MADR-MT/ST 220 INTRODUCTION TO PROBABILITY AND STATISTICS

IES Abroad Madrid

DESCRIPTION:

This course provides a comprehensive introduction to the fundamental concepts and techniques of probability and statistics. The course will equip students with the necessary skills to analyze and interpret data, make informed decisions, and address uncertainty.

Through a combination of theoretical foundations, real-world examples, and practical exercises, students will develop a solid understanding of probability theory, statistical models, and inference methods commonly encountered across disciplines. The course emphasizes the application of statistical tools and techniques to solving problems and identifying trends, enabling students to draw meaningful conclusions from data and effectively communicate statistical findings.

The course covers a wide range of topics, including but not limited to probability distributions, random variables, sampling methods, hypothesis testing, confidence intervals, regression analysis, and design of experiments. Students will learn how to model and analyze systems by applying appropriate statistical methods, with an emphasis on both parametric and non-parametric approaches.

Throughout the course, students will gain hands-on experience using statistical software packages and programming languages such as R. They will also develop critical thinking and problem-solving skills by working on practical assignments and projects that require data analysis and interpretation.

CREDITS: 3

CONTACT HOURS: 45

LANGUAGE OF INTRUCTION: English

PREREQUISITES: None

ADDITIONAL COST: None

METHOD OF PRESENTATION:

The course uses the following methodology:

- **Lectures:** To introduce students to fundamental concepts. These lectures will be available on the Moodle site.
- **Practice classes with computers:** A combination of theory, practical examples, and hands-on coding. The lecture would typically begin with an introduction to the statistical concepts or techniques being covered, followed by a demonstration of how to implement them using R.
- **Study of didactic materials in Moodle:** Essentials readings, videos, and online resources are curated to help students develop a comprehensive grasp of statistics and stimulate meaningful discussions.
- **Team presentations:** Students teams will give short presentation to the other teams of their work on the assignments. Students will be expected to give feedback and suggestions to the other teams. This assignment will be initially assigned one week before the due date.
- **Resolution of problems:** The course will follow a probling-solving classroom approach where students will discuss and present the ways in which a problem can be solved.

- **Course-related trips:** These trips serve as a source of inspiration for students' designs and provide them with valuable opportunities to receive feedback from experts in the field.

REQUIRED WORK AND FORM OF ASSESSMENT:

This course uses continuous evaluation. The final grade will be calculated as follows:

- Class participation: 10%
- Practical group work activity and team presentations: 15%.
- 5 questionnaires related to lab computer practice sessions with R: 15%
    - Each assignment: 3%
- 2 exams: 60 %
    - Midterm exam : 20%
    - Final exam: 40%

Class participation: Students are expected to participate actively in the in-class activities and discussions. Additionally, there will be short quizzes and resolution or reports related to the course materials.

Practical group work: The design and analysis of an experiment. This activity provides students with hands-on experience in applying statistical concepts to real-life scenarios, while also fostering teamwork and collaboration. There will be an entire session to prepare and elaborate this activity and the groups will have one extra week to finish the activity started in class. The research topics and the members of the team groups will be chosen prior to the preparation.

Questionnaires related to lab computer practice sessions with R: Students will have to complete and submit practical questionnaires to demonstrate their understanding of the sessions. These questionnaires will be initially assigned and explained in the previous sessions and are expected to be submitted in the sessions after they are assigned.

Midterms and Final exams: These exams will combine multiple-choice questions with the resolution of statistics problems.

LEARNING OUTCOMES:

By the end of the course, students will be able to:

- Explain fundamental concepts of probability theory and their application in varied contexts:
- Apply statistical models and interference methods to analyze data and make reliable predictions.
- Interpret and communicate statistical results effectively to both technical and non-technical audience.
- Employ statistical software and programming languages to analyze data and implement statistical methods.
- Critically evaluate the validity and limitations of statistical models and methods in engineering applications.
- Solve mathematical problems that may arise in a number of disciplines.
- Demonstrate the important role of statistics as a methodology in the study and resolution of problems.
- Appraise the possibilities of statistics in real-life scenarios.
- Review the historical evolution of statistics.
- Install and start working with the statistical software R.

ATTENDANCE POLICY:

As a member of our class community, you are expected to be present and on time every day. Attending class has an impact on your learning and academic success. For this reason, attendance is mandatory for all IES Madrid classes, including course-related excursions. Attendance will be monitored by the Absence Committee, and the student is responsible for regularly checking their attendance record in Moodle throughout the semester.

You are allowed a maximum of two unexcused absences for once-a-week courses and four unexcused absences for twice-a-week courses. Each additional unexcused absence will result in a deduction of 3 percentage points from your final grade and/or disciplinary action. Accumulating 8 or more unexcused absences in twice-a-week courses, or 4 or more in once-a-week courses, may result in a failing grade for the course.

Only when surpassing the allowed number of unexcused absences will you be able to excuse an absence. Absences should be reserved for documented medical or family emergencies only. Students should not, under any circumstances, plan their absences in advance for personal reasons other than those specified in the List of Authorized Absences.

Students are responsible for communicating with their instructor(s) regarding any missed graded in-class coursework or the in-class submission of a graded assignment resulting from an absence. Opportunities to make up missed graded in-class coursework or receive deadline extensions are granted at the instructor's discretion. Students must not be absent for exams except in cases of documented medical or family emergencies.

