Course title: From Prediction to Action: Modern Prescriptive Analytics
Language of instruction: English
Professor: Alberto Santini
Professor's contact and office hours: 20.1E52. Friday, 15:00 - 16:00.
Course contact hours: 45
Recommended credit: 6 ECTS credits

Course prerequisites:
This course has minimal prerequisites in mathematics. In particular, students must be familiar with mathematical notation. They must know about equalities and inequalities and be comfortable using basic notation, such as summation signs. Any student who has taken an introductory calculus or algebra class will be familiar with the required notation, as will students who have studied micro/macroeconomics or econometrics. It is not necessary to have taken courses in statistics because we will introduce the required concepts in a self-contained way. It is not required to have had any exposure to programming: we will make limited use of the Python programming language, and all the needed concepts will be introduced from scratch.

Language requirements:
Recommended level in the European Framework B2 (or equivalent: Cambridge Certificate if the teaching language is English, DELE or 3 semesters in the case of Spanish).

Course focus and approach:
This course teaches techniques for optimal decision-making in public policy and the industry. It uses a practical approach, in which real-life problems are solved hands-on using computer tools.

Course description:
Thanks to advances in machine learning, descriptive and predictive analytics are more accessible than ever. A descriptive analysis helps understand existing data, while a prescriptive analysis forecasts future data. Together, descriptive and predictive analytics allow policymakers, managers, and researchers to understand their data, find correlations and cause-effect relations, and predict future trends. Still, analysts and decision-makers who successfully build analytics solutions are often left with a "Now what?" question. Prescriptive analytics translates the insights from machine learning and statistical models into actions that produce an optimal real-world impact. It answers questions such as: "How to allocate a healthcare budget to reduce wait times?"; "How to route vehicles to deliver thousands of parcels at a low cost and on time?"; "How to purchase electricity to ensure that cheap, clean power is available when needed?". In this last example, descriptive and predictive models could forecast electricity prices, supply and demand; a prescriptive model will then build an

actionable purchasing plan using the predictions to procure renewable energy at the lowest expected cost.
The success of descriptive and predictive models is partly due to a vast repertoire of standardised models (from Simple Linear Regression to Deep Neural Networks). By contrast, prescriptive models tend to be uniquely tailored to specific applications. Therefore, the analyst developing a prescriptive solution must be well-versed in the "art" of mathematical modelling. This course will teach you the basics of mathematical modelling and introduce you to advanced techniques that combine predictive and prescriptive models.

Learning objectives:
At the end of the course, the students will:

1. Complement descriptive and predictive techniques with prescriptive ones to take optimal actions at the strategic, tactical and operational levels.
2. Build mathematical models to allocate resources optimally to deliver economic and societal improvements.
3. Obtain optimal solutions to complex problems that do not admit a closed-form solution.

Course workload:
Theory classes, lab classes. A final project (workload: 2-4 hours). A final exam (multiple-choice test).

Teaching methodology:
Classes are of two types: theory and lab. Theory classes are developed using the blackboard (no slides), and students can access lecture notes covering the theory topics. In lab classes, students are encouraged to bring their laptops. The professor will explain how to solve real-life optimisation problems using computer tools.

Assessment criteria:
Participation: 10%. Final group project: 60%. Final exam: 30%.

BaPIS absence policy:
Attending class is mandatory and will be monitored daily by professors. Missing classes will impact on the student's final grade as follows:

Absences	**Penalization**
Up to two (2) absences	No penalization
Three (3) absences	1 point subtracted from final grade (on a 10-point scale)
Four (4) absences	2 points subtracted from final grade (on a 10-point scale)
Five (5) absences or more	The student receives an INCOMPLETE ("NO PRESENTADO") for the course

The BaPIS attendance policy does not make a distinction between justified and unjustified absences. All absences—whether due to common short-term illnesses or personal reasons—are counted toward the total amount and cannot be excused. Therefore, students are responsible for managing all their absences.

Only in cases of longer absences—such as hospitalization, prolonged illness, traumatic events, or other exceptional situations—will absences be considered for exceptions with appropriate documentation. The Academic Director will review these cases on an individual basis.

Students must inform the Instructor and the International Programs Office promptly via email if serious circumstances arise.

Classroom norms:

- Students will have a ten-minute break in the middle of two-hour sessions.

Weekly schedule:
The course has three main theoretical components developed sequentially, plus one practical component developed throughout the course.

Weeks 1-4. An introduction to mathematical modelling via examples.
We introduce mathematical models by solving real-life examples. We learn how to translate the English description of a problem into a precise mathematical model. We then transform this model into computer code and solve it to obtain the optimal solution. Our examples come from logistics, supply chain, industrial production planning, and economics and social sciences.

Week 5-8. Simple Machine Learning models for predictive analytics.
We study two classes of simple Machine Learning models used for forecasting. First, we will introduce linear regression models from the point of view of predictive analytics (that is, with a focus on improving out-of-sample accuracy). Then, we will study decision trees for regression.

Week 9-10. Combining predictive and prescriptive methods.
We show how to solve some of the mathematical models introduced in Part 1 when their input data is not deterministic but instead predicted by a Machine Learning model (introduced in Part 2). This third part is the culmination of our journey, in which the concepts introduced in the first two parts come together to unleash the full potential of modern predictive and prescriptive analytics.

Week 1-10. Python Lab
Throughout the course, we will implement our models using the Python programming language.

Last revision: March 2025.

Required readings: Lecture notes that will be shared with the students.

Recommended bibliography:

H. Paul Williams. *Model Building in Mathematical Programming, 5th Edition*. ISBN: 9781118443330

Gareth James, Daniela Witten, Trevor Hastie, Rob Tibshirani, Jonathan Taylor. *An Introduction to Statistical Learning with Applications in Python*. https://www.statlearning.com/