THE USE OF EARTHQUAKE RESEARCH FOR DEVELOPING A STATE GOVERNMENT'S SEISMIC SAFETY POLICY

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SUMMARY

Public policies for earthquake hazards reduction should be derived from scientific information about risk levels that leads to accurate assessments of policy benefits which, in turn, may be compared with policy costs. Earthquake safety has a social cost, whether it is in risk to property and life or in dollars to mitigate the risk. This paper contains a method for deriving public policy from such information and assessments. In specific situations, one of which is treated in this paper, such an analytical procedure for policy development illuminates the ramifications of a particular policy action. In the development of the methodology, some research data could be used directly. However, most data required adaptation to the specific applied problems.

LINKAGE BETWEEN STATE SEISMIC SAFETY POLICY AND RESEARCH

State government actions in the United States greatly influence the extent to which earthquake safety concerns are included in land development and building construction. States have shaped seismic hazards programs through adoption of seismic safety policies, provision of statutory authorities to state agencies and local governments, and ascription of responsibilities to the private sector.

State seismic safety policies evolve largely from research information that scientists produce. In that sense, seismic safety policy is affected by the subject-matter, quality, thoroughness, and bias in such information. In this paper, we discuss how earthquake research has been used to develop seismic safety policy. In particular, we describe the use of available data to prepare a state policy for replacement or repair of existing buildings that may be vulnerable to earthquake damage. We discuss the method of policy analysis, the research data used, problems encountered in adapting the data, and the adequacy of available data for policy decisions.

In the process of adapting seismic research for use in public policy development, it becomes apparent that there is much that is unknown that is needed to draw more definitive conclusions about seismic risk, that new techniques are needed to put scientific data into a workable form, and that some conclusions must be drawn from incomplete or uncertain data. Uncertainty of some data causes special problems for policy decisions on seismic hazards when risk, although definitely present, is not high. Seismic safety policies are made whatever research

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deficiencies may remain. To illustrate the process of policy development, we shall outline procedures for analyzing possibly unsafe existing buildings and also the basis for an associated feasible program for replacing or retrofitting hazardous buildings in Utah's seismic environment. Other seismic safety programs, besides those for existing buildings, have evolved through the application of the procedures we describe.

DEVELOPMENT OF A SEISMIC SAFETY POLICY FOR SELECTED CLASSES OF EXISTING BUILDINGS

A Guideline For Decisions

Benefit-cost methodology was used as a guideline for policy decisions relating to seismically unsafe existing buildings. Estimates of losses to life and property in various seismic environments in Utah were compared with costs for retrofitting or replacing classes of potentially hazardous buildings. Such comparisons depend upon the quality of estimates of the probable seismic environment, of likely damage resulting from earthquakes of a different strength, and of hazards to life resulting from the likely damage. Information also must be compiled about existing buildings, such as their number, locations, construction types, and occupancy rates. Some of this information may be obtained to any desirable degree of accuracy from files or the field. Other information can only be estimated from research data.

The methodology used has implications statistically valid only for aggregate conditions among classes of buildings in given seismic zones and not for particular facilities. We also have eschewed postulating an epicentral location for a maximum credible earthquake and determining its consequences. Such a postulate, useful for emergency preparedness programs, does not allow consideration of the damage expected from a variety of earthquakes of different strengths and that are expected over many years. A single postulated earthquake, for instance, may entail damage to facilities that we desire to distinguish, since considerations given to facilities damaged only in a rare severe earthquake are different from considerations given to facilities that may be damaged even in moderate earthquakes. We have modelled earthquake damage on a statistical basis. Accordingly, we use a statistical basis for damage effects and policy recommendations for hazards reduction.

The Methodology Condensed

Simplified mathematically, the benefit-cost method implies that seismic hazards reduction through replacing or retrofitting potentially unsafe buildings is justified if $B > C \times i$, wherein B equals the mean annual benefits (building losses prevented, secondary damage avoided, lives saved), C equals the cost of replacement or retrofitting, and i equals the appropriate money discount rate. Use of this equation requires knowledge of earthquake effects on buildings, expected damage levels, and life safety hazards. The equation, although suspect as the sole determinant of policy, guides one to search for material relevant to policy.

Estimates of seismicity are indispensible in making estimates of losses and possible lives saved. The goal is to estimate all losses to

subdivided zone 33 into two new zones, zone 33A and zone 33B, and adjusted estimates of epicentral frequencies to account for geological evidence. With zone 33A defined as all locations within 20 kilometers of the Wasatch fault, combined with the fact that about 1/2 of all earthquakes of Intensity V or above in zone 33 have occurred in zone 33A, the following equations were obtained for the two subzones.

For zone 33A, $\log_{10} N = 2.40 - 0.52I$.
For zone 33B, $\log_{10} N = 2.70 - 0.58I$.

Given the zone-specific frequency estimates for epicentral intensities, frequencies of intensities at sites randomly chosen within a given zone are obtained by estimating the areas affected at such intensities within the zone (adjoining zones may have some significant effects) and dividing by the total area of the zone. Various modellings of attenuation patterns may be used to estimate the affected areas. The basic model used in the work reported here was derived from the equation

$$\text{Eq. 3} \qquad I_o - I = n \log_{10}\left[\frac{(\Delta^2+h^2)^{\frac{1}{2}}}{h}\right],$$

wherein Δ = The epicentral distance from I_o to I,
h = depth of focus,
I_o = maximum intensity at the epicenter,
I = intensity at Δ from the epicenter, and
n = an exponent determined empirically.

Seismic records of Utah earthquakes were used to establish a reasonable focal depth, which is an extremely sensitive parameter in the equation. For example, the choice of a focal depth of 10 km. as opposed to 5 km. would multiply loss estimates by four.

A further refinement in the attenuation model accounts for possible influences due to soil variations. Here, the procedure employed was borrowed from Algermissen, Steinbrugge, and Lagorio ([1], p. 77), with minor adjustments for Utah soil conditions.

Table 2 contains 100-year site-specific earthquake estimates that were computed in accordance with the techniques and assumptions outlined above. From these data, and using Equation 1, we derived the 100-year estimated losses for selected classes of buildings, as shown in Table 3. The estimate of a 15 percent 100-year loss to class 5E structures in zone 33A may be compared to the 144 percent 100-year structural loss expected for similar class 5E structures in the San Francisco Bay area (Cf. [1], p. 118).

Using data in Table 2 in conjunction with other data, we determined the following 100-year baseline mortality rates due to seismicity. These rates must be further adjusted to account for type of occupant and type of structure. Injury rates, not included here, are derived in a similar manner.

For zone 32, the mortality rate = 0.0004%
For zone 33A, the mortality rate = 0.1703%

REFERENCES

1 Algermissen, S.T., K.V. Steinbrugge, and H.L. Lagorio (1978) *Estimation of Earthquake Losses to Buildings (Except Single Family Dwellings)*. U.S. Geological Survey, Open-File Report 78-441.

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4 Algermissen, S.T. and D.M. Perkins (1976) *A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States*. U.S. Geological Survey, Open-File Report 76-416.