Course Syllabus

Department of Civil & Environmental Engineering

University of Utah

Fall Semester 2017

CVEEN 5920/6920 Optimization in Transportation

Instructor: Dr. Xianfeng (Terry) Yang

Meeting Time: Monday, Wednesday, and Friday 08:30-09:25

Meeting Place: WEB L120

CONTACT INFORMATION

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Office hours: By appointment

COURSE DESCRIPTION

Transportation engineers and researchers always have to face management, design, and control problems, such as delivery vehicles' routing, supply chain management and logistics, traffic signal plan design, and transportation network optimization. To solve those problems, it is essential to employ corresponding optimization models in the decision-making process. Particularly, most optimization tools can be found in the discipline of Operations Research (OR). This course aims to provide students with the fundamental knowledge and skills of quantitative techniques in OR. Topics covered in this course will include network concept introduction (shortest paths, minimum spanning tree, minimum cost network flows, maximum flows), linear programming, integer programming, network optimization, and application of OR in Transportation. Optimization software (e.g.,Excel, Lingo, Cplex, etc.) will be introduced in the course.

TEXT

There is no required text. Several suggested texts will be discussed.

COURSE CONTENTS

1. Network Problems

You will study the fundamental concepts of network-based problem representations and network optimization methodologies through practice in modeling and solving network-related problems (including shortest paths, minimum spanning trees and network flows). By the end of the semester, you should be able to create a network representation of a host of real problems. You should be able to solve a number of network-related problems to optimality using the appropriate techniques.

Topics:

Network representation

Shortest path problem

Minimum spanning trees

Maximum flow problems

Minimum cost flow problems

Multi-commodity network flow problems

2. Mathematical Modeling: Resource allocation problems

You will develop skills in mathematically modeling resource allocation problems. You will learn how to represent the decision problem through the use of decision variables. You will learn how to mathematically model the objective(s) and constraints of the decision problem such that it can be solved through appropriate mathematical programming techniques. These skills will be achieved through practice in modeling (linear) decision-making problems. By the end of the semester, you will be expected to be able to model a variety of decision problems as linear programs.

Topics:

Formulating a mathematical model with decision variables, objective function, constraints and parameters

Standard form of the model

Assumptions of linear programming (proportionality, additivity, divisibility, certainty)

3. Graphical Solution

You will learn how to solve linear programs through the use of graphical solution techniques. By the end of the semester, you will be expected to be able to solve a linear program via graphical solution technique.

Topics:

Feasible region

Optimal vs. feasible solutions

Corner-point feasible solution

Graphical method

Multiple optimal solutions

4. Solving Linear Programs: Simplex Algorithm

You will master the simplex algorithm for solving linear programs. This will be achieved through studying the steps of the algorithm and using it to manually solve linear programs.

By the end of the semester, you will be expected to be able to solve a linear program via the simplex algorithm and to understand how and why the algorithm works.

Topics:

A geometric perspective of an algebraic approach

Setting up the simplex method

Slack variables

Augmented form

Basic and nonbasic variables

Entering basic variables

Leaving basic variables

The basis

Basic solution

Basic feasible solution

Adjacent solutions

Optimality test

Simplex tableau

Pivot column and row

Tie breaking (for entering and leaving variables)

Unbounded problems

Multiple optimal solutions

Artificial-variable techniques

Conversion to proper form

Big M method

Surplus variables

Unbounded variables

Variables allowed to be negative

Postoptimality analysis, shadow prices and sensitivity

Binding constraints

Sensitive parameters

5. Duality Theory

You will learn the fundamental concepts of duality theory and you will be briefly introduced to sensitivity analysis. This will be accomplished through study of duality theory, practice in taking the dual of the original (primal) problem, solution of both the primal and the dual problems and study of the results. Further, the relationship of the dual variables with sensitivity analysis will be discussed. By the end of the semester, you should have a good understanding of the concepts of duality theory and an introductory understanding of sensitivity analysis.

Topics:

Primal vs. dual problem formulations

How to take the dual of a problem

Weak and strong duality theorems

Complementary slackness property

Adapting to other primal forms

Sensitivity analysis

6. Integer Programming

Thus far, in this portion of the course we have focused on linear programming, where decision variables can be any positive real value. However, many problems that arise in transportation require the decision variables to be integer-valued. We will study the branch-and-bound technique for solving pure linear integer programs. We will consider specific details related to formulating linear integer programs. The class will also be introduced to Lagrangian relaxation. By the end of the semester, you will be able to recognize when a problem requires the use of integer-valued decision variables, to formulate integer programs with either-or and if-then constraints, to solve a pure integer program by the branch-and-bound technique and the basics of Lagrangian relaxation.

Topics:

Either-or constraints

If-then constraints

Binary decision variables

Branch and bound

Branching

Bounding

Fathoming

Lagrangian relaxation

7. Software

You will learn how to use a software package to solve linear and linear integer programs. By the end of the semester, you should be able to model linear programs in the software package and run the software to solve the problem. You should be able to understand the output of the software.

Topics:

Excel Solver, possibly CPLEX

8 Heuristics and Metaheuristics

You will obtain a basic understanding of the difference between an algorithm and a heuristic and will learn the basic properties that make for good algorithms and heuristics. You will be introduced to the concepts of metaheuristics, including tabu search and genetic algorithms. By the end of the semester, you will be expected to understand the difference between an algorithm and a heuristic and to evaluate whether or not the technique is “good.” You will have a basic understanding of several metaheuristic approaches: how they work and the pros and cons of such approaches. You will have an opportunity to study one metaheuristic in greater depth through a small class project.

Topics:

Heuristics vs. algorithms

Properties of heuristics

Metaheuristics

Grading

4-5 homework assignments (10 percent)

Course project with short report (25 percent)

2 quizzes (10 percent)

Two examinations (25% for exam 1 on Topics 1-3 and 30% for exam 2 on Topics 4-6)