PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Pacific Earthquake Engineering Research Invitational Workshop Proceedings

May 14–15, 1998

Defining the Links between Planning, Policy Analysis, Economics, and Earthquake Engineering

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INTRODUCTION

by
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The recently established PEER Center is committed to integrating social science and earthquake engineering research. How should integration proceed? What can social scientists contribute to PEER's interest in performance-based engineering? These and other questions were addressed at a PEER Workshop on Planning, Policy Analysis and Economics in Earthquake Research which was convened (May 14-15, 1998) to help develop an appropriate research agenda.

Generally, it appears that whereas performance-based engineering seeks optimal solutions to the achievement of given standards, social scientists can contribute to the derivation of optimal standards. In this sense, the complementarity of social science and earthquake engineering is clear. The details, of course, are where the interesting issues lie. There is no single social science perspective. And, the aggregation of individuals' preferences to some social welfare function from which optimal standards of structural design can be inferred is problematic. These two thoughts were repeated in various forms throughout the two days of the meetings. Day One featured three papers by distinguished social scientists who were not known for previous research in the earthquake field but who were expected to be insightful. Their presentations as well as illuminating commentary from three discussants and spirited discussions from the workshop participants set the stage. Follow-up group discussions on Day Two sought to translate the discussions into tangible research questions.

DAY ONE

Professor John Quigley of UC Berkeley (Public Policy and Economics) described the use of economics in assembling information on individuals' risk preferences and on aggregating these. Quigley cited the literature on occupational choice as a source of information on how individuals trade off compensation for risk. Though the findings are inevitably varied and sometimes controversial, analysts have used these data to infer the "value of a statistical life".

Pointing to a large stock of unreinforced masonry buildings, Quigley of UC asked: "What is the appropriate policy towards [these] private buildings and towards the variety of other structures...?" He applied the cost-benefit template to evaluate various seismic retrofit options. He utilized the inferred value of life data in the calculation of "expected net costs" of various policies. He found that San Francisco policies that mandate retrofit are comparatively "cheap".

Respondent, Professor Al Ang of UC Irvine (Civil Engineering) noted how Quigley's approach complements traditional earthquake engineering research. He also remarked that Quigley's focus

on mean values (of willingness-to-pay for increments of risk reduction) left the door open to discussions of how other characteristics of the distribution might be useful.

Subsequent discussion from the floor brought out two other points: 1) Policy makers could run sensitivity tests, varying assumptions, to test the robustness of the findings; and 2) The approach could be expanded to determine distributional consequences of policies to be evaluated (who pays vs. who benefits) in order to address various political concerns.

Researcher Lynn Scarlett of the Reason Foundation probed the suggestion of Wildavsky that there may be an appropriate mix of anticipation (harm prevention) and resilience (coping after the event) policies. High levels of uncertainty suggest problems from particular policies that tilt too far towards the former. The "path to greater resilience" includes 1) knowledge-building about expected risks, 2) enhanced emergency-response capabilities, and 3) insurance that better aligns risk choices and risk burdens. Her broad view challenges the widely repeated lament that individuals (and societies) are underinvesting in harm prevention. Scarlett suggested that many of the recovery problems of Kobe could be linked to low levels of resilience.

Discussant Professor Martin Wachs of UC Berkeley (City Planning and Civil Engineering) noted that many of Scarlett's points fit his experiences researching the Northridge recovery. The emergency response successes of Los Angeles officials showed a resilience capacity had been accumulated by the time the earthquake hit. In part, the rapid recovery was attributable to high levels of redundancy in the highway infrastructure in a spread out metropolis. In part, recovery was aided by the "organizational learning" that officials had retained from the summer Olympics ten years before the earthquake. Wachs pointed out that officials responding to the 1989 Loma Prieta event had no such advantage. Military planners have long known that many key defensive choices carefully trade-off "hardening" vs. dispersing targets. Earthquake policy makers should look at the many trade-offs between retrofit and redundancy.

Professor John Ellwood of UC Berkeley (Public Policy) discussed "political engineering" (paper jointly authored with Linda Ellwood). Their discussion addressed the important questions: Which technical results can (will) policy makers actually use? How is policy adoption facilitated? How can winning coalitions be constructed? One important lesson is that concentrated benefits win over dispersed costs. Another is that exogenous events open "policy windows" that close rapidly. Also, simple as it seems, why don't more discussions begin by asking, "what is the problem"? Ellwood warned PEER researchers against trying "to be all things to all research agendas".

Professor Peter May of the University of Washington (Political Science) emphasized the importance of PEER's activities as a "research brokerage" that serves as a clearing house for synthesizing, publicizing and translating research findings. This function will not simply emerge from the various research projects but should be systematically developed by sticking to the key research questions: What are the costs? What are the benefits? Who pays? Who benefits?

DAY TWO

The second day of the workshop was devoted to group discussions. Each participant had been assigned to one of three groups on the basis of research ideas that each had submitted in advance. Group leaders reported each panel's thoughts to the plenary at the end of the workshop. Group I articulated some general research standards and advocated five research priorities.

1. How to better apply and exploit research on decision-making under uncertainty? How can the political process benefit from progress in decision-making mathematics?

2. Can a standardized loss accounting system be developed? Being a multidisciplinary field, earthquake research does not yet have a common language.

3. Can models from various disciplines be successfully linked? Models of ground motion, structural damage, economic loss ("direct" and "indirect") and incidence can probably be integrated in various ways.

4. What are the impacts of earthquake risk on labor markets? What are the impacts on land markets? To what extent do wage rates as well as land rents capitalize the risks?

5. Transportation models already show some integration of social science and engineering. Can this "platform" be extended?

Group II generated almost 40 proposals and assembled these under the "basic" (e.g., the things we do not know about behavior of people or institutions), "applied" and "policy" (e.g., the market issues that frame policy) categories. Prominent (and distinct from the previous list) among these were:

Basic: Why (or why not) do people undertake mitigation? Is it cost-effective? How is behavior affected by available insurance options? by public policies? by disclosure rules?

Applied: How can property owners be "incentivized" to protect life? How can we develop a common risk vocabulary across owners, users, lenders, engineers, regulators, etc.? How to use GIS for post-disaster management?

Policy: What is the effectiveness of mitigation across all systems (not just buildings)? What is the effectiveness of "neighborhood-based" (not building-based) responses? How would full-disclosure requirements promote mitigation?

Group III developed six questions.

1. What should standards look like? What are meaningful metrics? What is "acceptable risk"?

2. What are the social procedures for "discussing" standards? What is the role of experts? How can case studies best elucidate?

3. What are the financial implications of performance standards? How are building owners and other stakeholders affected?

4. What is known about the adoption, implementation and enforcement of performance-based codes? What are the alternatives? What are the weak links?

5. Beyond codes, what can be done via planning and plan implementation? Does planning get in the way? Does it foster resilience?

6. What are the processes? Does it involve social scientists. How does PEER trade- off research directions?

PEER Director, Professor Jack Moehle (UC Berkeley), and Research Committee Chair, Professor Frieder Seible (UC San Diego) both told the plenary that they were pleased with the workshop's accomplishments. The agenda developed by the workshop will be useful as PEER fashions a legacy of earthquake research that is integrated across the major disciplines but that focuses on the three major themes discussed throughout the workshop. That is, the need to define problems in terms of:

1. Quantifying the costs and benefits of risk reduction strategies.

2. Examining the trade-offs between expenditures on mitigation and recovery.

3. Analyzing the real constraints in implementing performance-based standards and/or other earthquake safety policies.

Postscript

To best benefit from the success of the Planning, Policy Analysis and Economics Workshop, PEER will probably have to augment its procedures in two ways. First, RFPs and related communications must be made available to the community of researchers that participated (as well as those who were invited but who could not attend, see participant list). These individuals should have access to the PEER website and should be included in PEER mailing (and emailing) lists. Second, a PEER Research Sub-Committee of social scientists should be formed. Members would meet with the full Research Committee on some deliberations but would also schedule more frequent deliberations to refine and monitor social science related work. The integration task is a daunting one. Yet, a noteworthy beginning as evidenced by the enthusiasm of workshop participants has been achieved.

Thursday, May 14th

Registration 9:00 - 9:30

9:30 Horizon Room

Welcome and Opening Remarks

Mary Comerio
University of California, Berkeley
Professor, Department of Architecture

Peter Gordon
University of Southern California
Professor, School of Urban Planning & Development and Department of Economics

Jack Moehle
Director, PEER Center

University of California, Berkeley

Professor, Department of Civil Engineering

10:00 Plenary I: Seismic Retrofit and Benefit-Cost Analysis

John Quigley
University of California, Berkeley
Professor, Department of Economics and Public Policy

Discussant: **Alfred Ang,**
University of California, Irvine
Professor, Department of Civil & Environmental Engineering

12:00 Lunch: Lanai Room

1:15 Plenary Session II: Balancing the Risk Ledger: Public and Private Choices Regarding Earthquake Safety

Lynn Scarlett
Reason Foundation
Executive Director of Research

Discussant: **Martin Wachs**
University of California, Berkeley
Professor, and Director, University of California Transportation Commission

3:00 pm Coffee Break

John Ellwood, University of California Berkeley
Professor, Department of Public Policy

Discussant: **Peter May, University of Washington**
Professor, Department of Political Science9:00 am

Friday, May 15

9:00 am Concurrent Break-out Sessions

Mendocino Room Category 1: The Dimensions of Earthquake Loss

Horizon Room Category 2: Efficient Incentive Structures for Hazards Mitigation

Napa I Room Category 3: Beyond Building Codes

12:00 Lunch Lanai II Room

1:15 pm Group Reports Horizon Room

2:30 pm Coffee Break

3:00 pm Wrap-up and Plenary Development of Research Agenda

4:00 pm Adjourn

NOTE: These are for use in the Friday morning break out sessions, when we will ask you to prioritize research directions and proposal ideas. They are intended to begin the discussion, not to limit it. Mary Comerio and Peter Gordon have assigned category numbers and attached minor edits to your submissions — our apologies if we inadvertently misrepresented your ideas.

Earthquake! The Use of Economics, Engineering, and Statistical Information to Invest in Seismic Safety

by
John M. Quigley
University of California, Berkeley

I. Introduction

The devastation of the Loma Prieta earthquake in October 1989 and the Osaka-Kobe earthquake in January 1995 refocused attention in the industrial world upon the danger, unpredictability, and the high cost in financial and human terms of earthquakes in developed urban areas. The earthquake in California, measuring 7.1 on the Richter scale, left 62 dead, more than 3,000 injured and about $8.5 billion in property damage. The earthquake five years later in Japan, measuring 7.2 on the same scale, left more than 4,400 dead and 22,000 injured. Property damage was estimated to be 10 to 15 times as great as in the San Francisco earthquake. The more severe consequences arising from the Japanese earthquake reflected the location of the epicenter (almost a direct hit on Kobe in Japan, instead of an hour's drive from downtown San Francisco) and the nature of the soil (soft alluvial soil in the entire region around Kobe, with much of the commercial and industrial center built on fill). However, it is also alleged that differences in property loss and human suffering arising from the two earthquakes reflected different engineering standards and practices in the two cities and the two countries. For example, a majority of the deaths in Kobe occurred in the collapse of buildings based on post-and-beam construction with heavy tile roofing - offering little resistance to the lateral forces of earthquakes. A great deal of the property losses occurred in commercial and industrial properties designed to pre-1981 standards, when the design specifications of Japanese buildings were less stringent than those in California.

The inventory of San Francisco buildings included several thousand unreinforced masonry buildings, many of which were destroyed or damaged in the earthquake. Indeed, 5 of the 62 fatalities in San Francisco occurred when a single brick office building collapsed onto autos. Nevertheless, when the immediate consequences of the earthquake were over with, there remained some 2,000 privately owned unreinforced masonry buildings in San Francisco.

What is the appropriate policy towards these private buildings and towards the variety of other structures — privately owned homes, offices and factories, government office buildings and facilities, public universities, and other institutions? The issue would be of little consequence if the incidence of earthquakes were *truly random and unpredictable. However, everybody believes these disruptions are quite predictable. Indeed, for San Francisco it is confidently predicted that a seismic event of 7.0 or larger will occur with a 20 percent probability at least once within the next 30 years (Ward and Page, 1989, pg. 5).*

Obviously, the appropriate policy depends upon individual attitudes towards risk and the tradeoffs that individual citizens make between safety and other valued commodities. However, appropriate policy depends as well upon broader societal norms about appropriate levels of risk to be borne by individuals - even those who volunteer for riskier activities. Notwithstanding the preferences expressed by individuals, as a matter of public policy society does not permit the enforcement of many voluntary agreements. A variety of contracts are unenforceable for moral or ethical reasons,

for example loan contracts at “excessive” interest rates or agreements involving involuntary service.

In a wide class of activity, valid agreements cannot be made which are contrary to reasonable health and safety standards. New automobiles may not be sold without seatbelts, regardless of the attitudes of individuals towards risk, and new buildings must conform to a variety of codes and safety standards. These public policies may be grounded in ethical notions about “appropriate” levels of risk to be borne by firms and individuals, but they also reflect societal views about the costs which should reasonably be incurred to reduce the risk of death or serious injury.

At a minimum, public policy intervention on these issues should reflect the underlying attitudes held by citizens about the permissible risks. Presumably, these attitudes are consistent with the ways in which informed individuals trade off increased risk of injury for reduced private expenditures and for other values. However, policy may also reflect society’s obligation to protect those who are unable to evaluate risk from the consequences of their own ignorance.

This essay investigates the policy alternatives involving seismic risk in a highly stylized way. Section II considers briefly the rationale for government action to enforce standards or seismic retrofit regulations upon the owners of existing buildings. It reviews related literature on the economic value of safety in the workplace, while Section III indicates the economic value of workplace safety that is implied by existing U.S. government regulation. Section IV applies these insights to an evaluation of the seismic retrofit issue in San Francisco. Decisions about the retrofit of existing buildings are particularly complex. Nevertheless this stylized analysis benefits from intensive engineering and seismic studies undertaken in San Francisco in the wake of the 1989 Loma Prieta earthquake. Section V is a brief conclusion.

II. The Valuation of Workplace Safety by Individuals

Individuals make tradeoffs between levels of safety and expenditures of money as a matter of course. Most of these tradeoffs are made implicitly and are only a part of more complex human decisions, but they are nonetheless real. Choices among jobs and among consumer goods, for example, may often entail the sacrifice of additional money to obtain a higher standard of safety and a reduced risk of death at home or in the workplace.

There are, by now, a variety of credible studies undertaken by academics and government officials which analyze individual behavior towards risk in the workplace. This evidence is generally based on statistical analyses of the revealed willingness of individuals to accept compensation in return for small changes in the risk of death or injury among various occupations.[1] For example, if each of 100,000 workers is willing to forego $20 in compensation for a reduction in risk on the job from three deaths per 100,000 to one death per 100,000, then the willingness to pay is $2,000,000 for two “statistical lives” saved. In this way, it can be inferred that workers as a group are willing to pay $1,000,000 for a statistical life.

These inferences must be made using rather sophisticated methods because risk is not traded directly in labor markers. Instead, differing levels of risk are selected, along with a variety of other job characteristics and compensation packages. The statistical analyses of worker behavior towards risk are based upon several testable assumptions. First, they assume that the marginal

worker is informed about risk differences across jobs.[2] Second, they assume that the marginal worker is able to move freely among jobs requiring similar skills.[3] Note that these statistical models do not reply upon assumptions about full information or full mobility for all workers, but only upon the behavior of the marginal worker.

A collection of studies of risk in the workplace is summarized in a paper coauthored by an official of the U.S. Environmental Protection Agency (Fisher, et al, 1989). That paper reviews some 21 credible analyses, indicating the advantages and shortcomings of each. A recent book by Viscusi (1992) reviews a number of other studies. Table 1 summarizes these reviews, reporting the estimated valuation of human life consistent with the most credible studies. Only a few estimates are available for non U.S. workers.

This evidence leads Fisher to conclude, "The most defensible empirical results indicate a range for the value-per-statistical-life estimates of $1.6 million to $8.5 million (in 1986 dollars).... The range of $1.6 million to $8.5 million per statistical life is directly applicable for evaluating policies or regulations expected to affect risks of fatal injury in the workplace...."

Viscusi concludes more cautiously, "The quest for estimates of the value of lives does not have the same precision as nuclear physics. Rather than isolating a single, best value-of-life number, a more appropriate policy approach would be to calculate the discounted costs per expected life saved and then to ascertain whether this figure is reasonable given the range of plausible value-of-life estimates which have been obtained in the literature (Viscusi, 1992, pg. 59)."

