Engineering Risk Analysis and Decision for Communities Facing Natural Hazards: A Talk in Four Parts

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ABSTRACT: This presentation is the culmination of a decade of research on the technological and social aspects of decision-making for the consideration of natural hazards in communities. It covers four different aspects, and as such, this paper consists of a short summery for each of the four parts, each followed by published references of the author and his graduate students regarding the subject of that part.

Part I. RELIABILITY METHODS FOR RISK MANAGEMENT AND RESILIENCE ON THE COMMUNITY SCALE

The concept of disaster-resilient communities has gained considerable acceptance and attention over the past decade, requiring the assessment of not only the monetary losses surrounding a hazard, but also the complex, time-dependent factors that influence community resilience. This paper presents an analytical, reliability-based approach to quantify seismic resilience based on the robustness and restoration rapidity of a portfolio of buildings following an earthquake event. The reliability problem is formulated using random variables to describe the spatially correlated seismic intensity, structural response and duration of post-hazard recovery for pre-defined building combinations within a portfolio. Based on these random variables, the First-Order Reliability Method (FORM) is used as a basis to develop a new algorithm to evaluate a probability distribution of resilience for a suite of spatially distributed buildings. In addition, sensitivity measures are computed within FORM, and used to prioritize cost-effective mitigation strategies to increase portfolio resilience. This assessment puts pre-hazard retrofit and post-hazard restoration measures into a common pre-posterior framework to determine the most optimal allocation of resources to improve resilience given budgetary constraints. Preliminary results indicate that pre-hazard retrofit is often most cost-effective for increasing resilience, however, post-hazard restoration efficiency is more cost effective for achieving high resilience thresholds characterized by lower return periods. (Reproduced from the first reference below).

Bonstrom, Holly and Ross B. Corotis (2016). “First-Order Reliability Approach to Quantify and Improve Building Portfolio Resilience,” ASCE *Journal of Structural Engineering*, 142(8), DOI: 10.1061/(ASCE)ST.1943-541X.0001213, American Society of Civil Engineers.

Bonstrom, Holly and Ross B. Corotis (2015). “Building portfolio seismic loss assessment using the First-Order Reliability Method,” *International Journal of Structural* Safety, 52(1),113-120, doi.org/10.1016/j.strusafe.2014.09.005, 0167-4730, Elsevier Ltd.

Bonstrom, H. and Corotis, R.B. (2015). "Optimizing Portfolio Loss Reduction using a First-Order Reliability Method Sensitivity Analysis," *Journal of Structure and Infrastructure Engineering*, 11(9), 1190-1198, online 26 August 2014, http://www.tandfonline.com/eprint/, UENk5WmrP48ZU2GA5cNn/full.

PART II. ISSUES OF RISK PERCEPTION

The goal of sustainable and resilient design encompasses a myriad of interdependent technical issues. One communication tool is the development of hazard mapping as an effective communication tool. Multi-hazard maps can assist regional planners in implementing effective measures to confront natural hazards and to better communicate hazard risks to the public. Another tool can serve to inform communities of the losses from different types of hazards, and to communicate those regionally. Furthermore, the social psychology concepts of risk perception, and particularly dread and familiarity are crucial to understand how the public will react and act on risk reduction plans for natural hazards. (Formed from the 2012, 2013 and 2016 references below).

Jones, Jennifer and Ross B. Corotis (2012). "The regional Consequences of Individual Natural Hazard Events," *International Journal of Risk Assessment and Management*, 16(1/2/3), 78-111, Inderscience Enterprises Ltd.

Oliver, Daniel and Ross B. Corotis (2013). "Risk Perception and Effective Communication of Consequences for U.S. Natural Hazards," (with D. Oliver), 11th International Conference on Structural Safety and Reliability, June 2013, New York.

Hurley, Maura and Ross B. Corotis (2014). "Perception of Risk of Natural Hazards: a Hazard Mitigation Plan Framework," *International Journal of Risk Assessment and Management*,17(3), 188-211, Inderscience Enterprises Ltd.

