Financial Optimization and Asset Management

FINASS

Lecture 1 – Introduction to the course

Federica Ricca

Sapienza
Università di Roma

General Information

General information

Course	Financial Optimization and Asset Management a.y. 2023-2024
Teacher	Federica Ricca federica.ricca@uniroma1.it **Office:** MEMOTEF Department – first floor – corridor B, room 148 **Office hours:** Tuesday at the end of the lesson. By appointment, to be fixed by sending an email to the teacher.
Timetable	Tuesday 10:00 – 12:00 Didalab (build. RM019 first floor) Friday 10:00 – 12:00 Didalab (build. RM019 first floor)
Aim and scope	Students are introduced to **mathematical modeling and decision tools**, based on **Combinatorial Optimization** and **Mathematical Programming**. They learn how to use these tools to tackle **relevant finance and asset management decision problems**, in particular those related to Portfolio Selection. They acquire the capacity of using, understanding, and developing computational tools suitable for the **efficient practical solution** of many relevant financial decision problems.

Topics

Course	Financial Optimization and Asset Management a.y. 2023-2024
Programme	1. **Optimization models and techniques**: Optimization and Mathematical Programming – Linear Programming (LP) – Integer and Mixed Integer Linear Programs (ILP, MILP) – Network optimization. 2. **Applications in finance**: Capital Budgeting – Asset Liability models – Portfolio Selection models: risk-return models, Risk Diversification and Index Tracking models. 3. **Computational finance**: (Excel, Matlab, other specific optimization software) Implementing mathematical models – Financial data preparation and processing – Optimization solvers – Practical solution of optimization models for financial applications.
Prerequisites	Basics of Algebra, Set theory, basics of Statistics and Probability.

Material

Course	Financial Optimization and Asset Management a.y. 2023-2024
Course books	**Teacher's handouts** The slides of the lectures are published in the **Moodle e-learning webpage** dedicated to the course (**after each lesson**). **Books** G. Cornuejols, R. Tutuncu (2018) – Optimization Methods in Finance, Cambridge Univ. Press, 2nd edition. P. Rardin, Optimization in Operations Research, Upper Saddle River, Prentice-Hall, 1998 (or Pearson, 2017, 2nd Ed.). E. J. Elton, M. J. Gruber, Modern Portfolio Theory and investment analysis, John Wiley and Sons, 1995 (2014).
Additional References	F. Cesarone (2020), Computational Finance. MATLAB oriented modeling, Routledge-Giappichelli Studies in Business and Management G.L. Thompson, S. Thore, Computational Economics, The Scientific Press 1992 . W.L. Winston, Operations Research, Third Edition Duxbury Press 1997 W.L. Winston e S.C. Albright, Practical Management Science, 2nd Edition, Brooks/Cole Publishing, 2001. S.A. Zenios, Practical Financial Optimization, Blackwell 2007.

Final Evaluation

Course	Financial Optimization and Asset Management a.y. 2023-2024
Final Evaluation	Students **attending** classes have the possibility of developing a **practical project** on the application of the models presented in the course (in group). In the final exam students first discuss their project (in group); then each component of the group has her/his individual oral examination. (the evaluation of the project is valid for the whole a.y., i.e., from January to October). Students **not attending** classes have a traditional exam.

WITH PROJECT

The aim of the project is to give students the opportunity of applying the theoretical tools illustrated in the course.

WITHOUT PROJECT

- 3 or more questions on the topics of the course
- students answer by writing on paper

Lectures and Exam registration

Lectures are in presence

Attending lessons is strongly suggested

GENERAL INSTRUCTIONS

- **Course dedicated webpage**: https://web.uniroma1.it/memotef/financial-optimization-and-asset-management-finass-cv-financial-risk-and-data-analysis-lingua
- **Administrative and technical information**: https://www.uniroma1.it/it/pagina/informazioni-e-aiuto

CLASSROOM

SAFETY RULES IN SAPIENZA

(Update August 2023)

https://www.uniroma1.it/en/pagina/airborne-infectious-diseases-italian

NOTE: Sometimes webpages are not available in English.

Each time you find a webpage in the website by La Sapienza dedicated to students which **has not the English version**, please report this in a file. We can try to trace which webpage needs to be updated in this sense, and provide a complete list to the appointed office in order to fix the bug.

Lectures and Exam registration

Lectures are in presence

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Exams dates and registration

Exam dates

- exam dates of the current academic year and related registration time windows are published in the webpage dedicated to the course
- extra exam sessions, held in the periods **April-May** and **October-November**, are **reserved** to students who are in one of the **special conditions** listed in the course webpage