III. The Valuation of Workplace Safety Implied by Government Regulations

Evidence on the implicit valuation of safety in U.S. government policies comes from a detailed study of all federal rules which were undertaken during the past quarter century and which were aimed at reducing risks of death.

This analysis, originally undertaken by the U.S. Office of Management and Budget, considers some 44 proposed, final, or rejected federal rules aimed at reducing risks of death for which "reasonably complete" information on risks, benefits, and costs was available at the time of rulemaking. The author believes that "this is an essentially complete set of such rules officially published in the Federal Register."[4] (Morrall, 1986, pg. 27).

Estimates of the benefits of these regulations, in terms of lives saved, comes from a variety of sources. These sources include the impact statements issued by the agency, but also the epidemiological and engineering evidence relied upon by the agency. (See Morrall, 1986, for a discussion.). Table 2 presents the implicit valuation standards of the policies adopted or proposed by the Occupational Safety and Health Administration (OSHA) as they relate to worker safety As is clear from this comparison, in its regulation of worker safety, OSHA regulates workplace risk as if it valued statistical lives saved at up to $2.8 million. This is a good bit less than the private valuation of life as revealed by the studies noted earlier. It is also a good bit less than the implicit valuation life in the regulation of health risk within OSHA and other federal agencies such as the

Table 1
Implicit Valuation of Fatality Risk in the Workplace

Study	Implicit Value of Life* (millions of 1990 dollars)
A. U.S. Workers	
R.S. Smith (1974)	$ 7.2 M
Thaler and Rosen (1976)	0.8
R.S. Smith (1976)	4.6
Viscusi (1978)	4.1
Brown (1980)	1.5
Viscusi (1981)	6.5
Olson (1981)	5.2
Arnould and Nichols (1983)	0.9
Butler (1983)	1.1
Lee and Folson (1984)	6.8
Smith and Gilbert (1984)	0.7
Dillingham (1985)	2.5
Gegax, et al. (1985)	1.6
Herzog and Schlottman (1987)	9.1
Moore and Viscusi (1988)	7.3
Garen (1988)	13.5
Viscusi and Moore (1989)	7.8
Moore and Viscusi (1990)	16.2
Kniesner and Leeth (1991)	0.6
B. British Workers	
Marin and Psacharopoulos (1982)	
Manual workers	2.8
Non manual workers	9.0
C. Canadian Workers	
Cousineau, et al (1988)	3.6
D. Australian Workers	
Kniesner and Leeth (1991)	3.3
E. Japanese Workers	
Kniesner and Leeth (1991)	7.6

*Best estimate, as reported in Fisher, et al. (1989), Viscusi (1992), or as defined in the original study.

Environmental Protection Agency. (See Viscusi, 1992, pg. 66, for a discussion.) Thus, $2.8 million seems to be a conservative estimate of the valuation of a statistical life saved.

Table 2
Implicit Valuation of Fatality Risk in Public Policies
Mandating Safety in Workplaces

Regulation*	Year Issued**	Expenditures Per Life Saved ($Millions)
Oil and Gas Well Service	(1983)	0.1
Underground Construction	1983	0.3
Servicing Wheel Rims	1984	0.5
Crane Suspended Personnel Platform	1984	0.9-1.2
Concrete and Masonry Construction	1985	0.7-1.4
Hazard Communication (Chemical Labelling)	1983	1.8
Trench and Excavation	1989	2.3
Grain Dust	1984	2.8

Notes:* Included are all worker safety regulations proposed by the Occupational Health and Safety Administration's Safety Division for which information on risks, benefits, and costs was available at the time of rulemaking.
**Year proposed is noted in parentheses for regulations not formally issued.

Sources: Morrall, John F., "A Review of the Record," **Regulation**, (November/December 1986): 25-34.
Border, Ivy E. and John F. Morrall, "An Examination of The Regulation Vs. Capital Market Incentives for Firms to Provide Safety," unpublished paper, National Science Foundation, January 1990.

IV. The Valuation of Seismic Retrofit in San Francisco

In this period immediately after the 1989 earthquake, the City of San Francisco organized a task force and commissioned a series of studies of the options to retrofit some 2,000privately owned unreinforced masonry buildings (UMB) in the city. The task force reported to the Chief Administrative Officer of the City. Two major studies were released by the task force — one analyzing structural and seismic issues (Rutherford and Chekene, et al, 1990), and another analyzing socio-economic and land use considerations (Recht Hausrath and Associates, 1990). The analyses are distinguished by two factors:

First, they provide detailed estimates of the costs of various retrofit alternatives — estimates which vary with the type of structure as well as the level of investment; second, they summarize extensive simulation evidence on the likely consequences of earthquakes in San Francisco, including estimates of loss of life, injury, and property loss.

The availability of these data permits a detailed analysis of the retrofit options and the benefits of investment in structural changes to these buildings.

We use these data to analyze the costs and benefits of several policies. We analyze three policies, described more fully in Rutherford and Chekene (pgs. 3-72-75), and compare them to the status quo:

1. Requiring Out-of-Plane Wall Strengthening. This policy would impose two primary requirements upon UMB's in the City of San Francisco, the adding of tension anchors ("wall anchors") to tie roofs and floors to walls and the strengthening of out-of-plane walls;

2. Adopting the Uniform Code for Building Conservation (UCBC) proposed by the Structural Engineers Association of Southern California. Adoption of this code would impose regulations for UMB's similar to those in force for newly constructed buildings in San Francisco, except for UMB's with wood diaphragms. For these latter buildings, the retrofit specified in the proposal — generally strengthening of those diaphragms — is less costly than the imposition of new construction standards;

3. Requiring strict compliance of each property owner with those portions of the San Francisco Building Code (SFBC) which govern additions, alterations, and repairs to existing structures. This is the most extensive retrofit policy, requiring out-of-plane strengthening, in-plane strengthening of exterior URM walls, and the strengthening of roof diaphragms in all URM's.

Each of these policies is described in technical detail in the specific regulations cited. For example, the standard for wood diaphragms in alternative 2 is detailed in UCBC, Section A107(i); the standard for alternative 3 appears in SFBC, Section 104(f). For each policy, retrofit cost estimates are available for each of fifteen types of unreinforced masonry buildings in San Francisco. These engineering cost estimates vary substantially by building type. For example, the estimated cost of alternative 1 varies from $3.73 per square foot for large area residential buildings to $11.35 per square foot for two and three story office buildings. Expected costs also vary among the alternatives. For large area residential buildings, the cost increases from $3.73 to $8.98 per square foot if policy alternative 2 is imposed and to $14.13 per square foot if policy alternative 3 is imposed (Rutherford and Chekene, 1990, pg. 4-1).

Estimates of earthquake damage are obtained from the Seismic Risk Model (SRM) exercised for each of the building prototypes in each area in San Francisco. Damage estimates clearly vary with the severity of an earthquake and its location, and simulations are reported in the source document for several scenarios. We consider the annual expected losses from all future earthquakes, rather than the damages associated with any particular earthquake scenario. This measure includes the expected property losses, deaths, and injuries occurring in San Francisco from all earthquakes,

reported on an annual basis.

A. Overall Effectiveness

We use these data to compare the annualized costs incurred by these three policy options with their expected annual savings in terms of damage reduced and fatalities averted.

The methodology employed closely parallels that discussed above for the analysis of public policy towards workplace safety and the behavior of individual workers towards workplace safety. For each alternative and for each property type and area of the city, we compute the annualized aggregate cost of the retrofit. We then subtract the expected annualized savings arising from that policy. Savings arise from two sources: property losses averted as a result of policy implementation and the value of the loss of occupancy to tenants averted as a result of that policy.[5]

The annual costs minus the expected annual savings yield the expected net cost of the policy. We compare this net cost to the number of deaths and injuries averted by the policy. This yields a lower bound to the value per statistical life saved implied by each of the alternatives.

The estimates presented are intentionally somewhat "conservative" in the following sense: the assumptions which are employed tend to overestimate the costs of the policies relative to the benefits in terms of lives saved. Thus, if the numerical analysis indicates that a policy alternative is effective with a low valuation of statistical lives saved, we can be reasonably certain that the policy is, in fact, "cheap" when measured against lives saved.

Some of these "conservative" biases are obvious and clearly appropriate. For example, we only consider the losses from the average of all predicted earthquakes, not from any of the worst-case scenarios. In addition, however, we employ an interest rate of ten percent in converting capital expenditures in retrofit to annual equivalents. For a variety of economic reasons, many analysts recommend using substantially lower interest rates in conducting cost benefit analyses of public policies. (See Gramlich, 1998 for an extensive discussion.) The effect of using a higher interest rate is to increase the computed annual costs of these policy alternatives relative to the benefits, that is, to be "conservative" in evaluating policy.

In addition, we estimate the occupancy losses to displaced tenants in a conservative manner by assuming the cost per occupant day lost is $20.00 (in 1990 dollars) and that building occupants permanently displaced by earthquakes find equivalent sites after 60 days.

We convert estimates of the number of injuries to equivalent "statistical" deaths at the rate of 50 to 1, following Morrall (1986). Again, this almost certainly underestimates the benefits to policies which increase worker safety.

We rely upon the engineering estimates reported by Rutherford and Chekene to the City of San Francisco for the cost of each retrofit, and the results in the paper are based upon these cost estimates. In addition, however, we have estimated the efficacy of these policies using additional cost premiums required for retrofit with occupants-in-place. These premiums were obtained from contractor interviews and are reported by Rutherford and Chekene. More detailed results and sensitiv-

ity analyses are available on request.

Table 3 presents the results of these calculations aggregated over all UMB's in the City of San Francisco. Column 1 indicates the aggregate annualized cost of each retrofit policy imposed upon all 2007 privately owned UMB's occupied at the time. All costs are in 1990 dollars and are comparable to the numbers reported in Tables 1 and 2. The annual cost of the least expensive retrofit, here called "wall anchors," is estimated to be $20.9 million, while the annual cost of requiring compliance with Section 104(f) of the San Francisco Building Code (SFBC) is $50.5 million. Column 2 indicates the annual property loss expected in all UMB's under these policies. A policy requiring mandatory wall anchoring would save approximately $15.9 million annually ($46.8 million minus $30.9 million) when compared to a policy requiring no retrofit. Column 3 indicates the additional tenant or occupant losses arising from the displacement and disruption of earthquakes. Column 4 presents the expected number of earthquake fatalities associated with each policy, and column 5 presents the expected injuries. Thus, a policy requiring wall anchoring would avert about 6.4 deaths per year and 25.7 injuries when compared with a policy requiring no retrofits.

The last column summarizes the efficacy of these three policies when compared to the status quo. The table indicates the net expenditures per statistical life saved which are implicit in each of these policies. A policy of mandatory wall anchors would result in net expenditures of $540,000 per life saved. A policy requiring UCBC standards would be even cheaper; net expenditures would be only $460,000 per life saved. The policy requiring strict conformity with SFBC would cost more and avert a greater loss of life — but the net cost would be about $1.4 million per life saved.

The clear implication of these calculations is that mandatory retrofit policies are very "cheap" when compared with the workplace safety measures which society routinely imposes on employers. Such policies are less expensive, in terms of lives saved, than many of the policies mandated by OSHA to protect workers. Even the most expensive policy requiring the highest expenditures is well within the range of worker safety policies pursued by government in other contexts.

The costs of these policies are, of course, even smaller in comparison to the individual valuations that workers place on safety; wall anchors and UCBC standards cost roughly one tenth the amount of money that workers actually place on the value of additional safety.

When the higher retrofit costs assumed for occupant-in-place construction are used (estimated costs of $26.5 million, $43.2 million, and $64.4 million respectively for alternatives 1, 2, and 3), the qualitative results, as they apply to wall anchors or UCBC standards, are essentially unchanged. At estimated costs of $1.3 million to $1.4 million per life saved, either policy is quite consistent with other safety requirements imposed on employers. Alternative 3 is consistent with the valuation of a statistical life of $2.5 million or more.

B. Effectiveness by Use and Type of Structures

Tables 4, 5, and 6 present estimates of the effectiveness of the three retrofit policies separately for residential, commercial, and industrial uses. For this analysis, building types which are typically

Table 3
Value of Life Implied by Mandated Seismic Retrofit Policies
All Buildings

Alternative	Retrofit Cost	Property Loss	Occupancy Loss*	Deaths	Injuries	Value of Life**
No Retrofit	$ 0.0 M	$446.8 M	$4.9 M	12.6	50.7	---
Alternative 1 "Wall Anchors"	20.9	30.9	3.7	6.2	25.0	$543,108
Alternative 2 "UCBC"	34.0	20.7	2.3	2.2	8.8	464,213
Alternative 3 "SFBC"	50.5	15.7	1.7	1.6	6.3	1,363,047

Notes:

*Value of Occupancy Loss is estimated as the number of "occupant days lost" times the estimated rent per occupant day. For buildings that are not repaired, it is assumed that occupants are displaced for sixty days before finding new quarters.

**Implied value of a life is calculated as the annualized cost of the retrofit, less the annualized monetary savings of that option, divided by the number of deaths saved. It is assumed, following Morrall (1986), that 50 injuries is equivalent to one death.

Sources:

Rutherford & Chekene, ***Seismic Retrofitting Alternatives for San Francisco's Unreinforced Masonry Buildings***, prepared for the Department of City Planning, City and County of San Francisco, 1990.

Paul Deutsch, Summary of Preliminary Findings to Date, Studies of UMB Program Alternatives," Department of City Planning, City and County of San Francisco, 1990.

John F. Morrall, "A Review of the Record," REGULATION, November/December 1986, pgs. 25-34.

of mixed usage were prorated among the various categories.

Table 4 indicates the costs of imposing the three policies, in terms of lives saved, upon UMB's in commercial use. The cost per life saved of imposing mandatory wall anchors is about $550,000 while the cost of mandatory imposition of Section 104(f) is only $430,000 per life saved. As the table indicates, the policy of requiring retrofit to UCBC standards is actually desirable on financial grounds alone. When compared to the policy of requiring no retrofits, such a policy costs about $13.6 million per year. As indicated in column 2, however, the policy results in reductions in expected property losses of $13.5 million and in reductions in expected occupancy losses to tenants of $1.3 million. Thus, on narrow financial terms, the policy yields a net "profit" of $1.2 million. In this instance, even if the value of statistical lives saved were zero, the policy of requiring UCBC standards is desirable. In this case, the 5.6 statistical lives saved is something of a "bonus."

The same pattern of results is repeated for retrofit policies applied to industrial buildings. As Table 5 indicates, any of the three retrofit policies would be warranted even disregarding the value of deaths and injuries averted in the event of an earthquake. For example, the policy of requiring wall anchors is estimated to cost about $3.9 million per year, and to save $5.2 million annually in property losses averted above.

In contrast, mandated retrofit policies for UMB's in residential use are much less efficient. Table 6 reports analogous calculations for the UMB's in residential use. The imposition of mandatory wall anchors in residential buildings would be appropriate if the implicit valuation of a statistical life were in excess of $2.1 million. The other policies imply higher required valuations. Even for residential buildings, however, the imposition of a mandatory policy of wall anchoring would not be grossly inconsistent with other public policies undertaken to ensure worker safety.

A closer inspection of the underlying data provides the intuition behind the dramatic differences in the cost effectiveness of retrofits for residential and non residential buildings. Investments in the retrofit of industrial buildings to comply with either of the alternative sets of regulations are relatively inexpensive, and the savings in property losses averted are quite large. Thus, the policies are quite effective, even though relatively few additional lives are saved.

The cost of retrofits in commercial buildings is substantially higher, but the property losses averted by retrofit policies are also higher. In addition, the number of lives saved through these mandatory policies is also greater. For residential buildings, in contrast, the cost of mandatory retrofits is high, the property losses averted are quite low, and the number of lives saved through mandatory policies is also rather small.

Quite clearly, mandatory retrofit policies in commercial and industrial buildings — in workplaces — are rather cheap when compared to other public policies adopted to promote worker safety in the United States.

