Risk Assessment: Estimating the Consequences of Earthquakes

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Risk vs. Hazard

Hazard – An extreme geophysical, hydrologic or meteorological event.

Risk – The threat to human life, safety, property and social systems caused by a hazard event.
What is Seismic Risk Assessment?

An analytic process that combines the ground shaking and other geological effects of one or more earthquake events with the characteristics of the built environment to estimate physical, economic and social consequences.
Why Assess Risk?

- Design Mitigation Measures
- Plan Emergency Response
- Set Insurance Rates
- Assess Portfolio Exposure
- Create Public Awareness
Determinants of Earthquake Damage

- How will seismic waves attenuate with distance?
- What is the probability of occurrence for an earthquake of specific magnitude?
- How will ground fail?
- How will damage affect social and economic systems?
- What is the damage probability at this location for a given structure type?
Probabilistic Risk Analysis for Public Decision-Making

STEP 1
- Identify Sources of Seismicity - on and off site
- Determine Attenuation Curve for relevant hazard sources
- Estimate Recurrence Curve for relevant sources
- Produce Probabilistic Shaking as maps for study area
- Conduct Geologic Investigation for study area
- Map Areas of Landslides and Liquefaction

STEP 2
- Produce Probabilistic Hazard Assessment
- Determine Damageability by Structure type

STEP 3
- Map Existing Land Uses and Individual Structures
- Estimate and Map Damage for Existing Land Uses

STEP 4
- Identify Future Land Uses by Individual Structures
- Estimate and Map Damage for Future Land Uses

STEP 5
Policy Decision
GIS Framework

Since hazard and inventory features are spatially distributed and spatial coincidence is an important determinant of damage, a geographic information system (GIS) is the natural platform for regional risk assessment.
Essential Facilities and Expected Ground Motion
Key Components of Risk Assessment

Geologic Information
Inventory of Property at Risk
Vulnerability of Buildings/Infrastructure
Social and Economic Consequences of Physical Damage
Geologic Information

Probability Distribution of Likely Earthquakes
Size and Location of Scenario Earthquakes
Attenuation from Source to Site
Ground Shaking Map
Secondary Hazards – Landslides, Liquefaction
Peak Ground Acceleration (g) Ground Motion Hazard by Census Tract

Description of Hazard Event

<table>
<thead>
<tr>
<th>Scenario Name</th>
<th>MEM 7.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Earthquake</td>
<td>Arbitrary</td>
</tr>
<tr>
<td>Longitude of Epicenter</td>
<td>-90.30</td>
</tr>
<tr>
<td>Latitude of Epicenter</td>
<td>33.16</td>
</tr>
<tr>
<td>Earthquake Magnitude</td>
<td>7.90</td>
</tr>
<tr>
<td>Depth (Km)</td>
<td>10.00</td>
</tr>
<tr>
<td>Attenuation Function</td>
<td>CEUS Event</td>
</tr>
</tbody>
</table>

Legend
Peak Ground Acceleration (g)
- 0.33 to 0.43 g
- 0.43 to 0.54 g
- 0.54 to 0.66 g
- 0.66 to 0.81 g
- Over 0.81 g

Hazard/Peak Ground Acceleration (Map 1)
Peak Ground Acceleration (g) Ground Motion Hazard – MAEViz Output

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<tbody>
<tr>
<td>Type of Earthquake</td>
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<tr>
<td>Longitude of Epicenter</td>
<td>-90.39</td>
</tr>
<tr>
<td>Latitude of Epicenter</td>
<td>35.16</td>
</tr>
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<td>7.98</td>
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<tr>
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<td>10.00</td>
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Hazard type: PGA

- 0.47 to 0.74
- 0.74 to 1.00
- 1.00 to 1.27
- 1.27 to 1.53
- 1.53 to 1.79
- 1.79 to 2.06
- 2.06 to 2.32
- 2.32 to 2.58

Map showing ground motion hazard with various intensity levels indicated by color coding.
Estimated Intensity from a 7.0 R Magnitude Earthquake on the Hayward Fault

Source: USGS
Expected Ground Motion in the Mid-America

PGA
- 0.20g
- 0.15g
- 0.10g
Inventory Information

Buildings by Structure Type
Infrastructure Systems
Transportation Networks
Essential Emergency Facilities
Hospitals
Police and Fire Stations
Schools and Potential Shelters
## Memphis Building Inventory