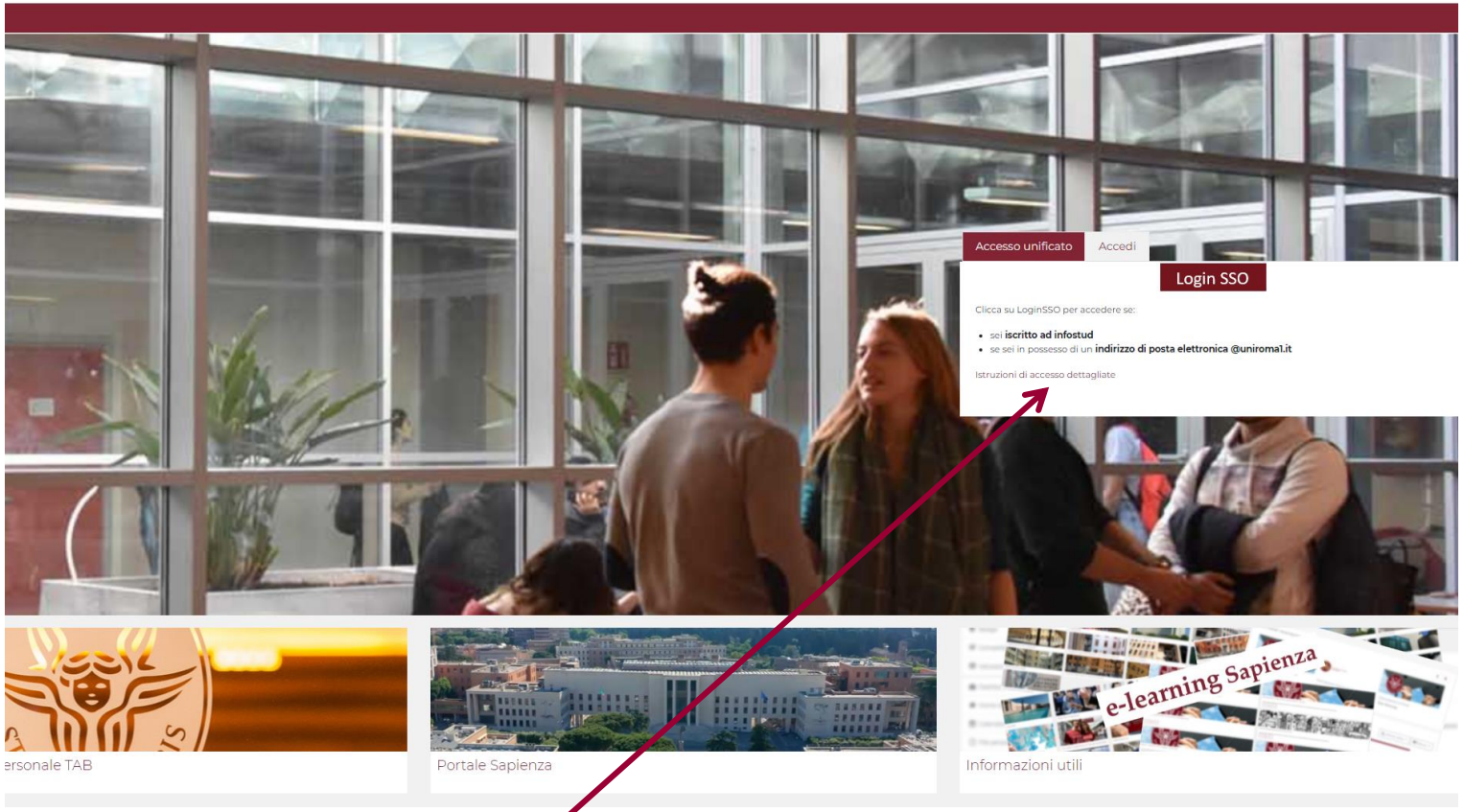
Exam registration

- it is mandatory to register on Infostud **whithin the fixed deadline**
- all the exams are already activated on Infostud **from September**

