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DISASTER RISK MODELING TRAINING COURSE FOR GRADUATE PROFESSIONALS AND RESEARCHERS OF LATIN AMERICA
e-Learning / e-Training and Internship

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INTRODUCTION

Disaster risk management is all about making effective decisions based on prospective forecasts of uncertain consequences. However, stakeholders usually do not have access to risk models, to prospective forecasts and even less to a measure of their uncertainty, then decisions are not well informed, and their effectiveness is left to chance. It is generally recognized that looking into the past is not enough to make appropriate decisions, not only because of the limited information regarding catastrophic events occurred in the past but also because, in most cases, the worst events are still yet to occur. Therefore, usually it is not possible to forecast the future consequences to be caused by extreme events based on the information available for the historically ones.

When looking into the future to assess the possible consequences of upcoming events, all kinds of uncertainties appear to blur the prospective view of the stakeholders, so that no reasonable decisions can be made under such scenario. This is the reason why risk assessment should be addressed with analytical probabilistic models that incorporate the related uncertainties in a rational manner and provide uncertainty-sensitive consequence metrics. Only by accomplishing this will the stakeholder be empowered to anticipate the occurrence of catastrophic events and their feasible consequences, while considering the uncertainties associated with estimating the severity and frequency at that they will occur.

COURSE DESCRIPTION

The disaster risk modeling training's objective is to build capacity on the data requirements, technical background and approaches, and outputs of risk modeling due to earthquakes and tropical cyclones. The training is organized in two modules which provide the required knowledge, tools, and general criteria to embrace hazard, exposure, vulnerability and risk modeling from a probabilistic perspective. There is a theoretical focus on probabilistic risk assessment, as well as key concepts on seismology and earthquake engineering for the Earthquake module, and cyclones meteorology and wind/storm-surge engineering for the Tropical Cyclones module. All practical activities are performed using the Next Generation CAPRA software.

The main instructors for this program are: Omar Dario Cardona Ph.D. Professor, Universidad Nacional de Colombia and Universidad Politécnica de Cataluña; Gabriel Bernal Ph.D. Professor Universidad Nacional de Colombia; Martha Liliana Carreño Ph.D. Professor, Universidad Politécnica de Cataluña; Alex Barbat Ph.D. Professor, Universidad Politécnica de Cataluña. All are researchers of the International Centre for Numerical Methods in Engineering CIMME from Barcelona and team-members of INGENIAR: Risk Intelligence and the Group of Disaster Risk Management. Other specialists will provide scientific and technical support as well.

Course Modality

The program includes an On-line training followed by a 5-day workshop for 20 participants. The candidates (teachers and graduate students), would be proposed by universities and they should submit a project proposal. After the workshop they would have a remote follow-up to complete the projects.

Content:

Modules for earthquake, tropical cyclone, landslide, flood, and drought risks.

Earthquake risk module

This module covers key seismological concepts as the earthquake generation mechanisms, seismic moment, waves propagation and strong motion. From the engineering perspective, site effects, structural response and building damage models are also included. It also covers the required mathematical models for the proper application, understanding of the probabilistic risk assessment theory and risk outcomes and metrics and how to use them to inform decision-making for disaster risk reduction (planning, public investment, retrofitting, fiscal protection, preparedness, among other structural and non-structural mitigation measures based on those metrics).

Tropical Cyclones risk module

This module covers key meteorological aspects regarding the generation of tropical depressions, storms and cyclones, their lifecycle, wind field and storm surge models, and modelling approaches. From the engineering perspective, topographic effects, gust duration transformations, housing response and building damage models are also included. It also covers the required mathematical models for the proper application, understanding of the probabilistic risk assessment theory and risk outcomes and metrics, and how to use them to inform decision-making for disaster risk reduction (planning, public investment, retrofitting, fiscal protection, preparedness, among other structural and non-structural mitigation measures based on those metrics).

