ISE 316
Optimization Models and Applications

Instructor: János D. Pintér   Term: Fall 2018

Office: MO 486   Lecture days: Mon-Wed-Fri

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Office hours: Mon and Wed 13:00-15:00, or (as needed) by appointment.

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1 Summary Course Description

Operations Research (O.R.) is appropriately labeled as *The Science of Better [Decision-Making]*, due to its significant positive impact related to improved systems performance in many real-world settings. To highlight just a few examples, the application of O.R. concepts and techniques helps to achieve better resource allocation, increased production and profits, improved services and customer satisfaction, and higher levels of safety.

Within the 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 real-world optimization problems requires advanced quantitative skills and techniques. In this course, we will discuss a range of model types to describe a significant variety of optimization problems. We will also discuss state-of-the-art O.R. optimization (solver engine) tools, and the interpretation and presentation of the results obtained.

2 Learning Objectives

Having completed this course, attendees will be able to:

- Formulate O.R. problems based on a not necessarily technical (verbal) problem description
- Select appropriate modeling techniques to handle specific O.R. problem types
- Solve the stated problems using appropriately chosen software tools
- Analyze and interpret the solution of optimization problems

3 Course Prerequisites

Key basic concepts and techniques from calculus, linear algebra and probability theory will be used during the course. Prerequisites for ISE 316 include ISE 230 and 240. (Students can enroll either in ISE 426, or in ISE 316, but not in both.)

4 Textbook

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. Note that the use of earlier textbook editions is allowed. However, please make sure to read materials from the current edition as needed, especially considering examples and exercises cited from the latest edition.

Additional reading materials will be provided as deemed appropriate.

5 Model Development and Solver Tools

Several prominent modeling languages can be put to good use in the context of optimization. We will be using the modeling language AMPL and its solver engine options. AMPL is described in details 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 has a student version that is freely available at www.ampl.com, to handle size-limited models. The AMPL website offers also other valuable resources, including all models discussed in the AMPL book.

In addition to AMPL – at your discretion – you can use other modeling and computing systems such as AIMMS, Excel, GAMS, Maple, Mathematica, MATLAB, Python, R, or SAS *in your independent studies*, including work on assignments. However, it is your own responsibility to learn how to use *optionally* these alternative software products. In general, familiarity with any of these tools can become useful also in your other courses, and eventually in your working career. Consult the available software products at Lehigh University's software site http://cf.lehigh.edu/software/info.cfm?SID=209.

6 Course Site

Lecture slides, accompanying reading materials, examples, homework 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/. Important course related information will be sent by email to all enrolled students via Course Site. All assignment solutions should be submitted via Course Site, unless stated otherwise. In addition to the lectures and in-class discussions, Course Site provides the primary way of communication related to this course.

7 Course Schedule and Lecture Topics

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 instruction time period, ISE 316 and 426 classes are scheduled either as three 50-minute activities or as two 75-minute activities per week, depending on the semester. In summer courses 5 weeks are available to cover the entire workload referred to above.

The following schedule within the current semester is tentative. Both Lehigh University and your instructor reserve the right to make changes if needed. Please note that in the following description the words optimization and programming are used as synonyms.

Lecture Topics

- Introductory discussion

- Introduction to optimization models, with examples

- A brief review of multivariate calculus essentials (in the context of this course)

- Model analysis: decision variables, constraints, objective function; convexity and non-convexity; global and local optima; good modeling practices

- Model relaxations and their applications

- An introduction to the AMPL model development environment

- Linear programming (LP) models; graphical solution; solution strategies; application examples

- Modeling and solving LP problems using AMPL, with examples

- Integer linear programming (ILP) models; binary and general integer variables; logical constraints and binary variables; solution strategies; application examples

- Graph and network ILP models; solution strategies; application examples

- Modeling and solving ILP problems using AMPL, with examples

- Nonlinear programming (NLP); solution strategies; application examples

- Modeling and solving NLP problems using AMPL, with examples

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

- Stochastic programming (SP); alternative model forms; multi-stage optimization; solution strategies; application examples

- Multi-criteria optimization (MCO); Pareto-optimality; solution strategies; application examples.

8 Class Attendance and Participation

Attendance of all lectures and active participation in classroom discussions are strongly recommended and expected. Please contact me in advance, if you have to be absent due to a valid reason.

Please also provide feedback about our joint work, in order to make the best use of the time for this course. See 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.

In all verbal or email communications, please observe proper business etiquette and communicate your messages carefully and politely. By sending an email to your instructor (me), you acknowledge that I can post your message to Course Site, in order to share the answer with all course attendees.

You can use your computer or calculator during class, when explicitly allowed, exclusively for the purposes of the course (e.g. to solve computer-based exercises). In all other cases, the use of cell phones, computers, tablets, or other devices and distractions is not allowed.

Audio or video recording of classes can be done 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 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 primary way to submit assignments, unless attendees are advised otherwise. Please submit well-prepared and neat 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 will be 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 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 key ethical guidelines will also help you to acquire active knowledge.

10   Exams

In principle, the exams 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 clarified in class.

There will be two midterm exams, scheduled respectively cca. 5 and 10 weeks after the beginning of the semester. In the summer course, 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, max. two handwritten pages) may be 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. You have to take the final exam, to pass the course. In case of substantial medical or other reasons, please inform your instructor and follow the procedures to obtain an Absence Information Report through the Associate Dean of Students Office. Upon receipt of the absence report – *at your instructor's discretion* – a make-up exam may be arranged.

11 Course Work Evaluation and Grades

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

Regular fall or spring semester   Summer semester

- Participation: 10%   10%
- Homeworks: 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 100.

Pay attention and be active in your classes. Study at a good, steady pace. Submit your homework assignments on time. Missing assignments will negatively affect your final grade, and your preparation to exams.

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

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 Related to the Course

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, see 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. You must have proper documentation from Academic Support Services before special accommodations can be granted.

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 all 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 students are encouraged to discuss homework problems, the eventual homework solution is your individual responsibility. Do not ask for other student's completed work, and do not share your completed work with others. Do not copy homework reports from other students currently or previously enrolled, and absolutely 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), consult https://www.lehigh.edu/~inprv/faculty/academicintegrity.html.

Some Other Lehigh University Activities and Services

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

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