E-learning platform Moodle

E-learning platform Moodle

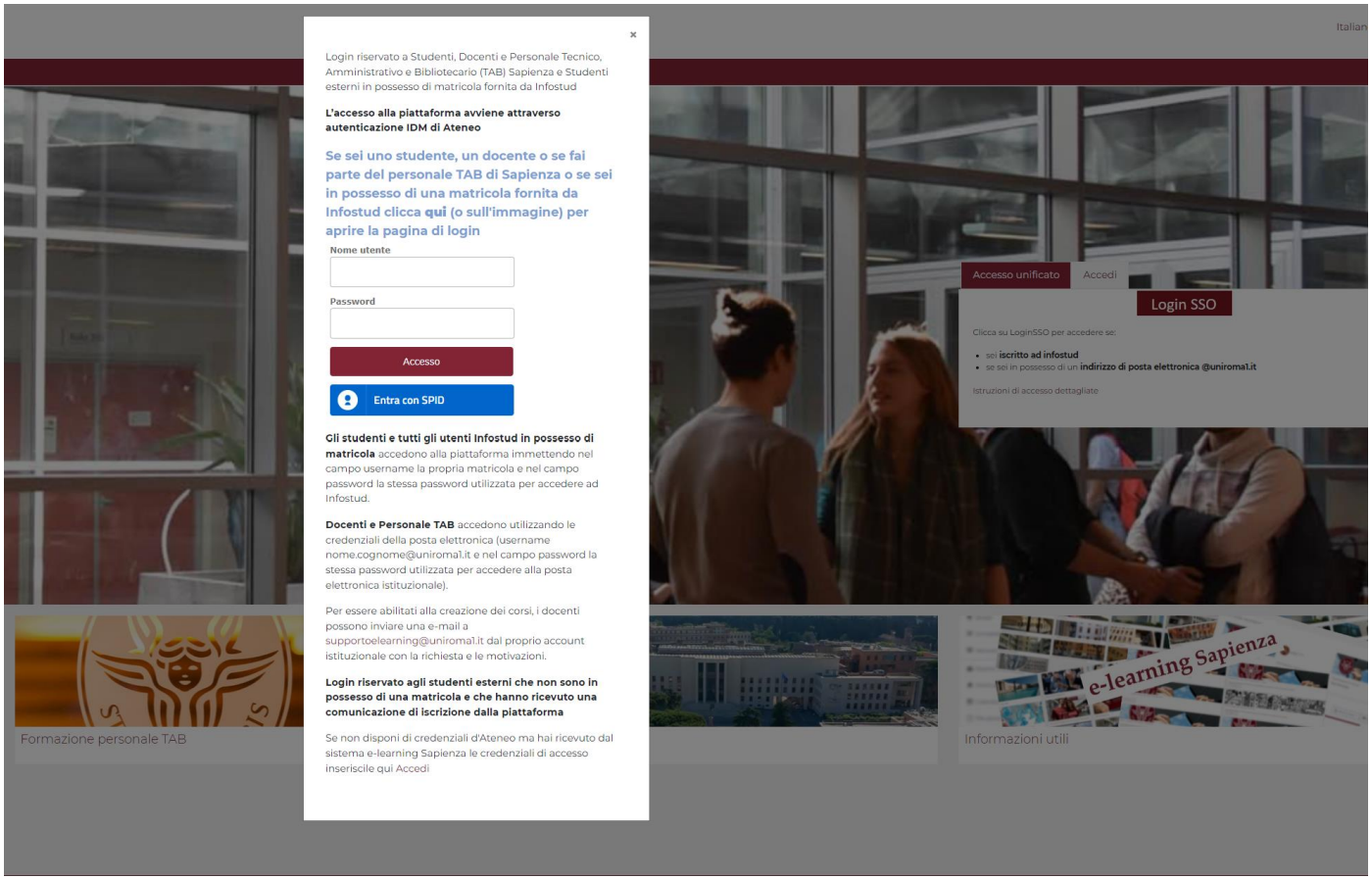
https://elearning.uniroma1.it/



1. Login or create an account

E-learning platform Moodle

https://elearning.uniroma1.it/



2. All the instructions are reported here.

E-learning platform Moodle

https://elearning.uniroma1.it/

Registration key: FinOpt_21-22

Moodle is used for different tasks:

- communications and announcements by the teacher
- sharing slides and course materials
- practical Assignments during the course

Each new action or communication by the teacher is automatically notified to the students via email.

IMPORTANT: This platform has already shown to be very useful for communication with students in case of emergency, such as possible communication about lectures suspension or postponement, expecially when the faculty website is out of order.

Students are kindly asked to:

- create an account in Moodle (using their institutional email) and enroll the course
- use the institutional email for communicating with the teacher

  (Please do not send electronic messages when logged within Moodle)

Webpage *dedicated to* the course

Course webpage

The course dedicated webpage is available at:

https://web.uniroma1.it/memotef/financial-optimization-and-asset-management-finass-cv-financial-risk-and-data-analysis-lingua

The webpage is regularly updated about:

- new decisions and guidelines by the Faculty and by the University
- communications and updatings related to the course
- communications and updatings related to the exams

Students should:

- **Look up** this webpage **regularly** for checking news and updates
- refer to this page for general information about the course
- refer to this page for general rules related to teaching and exams

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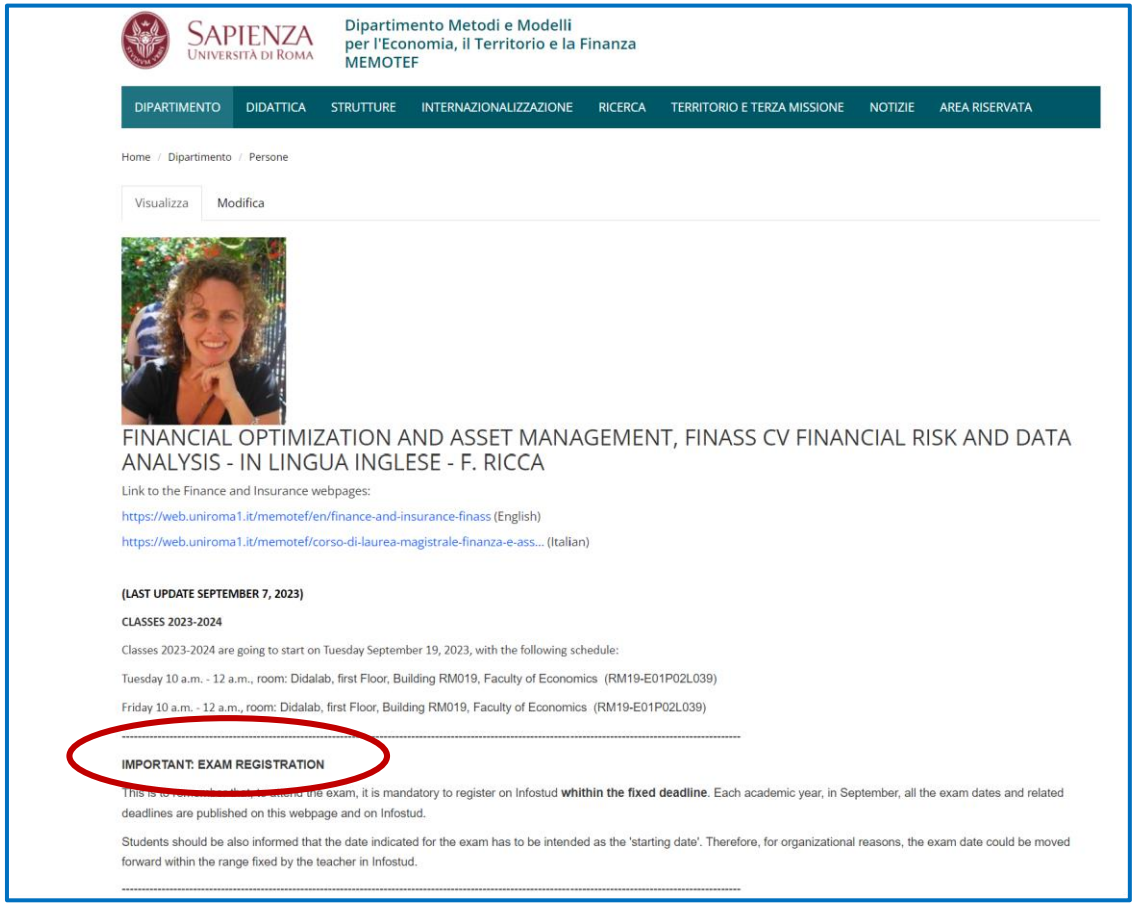

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FINANCIAL OPTIMIZATION AND ASSET MANAGEMENT EXAM ROUNDS 2022-2023

Exams Round starting date	Period for signing up for the exam in Infostud
January 12, 2023 (Thursday)	December 1, 2022 - December 31, 2022
February 10, 2023 (Friday)	December 1, 2022 - January 23, 2023
May 4, 2023 (Thursday)	March 1, 2023 - April 19, 2023
June 7, 2023 (Wednesday)	May 1, 2023 - May 23, 2023
July 5, 2023 (Wednesday)	May 1, 2023 - June 20, 2023
September 5, 2023 (Tuesday)	July 1, 2023 - August 28, 2023
October 10, 2023 (Tuesday)	September 1, 2023 - September 30, 2023