Landslides risk module

This module covers the assessment of landslide hazard and risk. Hazard is presented as a combination of landslide susceptibility and triggering factors (earthquake and rainfall), the latter requiring hazard models of their own. Risk is assessed in terms of the probability of occurrence of landslides at the location of the exposed elements. Specific aspects of probabilistic landslide risk modeling are incorporated, including for example Artificial Neural Networks for the assessment of susceptibility and probabilistic trigger thresholds for hazard evaluation. It also covers the required mathematical models for the proper application, understanding of the probabilistic risk assessment theory and how to translate landslide risk into the same type of results as any other natural hazard

Flood risk module

This module covers the assessment of flood hazard and risk, starting from the meteorological simulation of rainfall patterns to account for larger precipitation series than the ones observed in

history. Basin response is also covered in this module, as a very important aspect to account for flow levels at the exit of a hydrological basin. Hydraulic models are then studied, centered in the well-known modeling software HEC-RAS for the construction of 1D, 2D or coupled 1D/2D models. Vulnerability to flood, which highly differs from other hazards, is studied to account for losses on the exposed elements. All these items build up into a risk assessment module, fit for accounting risk in the same terms as any other hazard.

Drought risk module

This module covers the assessment of drought risk for crops. Stochastic simulation of meteorological values allows the creation of thousands of random years of information from which historically unobserved droughts are extracted and used to account for losses in crops. Losses are defined as the difference between the optimal crop yield (without water stress) and the resulting yield if any of those drought events occurs. From the simulated losses catalog, an statistical method allows the translation into probabilistic risk assessment figures.

Practical sessions will be performed following the CAPRA software state-of-the-art modules:

R-CRISIS

R-CRISIS (Developed mainly by Mario Ordaz from UNAM, Mexico) is the seismic hazard module of CAPRA. It is a versatile tool to perform Probabilistic Seismic Hazard Analysis (PSHA). Since the development of its first version in 1998, CRISIS has been used worldwide projects of seismic hazard assessment (e.g. for nuclear industry, insurance/reinsurance, earthquake building codes, seismic microzonation).

Strong Motion Analyst

Strong Motion Analyst (SMA) is a computer program for processing seismological information. SMA implements methodologies for signal processing, site response analysis, strong motion attenuation and processing of seismological catalogs.

TCHM

TCHM (Tropical Cyclones Hazard Modeler) is CAPRA's module for tropical cyclones hazard. It implements calculation methodologies for strong winds, storm surge and accumulated rainfall. TCHM allows to adequately simulate the strengthening and weakening of tropical cyclones as they progress along random tracks, as well as the ground effects in terms of hazard intensity. Climate change consideration is also a relevant topic to provide its effects on frequency and intensity of tropical cyclones.

Landslide Hazard Mapper

Landslide Hazard Mapper (LHM) provides tools for the probabilistic assessment of landslide hazard. Landslide susceptibility is assessed by using a black-box model in which an Artificial Neural Network (ANN) is trained to classify each site as susceptible or not (in terms of its probability of being susceptible) as a function of its intrinsic characteristics. Triggering factors are given as a set of seismic or rainfall events, accompanied with threshold definitions for both

seismic acceleration and rainfall intensity. LHM computes the probability of exceeding the thresholds given the occurrence of each triggering event, and then aggregates, for each site, the total probability of landslide.

Flood Analyst

Flood Analyst (FA) is the riverine flood hazard module of CAPRA. Within FA, the hydrological response of the catchment of the river is modeled by means of the modified Clark model (modClark) which accounts for the runoff transformation processes of translation and attenuation. The hydraulic engine of FA is HEC-RAS 5 (US Army Corps of Engineers, 2015). HEC-RAS is a widely used software for the hydraulic analysis of rivers. Version 5 of HEC-RAS allows the coupling of 1D and 2D hydraulic models, as well as flood defenses such as dikes. FA simply automatizes the execution of HEC-RAS, so that the hydrographs obtained from the catchment response to each stochastic storm are used as input to the hydraulic model. After HEC-RAS has competed the hydraulic analysis, FA gathers the results and constructs a flood scenario for each input storm.

Drought Pro

Drought Pro implements a state-of-the-art methodology to account for drought risk in agriculture. Within Drought Pro, a stochastic climate generator creates many simulations of weather variables (such as precipitation and temperature), based on the historical daily series available in the territory. These stochastic series are used to identify feasible droughts using standardized drought indices. Ones the simulated droughts are selected, Drought Pro performs water response analysis to the crops on the analysis region, to calculate the reduction in yield as consequence of the water stress caused by the drought. The results are added probabilistically to come up with actuarial metrics of risk.