Table 4
Value of Life Implied by Mandated Seismic Retrofit Policies
Commercial Buildings

Alternative	Retrofit Cost	Property Loss	Occupancy Loss*	Deaths	Injuries	Value of Life**
No Retrofit	$ 0.0 M	$24.2 M	$2.5 M	6.6	26.5	---
Alternative 1 "Wall Anchors"	9.3	17.1	2.1	3.6	14.1	$546,892
Alternative 2 "UCBC"	13.6	10.7	1.2	1.0	4.4	(189,948)
Alternative 3 "SFBC"	20.6	7.9	0.9	0.7	3.1	428,362

Notes:

*Value of Occupancy Loss is estimated as the number of "occupant days lost" times the estimated rent per occupant day. For buildings that are not repaired, it is assumed that occupants are displaced for sixty days before finding new quarters.

**Implied value of a life is calculated as the annualized cost of the retrofit, less the annualized monetary savings of that option, divided by the number of deaths saved. It is assumed, following Morrall (1986), that 50 injuries is equivalent to one death.

Sources:

Rutherford & Chekene, ***Seismic Retrofitting Alternatives for San Francisco's Unreinforced Masonry Buildings***, prepared for the Department of City Planning, City and County of San Francisco, 1990.

Paul Deutsch, Sum of Preliminary Findings to Date, Studies of UMB Program Alternatives," Department of City Planning, City and County of San Francisco, 1990.

John F. Morrall, "A Review of the Record," REGULATION, November/December 1986, pgs. 25-34.

Table 5
Value of Life Implied by Mandated Seismic Retrofit Policies
Industrial Buildings

Alternative	Retrofit Cost	Property Loss	Occupancy Loss*	Deaths	Injuries	Value of Life**
No Retrofit	$ 0.0 M	$10.7 M	$1.1 M	2.2	8.8	---
Alternative 1 "Wall Anchors"	3.9	5.6	0.6	0.7	2.7	($1,017,739)
Alternative 2 "UCBC"	6.3	3.8	0.4	0.3	1.0	(653,571)
Alternative 3 "SFBC"	8.3	2.8	0.3	0.1	0.8	(205,480)

Notes:

*Value of Occupancy Loss is estimated as the number of "occupant days lost" times the estimated rent per occupant day. For buildings that are not repaired, it is assumed that occupants are displaced for sixty days before finding new quarters.

**Implied value of a life is calculated as the annualized cost of the retrofit, less the annualized monetary savings of that option, divided by the number of deaths saved. It is assumed, following Morrall (1986), that 50 injuries is equivalent to one death.

Sources:

Rutherford & Chekene, ***Seismic Retrofitting Alternatives for San Francisco's Unreinforced Masonry Buildings***, prepared for the Department of City Planning, City and County of San Francisco, 1990.

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Table 6
Value of Life Implied by Mandated Seismic Retrofit Policies
Residential Buildings

Alternative	Retrofit Cost	Property Loss	Occupancy Loss*	Deaths	Injuries	Value of Life**
No Retrofit	$ 0.0 M	$11.9 M	$1.3 M	3.7	15.2	---
Alternative 1 "Wall Anchors"	7.7	8.2	1.0	2.1	8.0	$2,065,291
Alternative 2 "UCBC"	14.0	6.2	0.7	0.8	3.3	2,437,285
Alternative 3 "SFBC"	21.7	5.0	0.5	0.6	2.5	4,116,817

Notes:

*Value of Occupancy Loss is estimated as the number of "occupant days lost" times the estimated rent per occupant day. For buildings that are not repaired, it is assumed that occupants are displaced for sixty days before finding new quarters.

**Implied value of a life is calculated as the annualized cost of the retrofit, less the annualized monetary savings of that option, divided by the number of deaths saved. It is assumed, following Morrall (1986), that 50 injuries is equivalent to one death.

Sources:

Rutherford & Chekene, ***Seismic Retrofitting Alternatives for San Francisco's Unreinforced Masonry Buildings***, prepared for the Department of City Planning, City and County of San Francisco, 1990.

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V. Conclusion

This paper applies the standard tools of cost benefit analysis to evaluate potential public policies towards seismic safety and the investment of resources to avert injury and loss of life. The application can be compared to other policies affecting workplace safety and also to the behavior of individual workers towards risk in the workplace. The specific application applies to some 2,000 buildings which survived the Loma Prieta earthquake in San Francisco but which might be considered unsafe in a future earthquake. These conclusions seem well supported by the available data.

First, a policy requiring the mandatory retrofit of all these unreinforced masonry buildings is consistent with policies adopted to protect worker safety in other contexts. The costs of these policies, per life saved, may vary between $0.5 million and $1.4 million (in 1990 dollars) across technologies, while other government agencies behave as if they value worker safety at somewhat higher levels. Thus, public policies to mandate retrofit are rather "cheap." They are even cheaper when compared to the private valuations that individual workers place on safety in their workplaces.

Second, a narrower policy of requiring retrofits in all non residential buildings — in all workplaces located in UMB's — is considerably cheaper and is almost certainly less expensive than other government mandated workplace protection regulations. In fact, the data show that a policy of requiring retrofit to modestly higher standards would save more than its cost in property damage averted alone.

Third, the analysis illustrates the ways in which systematic information based on engineering, scientific, and economic reasoning can be combined to illuminate important policy choices. In this case, retrofit cost estimates are obtained from detailed analyzes by civil and structural engineers, forecasts of earthquake activity are obtained from geological and seismic analysis, and economic reasoning forms the basis for the cost-benefit evaluation. The structure of the analysis may be applicable to other circumstances where seismic safety is a concern.

Footnotes

[1] This method, the so-called "willingness-to-pay (WTP)" method, may be compared with analyses based on "contingent valuation," typically individual responses to hypothetical situations involving risk. Individual WTP for workplace safety may also be compared to WTP to reduce risk in the purchase of consumer goods.

[2] In fact, there is a growing body of literature suggesting that workers' perceptions of risk are quite similar to "objective" measures of that risk. See, for example, Viscusi and O'Connor, 1984.

[3] Again, the empirical evidence is broadly consistent with this view. See Dickens, 1984 and Olson, 1981.

[4] Most of these data were provided in the so called "impact statements" required by various Executive Orders. (See especially the ***Federal Register, Executive Order 12291,*** February 19, 1981, pgs. 13193-13198.)

[5] The value of the occupancy loss averted is estimated as the number of "occupant days" lost in buildings which are repaired times an estimated rent per occupant day in these buildings plus the number of occupants permanently displaced times the estimated rent per day times an assumed sixty day displacement.

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In his opening paper, Professor Quigley presents the proper perspective and sets the right tone for this Workshop, which has the objective of defining research topics in the social sciences and economics that can be integrated with research in earthquake engineering. With specific reference to retrofit of buildings in San Francisco, his paper illustrates the quantitative approach that is meaningful to engineers and derives results that are transparent to decision makers. Specifically, the results form the basis for evaluating the cost-effectiveness of different retrofit policies (including no retrofit) in terms of the cost of saving a life.

From a broader standpoint, one of the questions that this Workshop is intended to address, I believed, is "how do we or can we integrate social science and economics into the practice of earthquake engineering?" The necessary *integration is the key issue; however, it is easier said than done. Research for effective integration is non-trivial and requires new ideas and new directions – the motivation for this Workshop. To start with, it is important to recognize that this integration is most relevant at the decision-making level or for policy development.*

The importance of social science in earthquake engineering in broad terms has been recognized for some time, and has been addressed time and again in conferences, and in numerous papers and articles. From my perspective as a research engineer, I believe that successful integration will require the following.

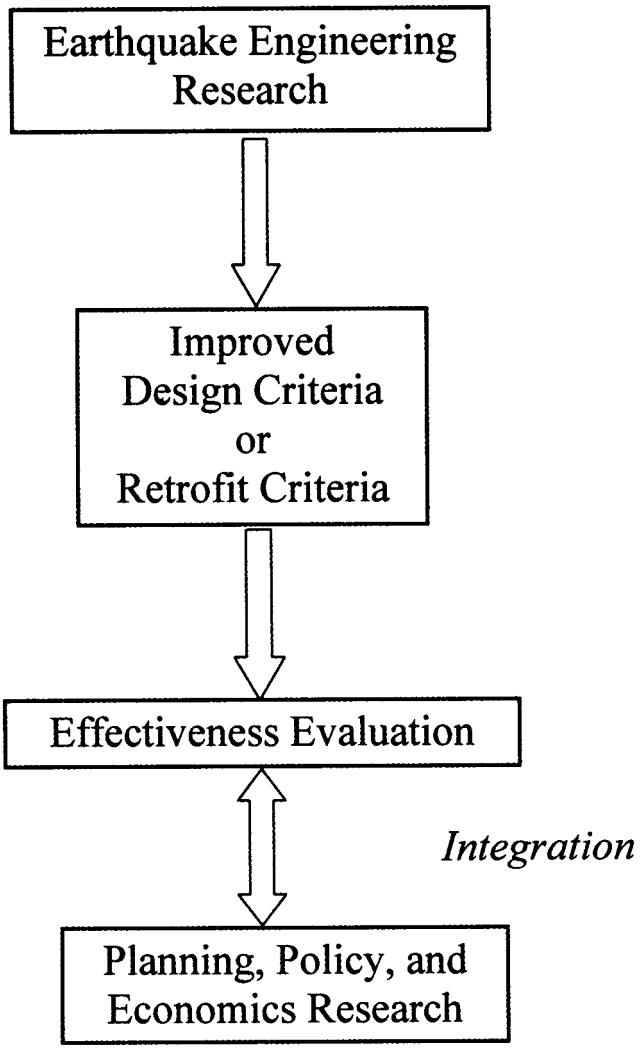
1. Recognition that such integration is aimed at the decision-making level.
2. To be useful, the approach must logically lead to results in quantitative terms.
3. Problem and solution must be specific and down-to-earth (*at the "atomic" level in the words of Allin Cornell).*
4. Results must be in terms that are transparent to decision-makers.

In my view, Professor Quigley's paper encompasses all the above elements. Some useful information and tools for research would include the following:

- Analytical tools for damage evaluation/assessment.
- Risk and reliability assessments, including structural fragilities.
- Loss estimation models, and supporting data.
- Socio-economic models, utility functions.
- System modeling – networks, GIS, etc.

Fig. 1 gives a graphical summary of the role of integrated research. Technical and scientific

research in earthquake engineering leads to improvements of criteria for design and retrofitting of structures. In order to properly evaluate or appraise the effectiveness of these criteria, socio-economic considerations are required. This is where integrated research between the social sciences (or policy, planning and economics) and earthquake engineering becomes important and should take place.



Balancing the Risk Ledger: Public and Private Choices Regarding Earthquake Safety

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I. Introduction

Background

In 1989, just as a World Series baseball game commenced at Candlestick Park in San Francisco, a 7.1 Richter scale earthquake rocked the area. Insured losses from this Loma Prieta quake reached $1 billion; total losses were many times greater. Five years later, before dawn in Los Angeles, the "Northridge" earthquake shook southern California, bringing down chunks of highway and damaging commercial and residential buildings. Insured losses exceeded $12.5 billion.By 1998, the insurance industry was estimating claims from a major temblor of a scale similar to the 1906 Great San Francisco Earthquake at over $50 billion; indirect effects from such a calamity could be substantially higher. Losses from all natural catastrophes in the United States grew from $22 billion in the decade from 1976 to 1985, or $2 billion per year, to $78 billion over the subsequent decade (1986-1995), or $8 billion per year (ISO, 1996). Daunting sums, these losses translated into a negative (-3.7 percent) rate of return on net worth for homeowners' insurance premiums over the past decade (NAIC, 1997).

While recent losses from earthquakes and other natural catastrophes have reached record levels, the challenges--public and private--of coping with disasters are not new. Earthquakes represent a classic low-probability, high catastrophe problem "for which the likelihood of exposure is low, but harm, if an event occurs, is great" (May, 1991). Low probability of harm to any specific individual or community reduces incentives for individuals and communities to act to reduce harms or increase resilience (Berke and Beatley, 1992).

Prevailing Policy Responses

Nonetheless, state and local governments have implemented numerous measures intended to reduce earthquake damage. Some individuals, too, through purchase of insurance and expenditures to upgrade structural integrity, have acknowledged earthquake hazards, though historically the percentage of homeowners within at-risk areas who have undertaken these measures ranges from miniscule to moderate (Wyner and Mann, 1986).

However, public policy endeavors have been largely limited to technocratic responses--geologic research and mapping, development of building codes, infrastructure and building upgrades, and some land-use management measures. A few states, especially California, Hawaii, and Florida, have dabbled in financial tools to manage risk, mainly through introduction of publicly shaped insurance or primary insurance programs. The federal response has combined technical and scientific tools such as earthquake research, building standards development, and so on, with basic

disaster relief through loans, grants, and other aid.

These policies have received some scrutiny. But the primary thrust of such scrutiny has tended toward examining the extent of implementation. “Success” has often been measured in these analyses not in terms of expected outcomes — that is, harms potentially averted at what cost relative to other harm-reducing activities. Instead, success has been measured in terms of inputs--that is, level of enforcement, numbers or percentage of buildings retrofitted, and so on. Other research has focused on increasing the stock of knowledge about earthquakes, identifying the location of faults or related geologic hazards, and better understanding the engineering dimensions of meeting the earthquake challenge.

What’s missing in many of these discussions is a broader social science framework within which to evaluate earthquakes, the risks and uncertainties they pose, and the kinds of policies that might be appropriate responses to the challenges posed by earthquakes. This paper provides a modest excursion into this framing realm, which has at least two dimensions. The first pertains to risk strategies: what mix of anticipation (harm prevention) and resilience (coping in the wake of disaster) is appropriate? (Wildavsky, 1988). The second pertains to risk choices: how much risk-mitigation is enough, who should decide which levels are appropriate, and in what decision-making context should people deliberate?

II. Risk Strategies: Resilience and Anticipation

The first major dimension of a social science framework within which to examine earthquake policy is a strategic one: how does one determine whether a strategy of anticipation (harm prevention) or a strategy of resilience (coping with dangers as they arise) or some combination of these is appropriate? Popular rhetoric about safety often intones that: “an ounce of prevention is worth a pound of cure.” Political scientist Aaron Wildavsky cautions against simple formulas, noting that such folk wisdom fails to identify the conditions under which the advice ought to apply (Wildavsky, 1988). The precautionary principle spelled out in Benjamin Franklin’s aphorism may well be appropriate in some circumstances but not in others.

Wildavsky offers a useful framework for considering what general strategies might be most applicable under what conditions. He distinguishes risk conditions in terms of two dimensions--the predictability of change and the amount of knowledge about effective response measures. (See Chart I

As a policy issue, earthquakes fall within the two lower quadrants. Specifically, whether, where, and in what magnitude earthquakes will occur is highly uncertain, making the ability to predict harm (change) elusive. While ability to predict an earthquake occurrence may increase over time, the ability to predict earthquake magnitudes and actual ground motion is even more elusive and may even be impossible. Yet, for public policy purposes, the magnitude matters a great deal. At Modified Mercali intensities (MMI) of VII, Reitherman (1991) notes that “even an unreinforced masonry building district in a California city will not be devastated but will only suffer predominantly parapet and similar light damage.” Of course, the difference between MMI VII and the maximum of IX (all but a handful of earthquakes in recorded history ever have exceeded an MMI

above IX) is very large (See Table 1).

Table 1:

Chart I
Appropriate Strategies for Different Conditions

	Amount of Knowledge	
	Small	Large
Predictability of change		
High	More resilience, less anticipation	Anticipation
Low	Low resilience	More resilience, less anticipation

Source: Aaron Wildavsky. Searching for Safety

In addition, knowledge about the effectiveness of responses to the many aspects of earthquake hazards varies. For example, knowledge of how to avoid hazards from certain kinds of surface faulting is moderate--and translates primarily into prohibitions on siting buildings along faults and requiring setbacks. Engineering knowledge of how to mitigate harm from some forms of ground shaking is moderate to good; but ability to predict how grounds will shake, and therefore, how to mitigate what essentially are unknown harms, is poor. Reitherman summarizes this state of affairs, "the consensus among geologic experts is high with regard to the identification of active faults, as compared to the agreement of geotechnical or geologic experts with regard to liquefaction and slides; there is even more disagreement among seismologists and structural engineers as to the forecasting of ground motion" (Reitherman, 1991). This low certainty about ground motion is important in the development of an earthquake policy framework, since it is precisely ground motion that is highly significant as a source of earthquake harms, accounting for 56% of geological hazards from earthquakes, according to the Division of Mines and Geology (Alfors, et al. 1973). Landsliding and flooding were estimated to account for 26% and 17% of earthquake hazards respectively; fault displacement, which to some extent is the main target of California's Alquist-Priolo law that prohibits siting on earthquake faults, accounts for a fraction of 1% of earthquake hazards. Outside of California, ground-shaking is possible over vast land areas where surface faulting is not evident. Siting restrictions are nearly impossible under these conditions and, in any event, are unlikely to reduce harms.