FINANCIAL OPTIMIZATION AND ASSET MANAGEMENT EXAM ROUNDS 2023-2024

Exams Round starting date	Period for signing up for the exam in Infostud
January 18, 2024 (Thursday)	December 1, 2023 – January 10, 2024
February 1, 2023 (Thursday)	December 1, 2023 – January 25, 2024
April 18, 2024 (Thursday)	March 1, 2024 – April 10, 2024
June 26, 2024 (Wednesday)	May 1, 2024 – June 18, 2024
July 18, 2024 (Thursday)	May 1, 2024 – July 10, 2024
September 19, 2024 (Thursday)	July 1, 2024 – September 11, 2024
October 15, 2024 (Tuesday)	September 20, 2024 – October 7, 2024

Course webpage

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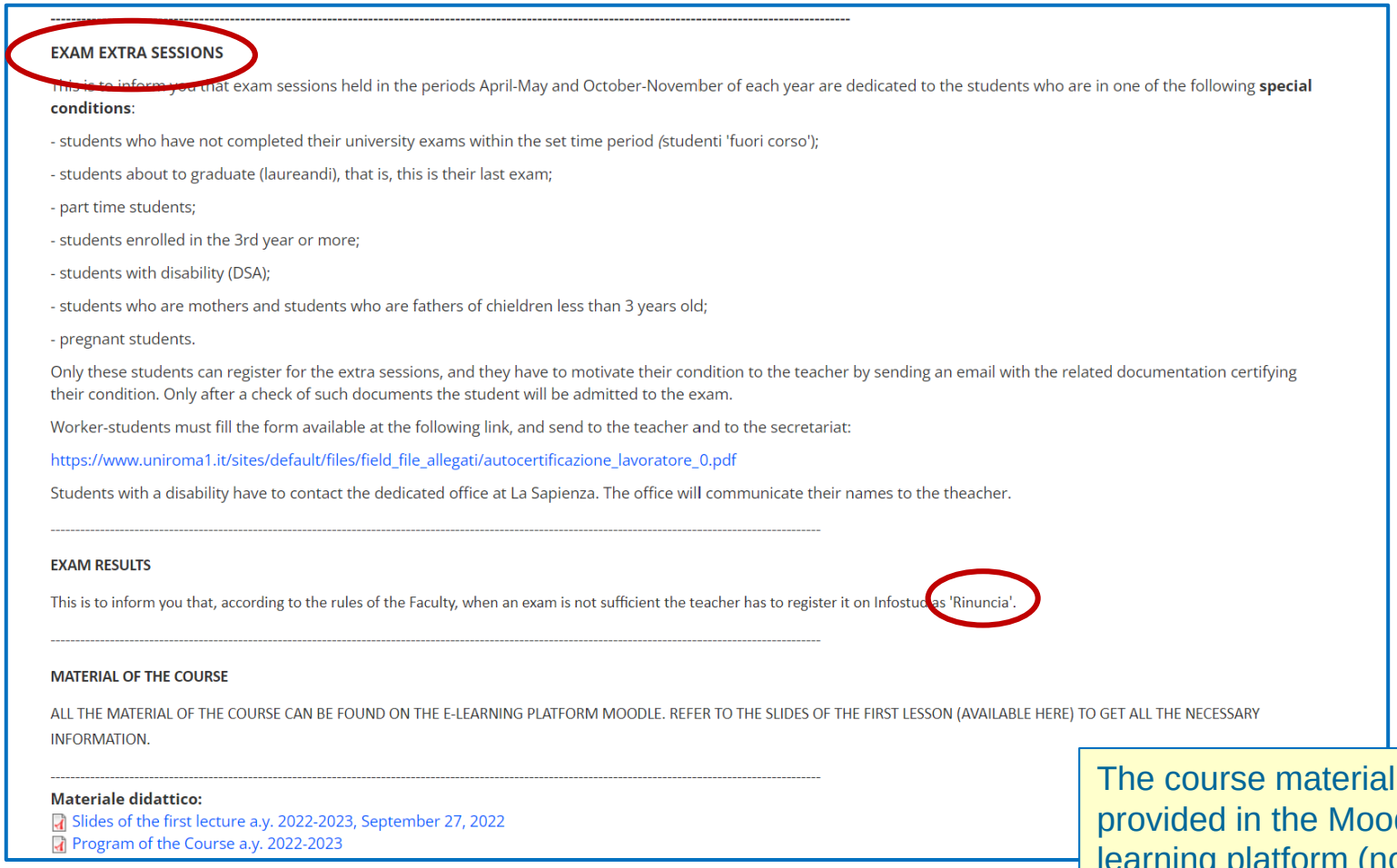

EXAM EXTRA SESSIONS

This is to inform you that exam sessions held in the periods April-May and October-November of each year are dedicated to the students who are in one of the following **special conditions**:

- students who have not completed their university exams within the set time period *(*studenti 'fuori corso');
- students about to graduate (laureandi), that is, this is their last exam;
- part time students;
- students enrolled in the 3rd year or more;
- students with disability (DSA);
- students who are mothers and students who are fathers of chieldren less than 3 years old;
- pregnant students.

Only these students can register for the extra sessions, and they have to motivate their condition to the teacher by sending an email with the related documentation certifying their condition. Only after a check of such documents the student will be admitted to the exam.

Worker-students must fill the form available at the following link, and send to the teacher and to the secretariat:

https://www.uniroma1.it/sites/default/files/field_file_allegati/autocertificazione_lavoratore_0.pdf

Students with a disability have to contact the dedicated office at La Sapienza. The office will communicate their names to the theacher.

EXAM RESULTS

This is to inform you that, according to the rules of the Faculty, when an exam is not sufficient the teacher has to register it on Infostudas 'Rinuncia'.

