A Framework for Risk Assessment of Infrastructure in a Multi-Hazard Environment

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Extended Abstract

Disasters from a variety of hazards – natural, accidental, and intentional – continue to impact our nation’s infrastructure at an increasing rate as our population increases, our existing infrastructure ages, our political relationships with foreign entities remain uncertain, our global climate changes, and our development of new infrastructure extends into hazardous areas. In 2005, the American Society of Civil Engineers (ASCE) reported in their Report Card for America’s Infrastructure that, “ASCE estimates that $1.6 trillion is needed over a five-year period to bring the nation's infrastructure to a good condition.” Clearly, this level of funding is not readily available, which leaves us with the classical problem of limited resources and competing priorities. Owners and operators of the nation’s infrastructure are faced with addressing questions such as:

- Where are the highest risks?
- What risks are acceptable?
- What should be mitigated first?
- Which mitigation options are most cost-effective?

For a single hazard, such as seismic, addressing these questions is relatively straightforward, and there are well-developed and readily-available methods and models. However, in the multi-hazard environment, when a variety of hazards must be addressed, the problem becomes significantly more difficult. The hazards are typically grouped as:

- Natural and weather-related (seismic, wind, flood, snow, etc.)
- Accidental and service-related (corrosion, fatigue, fire, impact, etc.)
- Intentional (sabotage, crime, terrorism, etc.)

Given the location and use of a facility, it is not likely to be subjected to all of these hazards, and there will be some that dominate over others; however, several hazards will be present and assessing the risk is difficult due to variations in the probabilities of occurrence, in the consequences if the hazardous event does occur, and in the availability and acceptance of design and analysis methods.

Despite the difficulties in evaluating risk to infrastructure from multiple hazards, there are significant advantages to including multi-hazard considerations in mitigation design for existing and new structures. Mitigation decisions typically involve cost-benefit trade-offs.
Mitigations that serve to reduce risk from more than one hazard are more beneficial, and also less costly due to efficiencies in design, construction, and reduced disruption to owners and occupants. Care needs to be taken, however, to avoid those few instances where a given mitigation decreases the risk from one hazard while increasing the risk from another hazard.

Decisions related to managing multi-hazard risk to infrastructure, such as those addressed by the questions noted above, are heavily influenced by the risk perception of owners and operators. This is one of the primary reasons that quantifying the true multi-hazard risk to infrastructure using a rigorous and rational method is so important. Without this quantitative risk assessment information for support, decisions can be subjective and biased resulting in problems such as inappropriate allocation of mitigation funding. For example, decision makers’ risk perception may be skewed by focusing on aspects such as: the catastrophic outcome of a single hazard regardless of the extremely low probability of the initiating event occurring, only the most recent hazard, and social and/or political pressure to address only a single specific hazard regardless of its contribution to the overall risk.

Quantification of multi-hazard risk to infrastructure – the topic of this presentation – begins with the classical risk equation, i.e., risk expressed as the product of the likelihood of a hazardous event occurring and the consequences if the event does occur. These two factors can be decomposed even further, for example by separately evaluating the initiating events, the loadings on the structure given the event occurrence, the damage to the structure given the loadings, the repair cost of the structure given the damage, the casualties to the occupants given the damage, and the loss of use of the facility given the damage. This decomposition naturally lends itself to implementation in an event or fault tree approach.

Event and fault tree approaches provide a straightforward framework for multi-hazard risk assessment of infrastructure. The various components that contribute to the risk are clearly identified and quantified, providing a rational basis for risk management decisions such as those related to prioritization and cost-benefit evaluations of mitigation options. The influence of assumptions and simplifications that are often needed to facilitate the combination of hazard information (e.g., subjective with empirical) and use of applicable standardized damage and loss models can be easily tracked.

When using the results of this multi-hazard risk assessment approach, it is important to keep in mind that the assessment is a snap-shot in time – the results may not be valid in the future as infrastructure attributes change, models are updated, and other assessment parameters are modified. It is also important to clearly evaluate and understand the sensitivity of the results (and the corresponding uncertainties) to the simplifications and assumptions needed to implement the assessment in the framework described herein.

Despite the assumptions and simplifications often necessary to keep the assessment manageable, this framework provides a basic approach for clearly decomposing the risk, providing owners and operators of existing and new infrastructure with the information needed to make rational risk mitigation decisions. Of course, having the assessment information and understanding the risk is just the first step – acting on that understanding is the next and typically more difficult step, requiring dealing with issues such as funding and other economic concerns, and several other social, legal, and political concerns – something beyond the scope of the engineering assessment of the risk.