ISE 316
Optimization Models and Applications

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Term: Fall 2019
Lecture days/time: M/W 10:45am-12:00pm
Lecture room: MO 375
Course Site: https://coursesite.lehigh.edu/

Office hours: M/W 3:00-5:00pm, or by appointment (as needed).

1 Summary Course Description

Operations Research (O.R.) is appropriately labeled as *The Science of Better (Decision-Making)*, due to its significant positive impact in many real-world settings. The prudent application of O.R. concepts and techniques helps to make our quality of life better, by carefully improved analysis and management of the environment, finances, healthcare, logistics, planning, production and distribution of goods, product design, resource allocation, services, and safety.

Within the broad context of O.R., optimization model development, the ability to solve such models with properly chosen tools and to interpret the results obtained is a competitive advantage. Modeling and solving complex optimization problems requires advanced quantitative skills and techniques. In this course, we discuss a range of model types to describe a broad variety of optimization problems. We also discuss and apply state-of-the-art optimization (solver) engines. The application examples presented originate from many areas, including the topics listed above.

2 Learning Objectives

Having completed this course, attendees will be able to develop and to apply the following skills.

- Formulate O.R. models based on an initial (often non-technical) problem description
- Select appropriate modeling techniques to handle specific O.R. problem types
- Develop code in an optimization modeling language(s), based on a mathematical O.R. model
- Solve coded problems using appropriately chosen solver techniques and tools
- Analyze and interpret the solution of optimization problems in their real-world context

3 Course Prerequisites

In the ISE 316 course, we will rely on basic concepts and techniques from calculus, linear algebra and probability theory. Prerequisites may include – as appropriate – the courses ISE 357 / 230 / 240. Students can enroll either in ISE 426, or in ISE 316, but not in both.

4 Textbook

Primary course text:

Frederick S. Hillier and Gerald J. Lieberman, *Introduction to Operations Research*, 10th Edition. McGraw-Hill, 2015.

The course will cover selected topics and chapters from this textbook. The use of earlier textbook editions is also possible. However, please make sure to read materials from the current edition as needed, especially considering examples and exercises cited from this edition.

We will also provide additional reading materials as deemed appropriate. Specifically, in the context of applying O.R. to address sustainability and environmental issues, we will recommend a selection of books, and will distribute articles to support project studies. We will discuss such issues by introducing various model types and solution approaches, based on the information used. Analogous conceptual development will apply also to other important O.R. application areas.

5 Model Development and Solver Tools

Several prominent modeling languages can be put to good use in the context of optimization. In this course, we will use the modeling language AMPL and its solver engine options. AMPL is described by the following book:

Robert Fourer, David M. Gay, and Brian W. Kernighan, *AMPL: A Modeling Language for Mathematical Programming*, 2nd Edition. Duxbury-Thomson, 2003.

An online version of this book is available at www.ampl.com. AMPL is freely available for educational purposes at www.ampl.com, to handle size-limited models (depending on the model type). The AMPL website offers also other valuable resources, including the model examples discussed in the AMPL book.

At your discretion, in addition to AMPL you can use other model development and computing systems such as AIMMS, Excel, GAMS, LINGO, Maple, Mathematica, MATLAB, MPL, Python, R, or SAS *in your independent studies*, including work on assignments and projects. However, it is your personal responsibility to learn how to use *optionally* these alternative software products. Familiarity with any of these or similar tools can be useful also in other courses, and eventually in your working career. Some of the software products listed above also have free educational versions.

Please consult the available software products at Lehigh University's software installation site http://software.lehigh.edu/install/?SID=209.

6 Course Site

In addition to lectures and in-class discussions, Course Site provides the primary way of communication related to this course. Lecture slides, accompanying reading materials, assignments and their solutions, exams with solutions, and announcements will be posted using the appropriate course folder at Lehigh University's Course Site https://coursesite.lehigh.edu/. Assignments completed by students will be also submitted via Course Site, unless requested otherwise.