MATERIAL OF THE COURSE

ALL THE MATERIAL OF THE COURSE CAN BE FOUND ON THE E-LEARNING PLATFORM MOODLE. REFER TO THE SLIDES OF THE FIRST LESSON (AVAILABLE HERE) TO GET ALL THE NECESSARY INFORMATION.

Materiale didattico:

Slides of the first lecture a.y. 2022-2023, September 27, 2022

Program of the Course a.y. 2022-2023

The course material is provided in the Moodle e-learning platform (not in this webpage) lesson by lesson.

OpiS

OpiS

After 2/3 of the lessons, around middle November, students are called to answer a questionnaire related to the course lessons, materials, as well as, rooms and structures.

Questions are of different type:

Questions about personal interests and course satisfaction

11. Are you interested in the topics of the course?
12. Are you globally satisfied with the course?

Questions on the student's preliminary knowledge

1. Was your previous knoledge sufficient to understand the topics of the course?
2. Does the study load of the course correspond to the number of credits?

OpiS

After 2/3 of the lessons, around middle November, students are called to answer a questionnaire related to the course lessons, materials, as well as, rooms and structures.

Questions are of different type:

Questions on the course's organization, material and teaching

3. Is the material of the course adequate for studying the subject?
4. The way the final exam is held has been adequately explained?
5. The start and ending hours of the lessons are respected?

8. Supplementary activities and lab lessons are useful?
9. Do the contents of the lessons correspond to those listed in the **website of the Degree Program**?
10. Is the teacher available for explanations and clarifications?

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In the email, please, specify which **course** you are referring to, and put your **signature**.

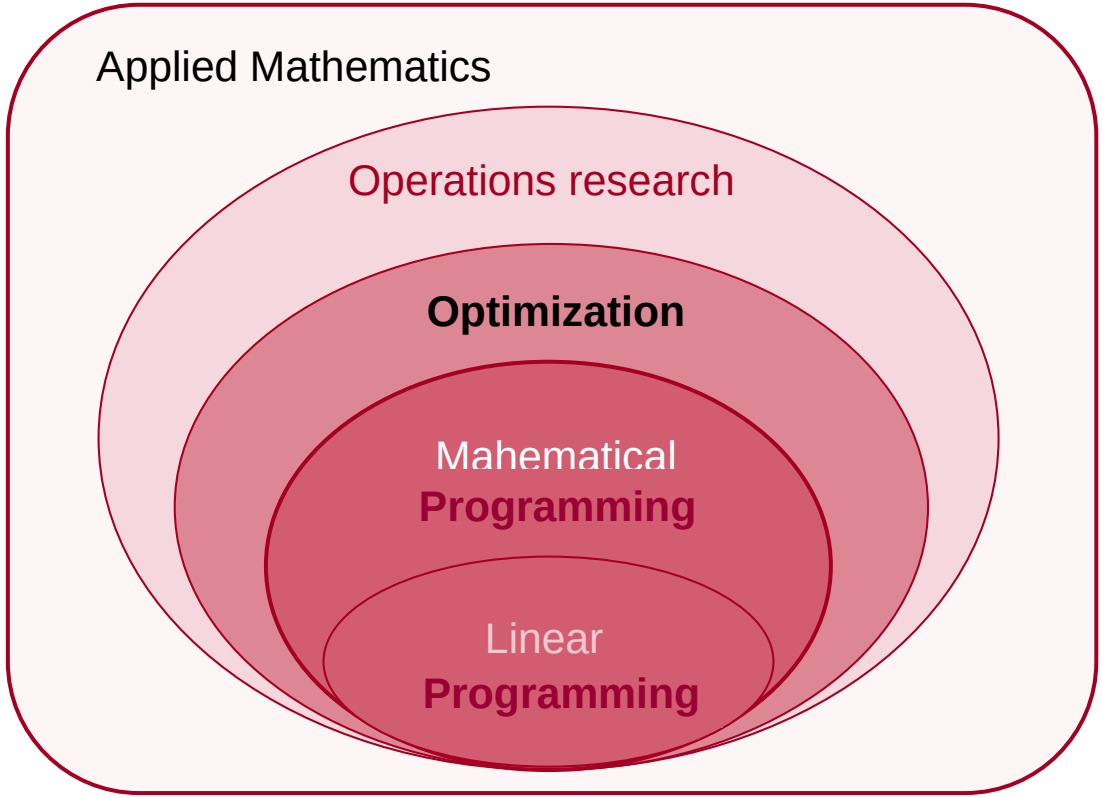
Introduction to the course: Optimization, Mathematical Programming, Operations Research

Operations Research, Optimization, Mathematical Programming

OPERATIONS RESEARCH

Discipline which studies the **efficient** use of **scarse resources** (as raw materials, workers, **money**, energy, time, etc.).

It had its maximum development all over the world after the II world war when it was widely applied in the industrial and service sectors where complex decision problems typically arise.



Typical **optimization** problems:

Industrial planning

Resources allocation in production processes

Logistics

Traffic and transport

Networks design, etc.

Mathematical Programming

Class	Constraints/o.f.	Variables
Linear Programming (LP)	linear functions	reals
Integer Linear Programming (ILP)	linear functions	integers
Non Linear Programming (NLP)	non linear functions	reals

The idea of **Mathematical Programming** is to represent a decision problem in an algebraic form as a mathematical model.

MATHEMATICAL MODEL

It is a formal description, by logical-mathematical tools, of all the elements and relations of a decision problem.

Mathematical Model and Mathematical Program

MATHEMATICAL MODEL

It is a formal description, by logical-mathematical tools, of all the elements and relations of a decision problem.

The decision problem consists of a **system** of relations between the fundamental elements of the problem:

- parameter data (kown)
- decision variables (unknown).

Formalizing decision problems by **mathematical models** allows an **efficient solution process**.

Efficient algorithms for mathematical models of different nature have been developed in the literature providing a **systematic** approach to the solution of complex decision problems.