Punctuality is essential for the smooth functioning of academic activities. Arriving more than 10 minutes later will be recorded as a late (L). Accumulating three lates will be considered equivalent to one absence (A). Additionally, arriving more than 20 minutes late will automatically be considered an absence.

For more information, please refer to the full Attendance and Punctuality Policy document.

CONTENTS:

Session	Content	Assignments
1	**Introduction to Statistics and Probability** • Statistics across disciplines in STEM • Objectives of Statistics	
2	**Introduction to Statistics** • The statistical method • Historical evolution • R-basics concepts	**Reading Previous to the session: Introduction to statistics with R**
3	**Descriptive Statistics** • Definition • Objectives • General concepts (Population, sample, variable, observation)	**Assignment 1: exercise in class.**
4	**Descriptive Statistics** • Types of data • Frequency distribution • Graphic representations • Measures of central tendency	
5	**Variability and Linear regression** • Measures of variability • Boxplot • Sample moments	**Reading Previous to the session:** Kulshreshtha, U. Introduction to measures of variability pp. 1-16 (16 pages))

6	**Variability and linear regression** • Variable management, database cleaning, missing data, simple linear regression **Activity in class:** resolution of problems	**Assignment 2**
7	**Variability and Linear regression** • Measures of inequality • Kurtosis • Multiple linear regression	
8	**Elements of probability** • Definition of probability • Sample space of a random experiment • Probability rule	**Deadline for submitting assignment 2** **Reading Previous to the session:** Montgomery, D. C. and Runger, G. C. "Probability", in Applied statistics and probability for engineers, pp. 25-45 (20 pages)
9	**Elements of probability** • Events • Types of events	

10	**Elements of probability** • Operations with events • Independent events • Conditional probability	**Reading Previous to the session:** • Montgomery, D. C. and Runger, G. C. "Probability," in Applied statistics and probability for engineers, pp. 46-58 (12 pages)
11	**MID-TERM EXAM**	
12	**Elements of probability** • Total probability theorem • Bayes theorem • Counting rules: permutations, variations, combinations	
13	**Discrete random variables** • Definition **Activity in class:** Resolution of discrete random variable problems.	**Reading Previous to the session:** • Montgomery, D. C. and Runger, G. C. "Discrete Random Variables and Probability Distributions," in Applied statistics and probability for engineers, pp. 59-71 (12 pages)
14	**Discrete random variables** • Moments of a Random variable • Transformation of random variables	**Assignment 3**
15	**Discrete probabilistic models** • Probability mass function • Probability distribution function • Measures of central tendency • Measures of dispersion	**Reading Previous to the session:** • Montgomery, D. C. and Runger, G. C. "Discrete Random Variables and Probability Distributions," in Applied statistics and probability for engineers, pp. 72-96 (24 pages)
16	**Discrete probabilistic models** • Models: Uniform distribution, Bernoulli, Binomial, Negative binomial, Hypergeometric distribution, Poisson distribution	**Deadline for submitting assignment 3**
17	**Continuous random variables** • Definition	**Reading Previous to the session:** Montgomery, D. C. and Runger, G. C. "Continuous Random Variables and Probability Distributions," in Applied statistics and probability for engineers, pp. 97-106; 157-170 (22 pages)
18	**Continuous random variables** • Moment of a random variables • Transformation of random variables	**Assignment 4**

19	**Continuous probabilistic models** • Probability density function • Probability distribution function	**Reading Previous to the session:** Montgomery, D. C. and Runger, G. C. Applied statistics and probability for engineers, pp. 107-121; 185-188 (17 pages)
20	**Continuous probabilistic models** **Activity in class:** Resolution of problems **Activity in class:** Team preparation about the Practical Group Work Activity	**Deadline for submitting assignment 4**
21	**Hypothesis Testing and analysis** • Hypothesis testing • P-value computation • Model testing	**Assignment 5** **Reading Previous to the session:** Montgomery, D. C. and Runger, G. C. "Tests of Hypotheses for a Single Sample," in Applied statistics and probability for engineers, pp. 277-304 (27 pages)
22	**Continuous probabilistic models** • Measures of central tendency • Measures of dispersion	**Deadline for submitting the Practical Group Work Activity**
23	**Sampling. Central limit theorem** • Types of sampling • Statistical distributions **Activity in class:** Team presentation about the practical group activity group	**Reading Previous to the session:** • Montgomery, Douglas C. and Runger, George C. Applied statistics and probability for engineers, pp. 109-121; 189-196; 238-246 (27 pages)
24	**Point and interval estimation** • Point estimation: method of moments and method of maximum likelihood • Estimators: definition and properties • Confidence intervals	**Deadline for submitting assignment 5** **Reading Previous to the session:** • Montgomery, D. C. and Runger, G. C. "Statistical Intervals for a Single Sample," in Applied statistics and probability for engineers, pp. 247-276 (29 pages)
	FINAL EXAM	

COURSE RELATED TRIPS:

- Visit to the "Statistical Institute of Calatonia".
- Visit to the permanent exhibition in the "Museum of Mathematics in Catalonia".

REQUIRED READINGS:

- Montgomery, Douglas C, and George C.Runger. *Applied Statistics and Probability for Engineers.* 7th edition. Nashville: John Wiley & Sons, 2020.

RECOMMENDED READINGS:

- Sawitzki, Günther. *Computational Statistics: An introduction to R.* Philadelphia: Chapman&Hall/CRC,2011.

- Ross, Sheldon M. *Introduction to probability and statistics for Engineering and the Scientists.* 6th ed. San Diego: Academic Press, 2021.