7 Course Schedule and Lecture Topics

Course Schedule

Lehigh University determines a semester as 14 weeks of instruction, followed by a brief reading, consultation and study period, in preparation to 9 consecutive calendar days of final examinations with four periods per day of 3 hour exam blocks. Within the fall and spring semester, classes are scheduled either as three 50-minute activities or as two 75-minute activities per week, as determined by Lehigh University. In summer courses, 5 weeks (as a rule, with four 95-minute class activities per week) are available to cover all coursework, followed by an exam period determined by Lehigh University.

The following list of topics is tentative: both Lehigh University and your instructor reserve the right to make adjustments as needed. Please note that in the following description we use the words *optimization* and *programming* as synonyms. For each problem class listed below, we discuss structural assumptions with graphical examples, model analysis and solution strategies; this is followed by modeling and solving corresponding problems using AMPL, with application examples.

Lecture Topics

- Introductory discussion
- Introduction to operations research and optimization, with examples
- A brief review of multivariate calculus essentials (in the context of this course)
- Model development and analysis: decision variables, constraints, objective function
- Convexity and non-convexity; global and local optima
- Model relaxations
- Good modeling practices and tips
- An introduction to the AMPL model development environment
- Linear programming models with continuous decision variables
- Integer linear programming models with binary and general integer decision variables
- Graphs and network models with continuous, binary and integer decision variables
- Nonlinear programming (convex and non-convex models) with continuous decision variables

Depending on the time available during the course, we will *optionally* discuss also the following topics.

- Stochastic programming with continuous decision variables and random variables
- Multi-criteria optimization with continuous decision variables, in presence of conflicting objectives
- Mixed integer nonlinear optimization with continuous and integer decision variables

8 Class Attendance and Participation

Attendance and *active participation* in classroom discussions are required. Please contact me in advance, if you have to be absent from class due to a valid reason.

In all verbal or email communications, please observe proper business etiquette and communicate your messages carefully and politely. By sending a course related email, you acknowledge that I can discuss content and answers in class, and/or post answers on Course Site, in order to share the answer with all course attendees.

You can use your computer or calculator during class, only when explicitly allowed, exclusively for the purposes of the course work (e.g. to solve computer-based exercises). In all other cases, the use of cellphones, computers, tablets, or other electronic devices and distractions is not permitted, in order to make the best use of your (our) class time.

Please feel free to provide feedback about our joint work, and ask questions (ideally, in class so that all attendees can benefit from the discussions). Please contact me (or my teaching assistant, when assigned to this course) during office hours or by appointment, if your questions could not be addressed during class time. Please understand that instructor availability cannot be always guaranteed, especially immediately before exams, and pace your work accordingly.

Audio or video recording of classes is permitted only with the approval of everyone present in the classroom. Please let me know in advance if you need to use audio or video recording, also indicating its purpose.

9 Homework Assignments

An essential part of this course is to gain hands-on experience in applying O.R. and optimization to a range of problems inspired by realistic decision-making scenarios. These problems will be often stated in "everyday language": your task is to translate the problem into an appropriate quantitative model, to solve it, and to interpret the results. All homework assignments have to be completed by their deadline, also in preparation for the exams. Late homeworks may be penalized or may not be accepted, at your instructor's discretion.

Electronic submissions via Course Site are the standard way to submit assignments, unless course attendees are advised otherwise. Please submit well-prepared documents to expect good feedback and grades. Use Word or a similar quality text processor to create high-quality documents, as opposed to poorly readable, hand-written notes. The experience gained from preparing these assignments will become useful also in your working career. For homeworks that include computer-based exercises, submit your properly documented code as well as its result, based on your own fully functional (working) code.

You can always discuss all course work and assignments in small groups. However, you must work out the solution by yourself, and you must write and submit your own homework, including computer code development. Following these ethical guidelines will also help you to acquire active knowledge.

10 Exams

In principle, each exam could cover *all* materials presented in class prior to the time of the exam, as well as *all* topical examples and exercises of the textbook, and *all* homework assignments. The final

exam is comprehensive. Before each exam, its actual content will be discussed and clarified in class.

