Course Title

RISK ASSESSMENT AND LOSS ESTIMATION

Instructors

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Teaching Assistant

Athanasios Papadopoulos

Course organization

After a first motivational lecture on the concept of risk, this *first part* of this course will start from the basics of probability and statistics applied to engineering problems related to the field of risk assessment at large. Less emphasis will be given to derivations and more to concepts. This necessary introduction will give you the mathematical tools necessary to compute the chance that "bad things" may happen to the assets that you are designing or evaluating in the engineering problem of your interest. All numerical examples will be dealing with real life applications.

The *second part* of the course will start with the basic mathematical framework of risk calculation and then will transition to how these concepts are applied in the catastrophe risk modeling industry of portfolios of structures for natural events such as earthquakes, tropical cyclones, volcanic eruptions, tsunamis, hail and rain. The examples discussed are typical of those found in the insurance/reinsurance industry, capital markets, and sovereign disaster risk financing applications. Therefore, some fundamentals of insurance/reinsurance will also be presented.

The *third part* will tackle in detail the state-of-the art approach to assess seismic risk of single buildings for both collapse and loss estimation purposes. The techniques that you will learn here are applicable both to the design of new buildings and to the assessment of existing ones.

Finally the *fourth and last part* of the course will focus on the application of the multi-hazard portfolio loss assessment theory to real case studies. In this part you will be using models already built and the emphasis will be in learning how to compute and interpret correctly their results.

The timeline of the course and the venues of the lectures are provided below.

Part 1
Course Overview and
Fundamentals of Probability and Statistics

Proff. P. Bazzurro and M. Ordaz
TA: Athanasios Papadopoulos

Day	Subject
M, February 6 **Sala del Camino**	**Overview of the course. Why do we care about risk? Why do we need probability and statistics?**
9:30 – 12:30	• Main Objectives of the Course • What is risk? Who cares and why
14:00 – 15:00	• Probability and Statistics. Why Bother? Do you have a good number sense?
TU, February 7	**Fundamentals of Applied Probability and Statistics**
Sala del Camino 10:30 – 12:30	• Looking ahead: Examples of use of probability and Statistics to model occurrences of natural events Set Theory and Probability Theory • Random Variables and Distributions- Jointly Distributed Random Variables • Expectations and Moments of Random variables
14:00 – 16:00	• Using Empirical Data • Common Probability Distribution Models: Models for Repeated Experiments
W, February 8	**Fundamentals of Applied Probability and Statistics**
Sala del Camino 10:30 – 12:30	• Common Probability Distribution Models: Models for Random Occurrences • Limiting Cases: the Normal Distribution, the Lognormal Distribution, the Extreme Value Distributions (Part I)
14:00 – 16:00	• Tutorial: Problems on Probability and Statistics
TH, February 9	**Fundamentals of Applied Probability and Statistics**
Sala del Camino 10:30 – 12:30	• Common probability distribution models: Limiting cases: the Normal (Gaussian) distribution – the Lognormal distribution – Extreme Value Distributions (Part II) • Uniform and Beta distributions • Functions of Random Variables • Rosenblueth's point distributions
14:00 – 16:00	• Tutorial: Problems on Probability and Statistics
F, February 10	**Fundamentals of Applied Probability and Statistics**
Sala del Camino 10:30 – 12:30	• Monte Carlo Simulation • Overview of Applied Classical Statistics: o Distribution Parameter Estimation o : Random Variable Model Selection • Basics of Linear Regression Analysis
14:00 – 16:00 **Classroom 1-15**	Tutorial: Problems on Probability and Statistics