Hahn, Daniel, Emmanuelle Viaud and Ross B. Corotis (2016). "Multi-Hazard Mapping of the United States," *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering,* ASCE, ISSN 2376-7642. DOI: 10.1061/AJRUA6.0000897, 2016 American Society of Civil Engineers

PART III. REALITY

In the realm of natural hazards and their effect on community sustainability and resilience, it is impossible to separate technological issues from the political and sociological ones. In particular, investment in infrastructure must include an assessment of the risks that a community is willing to assume. These risks are influenced by the realities of political careers and the social well-being of the community.

Even as complex is the responsibility of meeting these technical challenges, this is not in itself sufficient. The decision to invest resources today in order to create a better future requires buy-in from the political decision-makers, and hence the public at large, with its sociological, cultural and economic concerns. The engineer has foregone both a responsibility and an opportunity if he or she feels the task is completed when the numbers and options are generated. It is incumbent, in order to fulfill the true professional role of the engineer, to understand the power of framing and presentation, of communication, and receptivity; for only by incorporating these human factors can we help guide society and its decision-makers to a more sustainable and resilient future. (Formed from the 2010 and 2019 references below).

Hammel, Evan and Ross B. Corotis (2010). "Multi-Attribute Aspects for Risk Assessment of Natural Hazards," International Journal of Risk Assessment and Management, 14(6), December, 437-458.

Bonstrom, Holly, Ross B. Corotis and Keith Porter (2012). "Overcoming Public and Political Challenges for Natural Hazard Risk Investment Decisions," International Journal of Disaster Risk Management, IDRiM(2012)1(1) ISSN: 2185-8322, DOI10.5595/idrim.2012.0030.

Corotis, Ross B. (2019). "Engineering's Role in Policy Decision-Making for Natural Hazards and Community Resilience," 2nd International Conference on Natural Hazards & Infrastructure, ICONHIC2019, Chania, Greece, June 2019.

Part IV. GENERALIZED INFORMATION THEORY FOR ENGINEERING AND SOCIOLOGICAL RISK

Infrastructure decisions reflect multiple social, political, and economic aspects of society, leading to information/partial knowledge and uncertainty in many forms. Alternatives to classical probability theory may be better suited to situations involving partial information, especially when the sources and nature of the uncertainty are disparate. Methods under the umbrella of generalized information theory enhance the treatment of uncertainty by incorporating notions of belief, evidence, fuzziness, possibility, ignorance, interactivity, and linguistic information. Evidence theory offers an alternative method of assessing epistemic uncertainty and is well suited for expanded use in engineering applications. A protocol procedure can be developed for defining the frame of discernment, the initial assignment of belief mass, the selection of a combination rule and sensitivity analysis. (Formed from the 2015 and 2022 references below).

Corotis, Ross B. (2015). "An Overview of Uncertainty Concepts Related to Mechanical and Civil Engineering," *ASCE-ASME Journal of Risk Uncertainty in Engineering Systems, Part B: Mechanical Engineering*, December, 1(4). Paper No: RISK-14-1062 https://doi.org/10.1115/1.4030461

Ballent, Wendy, Ross B. Corotis and Cristina Torres-Machi (2019). "Dempster Shafer Theory Applications in Post-Seismic Structural Damage and Social Vulnerability Assessment Sustainable and Resilient Infrastructure," *Sustainable and Resilient Infrastructure*, Taylor and Francis, Abingdon, United Kingdom, 11 March, doi.org/10.1080/23789689.2019.1583488, 5(4).

Seites-Rundlett, William, Elena Garcia, Alejandra Alvarez Cristina Torres-Machi and Ross B. Corotis (2020). "Social Indicators to Inform Community Evacuation Modeling and Planning," *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, DOI: 10.1061/AJRUA6.0001069.

Seites-Rundlett, William, Ross B. Corotis and Cristina Torres-Machi (2022). "Development of a Protocol for Engineering Applications of Evidence Theory," A*SCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, 8(3), September, DOI: 10.1061/AJRUA6.0001241.