# Operational Research

## Prof. Francesca Maggioni

***COURSE AIMS AND LEARNING OUTCOMES***

Operations Research has its origins in planning and operations models from World War II through the seminal work of George Dantzig and his development of the simplex method.

This course provides a rigorous introduction to the theory and applications of linear, discrete and stochastic programming. In terms of theory, the student will learn the structural properties and state-of-the-art solution algorithms to solve decision problems. From a practical viewpoint, the student will learn how to model real- world problems as optimization models and how to interpret their solutions computed via commercial package programs.

Topics covered include the simplex method, duality in linear programming, sensitivity analysis, network-type problems, integer programming, complexity analysis and stochastic programming.

In terms of applications, decision problems from widely different contexts are considered: manufacturing industry, transportation, finance, health, energy, network models, applications in machine learning and data-driven optimization. At the end of the course the student will be also able to realize simple AMPL coding for solving the considered decision problems.

***ABILITY TO APPLY KNOWLEDGE AND UNDERSTANDING***

At the end of the course the student will be able to:

• Understand the conceptual approach of Operations Research as a tool to formulate, solve and evaluate decision problems relating to complex systems

• Understand the structural properties and state-of-the-art solution algorithms to solve decision problems.

• Model real-world problems as optimization models

• Interpret the solution computed via commercial package programs and provide its economic interpretation

• Implement a mathematical model in the AMPL environment

• Classify the problem in terms of its computational complexity (polynomial, NP-Hard)

• Formulate stochastic optimization models in the case the parameters of the problem are described by probability distributions

***CONTENTS***

* Mathematical programming
  + Convex programming
  + Linear programming
    - Equivalent forms
* Linear programming (LP)
  + Linear (integer) programming models for real case applications
    - Blending of products, assignment of machining operations, the transportation problem, the diet problem, the assignment problem, the scheduling problem
  + Geometry of linear programming: vertices and basic solutions
  + Revised simplex method
  + Duality in linear programming and economic interpretation
  + Sensitivity analysis and post-optimality in linear programming
* Integer linear programming
  + Theory of linear integer programming
  + Total unimodularity
  + Branch and bound algorithm
  + Cutting plane and branch-and-cut algorithm
* Graph theory:
  + - Minimum spanning trees and Prim’s algorithm
    - Shortest path problem and Dijkstra’s algorithm
    - Max flow problem and Ford-Fulkerson’s algorithm
* Some NP-Hard problems: knapsack problem, traveling salesman problem, plant location problem, set covering/partitioning problem.
* Introduction to stochastic programming and applications.

***REFERENCES***

* D. Bertsimas - J.N. Tsitsiklis, *Introduction to Linear Optimization*, Athena Scientific, Belmont, Massachusetts
* Matteo Fischetti, *Introduction to Mathematical Optimization*, Kindle Direct Publishing. ISBN: 9781692792022

Lecture notes and further reading will be posted to the e-learning platform.

***TEACHING METHOD***

The course will consist of lectures based on traditional teaching including theory and exercises. Some of the lectures will be based on exercise sessions using PC-labs.

***ASSESSMENT METHOD AND CRITERIA***

The final exam is based on a written test followed by an oral interview. The written test is composed of 4 exercises, one of which based on modeling and implementing under AMPL environment a real case problem. The oral exam is aimed at assessing the knowledge of the theory covered by the course. The questions of the written test will be evaluated with a score from 0 to 7 with exception of the exercise in AMPL (from 0 to 9). The final mark takes into account both the parts of the exam (60% of the written and 40% of the oral). The oral exam will take place on the same day of the written exam.

***NOTES AND PREREQUISITES***

Basic knowledge of Linar Algebra and Calculus.

*Office Hours*

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