Exposure Editor

The description, characterization and appraisal of the physical inventory of the exposed elements for a probabilistic disaster risk assessment has been, in every case and at any scale, a process that has presented serious challenges for modeling. Appealing to the law of large numbers, characterizations and evaluations are carried out assuming that the errors are compensated in the final results by involving large estimations of exposed assets (using coarse grain proxies, detailed building by building approaches) accordingly with the type of expected decision-making.

Vulnerability Studio

For probabilistic risk assessment, the vulnerability of exposed elements is modelled using mathematical functions that relate the intensity of the hazard to the direct physical impact. Such functions are called vulnerability functions and they must be estimated (or assigned from existing databases) for each one of the construction classes identified in the exposure database. Vulnerability functions are characterized by the variation of the statistical moments of the relative loss to the hazard intensity. This enables the estimation of the loss probability function at each level of intensity.

CAPRA-GRM

CAPRA-GRM is the risk calculation engine of CAPRA. CAPRA-GRM calculates the Loss Exceedance Curve (LEC) for any exposed database, due to any of the supported hazards, using the probabilistic framework. This means that CAPRA-GRM relies on the analytical solution of the loss exceedance rates. CAPRA-GRM is capable of aggregating losses from different hazards, into multihazard risk outcomes. CAPRA-GRM calculates the Average Annual Loss (AAL) and the Probable Maximum Loss (PML).

Tutorials/Manuals:

Modules have tutorials designed specifically for this academic offering, developed under FIU-USAID sponsorship. Two type of guidelines will be developed: Guidelines on theory and how to study and develop exercises using the CAPRA software modules, and guidelines related to the use itself of the software CAPRA modules; i.e. how to use the software programs to asses hazard and risk.

Activities:

This training program is based on five basic activities:

1. Development/review of the e-learning/e-training tutorials for the use of software modules
2. Adequacy and adjustment of theoretical and methodological guidelines and presentations
3. e-learning/e-training course implementation and remote follow-up of student activities/project
4. Development of the participant list and workshop agenda for the 5-day internship.
5. Internship of 5 days in a selected place from Latin America for the kick-off workshop

Each course will be scheduled for 10 months. The software programs guidelines and tutorials will be delivered to all students.

REFERENCES

Barbat, A.H., Carreño, M.L., Pujades, L.G., Lantada, N., Cardona, O.D., Marulanda, M.C. (2010). Seismic vulnerability and risk evaluation methods for urban areas. A review with application to a pilot area. Structure and Infrastructure Engineering, 6(4), 499-519.

Barbat, A.H., Carreño, M.L., Cardona, O.D., Marulanda, M.C. (2011). Holistic assessment of seismic risk in urban areas. Revista Internacional de Métodos Numéricos para Calculo y Diseño en Ingeniería, 27(1), 3–27.

Bernal, G.A., Salgado-Gálvez, M.A., Zuloaga, D., Tristancho, J., González, D., Cardona, O.D. (2017). Integration of Probabilistic and Multi-Hazard Risk Assessment within Urban Development Planning and Emergency Preparedness and Response: Application to Manizales, Colombia. International Journal of Disaster Risk Science 8(3), 270-283. DOI 10.1007/s13753-017-0135-8.

Birkmann, J., Cutter, S.L., Rothman, D.S., Welle, T., Garschagen, M., van Ruijven, B., O'Neill, B., Preston, B.L., Kienberger, S., Cardona, O.D., Siagian, T., Hidayati, D., Setiadi, N., Binder, C.R., Hughes, B., and R. Pulwarty, (2013b). Scenarios for vulnerability: opportunities and constraints in the context of climate change and disaster risk. Climatic Change. 133 (1), 53-68, Springer. Accessed 12 February 2018, DOI 10.1007/s10584-013-0913-2

Cardona, O.D. (2004a). Curriculum adaptation and disaster prevention in Colombia. In International perspectives on natural disasters: Occurrence, mitigation and consequence. J.P. Stolman, J. Lidstone, and L.M. DeChano, (Eds.) 397–408. Dordrecht, Netherlands: Kluwer Academic Publishers.

