.7 MB	Document
libcplex2010.so	Aug 4, 2022 at 4:34 PM	35.7 MB	Document
libgcc_s.lindo.so.1	Aug 4, 2022 at 4:34 PM	725 KB	Document
libgcc_s.so.1	Aug 4, 2022 at 4:34 PM	725 KB	Document
libgfortran.lindo.so.3	Aug 4, 2022 at 4:34 PM	5.8 MB	Document
libgfortran.so.3	Aug 4, 2022 at 4:34 PM	981 KB	Document
libgurobi95.so	Aug 4, 2022 at 4:34 PM	43.5 MB	Document
libiomp5.baron.so	Aug 4, 2022 at 4:34 PM	2.4 MB	Document
libiomp5.knitro.so	Aug 4, 2022 at 4:35 PM	2.1 MB	Document
libiomp5.lindo.so	Aug 4, 2022 at 4:34 PM	845 KB	Document
liblindo64.so.13.0	Aug 4, 2022 at 4:34 PM	16.5 MB	Document
libmosek64.so.9.2	Aug 4, 2022 at 4:34 PM	30.1 MB	Document
libquadmath.lindo.so.0	Aug 4, 2022 at 4:34 PM	944 KB	Document
libxprl.so.x8.13	Aug 4, 2022 at 4:34 PM	715 KB	Document
libxprs.so.39.01	Aug 4, 2022 at 4:34 PM	38 MB	Document
lindoglobal	Aug 4, 2022 at 4:34 PM	320 KB	Document
logo	Aug 4, 2022 at 4:34 PM	577 KB	Document
minos	Aug 4, 2022 at 4:34 PM	833 KB	Document
models	May 11, 2022 at 12:57 PM	--	Folder
ocract	Aug 4, 2022 at 4:34 PM	95 KB	Document
ocract-runtime	May 11, 2022 at 12:58 PM	--	Folder
README	Aug 4, 2022 at 4:34 PM	4 KB	Document
s22	May 11, 2022 at 12:57 PM	--	Folder
snopt	Aug 4, 2022 at 4:34 PM	1.3 MB	Document
x-ampl	Aug 4, 2022 at 4:34 PM	1.7 MB	Document
x-gurobi	Aug 4, 2022 at 4:34 PM	2.4 MB	Document
xpauth.xpr	Aug 4, 2022 at 4:34 PM	437 bytes	Document
xpress	Aug 4, 2022 at 4:34 PM	474 KB	Document

9 Mental and Physical Well-Being

William & Mary recognizes that students juggle different responsibilities and can face challenges that make learning difficult. There are many resources available at W&M to help students navigate emotional/psychological, physical/medical, material/accessibility concerns. **Asking for help is a sign of courage and strength.** If you or someone you know is experiencing any of these challenges, we encourage you to reach out to the following offices:

- W&M Counseling Center: Click [here](#) or call (757) 221-3620. Services are free and confidential.
- W&M Health Center: Click [here](#) or call (757) 221-4386.
- For additional support or resources, please contact the Dean of Students by submitting a Care Report at this [link](#), calling (757)221-2510, or by emailing deanofstudents@wm.edu.
- For other resources available to students, see [Health and Wellness Resources for Students](#), or this [link](#). The last link can also be reached through the following QR code:



As your instructor this semester, I also ask you to reach out to me if you are facing challenges inside or outside the classroom. I am happy to grab a cup of coffee together, make accommodations if you need any, or guide you to appropriate resources on campus if necessary.

10 Tentative Schedule

Below you will find a schedule based on the chapter numbers of the textbook. These may not match the chapter numbers in the lecture notes.

Date	Topics	Tasks
1. Wed Jan 25th	Syllabus discussion and introduction	
2. Fri Jan 27th	Ch 2: Deterministic Optimization Models in Operations Research	
3. Mon Jan 30th		
4. Wed Feb 1st		
5. Fri Feb 3rd		Deadline to email me if conflicts with exams.
Last day of add/drop		
6. Mon Feb 6th	Ch 3: Improving search	
7. Wed Feb 8th		
8. Fri Feb 10th	Workshop 1	<ul style="list-style-type: none"> • Submit workshop by end of class • Homework 1 posted
9. Mon Feb 13th	Ch 3 (cont.)	
10. Wed Feb 15th		
11. Fri Feb 17th	Ch 4: Linear programming models	Homework 1 due by the eod
12. Mon Feb 20th		
13. Wed Feb 22nd		
14. Fri Feb 24th	Workshop 2	<ul style="list-style-type: none"> • Submit workshop by end of class • Homework 2 posted
15. Mon Feb 27th	Ch 5: Simplex algorithm	
16. Wed Mar 1st		
17. Fri Mar 3rd		Homework 2 due by the eod

18. Mon Mar 6th		
19. Wed Mar 8th	Workshop 3	Submit workshop by end of class
20. Mar 9-10th: Midterm I (take home) – Contents: Lectures 1-17 – Office hours instead of class		
Mar 11-19th: Spring break – No class, no office hours		
21. Mon Mar 20th	Ch 5 (cont.)	
22. Wed Mar 22nd		
23. Fri Mar 24th		
Withdraw deadline		
24. Mon Mar 27th	Ch 6: Duality, Sensitivity and Optimality in Linear Programming	
25. Wed Mar 29th		
26. Fri Mar 31st	Workshop 4	<ul style="list-style-type: none"> • Submit workshop by end of class • Homework 3 posted
27. Mon Apr 3rd	Ch 6 (cont.)	
28. Wed Apr 5th		
29. Fri Apr 7th		Homework 3 due by the eod
30. Mon Apr 10th		
31. Wed Apr 12th		
32. Fri Apr 14th	Workshop 5	<ul style="list-style-type: none"> • Submit workshop by end of class • Homework 4 posted (optional)
33. Mon Apr 17th	Ch 7: Interior Point Methods	
34. Wed Apr 19th	Ch 11: Discrete Optimization models	Homework 4 due by the eod (optional)
35. Apr 20th-21st: Midterm II (take home) – Contents: Lectures 18-32 – Office hours instead of class		
36. Mon Apr 24th	Ch 11 (cont.)	
37. Wed Apr 26th		
38. Fri Apr 28th	Workshop 6	<ul style="list-style-type: none"> • Submit workshop by end of class • Homework 5 posted
39. Mon May 1st	Ch 12: Exact Discrete Optimization Methods	
40. Wed May 3rd		
41. Fri May 5th	Review session	Homework 5 due by the eod
Final exam: Thu May 11th to Mon May 15th – Contents: Lectures 1–41		