University of Pavia

IUSS School of Advanced Studies

Civil Engineering for Mitigation of Risk from Natural Hazards

Course Title

SEISMIC RISK ASSESSMENT

Instructors

Paolo Bazzurro, Dimitrios Vamvatsikos, Vitor Silva

Teaching Assistant

Omer Odabasi

Project Assistant

Petros Kalakonas

Course organization

This course will start with a very succinct overview of the basics of probability and statistics that are commonly used in the field of hazard and risk assessment. The knowledge of the subject is a pre-requisite of the course. After this preamble, in this first part we will move on to describe the basics of risk assessment and loss estimation for assets subject to natural events such as earthquakes, tropical cyclones. In this part we will also review the fundamentals of seismic hazard analysis and we will cover both probabilistic and deterministic approaches. Then we will deal with catastrophe risk modeling of portfolios of structures mostly for earthquakes but will briefly discuss tropical cyclones as well. The applications discussed are typical of those found in the insurance/reinsurance industry, capital markets, and sovereign disaster risk financing. Therefore, some fundamentals of insurance/reinsurance will also be provided. Then we will introduce the concepts of seismic risk for single structures and we will compare and contrast them with the approach for portfolio of assets. Time permitting, we will discuss the risk assessment of networks and of nuclear power plants. These cases have special aspects that are not found in the previous applications discussed during the course.

The second part will focus on the application of the portfolio seismic risk 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. Finally the third and last part of the course 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.

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

Part 1
Course Overview and
Fundamentals of Earthquake Risk Modeling

Prof. P. Bazzurro
TA: Omer Odabasi

Day	Subject
M, Sept 24 1-15	**Overview of the course. What is risk? Why do we need probability and statistics?**
10:00 – 12:00	• Main Objectives of the Course • What is risk?
14:00 – 16:00	• Basic of Probability and Statistics for risk assessment applications • Common Probability Distribution Models: o Models for Random Occurrences o Limiting Cases: Normal, Lognormal, Extreme Value Distributions • Theorem of Total Probability • Bayes Theorem • Monte Carlo Simulation • Overview of Applied Classical Statistics: o Distribution Parameter Estimation o Random Variable Model Selection • Linear Regression Analysis
TU, Sept 25 1-15	**Overview of Catastrophe Risk Modeling and Fundamentals of Earthquake Risk Modeling (Part I)**
10:00 – 12:00	• Overview of Catastrophe Risk Modeling. Motivation for using models to assess catastrophe risk. What is hazard and what is risk? What is the framework of cat risk modelling? Who cares about understanding risk of natural events and why? Which natural events? Risk to whom or what?
14:00 – 16:00	Fundamentals of Earthquake Risk Modeling (Part I) • Exposure • Hazard: o Overview of Probabilistic Seismic Hazard Analysis – Differences between Probabilistic and Deterministic approaches.
M, October 1 1-15	**Fundamentals of Earthquake Risk Modeling (Parts II and III)**
10:00 – 12:00	Fundamentals of Earthquake Risk Modeling (Part II) • Hazard: o Occurrence of earthquakes: Poissonian vs. Renewal Models o Ground Motion Modeling: Ground motion prediction – GMPEs – Ergodic vs. non-ergodig GMPEs. GMPEs vs. Simulation - Hazard curves and uniform hazard spectra. Random fields of correlated ground motion intensity measures. Tsunami waves Stochastic Earthquake Catalog Simulation
14:00 – 16:00	Fundamentals of Earthquake Risk Modeling (Part III) • Vulnerability: Construction classes, Fragility curves and damage functions

TU, October 2 1-15	**Fundamentals of Earthquake Risk Modeling (Part IV) and of Hurricane Risk Modeling**
10:00 – 12:00	Fundamentals of Earthquake Risk Modeling (Part IV) • Loss estimation (Impact on population - Casualties, homeless, etc.- Physical losses to properties - Ground-up and insured losses – Downtime. • Model Validation
14:00 – 16:00	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)
TH, October 4 1-15	**Risk Assessment for the Insurance/Reinsurance Industry, Capital Markets, and Sovereign Disaster Risk Financing**
10:00 – 12:00	Why do we talk about Insurance and Reinsurance in an engineering course? • Fundamentals of Insurance and Reinsurance • Metrics for Insured Losses • Pricing and Solvency • Traditional Indemnity Insurance vs. Parametric Insurance vs. Insured Link Securities
14:00 – 16:00	• Examples of Parametric Insurance: Caribbean Catastrophe Risk Insurance Facility (CCRIF) and Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) • Catastrophe Bonds Examples: CatMex and MultiCat
F, October 5 1-15	**Basics of Earthquake Risk Assessment for site-specific studies, Lifelines and Nuclear Power Plants with Examples**
10:00 – 12:00	• What is different in the risk assessment approach for site-specific buildings vs. portfolios of buildings? • Examples of Site-specific Earthquake Risk Assessment Studies (e.g., Metreon, UCSF, PacBell Stadium) and of Hurricane Site-Specific Studies (e.g., Freeport Industrial Plant)
14:00 – 16:00	• Seismic risk of lifelines. Why are they different than studies for portfolios of assets? Examples of Earthquake Risk Studies for Lifelines (e.g., SMUD, Sacramento - San Joaquin Valley Levee System) • Seismic risk of NPPs.