Under Wildavsky's schema, this characterization of the earthquake "problem" would suggest greater emphasis on resilience—coping with harms as they emerge--rather than on an anticipatory strategy of harm prevention through rigorous land-use restrictions, mandatory retrofitting, and so

on. As Reitherman notes, in the case of earthquakes, mandatory regulatory approaches essentially restrict the choices or rights of owners, tenants, and others in the absence of any reliable ability even to estimate if, when, and where harms might occur (Reitherman, 1991). Indeed, estimates of

Table 1
Intensity Benefit of Earthquake Resistance Based on Estimated Mean Property Loss

Construction Class	Mean Property Loss (Repair Cost/Cash Value)					
	5%	10%	15%	20%	25%	30%
Small all-metal	VIII ½					
Large all-metal	VIII ¼					
Superior steel frame	VII ¾	IX				
Interm. st. frame, superior reinf. conc., & sup. mixed	VII ½	VIII ½				
Interm. mixed	VI ¾	VII ¾	VIII			
Ord. reinforced concrete	VI ¼	VII	VIII ¾	VIII ½	IX	
Mixed reinforced concrete	VI ¼	VII	VII ½	VIII ¼	VIII ¾	
Lift slab	VI ¼	VI ¾	VII ¼	VIII	VIII ½	IX
Unreinforced masonry	VI	VI ½	VII	VII ½	VIII	VIII ½

Source: Robert Reitherman, M.EERI, *The Effectiveness of Fault Zone Regulations in California*, Table 3, p. 71.

potential property losses typically rely on models whose results vary by a factor of two or more, according to a report of the Panel on Earthquake Loss Estimation Methodology (1989). Anticipatory measures such as prohibition of development in at-risk areas may, as Reitherman notes, be "relatively blunt instruments to deal with hazards not primarily defined and demarcated geographically" (Reitherman, 1991). The same might be said of mandatory retrofitting policies, another form of anticipation, since the effectiveness of such measures in preventing harm will be highly uncertain even if an earthquake actually occurs, as was demonstrated in the recent Kobe earthquake and, in the United States, with the infrastructure failures that occurred in the Loma Prieto quake even where earthquake construction standards had been used.

These conclusions and their specific policy implications warrant further examination. Architects of earthquake policy typically use risk-reduction language. But economist Bruce Yandle notes the distinction between risk and uncertainty. (Yandle, 1996). Others have reinforced this distinction. Yandle suggests that a risk problem is one in which the decision maker is able "to list all the possible random outcomes (good and bad) and to assign a probability to each....[For risk problems, agreement exists] about the range of possible outcomes and the probabilities assigned to each" (England, 1996). Under conditions of uncertainty, neither all the possible outcomes nor an assignment of probability to any particular outcome is possible.

This quality of uncertainty means primary reliance on anticipation is likely to be costly — expen-

ditures may not achieve safety if the "wrong" harm is anticipated, or such measures will have high opportunity costs if the anticipated harm never occurs. This uncertain character of earthquakes does not imply that no anticipation is warranted. Again, using the Wildavsky framework, where there is a moderate or high degree of knowledge that a particular measure is likely to be effective, especially under a wide range of possible earthquakes, such anticipatory measures may be called for. The uncertain character of earthquake harm predictability also suggests that high-cost, comprehensive measures may absorb scarce dollars better expended on improving resilience in the form of emergency response capabilities and insurance capacity.

Improving insurance capacity is, however, difficult. The uncertainty of earthquake harms renders insurance less useful than in circumstances where the prospect of a harm occurring follows probabilistic patterns, as in the cases of automobile accident insurance or homeowner fire insurance. And, indeed, the earthquake policy literature makes much of the challenges (and possibly inadequacies) of an insurance policy approach. Some of these issues will be addressed in the final section of this paper.

III. Risk Ledgers and Risk Choices: How Much Safety?

In addition to a general presumption that an anticipatory approach is desirable, much of the earthquake planning literature also seems to assume that current expenditures on anticipatory measures are inadequate. Specifically, expenditures on earthquake-damage mitigation are viewed as per se desirable. The policy literature generally examines which particular measures might be used, but left largely unexplored is how much is enough safety and who should decide. Indeed, regarding this latter question, the presumption is generally that current harm-mitigation levels are too low; thus follows the conclusion that individuals (and particular communities) are irrational. They underinvest in levels of safety that might have been expected from "more rational" utility models of decision making. To reinforce this conclusion, the proponents of this argument point to the high levels of knowledge among citizens about the threat of earthquakes (Palm, et al., 1990). Despite this knowledge, earthquake protection investments remain modest to very low, a circumstance often interpreted as evidence of irrationality.

May and Birkland explain this alleged irrationality as a product of politics: suggesting that "local government risk-reduction programs have more to do with political demands and community resources than with objective risk" (May and Birkland, 1994). Berke and Beatley attribute the lack of interest in earthquake protection as the apparent "ability of humans to process information [that is] more limited than the rational approach would claim" (1992). Variations on this theme recur in the catastrophe risk literature. Slovic and his colleagues discuss the so-called gambler's fallacy, in which individuals assume that if a low-probability event has recently occurred, it will not occur again--that is, risk is zero (Slovic, Kunreuther, and White, 1974). Kunreuther speculates on the existence of a "probability threshold" such that if risks are perceived to be below some particular threshold, people respond as if the risk is zero (Kunreuther, et al. 1978).

Other observers of this mismatch between general knowledge that earthquake hazards exist and low investment in earthquake harm-prevention attribute it to the nature of the hazard. Slovic, for example, has proposed that, in general, people accept the potential for such hazards with some

degree of resignation, which contrasts markedly to how they view other, human-induced risks (Slovic, 1992).

This lack of concern about earthquake hazards, at least until very recently, showed both in earthquake insurance premium figures and in the extent of implementation of other earthquake harm-reduction efforts. In the 1970s, the percent of homeowners with insurance, even in at-risk areas, was sometimes under 5 percent, though such insurance was often available at modest cost. The percent of San Fernando Valley insured homeowners, which hovered at 40 percent, was an outlier in this sample (Wyner and Mann, 1986). For the most part, citizens have appeared "unwilling to insure against low-probability, high-loss events" (Palm, 1986). By the late 1980s, coverage had increased some 300% over 1970s levels, but the percentage of homeowners with earthquake insurance still remained relatively low overall.

How risk perceptions are formed is an interesting topic, but beyond the scope of this brief paper. For this discussion, the more critical question is whether failure to invest in earthquake-harm mitigation necessarily implies an "underinvestment." Assumptions regarding underinvestment in earthquake-damage mitigation suffer from what might be called a tunnel vision for addressing risks to life and property. Environmental scientist Kenneth Green has proposed—in other policy area—a "risk ledger" approach to supplant the single-risk (tunnel-vision) perspective found in many discussions of earthquake mitigation. The risk-ledger approach extends the traditional concept of opportunity costs to the realm of safety policy; it also adds to the notion of opportunity costs considerations of unintended consequences (Green, 1998). The point about opportunity costs is simple and well-acknowledged in most economic analysis of public expenditures. Specifically, opportunity costs build from basic notions of scarcity in time and resources such that a dollar (or time) spent in one endeavor is no longer available for other activities and investments that may be welfare-enhancing. In the context of earthquake mitigation, the fundamental question is never whether a particular measure (such as retrofitting of infrastructure) might reduce the potential for damages of a particular facility or building; rather, the fundamental question is whether those same dollars might be better spent on different actions, earthquake-related or otherwise.

This point itself is mundane, but its implications for safety policy are seldom fully appreciated. There are two aspects to these implications.

First is what Green describes as the potential unintended consequences of any given risk-mitigation measure. He writes, "while some safety improvement may be wrought through the impact of a given safety measure (also known as risk-reduction measures), we know that in many cases, the unintended (more often, unconsidered) consequences of the measure can produce countervailing impacts which erase some or all of the perceived benefit" (Green 1998). Sometimes these unintended consequences arise because the safety measure itself has ambiguous effects, as for example, in the case of air bags, which enhance safety for some but reduce safety for others. In other instances the unintended consequences are what might be called second-order effects. Earthquake-mitigation policies offer a potential instance of such effects. The costs of retrofitting multifamily dwellings, for example, may increase building operating costs and translate into increased rents, driving people into other, nonprotected, less-adequate living space.

The second, seldom-considered issue is the direct relationship between income and safety. Recent risk literature demonstrates that expenditures on safety which translate into reductions in economic activity may generate job losses and/or reduced income, which in turn are highly correlated with increased morbidity and mortality--i.e,, less "safety." (Keeney, 1997; Viscusi, 1994). Green summarizes this linkage between income and safety, noting that:

> people use their disposable income to weave what we might call a personal safety net around themselves and their loved ones. The more disposable income they have, the tighter the weave of their personal safety net. The less disposable income they have, the looser the weave (Green, 1998).

Several risk analysts have quantified this relationship, using data from the National Longitudinal Mortality Study relating income to the risk of dying. They estimate that, if costs are borne equally among the public, "each $5 million of regulatory cost induces a fatality" (Keeney, 1997).

Using this expanded opportunity cost framework, it is not self-evident that current levels of earthquake harm-mitigation are somehow irrational or represent underinvestments in safety. One needs to explore other factors that include, but are not limited to: 1) whether current decision-making institutions may be distorting individual and community perceptions such that earthquake risks are perceived to be lower (or higher) than they, in fact, are; and 2) what the expected net safety outcomes from proposed options might be.

Distorted Perceptions: Misalignments of Choices and Risks

There is some evidence of distorted perceptions of risk that result from a misalignment of incentives. Speaking of catastrophic risk decision-making, Klein argues that "any efficient solution must properly align incentives and choices with respect to risk" (Klein, 1998). He adds, "the greater the misalignment between risk choices and risk burdens, the greater the catastrophe losses that will be uninsured and the more inequitable will be the distribution of these losses" (Klein, 1998). Klein explains the problem another way, "when individuals bear the full costs and receive full benefits of the risks they incur, they should be motivated to mitigate this risk to the extent that it is cost-effective and purchase optimal insurance contracts (Klein, 1988).

For earthquakes, misalignment between risk burdens and risk choices takes several forms. First is the moral hazard problem in which, by externalizing risk costs from natural disasters through disaster relief or underpriced insurance, individuals and firms will have an incentive to take on greater risks than might otherwise be the case; they may also have fewer incentives to take prudent anticipatory harm-reduction measures. In the case of earthquakes the moral hazard problem results both from informational problems and from policies that have exacerbated rather than reduced the gap between risk choices and risk burdens. Most notable among such policies are those that provide subsidized insurance or mandatory insurance access and those federal, state, and local policies that offer disaster relief for rebuilding. For example, from 1988-1994, federal disaster assistance reached nearly $34 billion, with the Small Business Adminstration providing another $8.9 billion in special loans (ISO 1994b). State and local disaster assistance is also often provided to victims of natural catastrophes. Several studies have shown that the expectation of

disaster relief has translated into a reluctance by individuals to purchase insurance (Kunreuther, 1978; Rossi, et al., 1982).

Second is the adverse selection problem that accompanies low-probability, high-consequence risks where insurance prices are below expected costs. In the case of adverse selection, those most likely to experience extremely high losses are most likely to purchase insurance, while others choose to remain uninsured. Such decision-making prevents risk-spreading, which is a critical component of successful application of insurance to risk problems. Without risk spreading, the prospect of insurance firm insolvency in the face of a natural catastrophe becomes substantial. Indeed, after Hurricane Andrew in Florida, over 5% of insurers were bankrupted by the event. Presumably this problem could be overcome through better pricing of earthquake risk, reducing exposure concentrations, or diversifying the risk. Better pricing, however, requires better information. Palm notes that ideally insurers would have accurate information on expected shock damage, the frequency of potentially damaging earthquakes, the probabilities of different earthquake intensities, attenuation patterns of ground motion, and so on (Palm, 1990). This information is, of course, precisely what is lacking, making earthquakes an "uncertainty" rather than a typical "risk" problem, as noted earlier.

The Cost-Effectiveness Question

There is then some evidence of a misalignment of incentives resulting from a separation of risk-reduction choices and risk burdens. This misalignment may have resulted in some underinvestment in risk mitigation, both by individuals and communities. It may also have deterred investment in greater resilience (coping) strategies, including the purchase of insurance by individuals and the development of emergency-response programs.

However, two countervailing factors suggest that the very modest investment to date in anticipation strategies may be quite rational, contrary to many arguments advanced in the earthquake planning literature. The high degree of uncertainty about if, when, where, and how an earthquake might affect individuals, firms, and particular communities means investments in anticipation may yield small benefits relative to costs, and may compare disadvantageously with other investments. This is another way of saying that the opportunity costs of such investments may be high.

Many recently proposed earthquake policies fall into the category of "anticipation" — expending monies to reduce potential harms should an earthquake occur. These take many forms, ranging from surface fault zoning requirements that prohibit or restrict building along fault lines, to building codes, infrastructure and building retrofit mandates, and various land-use policies such as cluster development to concentrate building away from sensitive land forms (May and Birkland, 1994). See Table 2. Only a few policy efforts — in California, Hawaii, and Florida — have focused on insurance, and in these instances, the tendency has been to exacerbate rather than reduce the moral hazard problem.

The anticipatory measures have only haphazardly and generally unenthusiastically been implemented (Wyner and Mann, 1986; Berke, 1998). Yet interviews with local decision makers demonstrate several points: 1) most communities view other problems as more salient and that dollars

Table 2

Local Government Use of Earthquake Risk-Reduction Measures

	Percent of Cities Using Each Measure	
	California (n=27)	Washington (n=24)
General Risk-Reduction Measures		
Site plan review	52	83
Studies/impact assessments	41	58
Cluster development	19	21
Overlay zone	15	25
Dedication of open space	15	25
Conservation/hazard area zone	19	17
Disclosure of hazard	19	4
Impact fee	7	4
Downzoning	4	0
Earthquake-specific measures		
Retrofitting ordinance	44	0
Restrictions in unstable soil areas	22	25
More stringent seismic safety provisions	26	4
Mandatory setback	15	0
Landslide-specific measures		
Setback from head/toe of slope	22	50
Prohibition/density restriction	30	38
Special structural requirements	22	29
Site development standards	19	33

	Comparison of Dependent Variables[1]		
	CA (mean scores)	WA (mean scores)	*p*-value[2]
Extent of risk-reduction measures	3.89	4.17	0.76
	(3.57)[3]	(2.67)	
Extent of general risk-reduction measures	1.89	2.38	0.34
	(2.08)	(1.44)	
Extent of earthquake-specific measures	1.07	0.29	0.00
	(0.87)	(0.46)	
Extent of landslide-specific measures	0.93	1.50	0.15
	(1.30)	(1.53)	
Implementation effort	4.63	4.41	0.73
	(2.02)	(2.13)	

[1] Dependent variable measurement is discussed in Appendix 1.
[2] *p*-values are for pooled t-test for difference in means between California and Washington
[3] Standard deviation for mean scores shown in parenthesis.

Source: Peter J. May and Thomas A. Birkland, "Earthquake Risk Reduction: An Examination of Local Regulatory Efforts," *Environmental Management*, vol. 18, no. 6, 1994, Table 1, p. 927.

spent on other problems will have more clearly demonstrable results; and 2) knowledge about effectiveness of measures remains extremely low. In the latter case, engineering capabilities are high, but predicting just what ground movement will occur in any given location is low; hence, retrofitting may incur large costs to build for what is essentially "past" ground movement experience. Future experience may not replicate the past, and even retrofitted buildings and infrastructure may thus still fail in an earthquake. Both the knowledge and opportunity costs highlighted above suggest that current lackluster decisions about earthquake risk-reduction investments may, in fact, be rational. Put another way, the underinvestment problem may have been overstated.

IV. Earthquake Policy Revisited

Earthquakes can be devastating, as the 1995 Kobe disaster, with damages mounting to $100 billion, demonstrated. Three years after the quake, the city's recovery is still far from complete (Oakes, 1998). The scale of this disaster, and the recognition that a better anticipatory strategy might have prevented some harms, is just the sort of circumstance that seems to reinforce arguments for more prevention tactics.