BEFORE THE II WORLD WAR

Only **systems of relations** (equalities and inequalities) could be solved.

AFTER THE II WORLD WAR

An **objective function (o.f.)** was introduced in the models

OPTIMIZATION

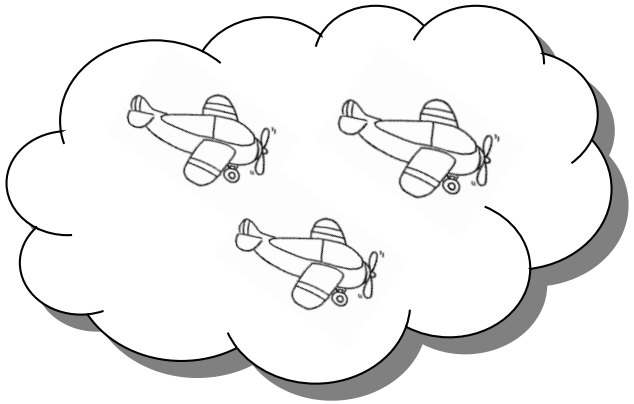
Origins of OR

Operations Research is a
"interdisciplinary discipline"

It was born at the end of the '30s, immediately before the beginning of the II world war, when *engineers*, *mathematicians* and *scientists with different quantitative skills* were called directly by the British Royal Air Force to develop methods and techniques for the

"**as efficient as possible use of the scarse military resources**".

(experiment for management and control of the air defence)

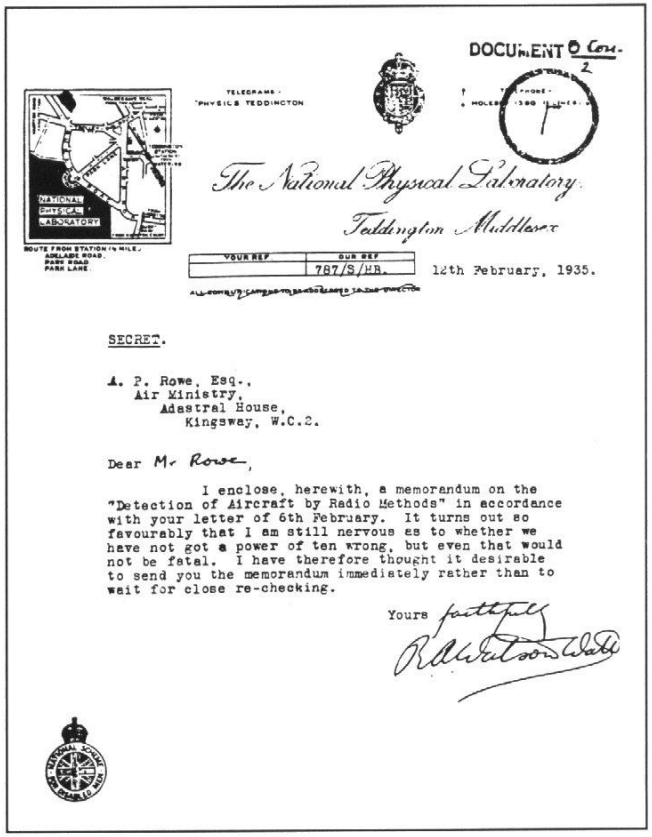


Origins of OR

Crucial steps:

1935 – U.K. - Bawdsey Research Station for anti-aircraft defence Project radar (radio detection and ranging)

1938 – Report to Superintendent Rowe. Here, for the first time the expression ***Operational Research*** is used (standing for “Research into (military) Operations”)



DOCUMENT No. Con-2

TELEGRAMS "PHYSICS TEDDINGTON"

The National Physical Laboratory
Teddington Middlesex

YOUR REF. | OUR REF. 787/S/HB. | 12th February, 1935.

SECRET.

A. P. Rowe, Esq.,
Air Ministry,
Adastral House,
Kingsway, W.C.2.

Dear Mr Rowe,

I enclose, herewith, a memorandum on the "Detection of Aircraft by Radio Methods" in accordance with your letter of 6th February. It turns out so favourably that I am still nervous as to whether we have not got a power of ten wrong, but even that would not be fatal. I have therefore thought it desirable to send you the memorandum immediately rather than to wait for close re-checking.

Yours faithfully,
R. A. Watson-Watt

Fig. 3 Letter suggesting radar and sent by Watson–Watt to A. P. Rowe on 12th February 1936

In the period **after the war** many groups of researchers in OR arise, both in the U.K. and in other allied countries, the aim being to exploit the recently developed techniques **to favor the reconstruction and the economic recovery** of the various countries after the war.

Models and methods were developed and tailored for the specific applications, mainly in **industrial planning**.

Origins of OR

OR Associations:

1948 – **U.K.**: the Operational Research Association is established

1952 – **USA**: ORSA (Operations Research Society of America), today **INFORMS** (Institute For Operations Research and Management Science) is founded

1961 – **Italy**: AIRO (Associazione Italiana di Ricerca Operativa)

1976 – **Europe**: **EURO** (Association of European Operational Research Societies) as the European group within IFORS (International Federation of Operational Research Societies)

- **50s** OR courses started in the **U.S. universities**
- **60s** OR courses started in the **Italian universities**

Mathematical Model and Mathematical Program

MATHEMATICAL MODEL

It is a formal description, by logical-mathematical tools, of all the elements and relations of a decision problem.

TYPICAL DECISION QUESTIONS

Are we exploing our **available resources** at best?
Are we minimizing our activity **costs**?
Are we limiting our **risk**?
Are we using our **time** at best?
Are we maximizing our **profit**?

Are we maximizing the **return of our investment**?
Are we minimizing the **risk of our portfolio**?

If an objective can be measured by a mathematical function, it can be included in a mathematical program representing the decision problem to be solved (optimization problem).

The optimization process can be handled under the condition that a set of constraints is also satisfied.