Part 2
Multi-hazard Risk Assessment for Portfolios of Structures: Theory

Proff. M. Ordaz and P. Bazzurro
TA: Athanasios Papadopoulos

Day	Subject
M, February 13	**Risk Theory (Part I)**
Sala del Camino 9:30 – 12:30	• The need of engineering models • The process of occurrence of losses in time • Contemporary characterization of the occurrence process • Main equations to compute risk • Main risk metrics
TU, February 14	**Risk Theory (Part II)**
Sala del Camino 9:30 – 12:30	• The building blocks of risk and their analytical requirements • Exposure • Hazard • Vulnerability • Hazard computation • Risk computation
W, February 15	**Risk Theory (Part III)**
Classroom 1-15 9:30 – 12:30	• Risk in a single structure • Risk in a portfolio of structures: the problem of correlation among losses and the need for an event set • Algebra of multi-peril risk assessment • Understanding risk curves
TH, February 16	**Overview and Fundamentals of Earthquake Risk Modeling**
9:30 – 12:30 **Classroom 1-15**	Fundamentals of Earthquake Risk Modeling (Part I) • Exposure • Hazard: o Overview of Probabilistic Seismic Hazard Analysis – Differences between Probabilistic and Deterministic approaches. o Occurrence of earthquakes: Poissonian vs. Renewal Models o Ground Motion Modeling: Ground motion prediction – GMPEs vs. Simulation - Hazard curves and uniform hazard spectra. Random fields of correlated ground motion intensity measures. Tsunami waves o Stochastic Earthquake Catalog Simulation
14:00 – 16:00	Fundamentals of Earthquake Risk Modeling (Part II) • Vulnerability: Construction classes, fragility curves and vulnerability functions. • Loss estimation (Impact on population - Casualties, homeless, etc.- Physical losses to properties - Ground-up and insured losses – Downtime. o Model Validation
F, February 17	**Fundamentals of Risk Modeling for Hurricanes and other perils**
9:30 – 11:30 **Classroom 1-15**	Fundamentals of Hurricane Risk Modeling: • Hurricane formation and structure • Catastrophe modeling – Hazard component (What are the parameters

	that are used to model a hurricane? How can we compute the wind field generated by a storm? How do some of the major climate signals influence hurricane activity?) Catastrophe modeling – engineering component (What is the mechanism that triggers wind damage? What attributes are important for modeling hurricane damage to buildings? Differences between damage functions for hurricane wind and damage functions for earthquake ground shaking)
11:30 – 12:30	Fundamentals of volcanic risk modelling • Volcanoes, a multi-peril phenomenon • Ash models • Pyroclastic flow models • Lava models
14:00 – 17:00	• Fundamentals of tsunami risk modelling o Mechanisms of tsunami generation o Equations of wave propagation o Run-up calculations o Parametric models o Vulnerability functions o Other modeling strategies • Fundamentals of rain risk modelling o Rain as a proxy of flood damage o Hydrology and storm modeling o Hydraulic calculations o Vulnerability functions • Fundamentals of hail risk modelling o Appropriate intensity measure o Source modeling o Attenuation of intensity with distance o Vulnerability functions
M, February 20	**Risk Assessment for the Insurance/Reinsurance Industry, Capital Markets, and Sovereign Disaster Risk Financing - Regulating Insurance**
9:30 – 11:30 **Sala del Camino**	Why do we bother to talk about Insurance and Reinsurance in an engineering course? • Fundamentals of Insurance and Reinsurance • Metrics for Insured Losses • Pricing and Solvency • Catastrophe Bonds Examples: CatMex and MultiCat • Parametric Insurance. Examples: CCRIF
11:30 – 12:30	Regulating Insurance • The need for insurance regulations • How does the regulator know if an insurance/reinsurance company is solvent? • Examples across the World

