EARTHQUAKE RISK

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Abstract

Understanding earthquake risk requires analysis of the constituent steps comprising earthquake risk or the earthquake loss process. Earthquake risk management starts by defining the problem – what is at risk? As a general rule of thumb, anything potentially subject to an earthquake hazard is at risk from earthquakes. If one is attempting to manage earthquake risk, the starting point is to define what one might possibly lose due to an earthquake. Loss due to earthquake begins with the occurrence of the earthquake, which results in a number of earthquake hazards. Depending on the earthquake, liquefaction, other forms of ground failure, tsunamis, or other types of hazards may be a significant agent of damage. Primary damage can vary from minor cracking to total collapse. Some building types are more vulnerable than others, but even when a building sustains no structural damage, the buildings contents may be severely damaged. Damage results in loss. Primary loss can take many forms – life loss or injury is the primary concern, but financial loss, as well as loss of function, are also of major concern. The likelihood of sustaining a loss is termed risk. Primary losses lead to secondary forms of loss, such as loss of revenues resulting from business interruption, and loss of market share and/or reputation.

Seismic risk is is the combination of three main elements – the earthquake hazard, the assets at risk (ie, the value that is threatened by the earthquake), and the vulnerability of the assets to the effects of the earthquake. The process of analyzing the risk involves a fourth crucial aspect – the mathematical and theoretical methods by which the three elements are combined to more or less rigorously and accurately estimate the risk. Seismic risk analysis is not an end in itself – rather, the risk must then be judged or assessed as to its acceptability, relative to social norms, and to other priorities. Seismic risk assessment is still not the end – rather, it is the foundation for seismic risk management, the appropriate and efficient allocation of resources for reducing the risk to acceptable levels. Key terms include:

- Earthquake: Tectonic movements of the earth's crust resulting in propagating broad-banded vibratory motion (volcanic earthquakes and human-induced events such as blast are not considered here).
- Assets: the humans, animals, property, business operations and other items of value whose reduction in value (loss) is a concern. In general, the economy and built, social and natural environments that may be affected by an earthquake. Similar terms include exposure, inventory, and portfolio. Note that assets include intangibles such as intellectual property, reputation, etc.
- Damage: Death, collapse, physical injury or other degradation in condition of assets.
- Seismic hazard: The phenomena and/or probability of an earthquake-related agent of damage, such as fault rupture, vibratory ground motion (i.e., shaking), inundation (e.g., tsunami, seiche, dam failure), various kinds of permanent ground failure (e.g., liquefaction, landsliding), fire, or hazardous materials release..
- Seismic Intensity: A metric of the effect, or the strength, of an earthquake hazard at a specific location, commonly measured on qualitative scales such as MMI, MSK, and JMA.

- Loss: the decrease in asset value resulting from damage. Loss may be direct, or indirect (the terms 'direct' and 'indirect' loss are used variously - see Table 3 for an example, and concordance of usage).
- Vulnerability generically refers to the probability of damage given the occurrence of a hazard. If damage is defined as the median damage, the relation with hazard is termed a vulnerability function or curve. In some cases damage and loss are combined, so that vulnerability can be the probability of loss given the hazard. Note also that in the social domain vulnerability has a somewhat different meaning, referring more to the lack of capacity of populations and social systems to cope with disasters.
- Fragility: complementing vulnerability is the concept of fragility, which is the probability of being in a damage state (eg, "1%" damage, or "light" damage) given the hazard.
- Seismic risk: potential or probability of a loss due to the occurrence of earthquakes and associated hazards.
- Risk analysis: Systematic use of information to identify sources and to estimate risk. Information can include historical data, theoretical analysis, informed opinions, etc.
- Risk assessment: Overall process of risk analysis and risk evaluation.
- Risk evaluation: Process of comparing the estimated risk against given risk criteria to determine the significance of the risk. Risk evaluation may be used to assist in the decision to accept or to mitigate a risk.
- Risk management: the process and acts to reduce risk in an orderly, efficient and desirable manner.

Earthquake risk assessment

Seismic hazard is the result of a process combining the probabilistic occurrence of one or more earthquakes (the 'source'), with the estimated effects of the earthquake at a site ('attenuated' to the site via the 'path'), considering the specific conditions at the site ('site-effects').

While the hazard is what 'nature does', assets are generally what humankind 'puts in the way of nature', although even the natural environment will be disturbed by an earthquake and may lose 'value' from a scenic or other perspective. Assets are people, buildings, contents, communications, organizational operations, etc. Any asset will have many relevant attributes, such as the age, health and income of a person, the location, age, size, materials of construction, lateral force resisting system and occupancy of a building, the location, age, size etc, nature and criticality of operations, and redundancy, of a financial data center, or water or other lifeline system.

Vulnerability or fragility functions are developed for each asset based on the general or specific seismic resistive characteristics of the asset. In general, one or both of two methods are employed:

(a) empirical, in which observations of the performance of similar assets are implicitly or explicitly assessed. Empirical sources can further be divided into three important sub-classes:

1. Field survey data – that is the qualitative and statistical record of observed damage in actual earthquakes.

2. Experimental and laboratory data, derived from tests of components and/or small scale models (although recently full scale model testing is becoming more feasible).

3. Expert opinion-derived, which is the estimate by knowledgeable persons with first-hand experience observing earthquake performance of structures. The expert opinions may be derived and expressed by more or less rigorous methods.

(b) analytical, in which the properties of the asset are analyzed using a theoretical model based on a mechanics of materials or other theoretical framework. Ideally, the two methods should agree, or be used in conjunction in a

If empirically-derived data are employed to calibrate an analytically-based model, the result is termed a hybrid model. Relatively few hybrid models have been developed.

Seismic risk assessment takes the results of a SRA and compares it against societal, organizational or personal norms. These norms vary with each situation –they may be legally mandated, or may be decided on the basis of more or less rational decision making criteria, such as benefit cost analysis.

Earthquake risk management

In general, loss is reduced by one or more of four general techniques:

- Structural methods, which tend to resist seismic forces;
- Locational methods, which tend to avoid seismic forces;
- Operational methods, which employ structural and locational methods typically in a 'just in time' approach; and
- Risk Transfer methods, which don't reduce the direct damage, but spread the loss and thereby mitigate its effects.

Deciding what combination of these methods is most appropriate is an exercise in multi-criteria decision-making, and typically involves determining the costs of various alternatives, and their benefits – benefits are defined as the reduction of losses. Given that a decision to implement a set of these mitigation alternatives has been made, the last step in Earthquake Risk Management is implementing the alternatives.

In summary, earthquake risk management consists of a series of rational steps aimed at

- identifying what is at risk – that is, what assets could be lost due to an earthquake
- assessing how the earthquake places these assets at risk,
- determining which alternatives might reduce this risk.