In the past 70 years there has been a constant development of optimization models and algorithms. This was possible also thanks to the fast development of technologies which improved a lot the computers' performances.

Analytical Optimization Model

MATHEMATICAL MODEL

It is a description, by logical-mathematical tools, of all the elements and relations of the decision problem.

OPTIMIZATION MODEL

It is a mathematical model combining a system of relations to be satisfied with an objective function (to be optimized).

Mathematical Programs are **analytical models**:

- every **element** of the problem is represented by a mathematical element (*known* parameter or *unknown* variable)
- every **relation** is represented by a mathematical relation (constraint: Left Hand Side (LHS), objective function).

Optimization models may have very different characteristics:

OPT. MODELS CLASSIFICATION	
deterministic	stochastic
discrete	continuous
static	dynamic
single-objective	multiobjective
one decision maker	multi-decisor

Analytical Optimization Model

The optimization problem can be formulated following two alternative approaches:

- **Maximizing** the output (*performance*) which can be obtained by a given amount of input (*resource*).

  Production problem: Given an amount of row material, an amount of work hours for workers, and an amount of work hours for machines necessary for the production of a good, the problem is to maximize the earning coming from selling all goods which can be produced with the available resources (maximize the production).

- **Minimizing** the input (*resources*) necessary to obtain a *prefixed* level of output (*performance*).

  Production problem: a minimum level of earning is fixed and it is required that at least that minimum level is obtained by producing and selling a good. The problem is to minimize the quantity of resources in order to produce an amount of goods which guarantees the minimum required earning.

Analytical Optimization Model

The mathematical model should reach a good compromise between its capacity of representing the problem and its tractability.

A TOO SIMPLIFIED MODEL: may turn out to be not sufficiently meaningful

A TOO COMPLICATED MODEL: may turn out to be too computationally difficult to solve.

DECISION AID (general case)

The validity of the model's solutions must be evaluated w.r.t. the accurancy level of the model in the representation of the problem.

The output solution of a model must be always considered as a support to the decision process which, in any case, must be evaluated by the decision maker on the basis of her/his knowledge and experience.
The model never takes the decisor's place.

Application contexts for optimization models

APPLICATION CONTEXTS

- industry
- marketing
- territory
- **finance**
- services

DECISION PROBLEMS

- Production
- Blending
- Transportation
- Location
- Territorial zoning
- etc.

MAIN FINANCIAL OPTIMIZATION PROBLEMS:

- CAPITAL BUDGETING
- ASSET LIABILITY MANAGEMENT (ALM)
- PORTFOLIO SELECTION
- RISK DIVERSIFICATION
- INDEX TRACKING
- ESG PORTFOLIO OPTIMIZATION

Course structure

Course structure

COURSE OUTLINE

- INTRODUCTION TO SEVERAL OPTIMIZATION MODELS
- THEORY AND ALGORITHMIC ASPECTS OF THE MAIN CLASSES OF OPTIMIZATION MODELS
- APPLICATION OF OPTIMIZATION MODELS TO FINANCIAL AND INSURANCE PROBLEMS
- DESCRIPTION, ANALYSIS AND APPLICATION OF THE MAIN PORFOLIO SELECTION MODELS
- NUMERICAL SOLUTION OF THE MODELS DESCRIBED WITH EXCEL OR WITH OTHER SOFTWARES

Course structure

MAIN FINANCIAL OPTIMIZATION PROBLEMS STUDIED

- CAPITAL BUDGETING
- RISK MINIMIZATION (OR DIVERSIFICATION)
- ASSET LIABILITY MANAGEMENT (ALM)
- PORTFOLIO SELECTION

METHOD

- Mathematical Programming
- Network optimization

Mathematical models ⟺ **Formal representation** of the decision problem

Algorithms ⟺ Perform a systematic evaluation of the possible problem solutions and find the **optimal one**.

SOFTWARE

- **EXCEL**
- MATLAB
- OPTIMIZATION SOFTWARE

Application software ⟺ For the **practical solution** of real problems and **post optimization analyses**.

Formal Modeling approach for problem solution

Modelling approach

The most difficult step is modeling a decision problem.

Once the problem is formalized by a suitable mathematical model, algorithms and solvers proceed automatically and find the **model optimal** solution.

- Model formulation must be performed **carefully**

Mathematical models ⇔ **Formal representation** of the decision problem

Algorithms ⇔ Perform a systematic evaluation of the possible problem solutions and find the **optimal one**.

Application software ⇔ For the **practical solution** of real problems and **post optimization analyses**.

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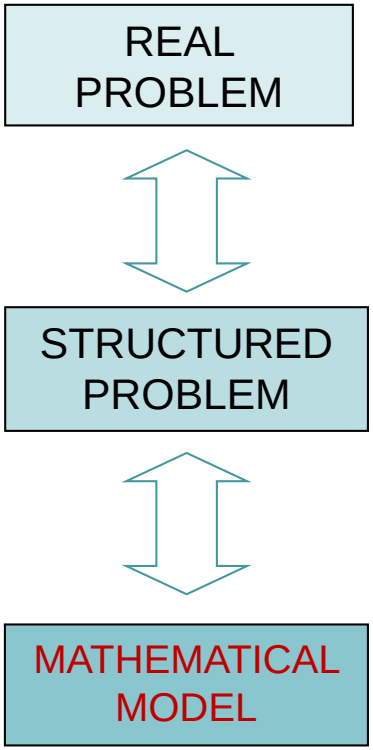

Mathematical models ⟺ **Formal representation** of the decision problem

The problem must be structured in order to identify all the relevant aspects (to be included in the model), but also all the secondary ones (to be excluded).

Globally, one should guarantee that the problem formally described by the model **corresponds to** (a simplified, but correct version of) the decision problem under study.