Cardona, O.D. (2004b). The Need for Rethinking the Concepts of Vulnerability and Risk from a Holistic Perspective: A Necessary Review and Criticism for Effective Risk Management. In Mapping Vulnerability: Disasters, Development and People. G. Bankoff, G. Frerks, D. Hilhorst (Eds.). 37-51. London: Earthscan Publishers.

Cardona, O.D. (2011). Disaster Risk and Vulnerability: Notions and Measurement of Human and Environmental Insecurity. In Coping with Global Environmental Change, Disasters and Security - Threats, Challenges, Vulnerabilities and Risks. H.G. Brauch, U. Oswald Spring, C. Mesjasz, J. Grin, P. Kameri-Mbote, B. Chourou, P. Dunay, J. Birkmann (Eds.). Hexagon Series on Human and Environmental Security and Peace, 5, 107-122. Berlin: Springer-Verlag.

Cardona, O.D, Ordaz, M.G., Reinoso, E., Yamín, L.E., Barbat, A.H. (2012). CAPRA-Comprehensive Approach to Probabilistic Risk Assessment: International Initiative for Risk Management Effectiveness. Proceedings of 15th World Conference on Earthquake Engineering, Lisbon.

Cardona, O.D., Bernal, G.A., Mora, M.G., Londoño, J.P., Marulanda, M.C., Gonzalez, D. (2016). Probabilistic hazard and risk assessment for urban planning, financial protection and building retrofitting: The case of Manizales. Proceedings of International Conference on Urban Risks, ICUR2016, Lisbon.

Carreño, M.L. (2006). Técnicas innovadoras para la evaluación del riego sísmico y su gestión en centros urbanos: Acciones ex ante y ex post. Tesis Doctoral, Barcelona: Universidad Politécnica de Cataluña.

Carreño, M.L., Cardona, O.D., Barbat, A.H. (2007b). Urban seismic risk evaluation: A holistic approach. Natural Hazards, 40(1), 137–172.

Carreño, M.L., Barbat, A.H., Cardona, O.D., Marulanda, M.C. (2014b). Holistic Evaluation of Seismic Risk in Barcelona. In Assessment of vulnerability to natural hazards: A European perspective. D. Alexander, J. Birkmann, and S. Kienberger, (Eds.), 21–52. Oxford: Elsevier.

Khazai, B., Bendimerad, F., Cardona, O.D., Carreño, M.L., Barbat, A.H., Burton, C.G. (2015). A guide to measuring urban risk resilience: Principles, tools and practice of urban indicators. Quezon, Philippines: Earthquake Megacities Initiative.

Marulanda, M.C., Cardona, O.D., Barbat, A.H. (2009). Robustness of the holistic seismic risk

evaluation in urban centers using the USRi. Natural Hazards, 49(3), 501–516.

Marulanda, M.C., Carreño, M.L., Cardona, O.D., Ordaz, M.G., Barbat, A.H. (2013). Probabilistic earthquake risk assessment using CAPRA: Application to the city of Barcelona, Spain. Natural Hazards, 69(1), 59–84.

Marulanda-Fraume, M.C., Cardona, O.D., Mora, M.G., González, D.M., (2016). Seismic Risk Assessment for Risk Transfer: The Voluntary Collective Insurance in Manizales, Colombia, Proceedings of International Conference on Urban Risks, ICUR 2016, Lisbon.

Salgado-Gálvez, M.A., Zuloaga, D., Velásquez, C.A., Carreño, M.L., Cardona, O.D., Barbat, A.H. (2016). Urban seismic risk index for Medellin, Colombia, based on probabilistic loss and casualties' estimations. Natural Hazards, 80(3), 1995–2021.

Salgado-Gálvez, M.A., Bernal, G.A., Zuloaga, D., Marulanda, M.C., Cardona, O.D., Henao, S. (2017). Probabilistic Seismic Risk Assessment in Manizales, Colombia: Quantifying Losses for Insurance Purposes. International Journal of Disaster Risk Science, 8(3), 296-307, DOI 10.1007/s13753-017-0137-6.