But the very uncertainty of earthquake hazards suggests that, using Wildavsky's formulation, a strategy that relies more on resilience than anticipation may add up to a better safety investment. Some level of anticipation is likely appropriate for two reasons. First is the potential for extremely large harms, some of which are at least moderately predictable. Second is the availability of some technical tools that can enhance safety at relatively low costs, particularly in new construction. But these anticipatory measures are warranted only where the connection between the investment and hazard reduction is reasonably assured and net benefits over time are likely. Not siting directly on surface faults is one such example; discouraging siting on unstable soils may be another. Incorporating basic earthquake safety features in new buildings is likely another. Evaluating the cost-effectiveness of various anticipatory options is beyond the scope of this paper, but any such evaluation should use a total risk ledger approach, rather than a unidimensional one.

The Path to Greater Resilience

A catastrophe risk strategy that emphasizes resilience has at least three obvious components: 1) knowledge-building about the nature of expected risks, so that harm prevention may become increasingly cost-effective; 2) enhancement of emergency-response capability to improve the ability to "bounce back" after a catastrophe; and 3) improvement of insurance mechanisms in order to better align risk choices with risk burdens and improve "bounce back" capabilities.

This third dimension of a risk strategy warrants some further discussion. Insurance presents a choice structure that potentially can internalize the private harms incurred in the event of a catastrophe. Certain private risks, such as automobile damage from accidents, have been managed relatively well (though not perfectly) through private insurance markets. Klein (1998) points out that private insurance has functioned well in circumstances where "exposures are independent and diversified so that an insurer does not face potential losses for one or a series of events that will overwhelm its financial capability." He adds that in theory, "under certain conditions, individuals and firms will make optimal decisions about risk and insurance of their own volition that will

maximize social welfare" (Klein, 1998).

These conditions include an absence of externalities, open insurance markets, and good information about risks, none of which applies to earthquake catastrophes. Moreover, the potentially severe nature of natural catastrophes, the high levels of uncertainty, and the inevitably collective dimension of some harms, especially to public infrastructure, make pure "privatization" of catastrophe hazards through insurance improbable.

However, public policies and private institutional changes can improve the prospects that catastrophe insurance will provide substantial "bounce back" capabilities and better align risk choices with risk burdens. These public and private initiatives involve three tactics: 1) diversification of insurance risk; 2) reduction in risk externalities; and 3) adjustment of regulatory and fiscal policy incentives.

In the first instance, the insurance industry is already moving toward diversification in the wake of recent huge natural catastrophe losses. These endeavors include the expansion of reinsurance, the growing use of catastrophe-hedging financial instruments that include the selling to investors of risk packages in the form of catastrophe (cat) bonds (The Economist, February 28, 1998; Klein, 1998); and modifications in insurance contracts, including price and deductibility changes. The use of cat bonds in effect puts investors into the role of reinsurers. As The Economist (February 28, 1998) noted, through cat bonding an insurer's viability may hinge increasingly on "its ability to separate good risks from bad, and its system for shuffling those risks into the hands of investors." This risk packaging is important because, in effect, it reduces the significance of the uncertainty problem associated with earthquakes.

The second tactic is simple to construct theoretically but difficult to implement politically. Specifically, current disaster relief grants and loans play a key role in externalizing what would otherwise be private risks. Such payments reduce perceived private losses, thereby diminishing incentives to purchase insurance and to take prudent risk-mitigation measures (Klein, 1998). An alternative to disaster relief in the form of construction grants and loans would be the provision of short-term aid and emergency-response assistance. A transition away from construction grants and loans is, however, likely to be politically difficult.

The third tactic is a restructuring of regulatory and fiscal policies that affect risk choices and insurance effectiveness. Most notable are tax policies that limit insurers' ability to build catastrophe reserves. Under current U.S. tax policy, catastrophe reserves are treated as taxable income, hence insurers have a reduced incentive to accumulate such reserves. Tax law also may discourage homeowners from insuring against catastrophes, since property losses are deductible but catastrophe insurance premiums are not (Klein, 1998). The trend toward regulating insurance may also inhibit evolution of the industry toward greater diversification and toward adjustments that permit better risk-spreading. Price and access regulations, in particular, reinforce rather than reduce the misalignment of risk choices and risk burdens.

Conclusion

Catastrophes create crises. Their drastic potential consequences also invite Cassandra-like depictions of future chaos and destruction. The seemingly logical response to spectres of crisis and chaos is precaution. Translated into public policy this precaution typically means appeals for preventative measures. For earthquake hazards, this has meant a steadily growing voice for building and infrastructure retrofits, stricter building codes, and prohibitions or restrictions on development. This paper has argued that a policy relying more on resilience, with modest doses of anticipation, is likely more appropriate given the high levels of uncertainty both about whether and how a prospective catastrophe will occur and just what measures reliably will generate net benefits. Equally important are measures that will reduce risk externalities so that private risk choices are better aligned with potential risk burdens. Better aligning risk choices and burdens is likely to unleash more private investment in personal resilience as well as risk mitigation, with the private decision maker weighing costs with expected benefits.

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Lynn Scarlett's very insightful paper makes several important points that should be taken very seriously in crafting a social science research program related to each quake risks and responses. I think she is right when she points out that earthquakes are not subject to risk analysis, but rather should be considered in terms of uncertainty rather than risk. The possible outcomes of the event are unknown, and the probabilities of each outcome are unknown.

I think she is also correct to point out that most responses to our perception of earthquake threats are technocratic and deal with hardening targets rather than with resiliency....we don't pay sufficient attention to planning or analyzing institutional responses when institutions are under severe stress, such as after an earthquake, nor do we worry much about economically rational collective policy responses to disasters. She makes a compelling point when she argues that strengthening structures to withstand earthquakes is probably less cost effective, given the high degree of uncertainty as to where and how the quake will hit, than would be spending money on what she calls resiliency — the capability to respond effectively at short notice to a much wider variety of potential conditions — to earthquakes of large magnitude disrupting economic, social and governmental organizations.

She is also right to raise the question of whether our public policies actually discourage people from acting individually to protect themselves against losses. If FEMA and SBA rush to help us obtain low interest loans and grants, it is economically rational to "underinvest" in insurance.

Because I agree with so much of what Lynn says, rather than devoting my time to disagreeing with anything she said, I would like instead to comment on some related issues that came to mind when I read her paper, but which are outside of the particular points on which she touched.

And just as background, I'd like you to know that my own very limited experience in earthquake research was a farily systematic comparison of the impacts of the Loma Prieta and Northridge earthquakes on the transportation systems of the two metropolitan areas that they hit.....The Bay area and Los Angeles, and in particular the institutional response of transportation agencies to the emergency situations they faced in each city. At the time of the Northridge earthquake I was "transportation advisor" to Mayor Richard Riordan of Los Angeles, and in the weeks following the earthquake, I attended a couple of dozen meetings at which responses to the earthquake were discussed and different interests and organizations coordinated their responses. I base some of my reactions on what I observed happening at those meetings, which is admittedly less "scientific" than the research that I did, but which also strongly influenced my thinking.

For one thing, I was struck by the extent to which people attending these meetings — public officials, agency directors, seemed to be having such a good time. Rather than observing a scene in which people were seriously distressed over economic losses and deeply concerned about public health and safety, I saw people who were almost elated — they were the center of attention, newspaper and television reporters wanted to interview them; they felt extremely important and seemed to me gratified that the earthquake had come along to give them the opportunity to shine.

Lynn argued that some of our public policies are perverse in that they encourage citizens to transfer risk from themselves individually to instead depend upon public programs to cover their losses. Lynn did not comment on the logical extension to this, which I believe is also true, and that is that public agencies and entities act similarly. Caltrans and the University of California and those who manage our water supply and sewerage systems, who under normal circumstances would be expected to be "self insured," also are able to call upon legislative bodies for special taxes and for large grants to repair earthquake damage, and so they need not and do not create very large reserve funds for the purpose of covering unexpected losses. In fact, special allocations of money by the State Legislature and the U.S. Congress, enabled Caltrans to bear a substantial proportion of the cost of repairing roads and bridges from sources of funds beyond their usual budgets.

Not only were those allocations forthcoming rather quickly, but they had fewer reviews, fewer means tests, fewer legislatively imposed restrictions on how they could be spent.

The issue can be presented in fiscal terms, but it actually is much broader than a funding issue alone. For a brief period of time following a disaster, we seem to suspend our usual complex governmental processes of checks and balances and approvals and reviews and study commissions, and grant to public agencies the power to act quickly and without review and approval. The agencies respond by reveling in their temporary freedom to act on our collective behalf, and to be reimbursed by generous legislatures. Caltrans was pulling down overpasses, letting contracts for new construction, designing overpasses, paying bonuses and This leads to the distinct possibility that under our existing institutional arrangements there are actually benefits to certain agencies from major disasters rather than only costs. Agencies can increase cash flow, hire more consultants, increase their prestige and political capital by proving that they can get things done under pressure of emergency situations. And, as time passes and damage is repaired, we do lapse back into our usual slower and more costly and more democratic consultatative processes....leading to fewer decisions and more disagreements. An important question for researchers would be: why are we unable to streamline decision processes under normal condisions, after having learned from disasters that they can be streamlined when they need to be?

I was shocked at the number of people who told me that they thought the governmental system in LA performed brilliantly during the period of preparation for the 1984 Olympics, and when the Olympics were over they lapsed back into the usual bickering and backbiting.....and that the post-earthquake period was in fact very similar to the pre-Olympics period. It was satisfying to the agency personnel, and they believed they lived up to the public trust and produced real results. But, that effect wore off with time.

Transportation System worked well in both Loma Prieta and Northridge. Few economic losses due to failure of transportation system. Few businesses closed because workers failed to access their work places; because materials were undeliverable to factories. Etc. Reason was redundancy. Infrastructure so highly developed that there were alternatives that enabled us to bypass damaged routes.

Lynn suggested that given the very high degree of uncertainty, it might not be logical for me as a

private owner of property to invest heavily in strengthening that property against earthquakes. The probability is so low that my structure will be damaged that the expected payoff from the investment might be not worth the costs.

I would like to propose that we ask whether the same sort of question can be raised about such projects as the replacement of the eastern span of the Bay Bridge. If we have a choice between strengthening key elements of the regional network or using those resources to extend the network, should we perhaps be asking whether the Bay area would be better off NOT reinforcing the Bay Bridge or replacing the eastern span, and instead using the resources to build another bridge across the bay at another location? While a really strong earthquake might bring down the reinforced eastern span, it might be less likely to knock down two spans at two locations than one reinforced span, and the benefits of redundancy might be greater than the benefits of a strengthened bridge. Politically this is probably not a question worth asking, but intellectually it is, and the answer might be of great interest.

Political Engineering For Earthquakes

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I. Introduction

Several years ago one of the authors of this paper attended a meeting of the Carnegi Commission on Science and Technology in Aspen Colorado. The stated purpose of the gathering was for the scientists on the Commission to quiz a number of political scientists on how to improve the average Congressperson's understanding of science. In short the stated goal was "science for policy rather than policy for science." Of course the real goal was just the opposite, how to build public and elite support for continued funding for science in a post Cold War Era. When the scientists present finally "fessed up" to their real fears and desires, the political scientists recommended that, rather than engage in a campaign to educate the general membership of Congress, the scientific community should continue to exploit its current advantage of having science policy controlled within the Congress by a small group of elite Members. In the jargon of social science our view was that the scientific community's power in the Congress derived in large part from its asymmetry of information, and that it should exploit that asymmetry rather than eliminate it through an education process. Unhappy with this seemingly anti-democratic advice a noted scientist turned to the political scientists and said that they were nothing but "political engineers."

Taking this slur as a badge of honor the goal of this paper is to sketch out political engineering for earthquake protection. We admit that we lack all technical knowledge of earthquakes and earthquake protection. So if we make mistakes about the science please view us as your typical Californians. But then one of your problems in creating better public policy for earthquake protection is precisely to deal with typical Californians and their representatives.

What we hope to offer is a summary of what we know about the creation, adoption and implementation of public policy. Two caveats: First, although the ultimate goal is to improve public policy for earthquake protection, knowledge about the creation, adoption and implementation of public policy can be used to create worse as against better public policy. In short, and unfortunately, good politics does not necessarily imply good policy (and visa versa). In fact knowledge about politics is often uncorrelated with knowledge about the substance of policy. Second, although many of you will find our knowledge about the benefits and costs of the substance of public policy imprecise compared to your scientific knowledge, our knowledge about the creation, adoption and implementation of public policy is even less developed (and precise). For this reason the potential research agenda for any student of the politics and policy of earthquake protection is long indeed.

We will first address what academics can offer experts who want to translate their ideas into policy. Then, at the end of the paper, we will offer some research agendas for improving our knowl-

edge of political feasibility when it comes to earthquake mitigation and recovery.

II. The Problems

At one level the creation, adoption and implementation of public policies toward earthquakes are no different than the creation, adoption, and implementation of any and all public policies. The analytic problems are in the larger sense the same. A policy has to get (or be put) on to the political agenda (what political scientists have called agenda setting), policy options have to be created and pushed, in a representative system majorities have to be created for the enactment of a policy option, and the option has to be interpreted and implemented by a bureaucracy and the judiciary. The academic models that have been suggested to explain these processes are not policy area specific.

But public policies for earthquakes are different from many policy problems in the following respects:

Two Problems: Preparing for Disaster and Dealing With the Fallout of Disaster. As Peter May points out, public policy for earthquakes involves questions of what should be done between disasters (support of research, creation and implementation of building codes and the creation and maintenance of bureaucracies to write and enforce those codes and to be in place when the earthquake strikes) and the management of the aftermath of an earthquake catastrophe (including the short term saving of lives and the medium and long term tasks of reconstruction) (May, 1988, pp. 239). For Peter May, at least these are two very different political worlds.

Episodic Catastrophes. Major earthquakes are periodic events that have the potential of great loss of life and infrastructure. Although you are now able to place (reliable?) probabilities on the fact that a major earthquake will occur within a multi-year period, your science has not advanced to the point where you can tell the public and their representatives when during that multi-year period the earthquake is likely to occur.

Massive Investment Needed. The amount of investment needed to retrofit existing structures for earthquake safety is quite large. UC Berkeley, for example, has just estimated that its current retrofit needs will cost it around $700 million.

Safety Requirements Keep Changing. Not only will retrofit requirement be very expensive, but their cost keeps rising as you learn more about earthquakes from past failures. Thus, prior to the Kobe earthquake the scientific community pointed to Japanese standards as a model for the US. Now we are not so sure. We gather that the Northridge earthquake was caused by the existence of faults that were unknown and thus were not planned for in existing earthquake standards.

High Technical Skill Required. At one level earthquake preparedness is readily understandable - bolt and sheer wall. At another level, however, the science of earthquake prediction and prevention is highly technical and (as pointed out above) constantly changing as the scientific community gains knowledge. As such, earthquake politics is like much of science politics in the gap between the knowledge of the elite and the policy decisions faced by the mass.

Earthquakes Occur Across Political Jurisdictions. We are in an era of political decentralization, yet earthquakes do not stay within governmental boundaries. Thus preparedness, disaster mitigation and recovery require coordination among governments, a seemingly simple task that is surprisingly hard to bring off.

What are the political implications of the above? First, you (the experts) are asking politicians to support massive investments of capital and other resources for an event that is likely to take place outside their political lifetimes. And, you want the public to invest their resources for an event that can occur when they move out of an earthquake zone or after they have died.

Second, the episodic nature of earthquakes and the scientific community's inability to create better probabilities as to when earthquakes will occur reinforces the public's tendency to either go into denial or to make a rational decision not to invest in earthquake preparedness. As put by Peter May:[1]

Despite the extent of moderate to high earthquake risks, there is not much of a public constituency pushing for efforts to avert earthquake losses. This deficiency cannot be explained by a lack of awareness of earthquake hazards, because in fact there is a fairly high degree of public awareness within areas subject to moderate to high seismic risks. The awareness, however, is accompanied by varying degrees of indifference about their risks....

Reflecting fatalistic attitudes toward earthquake risk, organized public demand for governmental action in reducing earthquake risk appears to be both rare and short-lived....

The lack of a public constituency, coupled with local officials' own limited concern about earthquake risks, has created minimal incentives for local governments to address earthquake risks. Left to their own devices, relatively few of the high- to moderate-risk communities would be expected to initiate risk reduction efforts (May, 1991, pp. 268).

Third, the changing of earthquake standards undermines your credibility when you ask society to make massive investment in earthquake mitigation. As a result political elites might simply see you as another interest group asking others to fund your special interest.