Modelling approach

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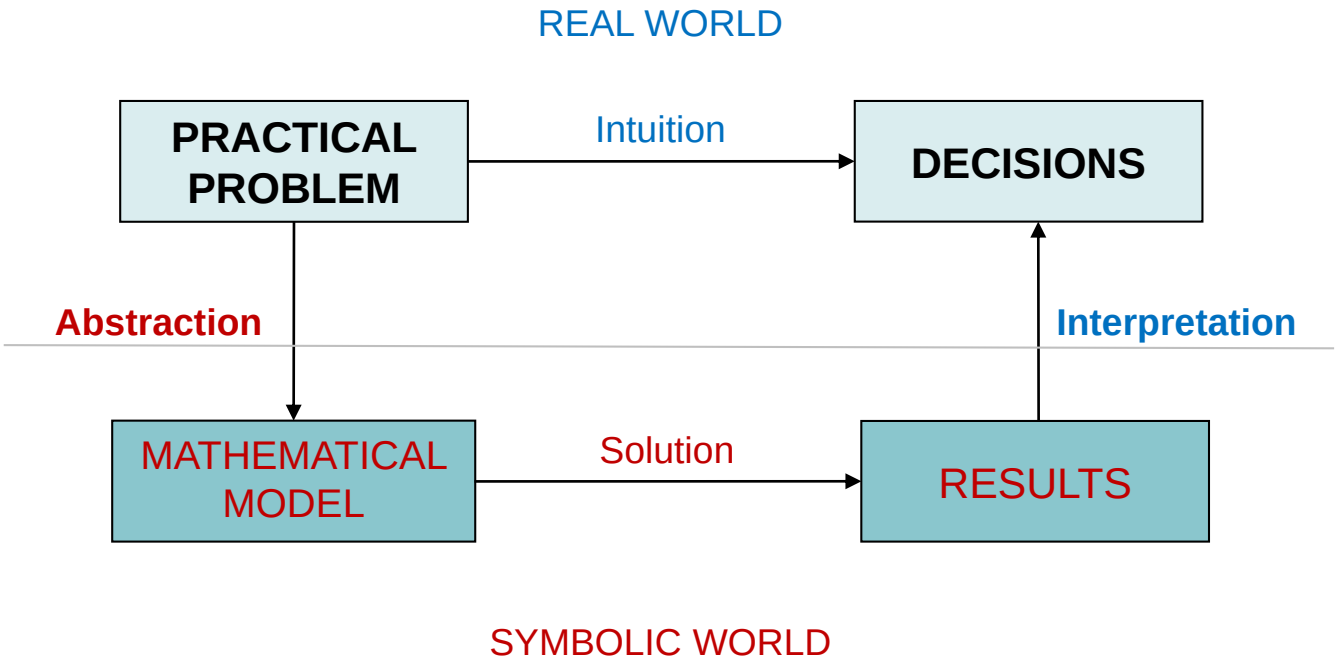

Problem abstraction and results interpretation play a delicate role, since they must be performed so that **model solution is coherent with decision intuition**.

Modelling approach

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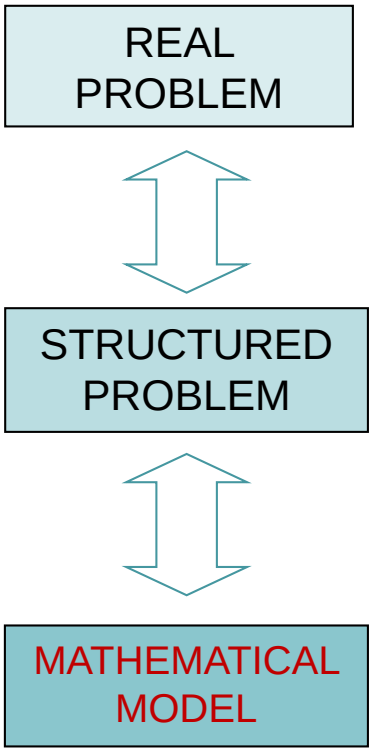
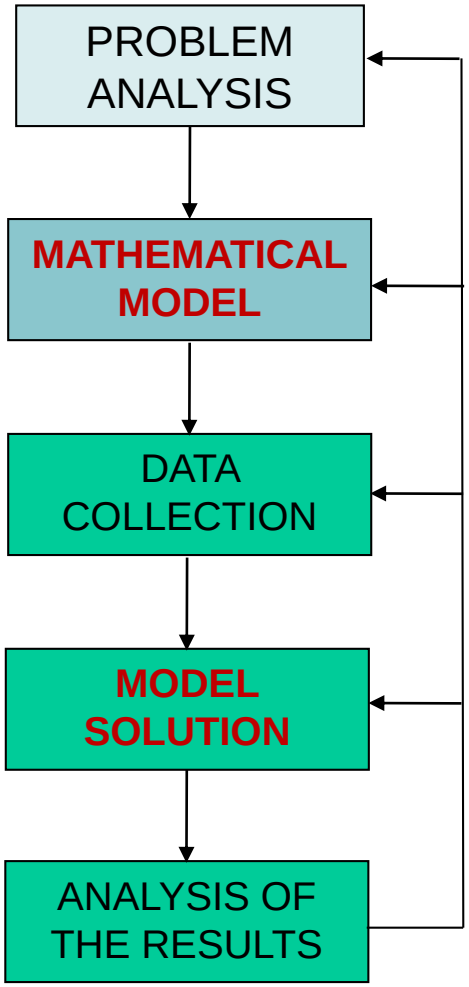


Mathematical models ⟺ **Formal representation** of the decision problem

- It is possible that the right model is obtained after some **adjustment steps** in which the model is tested in order to understand whether its solution fits the decision context expectations

Modelling approach



The analysis of the results obtained in the model testing may suggest to re-start from some previous step.

It may even require to come back to the original decision problem, for example to change or add, or remove some constraints in the model.

The model testing may also require to be repeated more than once.

- It is possible that the right model is obtained after some **adjustment steps** in which the model is tested in order to understand whether its solution fits the decision context expectations

Course structure

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