In courses held during the fall or spring semester, there will be two midterm exams, scheduled approximately 5 and 10 weeks after the beginning of the semester. In 5-week courses held during the summer, there is one midterm exam, scheduled approximately 2.5 weeks after the beginning of the semester. All exams are *closed book and closed notes*, unless agreed otherwise. The usage of hand-written summaries (typically, maximum two handwritten pages) and a calculator is allowed, at your instructor's discretion.

Please do your best to attend all exams, to avoid creating problems for yourself, and extra work for all else involved. In order to pass the course, all students have to take the final exam. In case of substantial medical or other reasons that lead to missing an exam, please inform your instructor as soon as possible, and follow the procedures described at https://studentaffairs.lehigh.edu/content/student-absence. Upon accepting the absence report, *at your instructor's discretion*, a make-up exam may be arranged.

11 Course Work Evaluation and Grades

The evaluation of course work is based on the following weighted components:

	Fall / Spring courses	Summer courses
• Participation:	10%	10%
• Assignments:	30%	30%
• Midterm 1:	15%	25%
• Midterm 2:	15%	
• Final exam:	30%	35%

- Your final exam score has to be at least 60 out of max. 100 points.

Students who participate in classroom discussions and work diligently on all homework assignments typically do well also on their exams. Consider all classes and homework assignments as an opportunity to learn, to challenge yourself and to get feedback, rather than viewing these as just a "grade component of your final grade".

Please pay close attention and be active in all your classes. Study at a steady, manageable pace. Submit your assignments on time. Not participating and missing assignments could negatively affect your preparation to exams, your final grade, and – most importantly – your professional knowledge.

The following correspondence between numerical grades (based on the weighted average of the component scores, each normalized by a maximal score of 100) and letter grades is used:

Numerical Grade	≥93	≥90	≥87	≥83	≥80	≥77	≥73	≥70	≥67	≥63	≥60	<60
Letter Grade	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F

12 University Policies, Activities and Services

Principles of Equitable Community, Diversity and Inclusion

Lehigh University endorses the above stated principles, and we expect all course attendees to

acknowledge and to practice them. Respect for each other, and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.
For more information, visit https://www1.lehigh.edu/diversity.

Accommodations for Students with Disabilities

If you have a disability or some other valid reason to request special accommodations, then please contact both your instructor and the Office of Academic Support Services as early as possible during the semester. Please obtain proper documentation from Academic Support Services before special accommodations can be granted. Please visit https://studentaffairs.lehigh.edu/disabilities for further information.

Academic Integrity

Irresponsible behavior can ruin opportunities for you and/or for other attendees of the course, and there is no room or excuse for such behavior. Examples of irresponsible behavior include cheating, copying the work of others and other forms of plagiarism, slacking on responsibilities, unfairly exploiting the efforts of others, making false statements about the work of others, creating hazards or disruptions, and lacking civility. Various forms of carelessness or disregard for safety considerations, abuse of others, compromising opportunities for others, failing to work in good faith can also have serious consequences.

It is the firm policy of this course, and of all Lehigh University courses, that cheating or plagiarism are unacceptable violations of academic integrity: all such actions will earn an F semester grade in the course. Please meet all coursework requirements honestly and in good spirit, and always do your fair share of assigned work.

While all students are encouraged to discuss assignments, the eventual solution is your individual responsibility (or team responsibility as applicable). Do not ask for other student's completed work, and do not share your completed work with others. Do not copy assignment reports by other students currently or previously enrolled, and avoid any form of cheating on exams. Offenders may lose points from their course totals and may fail the course. Serious offenders could be expelled from the course, and even from the University.

For further explanation and guidelines regarding academic integrity expectations at Lehigh University, with illustrative cases, please consult https://www.lehigh.edu/~inprv/faculty/academicintegrity.html. See the link to downloadable Academic Integrity Vignettes and the section titled Resources for Students.

Further Lehigh University Activities and Services

Lehigh University Library & Technology Services: https://lts.lehigh.edu/services.

Religious Life at Lehigh University: https://chaplain.lehigh.edu.

The Center for Dialogue, Ethics and Spirituality: https://dialogue.lehigh.edu.