III. Approaches for Integrating Specialized Knowledge into the Public Policy Making System

Given the technical nature of earthquake research, should scientists who have specialized in this area try to influence the policy making process? If so, how?

Many researchers (including social scientists) see politics and the political process as a cost. That is, they see their task as creating the best science or, in the case of social scientists engaged in policy research, the best policy proposal. To get that proposal adopted and implemented the scientist then allows it to be watered down until it is politically acceptable. Sometimes the scientist does this herself in anticipation of the needs of the political system. Most times, however, she allows others to modify her plan - often with sadness if not disgust.

Two generic models have been suggested for incorporating political feasibility into policy research. One, put forth by Arnold Meltsner, calls for the researcher or analyst to gain political as well as technical skill (Meltsner, 1976).[2] In the best empirical study we have of who policy analysts are, what they do, and how they interact with their environment, Meltsner classified his sample of analysts along two dimensions: their degree of technical skill and their degree of political skill. This allowed him to classify his analysts into four categories: those with low technical and political skills, who he labeled Pretenders; those with high technical skills but low political skills, who he labeled Technicians; those with high political skills but low technical skills, who he labeled Politicians; and those with high technical and high political skills, who he labeled Entrepreneurs (Meltsner, 1976, pp. 17-49).

Being the faculty member responsible for political and organizational analysis at Berkeley's Goldman School of Public Policy (GSPP) Meltsner is clearly biased in favor of the Entrepreneur. For him, "Much of the effectiveness of future policy analysis will depend on them, a subject I will return to... when I urge the need for greater political sensitivity on the part of policy analysts" (Meltsner, 1976, pp. 37).

A large literature has accumulated over the past two decades - largely created by academic who have served in government - that attempts to set out the skills and "do's and don'ts" that will allow the analyst to be effective in the political environment (see, for example, Behn, 1981; Enthoven, 1975; Leman and Nelson, 1981; and Verdier, 1984). The implication of this literature (and the Meltsner approach) is that, to be effective in the policy making process, earthquake researchers should build their own political skill. That they should be active in the political as well as the technical aspects of the policy making process.

A very different model for the researcher has been suggested by James Sundquist (Sundquist, 1978). For Sundquist:

As in the marketing of physical goods, the producer of social science knowledge rarely deals directly with the consumer.... There are exceptions — John Maynard Keynes once talked with Franklin D. Roosevelt[3] but such a situation is analogous to a farmers' market: not a very large proportion of agricultural produce is sold that way (nor is it clear that Keynes made a sale on that occasion. Agricultural marketing is the responsibility of a chain of intermediaries. So it is with the marketing of social science research. (Sundquist, 1978, pp. 127)

Rather than positing an Aristotelian ideal of the researcher with high political as well as technical skills, Sundquist posits a system of knowledge marketing. This system involves a chain in which "pure" research of (academic) researchers is interpreted by academic intermediaries - those "who have a flair for interpreting, in nontechnical or at least semi-technical language, the technical findings of their colleagues..." (Sundquist, 1978, pp. 128). In the Sundquist model the output of the Academic Intermediaries is then made accessible to policy makers by Research Brokers - those who take academic research and make it useful for a particular policy maker or set of policy makers facing a particular policy problem. The Sundquist research brokerage chain looks like the following:

Researcher → Academic Intermediaries → Research Brokers → Policy Makers

For the present discussion a key to the Sundquist model is the fact is that in contrast to the Meltsner approach it is an organizational solution to the melding of technical and political knowledge. The Researchers in the model are not asked to gain political skill. Rather, as one progresses from left to right the amount of political skill and interest increases. The hiring experience of the Clinton Administration appears to support the Sundquist approach. Over the past five years fourteen Berkeley economists have held high (Deputy Assistant Secretary and above) positions in the Clinton Administration. Most were hired because of their technical skills and knowledge. In their jobs their were either shielded from the political process or worked in teams with what they describe as the "political types."[4] What is surprising is the fact that very few professors from schools of public policy — the institutions that were created to educate Meltsner's Entrepreneurs — have served in the Clinton Administration.

IV. Political Engineering

Assuming that one knows what the best policy is for earthquake mitigation, preparedness, recovery and/or reconstruction, how can one get that policy adopted? One alternative is to simply turn over the political aspects of the adoption and implementation process to those with political skills — old political hands, lobbyists, etc. This approach is fine as long as one is willing, like the author of a novel that is being turned into a film, to walk away and let one's ideal be modified for the political process. But if one is interested in creating a policy that is both politically acceptable and that leads to an improvement in social welfare one might want to build political feasibility into the original design of the policy option.

If one wants to build political feasibility into one's **proposal** one would first naturally turn to the scholars of politics — political scientists — for insights and models. Unfortunately, as Donald Stokes points out, political science is largely a descriptive rather than an instrumental discipline (Stokes,). Only in the last several decades has the discipline moved away from case studies toward formal models of political behavior and political institutions.[5] Recent models can generally be grouped under two rubrics: the deterministic model of social choice (or public choice) theory and the stochastic models or organizational decision making.

(1) Deterministic Models

Although quite complex mathematically, the models of social choice theory are in effect applications of interest group theory. One starts with the assumption that the policy outcome is the resultant of conflict among interests. In the language of economists, policy is the result of the supply and demand for public policy.[6] The basic model assumes that the winner of a political conflict is determined by the following factors:

- To What Extent Will An Interest Be Active? Since the work of Mancur Olson students of political behavior know that free riding makes the organization of interests extremely difficult (Olson, 1965). As a result in any policy debate some interests will be much more active than others. In fact, one approach to politics (and resulting predictions of who will

win) holds that the side who will receive or bear concentrated benefits or costs will almost always beat the side whose benefits or costs are dispersed. Put another way, the higher the per capita benefit or costs the more political activity an individual or group will engage in. This insight lies behind the University of Chicago view of the politics of regulation (Stigler, 1971; Peltzman. 1976; Wilson, 1980). In the past the American scientific community's power in the policy process has in part arisen from the fact that it has been highly active in support of its goals (because of the high per capita benefits obtained by its members) while potential opponents have been largely non active.[7]

- What Endowments Will Each Interest Group Bring to the Policy Debate? Holding activity constant, the interest that will win the policy debate will be the one that has the most assets. Assets vary from numbers of members, to money, to asymmetries of knowledge, to ease of organizing, to geographic coverage in a representative system, to political skill. Although this aspect of the interest group conflict has the longest history of study, we still know very little about which assets (or balance of which assets among competing interests) are the most important in given situations. This is clearly one area for future research.

- The Effects of Institutional and Procedural Arrangements. Even in a situation in which one side of the policy debate is more active than the other side and in which the more active interest has greater assets it is still possible that the other (less active, fewer assets) side will win. This is because power is not evenly distributed in the political process. For example, a committee chairman is able to block a proposal even if he is in the minority. The analysis of the distribution of power is both at the heart of political science and one of the reasons it has never become as "useful" a field as economics: for power is almost impossible to quantify. But one can get a crude notion of power by asking whether a person, a group or an organizational unit is in a position to block a proposal. Such actors are able to gain rents. Measuring the magnitude of those rents provides a rough guide to the power of the individual, group or organizational unit.

  In the strategic politics literature these individuals/groups/organizations are frequently labeled gatekeepers. But their location varies from system to system. That is, the gatekeeper in Chicago, Illinois is in a very different place (most often the Alderman) than in Berkeley, California. Knowing the location of gatekeepers and their relative ability to block the adoption or implementation of a policy is institutional knowledge, and therefore needs to be hired on the spot.

- The Art of Politics (Heresthetics). One of the major insight of modern social choice theory is that there is no one stable or right way to make policy decisions. No one right voting mechanism. No one right policy making process. No one right, stable equilibrium. Rather any process that we adopt induces a particular outcome; what Kenneth Shepsle and Barry Weingast have labeled a "structurally induced equilibrium."

  The battle over the appropriate equilibrium opens the way for a set of political process games. Games over which voting mechanism to use, which items will be on the political agenda, which dimensions of a multi-dimensional policy will govern the debate and decision, and strategic voting behavior. William Riker has labeled the manner in which these

games are fought out, the art of heresthetics (a made up work from the Greek roots for choosing and electing) (Riker, 1982 and 1986).

Unfortunately, although a center for formal modeling, for practitioners heresthetics remains an art rather than a science. As put by Riker, "There is no set of scientific laws that can be more or less mechanically applied to generate successful strategies. Instead, the novice heresthetician must learn by practice how to go about managing and manipulating and maneuvering to get the decisions he or she wants." (Riker, 1986, pp. ix) At this point we have come full circle back to the practical experience of old political hands. Clearly one area for further research is to do for heresthetics what student of business strategy have done for their field. This would not only involve continued work in formal political theory but would also call for the application of game theory and other techniques to create a field of applied public or social choice theory.

- Credible Commitments. In the last decade a literature has been created to address strategies used by winning majorities (in the legislature, in the executive branch, or among interest groups) to increase the probability that future majorities will not undo their policy innovation (Shepsle, 1992; Patashnik, 1997). For example, interest groups seek to gain entitlement status for their programs so that they will not be subject to an annual appropriations process. Earmarked taxes and trust funds have been shown to change the nature of the politics surrounding a program. Programs can be designed so as to build lasting public support, the most famous case being Franklin Roosevelt's design of the Social Security Program to convince the American public that it was an insurance rather than a welfare program.

Although formal social choice approaches have been most frequently applied to legislative behavior they are equally applicable to organizational analysis. Oliver Williamson's Transaction Costs Economics (TCS) and principle-agent theory are but two of the approaches that have been developed not only to go beyond the traditional case study approach of much of organizational behavior but to develop a framework for predicting winners and losers. Again, as with the social choice theory of legislatures, what needs to be developed are applied strategic models.[8]

How could these models be used to engineer the politics of earthquake prevention, mitigation, recovery and reconstruction? You might want to ask: Who will be active in the debate and to what extent? That is, is it in our interests to widely publicize the issue or do we have a competitive advantage in the present situation? Who will benefit and who will bear the cost of the policy? Are these benefits concentrated on a few individuals or widely dispersed across many individuals? If we have to publicize the issue, on what dimension of the issue, or allied issues, will be most likely be victorious? Who are the gatekeepers and what is the price of their support?

In answering each of these questions the designer of the policy might want to create and incorporate incentives for political support. For example, highway demonstration projects in fact are relatively cheap ways of gaining the support for the passage of an omnibus highway bill (Ellwood and Patashnik, 1992). A more interesting case involves the effectiveness of workers' compensation systems. It appears that more effective systems (higher payments to injured workers for lower premiums) occurs with those systems where the prime beneficiaries of the system (workers and busi-

nesses) gang up on providers (insurance companies, the medical community, lawyers, etc.). In many states the natural hostility between labor and management has allowed providers to split the worker-management coalition. In California, for example, the politics of workers' compensation finds management allied with the insurance companies, the medical community and the Republican Party with labor allied with the trial lawyers and the Democratic Party (and those parts of the medical community who earn a good living off the current system). What is needed is a policy design that will create an incentive for the two principles — business and labor — to join against their agents (insurance companies, the medical community and lawyers (particularly trial lawyers). In Washington State a few such incentives have been added to the system. Workers, for example, have to directly pay for part of the program's premium. Employers are paid by the State to allow the state to come into the workplace to provide advice on how to improve the firm's safety record; which in turn results in lower premiums. Finally, the program is jointly run by representatives of the business community and organized labor.

2 Stochastic Models

A great virtue of social choice theory is that it seeks to build formal predictive models. A disadvantage is that there are types of politics (or political situations) that it cannot explain or whose outcome it would not predict. This is particularly true for situations where the side with dispersed (low per capita) benefits or costs wins out over the side with concentrated (high per capita) costs or benefits. Moreover, it is not very useful in explaining why a given policy topic is or is not on the political or policy agenda. Finally, it cannot explain the general pattern of policy development: where large non-incremental policy change occurs episodically after long periods of small incremental changes.

In recent years John Kingdon's version of the Michael Cohen, James March and Johan Olsen Garbage Can Model of Organizational Choice (Kingdon, 1995; March and Olsen, 1972) has come to dominate our understanding of agenda setting. While lacking predictive power the Garbage Can model provides several managerial insights that are particularly relevant for designers of better public policy for earthquakes.

The Garbage Can model was developed to explain particular organizational and decision making situations - those that its creators label "organized anarchies." Although the original intent was to explain University decision making, the model is equally applicable to public sector decision making. Organized anarchies are those decision making procedures and institutions characterized by uncertain and/or multiple preferences, uncertain technology or technological processes, and variable and floating participation of decision makers. I am sure that you will all agree that Universities fall within this description. We would argue that public sector decision making about earthquakes also falls within the scope of the model.

The basic model posits a series of separate streams. In the Kingdon version there are three streams: a stream of problems, a stream of policies, and a stream of politics. The streams are not particularly corrected. Rather they can be thought of a series of chemicals in a beaker. But every once in a while an exogenous event occurs that causes the streams to be joined or coupled. In the beaker analogy can think of lightening randomly striking the primordial sea of early Earth and

causing the creation of the building blocks of life.

In the model the exogenous event opens a “policy window.” The opening of such a window is the necessary (but not the sufficient) condition for large, non-incremental, policy change. Because the exogenous events are random, however, the opening of the policy window cannot be predicted. Moreover, in the model policy windows close rapidly.

Through a secondary analysis of a series of ten case studies Elliott Mittler found that state adoption of flood and hurricane mitigation laws followed the Garbage Can model (Mittler, 1988, pp. 106-107). All three streams had to be present and active for a state to adopt a law (five of the ten states adopted) laws. When one or more of the streams was absent the legislation was not adopted.

One of the key insights from the Garbage Can model is the need for pre positioning of policy plans. We know from studies of public opinion on earthquakes that right after a major quake the public and the political system are susceptible to the adoption of major changes in earthquake policy. But we also know that the public and political elites soon return to their normal equilibrium of living with the earthquake risk. This is a perfect illustration of an unanticipated policy window (the major earthquake) that quickly closes. Unfortunately for the advocates of earthquake prevention and amelioration, in the days, weeks and maybe months after the quake they are usually so busy with recovery and reconstruction that by the time they have created and moved their policy changes the window has closed and the political system has returned to its pre-quake equilibrium.

The solution to this dilemma is to preposition the plans (legislation, regulations, etc.) for earthquake prevention and amelioration. When the window opens the task is then to shove the plans through as quickly as possible. Of course, opponents of the plans also have a strategy that flows from the Kingdon model — stall, stall until the window closes.

A second major insight of the Garbage can model is that the making of public policy often has the opposite logic of the study of public policy. The study of public policy almost always starts with asking, “what is the problem?” Once this goal is set out the analyst then creates a series of policy options, determines the criteria that will be used to judge those options, collects data, and uses those data to see which option scores the highest on the set of criteria.[9]

A key actor in the Garbage Can model is Kingdon’s policy entrepreneur. For Kingdon policy entrepreneurs are advocates of a particular policy who “are willing to invest their resources — time, energy, reputation, money — to promote a position in return for anticipated future gain in the form of material, purposive, or solidary benefits” (Kingdon, 1996, pp. 179). One function of policy entrepreneurs is to soften up the system by constantly pushing their policy solution. In so doing they reverse the direction of the causal arrows of the policy researcher. Instead of starting with a problem and then determining the best solution, the policy entrepreneur is constantly selling her solution for your problem. The goal here, of course, is to broaden the coalition behind the entrepreneur’s solution. Thus, your earthquake policy should not only affect health and safety but as many aspects of the quality of life (higher growth, lower unemployment, lower inflation, etc.) as you can reasonably tie to its substance.

3 Implementation Models

The enactment of a public policy is no guarantee that it will actually do what its sponsors sought to achieve. Beginning with the work of Aaron Wildavsky and Jeffrey Pressman (Wildavsky and Pressman, 1973), students of public policy have sought to study how, in Eugene Bardach's words, we can arrange the "Patterns of social conduct so as to honor the prescriptions set forth in some policy mandate..." (Bardach). As Bardach further points out,

> The implementation process is the social activity that follows upon, and is stimulated by, an authoritatively adopted policy mandate, which prior to implementation is only a collection of words. This policy mandate might be a piece of legislation, a court decision, or a bureaucratic command. If the implementation process is bounded on its near side by the policy adoption process, it has an analogous boundary on its further side: at some point in time it turns into a relatively fixed set of operating routines (Bardach, 139).