Part 3
(Analytical) Seismic Risk Assessment for Single Buildings

Dr. V. Silva
TA: Athanasios Papadopoulos

Day	Subject
M, February 20	**Seismic Risk Assessment for Single Buildings (Part I)**
Eucentre Classroom 1 14:00 – 16:00	Selection of ground motion records Conditional versus Unconditional approaches Uniform Hazard Spectrum versus Conditional Mean Spectrum Intensity measure efficiency and sufficiency
TU, February 21	**Methodologies for calculations of structural response**
Eucentre Classroom 1 11:00v 13:00	Structural modeling and pushover Analysis Nonlinear dynamic analysis (3D MDOF to SDOF) Nonlinear statics procedures Displacement-based earthquake loss assessment method
14:30-16:30	Derivation of fragility and vulnerability functions Propagation of uncertainties in fragility assessment Building-level versus component/story-level fragilities
W, February 22	**Assessment of single-building losses**
Eucentre Classroom 1 10:30 – 12:30	Estimation of annual collapse probability Estimation of AAL, PML and EP curves (SAC/FEMA method)
14:00 – 16:00	Retrofitting/strengthening techniques Impact on the average annual losses Benefit-cost analysis
TH, February 23	**Exercises/homework**
Eucentre Classroom 1 10:30 – 12:30 14:00 – 16:00	Exercises: Running pushover curves, derivation of fragility functions, estimation of AAL

Part 4
Multi-hazard Risk Assessment for Portfolios of Structures: Applications

Dr. M. Salgado

Day	Subject
M, February 27	**Application of Portfolio Multi-Peril Risk Assessment**
Sala del Camino 9:30 – 12:30	Calculation of multi-peril risk. The need for a uniform characterization of exposure, hazard and vulnerability. The need for peril-agnostic computations. Introduction to CAPRA representations. Temporalities
14:00 – 16:00	Introduction to CAPRA. Introduction to final project
TU, February 28	**Application of Portfolio Multi-Peril Risk Assessment**
Sala del Camino 9:30 – 12:30	Approaches for the development of exposure models (residential, commercial and industrial building stock, education and healthcare infrastructure). Development of empirical and analytical fragility functions. Presentation of examples for exposure modelling and vulnerability assessment.
14:00 – 16:00	Performing single-peril scenario and probabilistic risk calculations for a specific region of interest with CAPRA
W, March 1	**Application of Portfolio Multi-Peril Risk Assessment**
Sala del Camino 9:30 – 12:30	Performing multi-peril scenario and probabilistic risk calculations for a specific region of interest with CAPRA
14:00 – 16:00	Performing multi-peril scenario and probabilistic risk calculations for a specific region of interest with CAPRA
TH, March 2	**Application of Portfolio Multi-Peril Risk Assessment**
Sala del Camino 9:30 – 12:30	The needs of disaster risk management (DRM) experts. Presentation of application of science for risk reduction. Preparation for final project

Final Exam: Friday, March 3, 9:30v 11:30 **Sala del Camino**

Portfolio Risk Assessment Assignment Presentation: Saturday, March 4, 9:00v 12:00 **Sala del Camino**

Grading structure

- Homework: 20%
- Portfolio Multi-hazard Loss Estimation Assignment: 30%
- Final written exam: 50%

Useful References

Ang, A. H. and Tang, W. H. (2007). "Probability Concepts In Engineering: Emphasis On Applications In Civil & Environmental Engineering," Wiley.

Benjamin, J. R. and C. A. Cornell (1970). Probability, Statistics, and Decision for Civil Engineers. New York, McGraw-Hill.

Kutner M.H., Nachtsheim C., and Neter J., 2004. *Applied linear regression models*, McGraw-Hill, 1396 p.

Ross, S. M. (2004). Introduction to Probability and Statistics for Engineers and Scientists. Amsterdam, Elsevier Academic Press.

Gordon Woo: The Mathematics of Natural Catastrophes' (ISBN-13: 978-1860941825) and 'Calculating Catastrophe' (ISBN-13: 978-1848167391) published by Imperial College Press

Grossi, P. and Kenreuther, H. Editors (2005) "Catastrophe Modeling: A New Approach to Managing Risk, Huebner International Series on Risk, Insurance and Economic Security (ISBN-13: 978-0387241050)