### Structure Type Frequency

<table>
<thead>
<tr>
<th>STRUCTURE TYPE</th>
<th>CODE</th>
<th>NUMBER</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete MRF</td>
<td>C1</td>
<td>461</td>
<td>0.16%</td>
</tr>
<tr>
<td>Concrete Shear Wall</td>
<td>C2</td>
<td>115</td>
<td>0.04%</td>
</tr>
<tr>
<td>Concrete Tilt-up</td>
<td>PC1</td>
<td>1,060</td>
<td>0.37%</td>
</tr>
<tr>
<td>Precast Concrete Frame</td>
<td>PC2</td>
<td>140</td>
<td>0.05%</td>
</tr>
<tr>
<td>Reinforced Masonry</td>
<td>RM</td>
<td>1,524</td>
<td>0.53%</td>
</tr>
<tr>
<td>Steel Frame</td>
<td>S1</td>
<td>479</td>
<td>0.17%</td>
</tr>
<tr>
<td>Light Metal Frame</td>
<td>S3</td>
<td>7,364</td>
<td>2.57%</td>
</tr>
<tr>
<td>Unreinforced Masonry</td>
<td>URM</td>
<td>6,033</td>
<td>2.10%</td>
</tr>
<tr>
<td>Wood Frame</td>
<td>W</td>
<td>269,475</td>
<td>93.88%</td>
</tr>
<tr>
<td>Unknown</td>
<td>Unknown</td>
<td>406</td>
<td>0.14%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>287,057</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
Building Data Fields

1. Structure Type Category
2. Configuration (Footprint)
3. Configuration (Massing)
4. Height
5. Building Size
6. Age
7. Location
8. Use (Occupancy)
9. Building Value
10. Content Value
Figure 2. Water Network in Shelby County, Tennessee
Water System Pipe Data

1. Material
2. Diameter
3. Length
4. Age
5. Location
6. Network Connectivity
Inventory of Transportation Facilities
Vulnerability Function

Function that predicts the damage that will result to a structure at different levels of ground shaking. Also known as a fragility curve. Typically based on laboratory experiments, analytic models or expert judgment.
Typical Fragility Curves

Fragility Curves for different Damage Levels
(THREE STORY STEEL MRF)

Probability of exceedance

First Mode Spectral Acceleration, $S_a(g)$

- ISD=1%
- ISD=2%
- ISD=8%

A
Developing Fragility Curves

Expert Judgment
Laboratory Testing (1) (2)
Analytic Models
Building Counts Exceeding Moderate Damage State by Census Tract

Description of Hazard Event

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<thead>
<tr>
<th>Scenario Name</th>
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<tr>
<td>Return Period</td>
<td>500 Years</td>
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<tr>
<td>Earthquake Magnitude</td>
<td>7.90</td>
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Legend

Counts Exceeding Moderate Damage

- Green: Under 69 Structures
- Light Green: 69 to 139 Structures
- Yellow: 139 to 216 Structures
- Orange: 216 to 362 Structures
- Red: Over 362 Structures

Building Damage (Map 2)
Social and Economic Consequences

Physical damage can produce social and economic consequences, including the need for temporary shelter, household displacement, direct economic losses, business interruption, changes in employment and loss of tax revenue. Understanding these consequences is key to planning response, recovery and mitigation.
Links between Fragility and Social Impact

Fragility determines Damage State
Damage State determines Consequences
Description of Hazard Event

- Scenario Name: MEM 7.9 Prob
- Return Period: 500 Years
- Earthquake Magnitude: 7.90

Legend

Daytime Injuries
- Green: 1 Injuries
- Light Green: 2 Injuries
- Yellow: 3 to 4 Injuries
- Orange: 5 to 6 Injuries
- Red: Over 6 Injuries
Figure 8. Example Output of the Assessment Module

Legend:
- Pipe Lines Broken After Earthquake
- Pipe Lines Connected After Earthquake
- Pipe LinesDisconnected After Earthquake
- Streams
- Pump Stations or Tanks
- River

Summary Table

**********AFTER EARTHQUAKE**********
Water is unable to flow to the BLACK pipelines serving 10180 HOUSEHOLDS. This is calculated at the CENSUS BLOCK level.
Understanding Risk

Risk assessment can

identify the sources and types of risk
help to prioritize mitigation efforts
identify emergency response needs

Risk assessment can also allow planners to test alternative plans and mitigation investments to see which will be more effective.
Conclusions

Risk Assessment is useful when planning in hazardous areas

Risk Assessment is required for local mitigation plans prepared for FEMA

Risk Assessment should be extended to include social and economic consequences

Risk Assessment should be built on a GIS framework
Future of Risk Assessment

Workshop July 14-15, 2006
6 commissioned papers
18 commissioned reviews
Produced an edited book