Implementation analysis of public policies for earthquakes is particularly relevant because of the need to build and gain coordination among governments. Thus, a number of scholars including Peter May and Walter Williams have studied the implementation of disaster policies (May and Williams, 1986).

If truth be told, however, implementation analysis has never lived up to its promise of providing the analytic underpinnings that would differentiate policy analysis from applied economics. It has never gone beyond the traditional studies of organizational analysis and design. Its findings come all too close to the "proverbs of administration" that Herbert Simon criticized forty years ago. In short, implementation research is still in the stage of a contingency analysis — it all depends and context is almost everything. And because of this it all too often consists of a series of case studies with non-generalizable results. Yet it is also true that a failure to incorporate an implementation analysis in most cases guarantees the failure of a policy innovation. The task is to save implementation studies from its current role as the policy analysts' equivalent or organizational development.[10] As such it remains a major area of potential research.

II. CONCLUSION: A RESEARCH AGENDA FOR STUDYING FEASIBILITY AND POLICY ANALYSIS

The title of this conference includes policy analysis as one of the topics. Before turning to a research agenda for political feasibility one should first define policy analysis. David Weimer and Aidan Vining define policy analysis as "analyzing and presenting alternatives available to political actors for solving public problems." (Weimer and Vining, 1989, pp. 3).[11] It involves the "synthesis of existing research and theory to estimate consequences of alternative decisions"... for "a specific decision maker or collective decision maker" (a client) (Weimer and Vining, 1989, pp. 3).

Table 1, taken from Weimer and Vining's text, compares policy analysis to other forms of social science research such as pure academic research and policy oriented research, as well as classical planning and public administration. In this typology, pure social science research involves the "construction of theories for understanding society" by employing "rigorous methodology to con-

struct and test theories," often retrospectively (Weimer and Vining, 1989, pp. 3). Policy research (or applied social science research) involves the "prediction of impacts of changes in 'variables' that can be altered by government," through "applications of formal methodology to policy-relevant questions," often involving the prediction of consequences (Weimer and Vining, 1989, pp. 3).

Given these three descriptions we believe that the task before this group is not to recommend a research agenda for the policy analysis for earthquakes, but to step back and create a research agenda for policy research for earthquakes. But that applied research should be constrained by the application of realistic models and assumptions. Eugene Smolensky has suggested the following test to differentiate true policy relevant research from the standard example of applied research. As we all know almost every article these days includes a section — toward the end — labeled "policy implications." The test is to tell the author that they have been elected dictator and are now free to implement the suggestions of this section. Smolensky's prediction is that the author will recoil in horror, exclaiming that you have to understand that these results come from a highly stylized model, under rigorous assumptions, etc.

The first question that PEER must ask is whether it seeks to support pure research, applied policy research, or policy analysis? In the area of political feasibility, given our limited knowledge, we would suggest a combination of pure and applied policy research. Below is a list of pure research topics. But, the real danger for PEER is to try to bee all things to all research agendas.

Source: David L. Weimer and Aidan R. Vining, **Policy Analysis: Concepts and Practice** (Engelwood-Cliffs, NJ: Prentice-Hall, 1989), p. 3

Given this background here are some suggestions for research funding:

> 1. The Strategies of Political Feasibility. The development of the equivalent of business strategy for political feasibility. That is, the task is to turn descriptive political science, where one stands back and describes the political universe, into a instrumental discipline.
>
> This would involve the application of game theory to the decisions faced by political actors and a significant advance in social choice theory. It would involve an attempt to shift heresthetics from an art toward a science. It would move the analysis of political phenomena from case studies toward formal modeling.
>
> 2. Designing Public Policies To Increase The Likelihood of Political Feasibility. As previously stated the typical pattern is for policy analysts to choose the "best" policy and then seek to minimize the damage required to make the policy acceptable to the political process. An alternative would be to study how incentives can be incorporated into the policy design to improve its political feasibility without (or with a minimum) loss the policy's efficiency.

Table 1

Policy Analysis in Perspective

Paradigms	Major Objectives	"Client"	Common Style	Time Constraints	General Weaknesses
Academic social science research	Construction of theories for understanding society	"Truth" as defined by the disciplines; other scholars	Rigorous methodology to construct and test theories; often retrospective	Rarely external time constraints	Often irrelevant to information needs of decision makers
Policy research	Prediction of impacts of changes in "variables" that can be altered by government	Actors in the policy arena; the related disciplines	Applications of formal methodology to policy-relevant questions; prediction of consequences	Sometimes deadline pressure, perhaps mitigated by issue recurrence	Difficulty in translating findings into government action
Classical Planning	Defining and achieving desirable future state of society	The "public interest" as professionally defined	Established rules and professional norms; specification of goals and objectives	Little immediate time pressure because deals with long-term future	"Wishful thinking" in plans when political process is ignored
The "old" public administration	Efficient execution of programs established by political processes	The mandated program	Managerial and legal	Routine decision making; budget cycles	Exclusion of alternatives external to program
Journalism	Focusing public attention on societal problems	General public	Descriptive	Must move while issue is topical	Lack of analytical depth
Policy analysis	Analyzing and presenting alternatives available to political actors for solving public problems	A specific decision maker or collective decision maker	Synthesis of existing research and theory to estimate consequences of alternative decisions	Completion of analysis usually tied to specific decision point	Myopia produced by client orientation and time pressure

Source: David L. Weimer and Aidan R. Vining, Policy Analysis: Concepts and Practice (Engelwood-Cliffs, NJ: Prentice-Hall, 1989), p.3

An example, that to our knowledge has yet to be studied, is the Federal Emergency Management Agency's (FEMA) shift from worrying about minimizing the number of recipients who received disaster aid who did not deserve that aid to minimizing the number of recipients who were denied aid when they deserved that aid. This shift from worrying about Type I to Type II error has significantly improved he public's reaction to FEMA during the Clinton Administration. But there is some indication that it is undermining the internal efficiency of the organization.

3. Improving Our Understanding of Interest Group Politics. For all its mathematical rigor much of the social choice literature has not progressed beyond the crude interest group model of David Truman. One would like to be able to understand under which conditions, and how, interest group alignments form, are sustained, or break apart. One would like to know which interest group assets are more important in which situations.

4. Improving Our Understanding of the Effects of Institutional Arrangements on Political Outcomes. As with interest group politics, our understanding of the effects of various institutional arrangements on political feasibility and the successful implementation of various public policies is limited. Once again we need to go beyond the case study approach.

   Using More Formal Models of Organizational Behavior — Such as Transaction Costs Economics and Principle-Agent Theory — to Take Implementation Studies Beyond case Studies. In the 1950s Herbert Simon and James March moved their unit of analysis from the organization to the decision in order to avoid the limits of case studies and the "proverbs of administration." What was gained was scientific rigor. What was lost, however, were findings that could be used by the policy analyst to design implementable policies. The recent work of Williamson's students in applying TCE to the redesign of New Zealand's public sector suggests that the new economics of organization might have reached the point of being applicable to policy analysis.

5. Credible Commitments. How is political support for a given public policy sustained? How can it be maintained over time through policy design? Through institutional arrangements?

Footnotes

[1] See also, Arnold J. Meltsner, "Public Support for Seismic Safety: Where is it in California?," Mass Emergencies, Volume 3 (1978), pp. 167-184.

[2] Meltsner's analysis and resulting typology was meant to classify policy analysts. I am extending it here to all researchers.

[3] Once can certainly substitute a number of noted scientists for Keynes.

[4] Based on interviews conducted by John Ellwood and his students in his seminar on the Politics of Political Advising in the fall of 1997.

[5] I accept the criticism that this assessment is unfair to the long history of empirical political science - especially as applied to the study of voting behavior. But even the literature on voting behavior - in the electorate and in legislatures - has been largely descriptive.

[6] The classic statement of this approach for interested parties is found in a business school text by David Baron. See, David Baron, *Business and its Environment, 2nd edition* (Upper Saddle River, NJ: Prentice-Hall, 1996), especially Chapter 6, pp. 149-172.

[7] The Carl Sagan notion that if everyone on Earth contributed only a nickel we would have enough money to send a group to Mars is a classic example of concentrated benefits and dispersed costs.

[8] One interesting attempt is by Terry Moe who has set out a strategic analysis for the head of an interest group. See Terry Moe, *The Organization of Interests* **(Chicago: University of Chicago Press, 1980).**

[9] In the real world it is rare to have one option receiving the highest score across all criteria. In this case the analyst has to "confront the tradeoffs" among the criteria. See Eugene Bardach, *The Eight-Fold Path* (Goldman School of Public Policy, University of California, Berkeley).

[10] The organizational development flavor of incorporating implementation analysis into the design of programs can be found in Eugene Bardach's suggestions of strategies to use when incorporating implementation into the design of a public policy.

"First, the basic social, economic, and political theory behind the policy must be reasonable and sophisticated.... Second, a basic administrative strategy must be selected. Such a strategy should be simple. It should entail as little reliance on bureaucratic processes as possible, relying instead on actual or simulated markets...The third step is to make a list of requisite program elements and to note beside each one who - whether organizations, groups, or individuals - might be in a position to contribute to them. With this list in hand, the fourth step is for the policy designer to go through the list of implementation games... or any other games that come to mind and ask, 'Who, if anyone, is likely to play this game? With what effects?... The fifth step is to think about how to establish some of the facilitative and fixing mechanisms described above, if appropriate, e.g., third-party mediators, project management, encouragement through agents of 'organizational development,' a fixer and his immediate staff, the fixer's network of 'eyes and ears' in the field... Finally, the policy designer should think about how to 'phase in' a new policy so that it makes more friends than enemies, especially in its early and vulnerable months (or years, or weeks, as the case may be). More to the point, perhaps, it must make more influential friends than influential enemies..." (Bardach, pp. 154).

[11] A more formal definition is offered by Walter Williams, "Policy analysis... describes a policy-oriented approach, method, and collection of techniques of synthesizing available information including the results of research: (a) to specify alternative policy and program choices and preferred alternatives in comparable, predicted qualitative and quantitative cost/benefit type terms as a format for decisionmaking; (b) to assess organizational goals in terms of value inputs and to specify the requisite output criteria for organizational goals as a basis of goal determination and measurement of outcome performance; and (c) to determine needed additional information in support of policy analysis as a guide for future decisions concerning analytic and research activities." (Williams, 1971, pp. 12).

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Discussant: Peter May
University of Washington

My remarks address three topics: (1) a response to the paper by the Ellwoods; (2) some comments about principles for shaping a PEER research agenda in planning, policy, and economic aspects; and (3) some criteria for evaluating social science related research to be funded by PEER.

This paper and presentation provide a number of insights concerning the political dimensions of earthquake policy and effective means to move engineering advances into policy. The presentation provided a tutorial about political science as well as a practicum about political strategies.

Three topics struck me as being particularly important to the PEER agenda. First is the Ellwoods' discussion of the constraints and opportunities as they relate to policy adoption and implementation for earthquake-related innovations. The review of the constraints points to a number of issues that have been cited in the literature and that are evident in practice. The practical advice about political strategies offers insights into what it takes to build coalitions in support of action. One of the lessons that I have drawn from a recent study of successful mitigation from energy conservation, radon reduction, and termite control programs is the importance of mobilizing constituencies and creating markets for services. This is not something that researchers along can accomplish, but it is an important aspect of the bigger picture that the Ellwoods address.

The second contribution of the Ellwoods' paper is to draw attention to what constitutes policy research and the mechanisms that help to foster utilization of such research. Here an important distinction is made among policy analysis, policy research, and social science research. The Ellwoods see policy research, aimed at addressing particular problems using social science methods, as the appropriate focus for PEER-funded activities. The most effective means for translating such research is through "research brokerages" that serve as clearing houses for synthesizing, publicizing, and translating findings. This is an important function that can be played by PEER and is represented to some extent by the education and outreach elements of PEER. The key point, to me, is that such a function needs to be systematically developed and cannot be expected to emerge from individual research projects.

Principles for a Policy, Planning, Economics Research Agenda

The third contribution is comments about research directions as they related to the political and policy dimensions of the PEER function. Here the Ellwoods call for a mix of problem-focused and more theoretical contributions relating to developing a better understanding of how to bring about change with respect to innovations in this arena.

Moving beyond the paper, I think it is useful to think about the principles that should govern a PEER research strategy for policy, planning, and the social sciences. These are considerations that apply to a set of undertakings and not necessarily to each project. They can be used to gauge the quality and success of the overall research program for this area. Five principles strike me as being important:

#1: Keep Focus on PEER Theme(s). It is easy to come up with wish lists of research topics,

especially when there is a large group with disparate interests. The comparative advantage of cen

ters like PEER is to establish a direction and to follow through on that direction. This gets dissipated quickly when that direction is watered down with tangential projects.

The initial challenge for the PEER leadership is to provide a broad enough vision/direction to allow for innovation and creativity. The management challenge is to keep focus sufficiently to move ahead on that direction.

To me, this means that projects must show clear link of how they contribute to an understanding of or implementation for performance-based design and urban earthquake risk. The effort should not be one of duplicating the unsolicited proposal functions of NSF.

 # 2: Address the Big Picture. One comparative advantage of social scientists is to step back and ask the bigger questions: What percentage of the problem will this address? Who will use this approach? What will it cost? Who will be affected? PEER research and associated efforts to translate that research, through the brokerage function, should be providing answers to the bigger questions. The inability, or fuzziness, with which these questions are currently being answered by the earthquake community is a stumbling block to selling programs, and may someday provide a basis for funding reductions. As a practical matter this means that PEER needs to be able to answer basic questions about the marginal costs and benefits of different increments in performance-based design standards.

 # 3: Identify Relevant Policy and Implementation Questions Up Front. This is a corollary to addressing the big picture. It entails breaking the big questions into a set of relevant policy and implementation research questions. A simple way to think about this is that for any research project or topic to be considered there needs to be: (a) a clear policy or implementation question that is being addressed, and (b) following from point 1, linkage to PEER theme(s). Too often it is unclear what the research question is that is being addressed by social science related projects.

#4: Design Research to Draw Lessons. Social Science research concerning natural hazards seems to be long on case studies of events and descriptions of what happened and short on cross-case or empirical conclusions. From my perspective, there is too much description and too little analysis and generalizing. This tends to be the situation for less mature fields of inquiry, but I also think it is because researchers tend to be fixated on single events. To me, the relevant issues are ones of comparison – across events, settings, or policy approaches.

#5: Recognize Ability to Contribute to Disciplinary Knowledge. There is a tendency to lose sight of the fact that many aspects of research about hazards has potential for contributing to disciplinary knowledge in the social sciences. To me, good studies have both a policy relevant portion and a scholarly portion. The latter is important for professional reasons (promotion, especially for untenured academics) and for providing strong peer review of the basis for research conclusions. Important contributions are possible from this research in addressing topics such as economic uncertainty, real estate markets, decision-making, risk perception, regulatory theory, and policy implementation. The recognition of the ability to contribute to disciplinary knowledge strikes me as being important for expanding the pool of talent interested in addressing earthquake

hazards.

Evaluation Criteria

Based on the preceding comments, it is useful to consider criteria for evaluating social science related research projects. Three criteria strike me as being particularly relevant:

Fit with PEER theme(s). How does this topic relate to performance-based design and urban risk?

Importance of policy or implementation question that is being addressed (assuming there is a question). How does this relate to the big picture? How does this fill in gaps in existing understanding?

Feasibility of drawing lessons/conclusions about the question with limited funding and time. How feasible is this study? Can this serve as a useful foundation for other work?

Conclusion: Challenges Ahead

I conclude by considering the challenges for social science related research within the context of an engineering center. We should recognize that the policy and social science aspects have been weak links for such centers. This has been a criticism of NCEER and was a basis for discussion as part of the NSF review of the PEER and proposals for creating the centers.

The difficulties are easy to attribute to different cultures of engineering and social science, not to mention those of physical sciences. As a consequence, it is easy for social scientists to blame shortfalls on engineers who comprise the bulk of such centers and who do not seem to appreciate social science (at least from the perspective of social scientists in their complaints). There may be some truth to this, but it is also a convenient posture for social scientists to take.

A different way to pose the disjunction is that it represents a challenge to social scientists for them to come up with relevant agenda and sell that agenda to others in a meaningful way. This is a key aspect of this workshop and a challenge to which we can respond.

