OPINION

No Free Lunch

Imagine that your department is about to build a new building. Because the area is seismically active, you raise the issue of earthquake-resistant construction when meeting with the architect and engineer. They tell you to decide on the level of seismic safety you want, and they will provide it. The more safety you want, however, the more it will cost.

Thus you have to decide how much of the construction budget to put into seismic safety. The more you spend, the better off you will be in a future large earthquake. You are worse off in the intervening years, however, because that money isn't available for office and lab space, equipment, etc.

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Deciding what to do involves cost-benefit analysis. This involves trying to estimate the maximum shaking expected during the building's life and the level of damage you will accept. There turns out to be a range of scenarios, each involving a different cost for seismic safety and a different benefit in damage reduction. You and colleagues weigh these, accepting that your estimates for the future have considerable uncertainties, and somehow decide on what seems like a reasonable balance between cost and benefit.

This process, which society faces in preparing for earthquakes and other natural disasters, illustrates two simple principles. The first, "There's no free lunch", is that using resources for one goal means they are not available for another. This is easy to see in the public sector, where there are direct trade-offs. Funds spent strengthening schools are not available to hire teachers, stronger bridges may result in hiring fewer police officers and fire fighters, etc.

The second principle is that there's "no such thing as other people's money"—costs are ultimately borne by society as a whole. A few percent increase in costs may decide whether a building is built or renovated, or whether other worthy programs are conducted. Hence imposing costs on the private sector affects everyone via reduced economic activity (firms don't build or build elsewhere), job loss (or reduced growth), and the resulting reduction in tax revenue and thus social services.

As a result, mitigating the risks to society from earthquakes involves economic and policy issues as well as the scientific one of estimating the hazard itself and the engineering one of designing safe structures. The challenge is to develop sensible policies that balance costs and benefits, given what we know and don't know about future earthquakes and their effects. I suggest that several approaches can help seismologists and engineers contribute most usefully.

First, we should recognize that although science and engineering are important, the issues are ultimately economic and societal. There are no unique or correct strategies to be followed, so society has to make tough choices. Our goal is to use what we know about earthquake hazards and recurrence to help society decide how much to accept in additional costs to reduce both the direct and indirect costs of future earthquakes. To date, policy has evolved by trial and error after major earthquakes. This probably is fine in areas with frequent large earthquakes and considerable resources to spend on hazard mitigation. Generalizing that experience to other places, however, in particular ones where we don't have much experience of the effects of large earthquakes, is hard. Doing so should involve detailed analysis, which we don't have yet, of the costs and benefits of various policies. Especially given the uncertainties involved, the strategy chosen shouldn't be a technocratic decision to be imposed from above, but one made openly through the democratic process on the community level, where the costs and benefits of the policy accrue.

Second, we should thoughtfully address life safety issues. In the U.S. the earthquake risk is primarily to property, with annualized earthquake losses estimated at about $4 billion. Earthquakes also cause about ten deaths per year, averaged over larger numbers in individual earthquakes. To date annual fatalities have remained roughly constant since 1800, presumably in part because population growth in hazardous areas has been offset by safer construction. It seems likely that this situation could be maintained or even improved by strengthening building codes, so the issue is how to balance this benefit with alternative uses of resources that save lives otherwise. Different strategies are likely to make sense in different areas both within the U.S. and elsewhere, depending on the earthquake risk, current building codes, and alternative demands for resources.

Third, we should explicitly discuss uncertainties. We know something about earthquake recurrence and hazards, but a lot less than we'd like. Doing better is a challenge in the face of the Earth's perversity, illustrated by the nonoccurrence to date of the Parkfield earthquake predicted in 1985 to have a 95% probability by 1993 and by the apparent preference of large earthquakes to occur outside predicted seismic gaps. Although we hope to do better, we don't know if we can, given the complexity shown by long earthquake records and the growing suspicion that earthquake occurrence has a large random component. We still don't know whether to view earthquake recurrence as time-dependent or independent, and so don't even know whether earthquakes are less likely in recently active areas. Still, we hope that on some time scale, perhaps a few hundred years, we will have made and tested forecasts adequately to have reasonable confidence in them. Until then, we should explain what we know and what we don't. For example, the recent USGS estimate of a 62% probability of a magnitude > 6.7 earthquake in the San Francisco Bay area by 2032 would have been strengthened if its estimated uncertainty range of 37–87% discussed in the text had been stated in the summary and emphasized. There's no harm in discussing the limits of what we know. Individuals and society are used to making decisions in the presence of uncertainty. We buy life insurance and decide how much to spend on safety features in cars. Business and political leaders routinely consider risks in deciding whether and how to invest large sums. In fact, we help ourselves by explaining what we don't know, since we want public funds to learn more.

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Fourth, we should avoid biasing hazard estimates. Estimates biased toward high ("conservative") values distort policy decisions by favoring seismic safety over other resource uses. A useful analogy might be the tendency during the Cold War to overestimate Soviet military power, leaving the U.S. with enormous military strength but diverting resources from health, education, and other societal goals.

Fifth, hazard assessments and mitigation policies should undergo disinterested peer review. As in any other scientific area, the best results come when the review process is at arm's length. Editors, after all, do not review their own papers. Hence hazard estimates prepared by one organization should be reviewed by a different one. Doing so would ensure that crucial issues are fully explored before a decision is made. For example, the arguments used to infer that the New Madrid zone is as hazardous as California should have been carefully analyzed. Similarly, the major cost implications of the recent move to change building codes in the east and central U.S. from preparing for the largest shaking expected every 500 years to that expected every 2,500 years should have been fully studied.

Sixth, we can use the fact that time is generally on our side, because major earthquakes in a given area are infrequent on the human timescale. This can help on both the cost and benefit sides. As older buildings are replaced by ones meeting newer standards, a community's overall earthquake resistance increases. Similarly, even in situations where retrofitting structures isn't cost-effective (as I suspect is the case for the Memphis VA hospital retrofit that cost almost $100M), raising standards for new ones may be. Technological advances can make additional mitigation cheaper and hence more cost-effective. Eventually, if our understanding of earthquake probabilities becomes sufficient to identify confidently how the probability of large earthquakes varies with time, construction standards could be adjusted accordingly where appropriate.

Finally, we should benefit from research on other issues where society has to formulate hazard mitigation strategies in situations with considerable uncertainties. There's increasing recognition of the need to make policy more rationally. The challenge, summarized by a joint project of Brookings Institution and American Enterprise Institute (http://www.aei.brookings.org/), is that "The direct costs of federal environmental, health, and safety regulations are probably on the order of $200 billion annually, or about the size of all federal domestic, nondefense discretionary spending. The benefits of those regulations are even less certain. Evidence suggests that some recent regulations would pass a benefit-cost test while others would not." Hence we can gain useful insight by looking at other situations.

In summary, I think that viewing seismology and engineering as part of a holistic societal and economic approach to hazards mitigation will make our contributions more useful, and that this utility will grow as we learn more about earthquakes and their effects in different areas.

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