QUANTITATIVE SEISMIC RISK ANALYSIS: EVOLUTION OF MODELS AND DATA

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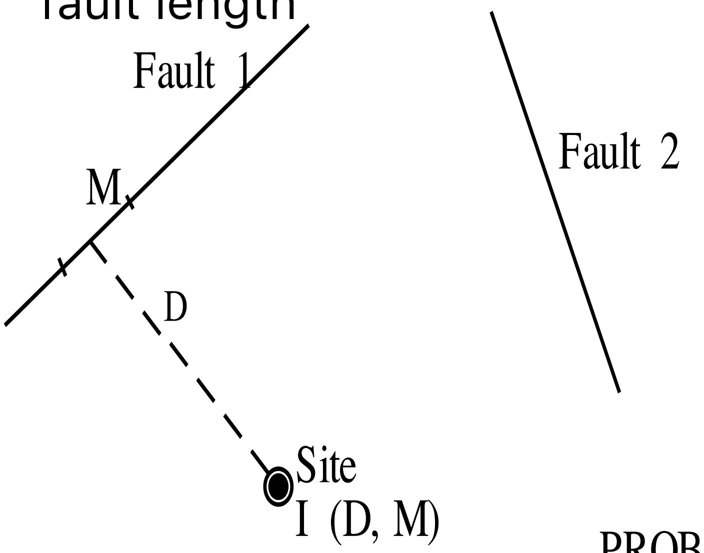
Seismic Hazard (Probabilistic Analysis)

Allin's "cocktail-napkin" description of his original model (Allin Cornell was my late husband)



Sum over fault length

Sum for all faults

M: MAGNITUDE OF AN EARTHQUAKE (MEASURE OF THE ENERGY RELEASED AT THE SOURCE) 1 TO 9 (RICHTER)

I: INTENSITY AT EACH SITE RELATED, FOR EXAMPLE, TO P.G.A.

PROBABILISTIC DESCRIPTION OF THE EARTHQUAKE AT THE SOURCE: FOR EACH SEGMENT OF FAULT, PROBABILITY THAT IT CONTAINS THE EPICENTER OF AN EARTHQUAKE OF MAGNITUDE M AT EACH YEAR

A. Seismic risk: evolution of model and data
More physics-based models => simulation
B. Another case where I addressed a similar problem: the tiles of space shuttle

What follows is a very partial list of evolutions and contributions to the field of seismic hazard analysis.

My thesis (1978): Seismic risk

Included:

- Seismic hazard model (iso-intensity curves for discrete probabilities of exceedance per year
- Consequence model: damage, human casualties, economic effects (primary and secondary)
- Based on a superposition of probabilistic maps (loads, occupancy and capacities) => min-zones
- Results: costs and benefits of various risk mitigation measures including codes and earthquake “prediction “ (with uncertainties)
- Since then, I have applied a similar model to other fields (e.g., the tiles of the space shuttle)

Data sources and Bayesian analysis in the original PSHA model (1968)

- Data: statistics, models, expert opinions for each of the factors such as
  - <u>Energy released</u> on each segment of each fault,
  - <u>Attenuation functions</u> => intensity distribution at the site
- Then: statistical and empirical data on the response of various structures
- Mathematical integration. Poisson assumption in earthquake recurrence

A lot has happened since 1968, both in Allin’s work until 2007 and since then Including (but not restricted to):

1. Decomposition of intensity into its components: pga, duration, frequency content, and dependencies among them
2. More emphasis on fundamental, physical mechanisms
3. Large computer simulation of complex models
4. New ways of gathering data (ex: cutting through faults, satellite images, etc.)

Some extensions of loads and capacities

1. <u>Design rules</u>

   Set deterministic criteria based on probabilistic estimates with “reasonable confidence”

2. <u>Joint distributions of load parameters</u>

   at each site, and dependencies (<= finite amount of energy). Spectra and hazard contours as bases of building codes.

=> Practical use in building codes

3. Validation of “forecasts”

<u>Observation of old earth features</u>

- A 30,000 years old piece of rock at Yucca Mountain in precarious balance
- Behavior of earth rock with fragile geological features (ex bubbles in rock)

⇒<u>Validation of some statistics</u> by looking further at the earth geological features.

⇒Another example: <u>cutting through faults</u>. Better likelihoods. Reduction of epistemic uncertainties

4. Simulation of ground motion

- Models based on physics
  Both in source modeling and motion attenuation
- Focus on slipping of faults in addition to simple local release of energy
- Kinetic description of waves and energy propagation (=> attenuation)
  Mathematical wave equation to represent attenuation including both initial disturbance and stiffness of material => simulation

5. Dynamics of earthquakes' recurrence

- Not strictly Poisson (at least after some time following an earthquake) BUT?
- Memory duration after an earthquake?

The debate continues.

- Transfer of energy/stress across faults? Dependences in seismic hazards from different sources => at the frontier: simulation of the dynamics of plate tectonics

6. Structural dynamics: capacity of bdgs

Observation by satellites, modeling, testing

Some aspects of ongoing research

- The basic framework is still the same but
- Need to understand the physics better to complete/replace purely empirical data
- <u>Improvements of the study of structural capacities</u>

Similar problem in my own research

- I moved on (e.g., to space systems).
- Same problem of raw global statistics versus systems' analysis and decomposition of the problem (partition).
- Use of physical/spatial models and statistics for each part of them, but also engineering models, test results direct physical measurements etc.
- Problems with statistics: relevance (system stability?) and sample size

Example of the heat shield of the shuttle

- Statistics after 68 flights: 2 tiles lost in flight, no mission failure=> conclusion from an aerospace firm: very small risk
- My work with one of my assistants (P. Fischbeck)

  Systems analysis to decompose the problem and get better data: initial loss of tile, loss in flight due to debris hits and poor bonding, formation of a larger gap (aerodynamic forces), gap in the skin of the orbiter, failure of critical systems under the skin => loss of mission and probabilities.
- The results were much more stable:

  p(Loss of mission due to the tiles): 10^{-3}/flight

And for most of the information included here:

All my thanks again to
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In memory of Allin who would be 80 years old this week.