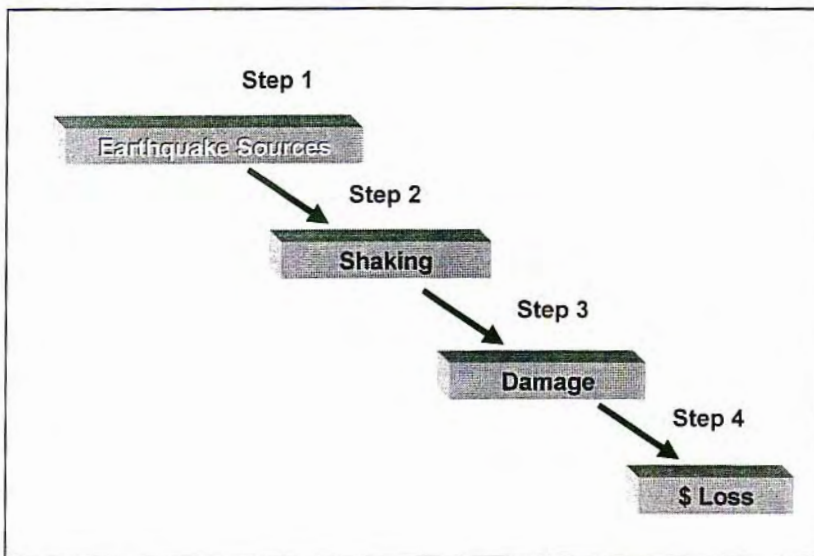

Relevance of Earthquake Science and Engineering to Insurance

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The interest of the insurance sector in earthquake science and engineering derives from the infrequency and catastrophic nature of earthquake loss. Only four earthquakes – 1906 San Francisco, 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes, in California – have caused property damage greater than \$1 billion in the United States. Thus, unlike other insured perils such as fire and theft, experience with the earthquake peril is insufficient to permit well defined estimates of future loss. Consequently, actuaries have turned to geologists and engineers to estimate future losses based on their understanding of the earthquake process and dynamic building response.

Figure 1: Steps required to estimate impact of earthquakes on the built environment.



Four aspects of geology and engineering must be addressed to estimate the impact of earthquakes on the built environment within a particular area or for a given portfolio (Fig. 1). First, the locations and magnitudes of future earthquakes – earthquake sources – must be described (D. Schwartz, this volume). Second, the regional pattern of shaking from these potential earthquakes must be estimated (M. Petersen, this volume). Third, shaking damage for different types of buildings must be predicted (T. Anagnos, this volume). And fourth, the losses incurred as a result of the damage must be estimated (T. Anagnos, this volume).

Step one, description of potential earthquake sources, includes identifying locations, potential sizes (*i.e.* magnitude), and frequency of future earthquakes. This requires geologic data and judgment. Locations of potential future earthquakes are inferred by identifying geologic faults

and evaluating whether they are seismically active. If the locations of faults are poorly known, earthquake potential may be assigned to and distributed over a region. Estimating earthquake magnitudes typically requires judgment about either the lengths of fault segments that will rupture in future earthquakes or the largest earthquake a fault or region can generate. Earthquake frequency is commonly inferred from average rates of fault slippage, geological dating of prehistoric events, and historical seismicity.

Step two, estimation of shaking, requires accounting for magnitude, distance from faults (or earthquake sources), and the capability of local geology, particularly near-surface soils, to amplify the shaking. Statistical analyses of recordings of ground shaking during earthquakes in California are the most widely used basis for estimating how shaking decreases with magnitude and distance from faults. In rock, shaking typically diminishes with distance from faults, but it may be locally amplified by thick accumulations of soil beneath a specific site. Laboratory studies of the dynamic response of soils and records of shaking on different types of soils provide a basis for predicting levels of amplification. To identify sites where amplification occurs, detailed maps of near-surface geologic units are often useful.

Step three, computation of damage for different types of buildings, can be based on observed performance of buildings during earthquakes, but often is based on engineering judgment. Observations of the performance of buildings in recent California earthquakes are useful in this regard, but variations in building practice in the western United States require modification of these observations. In some situations, engineering analysis of building response is substituted for empirically observed response.

Finally, step four, calculation of potential loss for a given area or portfolio, requires a detailed inventory of the building stock. The inventory must include physical descriptions or classifications of buildings that characterize their engineering properties and structural resistance to earthquake shaking as well as occupancy characteristics, which can affect both cost of repairing damage and business interruption.

Public policy recommendation: Coordinated postearthquake investigations by public agencies and the private sector that focus on improving loss estimation techniques are critically needed. Large earthquakes, although infrequent, offer excellent opportunities to learn about the vulnerability of different types of buildings to earthquake shaking. Understanding the relation between earthquake hazards and loss would be improved if scientific and engineering investigations were coordinated and insurance claim information was accessible in heavily damaged areas. For example, these investigations could (1) include public agency deployments of seismic instruments to better understand local variations in shaking and documentation of collateral hazards such as liquefaction and landslides, and (2) private sector disclosure of insured losses.