Part 2
Earthquake Risk Assessment: Application for Building Portfolios

Prof. V. Silva
TA: Omer Odabasi
PA: Petros Kalakonas

Day	Subject
M, October 8 **Sala del Camino**	**Application of Portfolio Earthquake Risk Assessment**
10:30 – 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 (challenges and advantages). Presentation of examples of exposure models in Latin America, Europe and South-East Asia.
14:00 – 16:00	Earthquake loss estimation and seismic risk assessment. Presentation of examples for seismic hazard in Europe and seismic risk in Costa Rica.
TU, October 9 **1-15**	**Application of Portfolio Earthquake Risk Assessment**
14:30 – 17:30	Introduction to the OpenQuake-engine, the open-source software for seismic hazard and risk analyses of the Global Earthquake Model Foundation. Discussion of the Portfolio Earthquake Loss Estimation Assignment. Exercises with the OpenQuake-engine: Earthquake Scenarios
W, October 10 **1-14**	**Application of Portfolio Earthquake Risk Assessment**
9:30 – 12:30	Exercises with the OpenQuake-engine: Probabilistic Earthquake Risk
14:30 – 16:30	Support with the Project Assignment

Portfolio Earthquake Risk Assignment Presentation: To be decided

Part 3
(Analytical) Seismic Risk Assessment for Single Buildings

Prof. D. Vamvatsikos
TA: Omer Odabasi

Day	Subject
M, October 15 **1-15**	**Introduction: Seismic hazard and ground motions**
10:30 – 12:30	Conditional versus Unconditional approaches and the Intensity Measure Probabilistic seismic hazard analysis Intensity measure efficiency and sufficiency Uniform Hazard Spectrum versus Conditional Mean Spectrum
14:00 – 16:00	Natural ground motion selection, modification and scaling Spectrum compatible ground motions Artificial ground motion generation
16:00 – 18:00	TA session: Select records for analysis
TU, October 16 **1-15**	**Structural Analysis**
10:30 – 12:30	Incremental Dynamic Analysis versus cloud analysis (with/without scaling) Nonlinear Static approaches: Equivalent SDOF, coefficient method, N2 and equivalent linearization.
14:00 – 16:00	Nonlinear Static approaches: R-μ-T relationships, connection of nonlinear dynamic and static methods Modal Response Spectrum Analysis and elastic static methods
16:00 – 18:00	TA session: Run pushover analysis of building
W, October 17 **1-15**	**Fragility and Limit-States**
9:30 – 12:30	Concept and definition of the fragility function IM versus EDP basis and the incorporation of global collapse Deterministic capacity versus probabilistic capacity Building-level versus component/story-level fragilities Fragilities for multiple triggering conditions (union of fragilities) Analytical and numerical methods for fragility estimation Epistemic uncertainty versus aleatory variability
14:00 – 16:00	Estimation of uncertainty: FEMA P58 and computational method Convolution of fragility with hazard: SAC/FEMA approach
16:00 – 18:00	TA session: Determine Green/Yellow/Red tagging
TH. October 18 **1-15**	**Loss assessment**
10:30 – 12:30	PEER format: Damage states and decision variables From component fragilities to damage states and costs Structural/non-structural/content loss Component correlation, cost correlation, demand-capacity correlation

	Residual drifts and demolition
14:00 – 16:00	Vulnerability functions and normalization: Cost replacement new Monte Carlo LHS methods for assessing vulnerability and loss
16:00 – 18:00	TA session: Building inventory and use of PACT tool
F, October 19 **1-15**	**Wrap-up: Final exam and assignment discussion**
10:30 – 12:30	Q&A session: DV asks the questions and the students give the answers Project discussion: Teams Group 1
14:00 – 16:00	Project discussion: Teams Group 2

Exams

- Single Building Risk Assignment Presentation: F, October 19, 14: 00-16:00
- Portfolio Risk Assessment Presentation: W, October 24, 9:00-13:00
- Final Exam: F, October 26, 9:00-12:00

Grading structure

- Portfolio Earthquake Loss Estimation Assignment: 25%
- Single Building Risk Assessment and Loss Estimation Assignment: 25%
- Final written exam: 50%

Useful References (copy of journal papers will be provided)

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)