SUGGESTED RESEARCH TOPICS

Category 1: The Dimensions of Earthquake Loss

Genevieve Giuliano & Rena Sivitanidou
1: Business Sectors/ Land Market Data

See also Pogodzinski, Kiremidjian

Hedonic value analysis is often used to assess the effects of natural hazards on economic markets. Existing studies have already investigated the effects of floods and other natural hazards, including earthquakes, on urban housing markets [see, for example, the study on the effects of the Loma Prieta earthquake by Murdoch et al., AREUEA,21:167-184 (1993)]. However, empirical research on the effects of earthquakes on commercial land and property markets is scarce. A potential topic for future research, therefore, might involve the analysis of the effects of the Northridge earthquake on business land and property values.

A potential topic for future research involves the analysis of business property values across commercial sites within metropolitan Los Angeles that differ in earthquake risk (soil type, proximity to faults, etc.). Once potentially confounding variables are controlled for, such analysis can indicate the extent to which business property values capitalize the risk of earthquake damage. Further, comparison of pre- and post-1994 data would help to test for changes in "risk premia" after the Northridge event.

Linda B. Bourque & Kimberley I. Shoaf
1: Injury Costs

In order to identify and understand the nature, severity, correlates, causes and impacts associated with injuries as a result of earthquakes, further research needs to be undertaken to identify the rates and extent of injuries; factors predictive of being injured in an earthquake; and the costs associated with injuries in earthquakes. Existent data collected after the Northridge earthquake by the UCLA Center for Public Health and Disaster Relief (CPHDR), the Southern California Injury Prevention Research Center (SCIPRC) and the Los Angeles County, Department of Health Services Injury and Violence Prevention Program (LAC-DHS) can be used to estimate:

- The risk factors for physical injuries (building damage, activities of occupants, etc.).
- The severity of injuries sustained
- The costs associated with different types and severity of injuries
- The overall economic impact of physical injuries in earthquakes.

Marjorie Greene & Sarah Nathe
1: Fiscal Impact Tax Credits, Impact of No Insurance

See also Chapman

1. Conduct an analysis of fiscal and economic impacts associated with a state property tax credit and a state income tax credit for seismic retrofit (similar to the study conducted for Oregon).
2. Conduct an analysis of the fiscal and economic impacts associated with Fannie Mae and/or Freddie Mac offering discounts (reducing points or loan guarantee fees) for strengthening.
3. Conduct an analysis of the fiscal and economic impacts associated with a federal income tax credit for strengthening. Compare the costs to the Treasury of that credit to the amount of disaster assistance funds that would be required if no strengthening occurs.
4. Determine the impact on the federal (and state?) treasury of the California (and possibly Florida) insurance programs. Assume people are not buying insurance, and therefore will be requesting various types of disaster assistance. Compare several types of situations:

- You can stay in your strengthened home.
- You can use insurance.
- You need to take advantage of all the disaster assistance programs available.

Al Ang
1:Improve Cost Models

See also Scawthorn, Dong, Meyers

Better or improved models for estimating direct and indirect losses from earthquakes of different magnitudes (regionally), and of different intensities (locally). Besides economic and financial losses, also models for predicting social impacts of earthquakes.

Weimin Dong
1: Improve Cost/Risk Estimation

See also Scawthorn, Meyers, Ang

One of the major problems facing risk management efforts today is the lack of an economically sound risk-based rationale for policy making. Developing such a rationale requires first improving loss estimation technologies to provide better estimates of the risk, and then developing an approach to combine different pieces of information provided by the techniques into regional measures.

1: Standardize Procedures in Cost Estimating Methodology

See also Dong, Meyers

The total cost of earthquake loss is unknown at present. For example, the best estimate of total economic loss for the Northridge earthquake was compiled for OES by EQE, and is quite approximate in several areas. The economic impacts due to disruptions to the trans-

portation system in the Loma Prieta earthquake were apparently quite severe (emergency ferry service while the Bay Bridge was repaired; reported significant business losses in Chinatown/North Beach due to permanent loss of the Embarcadero Freeway), but in reality are unquantified. Therefore, a interdisciplinary research project, with example application, would be an excellent contribution for this problem. Specifically, it is proposed to conduct research to create a comprehensive systematic accounting scheme for damage, direct and indirect economic impacts. The accounting scheme would (a) provide a 'checklist' to assure that all costs are accounted for, (b) provide methods, suggested procedures and other standards so that costs are consistently accounted, and (c) include examples of data resources and other ways in which to determine the costs. The example application would have to be either the Northridge or Loma Prieta events - enough time has elapsed for either event for research results, sales tax and other trends, and other data sources, to be available.

Jennifer Wolch
1: Long-term Comparison of Neighborhood Impacts

It might be useful to develop a series of comparative retrospective case studies designed to document the longer-term and indirect economic and social costs accruing to neighborhoods that sustain different magnitudes and types of earthquake-related structural damage. Such a study could consider the negative (as well as positive) multiplier effects of structural damages on business by industrial sector, public sector costs including law enforcement, public health, mental health, etc., and social impacts on neighborhood residents (health effects, rates of work/school absenteeism, strength of neighborhood social network attachments, neighborhood decline as in the post-Northridge 'ghost town' situation, etc.). In addition, by selecting a set of case study sites located in jurisdictions with different local government political orientations, levels of public sector activism, and legal status (i.e. general law versus chartered cities), the study might document and evaluate local policy measures taken in response to earthquake loss, an analysis that in turn might form the basis for a "best practices" manual to help local governments plan more rationally for earthquake loss.

Mary Fran Meyers
1:Improve Cost Models

See also Scawthorn and Dong

This research would assemble and test new ideas, models, and methodologies for estimating the direct and indirect (e.g., disrupted market systems, transportation routes, and education delivery) costs associated with earthquakes. The data assembled and methods developed would enable policy makers to estimate the benefits and costs of alternative mitigation actions. This project would also point to needed future research to push forward on important new losses and costs estimation frontiers.

Anne Kiremidjian
1: Economic Losses to Business Sectors

See also Giuliano / Sivitanidou

Economic losses to various business sectors an implications to the local economy continues to be a difficult issue. It is only vaguely addressed in current methods and does not capture many of the complexities of dependent business sectors. There are numerous issues that need to be addressed, including: how do we quantify losses due to limited resources, how do we account for new business entities developing as a result of the shortage created by the earthquake?

James Moore II
1: Evaluating Input/Output Modeling

1. Optimal mitigation of near term response budgets, trading off cost of recovery against pre-event investments.

2. Comparing input/output and computable general equilibrium models as vehicles for estimated exogenous shocks such as earthquakes.

Frieder Seible
1: Change Engineering Research to Include Consequences

Earthquake losses in general (structural and non-structural) are caused by the failure of man-made structures. Consequently, structural earthquake engineering has traditionally focused on reducing earthquake losses through specific structural hazard mitigation without consideration of the larger regional impact. How should structural engineering research change to address not just the specific structural problems but also the consequences of non-performance on a regional level.

Dorothy Reed
1 or 3: Evaluate Lifelines, Cost and Policy

Consideration of the performance of electric utility lifeline networks under seismic hazards and public policies.

Marty Wachs
1 and 3: Economics of Traffic Flow Interruptions, and How Preparedness Plans Get Implemented

Develop a method for estimating economic loss due to interruptions to the flow of traffic as a result of damage to transportation facilities. This would include highway and rail and

port and airport facilities. Such estimates would be a useful part of the process of evaluating the returns from such investments as strengthening bridges and overpasses against seismic risk.

Understanding how leaders image earthquake hazards and incorporating these images into preparedness planning. Earthquakes are rare events, their consequences are severe but localized. After a serious earthquake there are commitments made to long term preparedness. However as the consequences of the event fade in time, the subject slips to the back burner of policy making. How do public decision makers understand the process of responding to and preparing for earthquakes, and how can we inform decision makers so that their consideration of risk is more systematic, continuing, and rational?

Allin Cornell
1 or 3:Estimating Costs Saved With Mitigation

I would recommended what is needed in PEER research - is a concrete link between (A) what we engineers aspire to being able to estimate for a specific building (a proposed new design or an existing structure) and (B) quantitative decision making criteria. The former at its best (A) includes the probability per year that the structure will collapse (killing x% of its occupants); the probability per year that damage will exceed y dollars and n lives lost - versus y and n; if I increase the design PGA by 10% it will cost 5% — is it worth it? (what elements should I include in my cost/safety trade-off?), etc. The answers we need for design and retrofit decisions are: what are tolerable life risks given the benefits the structure provides, should we have maximum live loss limits plus a cost-benefit-risk criterion, should there be both a maximum individual life loss criterion and a public loss criterion (an f-n curve), etc.? In several closely related technical fields that I have various degrees of familiarity with: offshore structures (US and, better, UK and Norway), the commercial nuclear power and DOE facilities field, large dam safety, chemical plant risk criteria, etc., our technical counter-parts are being provided criteria in such terms within their design codes and guidelines (in more or less transparent form).

It is crucial to the stated performance-based design objectives of PEER that this global-to-atomic link be forged. From general policy levels “down” to design norm criteria. Current “stabs” at quantitative performance levels and formats (e.g., the SEAOC 2000, FEMA 273) are admittedly - by those who wrote them! - rough cuts made in the dark “just to get going”.

Mike Pogodzinski
1 or 2:Effect of Disclosure on House Prices

See also Giuliano and Sivitanidou

The purpose of the study is to determine the effect of the disclosure of seismic risk on house prices. The (state?) law presently requires disclosure of the proximity of the house to a known earthquake fault if the fault is within a certain distance (I think it is 600 yards)

from the property. If the fault is 601 yards away, that fact does not need to be disclosed. There are other risks that also require disclosure under the same law, e.g., slide risk, but again, there is some distance specified in the law.

Jeff Chapman
1 or 2: Mitigation vs. Insurance

See also Greene, Nathe

How do ex-ante mitigation attempts (e.g. insurance) compare to ex-post mitigation attempts (e.g. government aid). The study would attempt to determine such ex-ante costs as insurance and excess building costs brought about by codes, them determine actual earthquake damage, and then determine the costs of remediation. The subject area could be Santa Cruz or Northridge.

Jane Preuss
1 or 2: Rental Housing Recovery Comparison

See also Shapiro

Comparison of rental housing losses and reconstruction in Kobe and Northridge particularly with respect to a) factors creating the ghost towns issues and b) incentive policies to build the housing. This research would tie together economic factors as well as government policies with respect to location, occupant preferences, land acquisition and others.

Stephanie Chang
1 or 2: Survey of Homeowners

Social and Economic Factors in Seismic Risk Acceptance

While risk can be quantified based on engineering and geoscience information, the acceptance of such risk and the associated demand for hazards mitigation depend critically upon social and economic factors specific to individual agents (e.g., households). I propose to conduct a mail survey of residential property owners in the Seattle area to examine how factors such as risk awareness, earthquake experience, property value, owner/tenant occupancy, duration of ownership, etc. affect decisions regarding seismic hazard mitigation, including insurance purchase. The survey would target two groups: participants in Seattle's recently-launched home seismic retrofit program and a control group.

Category 2: Efficient Incentive Structures for Hazards Mitigation

Kenneth Verosob

2: Insurance Rate Structure

The California Earthquake Agency (CEA) was supposed to have used proven methods of risk assessment in developing a rate structure for the state-funded earthquake insurance program. Instead it used a proprietary computer code that was apparently based on an untested methodology. The resulting rate structure shows little correspondence to the generally perceived distribution of seismic risk in the state and appears to have been strongly influenced by political considerations. I think it would be appropriate for PEER to sponsor a research effort designed to evaluate the methodology used by the CEA and develop an alternate rate structure that is based more on scientific knowledge and less on political factors.

Elliott Mittler

2: Community Preparedness Scale

Investigation would develop a scale measuring the ability of a community to withstand both a catastrophic and an expected earthquake by estimating damages to critical facilities, lifelines, and buildings, and then ranking them according to some definitions of survivability, functionality, recoverability, substitutability, and habitation following these events. The scale would then be used to identify the most at risk communities and to set priorities for funding mitigation projects on a community basis. Definitions of community, including regional impact and assistance, would need to be determined.

Laurence Kornfield

2: Perception and Information on Building Safety

Proposal # 1: The public has no idea how “safe” they are in any building, and often make optimistic assumptions as to their safety. As a precursor to addressing either topic two or three, I recommend an investigation, using accepted statistical methodology, to survey the public’s perception of their safety which would then be compared to a determination of the actual level of safety in their building. This could then guide a rational policy discussion of disclosure of levels of building safety, leading to . . . .

Proposal #2: Under topics #2 and #3, an exploration of a method to quantify and post “building safety”, somewhat like the state-mandated URM notices. Entering the building, we would see a sign saying “This is a Level 3 building” with fine print below. Tenant or user knowledge of the hazard might drive hazard mitigation through the marketplace, don’tcha think?

Holly Brown Williams
2: Evaluate Cost/Operations of CEA

I'm sure you are aware of the growing concern, which I believe has coalesced into at least one piece of legislation (through Assm. Figueroa, who chairs the Insurance Committee), over the costs and operations of the CEA. I think this is one area that definitely deserved some attention in this type of setting. I have grudgingly paid our outrageous EQ premium recently, so that I'd like to see some action on this as a citizen!

Richard Mc Carthy
2: Incentives for Mitigation

See also Greene/Nathe

Specifically focus on education. The State Department of Finance in any state should give financial incentives to those who mitigate. If Finance is convinced, legislation can be passed.

Brian Cowan
2: Identify Risk Transfer for Mitigation

Identify appropriate balances of risk transfer to be achieved through a mitigation implementation action. Identify appropriate mechanisms for internalization of risk reduction decisions that are financially supported by institutions or organizations, unable (or unwilling) to verify the effective implementation of those decisions.

John Hall
2: Implementation Incentives for Non-ductile Concrete

See also May

Issues associated with retrofit ordinances for non-ductile concrete frame buildings. Tasks could include an economic analysis of cost/benefit, a study of implementation issues and the role of incentives, an assessment of possible reactions of building owners, documentation of the recent failed attempt to pass an ordinance in LA, a poll to determine public awareness of the problem, etc.

Dan Shapiro
2 or 3:Cross Earthquake Comparison of Wood Damage

The extent of seismic retrofit required in residential construction to reduce damage to non-structural components and finishes to "acceptable" levels. This may be possible by comparison of damaged and undamaged construction from selected earthquakes.

Category 3: Beyond Building Codes

Robert Olson
3: Look at What Governs Code Adoption

See also May, French

Introducing and adopting base isolation and other new earthquake engineering innovations;

How, why, and under what conditions are new and innovative earthquake engineering technologies introduced to buildings? While codes now recognize base isolation, the earliest applications were "beyond codes," and now other technologies (e.g. structural control) are poised for greater use. This project would investigate what governs the decision processes of adoption/implementation or rejection of earthquake engineering innovations with the goal of providing the community with information about the relative importance of factors that influence the acceptance of new technologies in the hope that such processes might be accelerated in the future.

Henry Lagorio
3: Planning Implementation

See also French

There is a continuing frustration among planners with the way cities face metropolitan development through and urbanism that is in direct conflict with pre-earthquake mitigation strategies and post-earthquake mitigation goals. There are vast differences between what's taking place in the planning and growth of metropolitan centers and what emergency contingency planners would prefer to have addressed in zones of high seismicity. Specific research issues that impact this area need to be identified and investigated through an integrated and innovative approach.

Cynthia Kroll
3: Private Business Earthquake Preparedness

One problem with examining business experience after an event was that we had to rely on people's after-the-fact recollections of what they had done, and we had great difficulty in reaching owners of establishments that might have completely gone out of business after the earthquake. A baseline study of firm preparedness would provide information for public policy on the level of knowledge and preparations of business owners, and would also provide a background against which to compare experience after an event (assuming something major happens within a reasonable timeframe after the study is completed). The study would include a literature review of existing studies, a survey of a stratified sample of firms in selected California sites (covering both areas with recent experience with damaging earthquakes and areas that have been free from damaging earthquakes in the past 20 years), and a more limited number of in-depth interviews. The study would report on the findings of past research and of the survey.

Richard Willson
3: Factors in Proactive Strategies by Local Government

See Also Chakos

Beyond Building Codes: Factors That Influence Local Innovation in Earthquake Preparation

The research project will investigate the factors that lead to proactive and comprehensive earthquake preparation strategies by local municipalities. A mail survey of Southern California jurisdictions will be used to identify best practices, and in depth case study interviews would be conducted with key decision makers. The research instruments would focus on issues relating to personal, organizational and political dimensions of risk perception, disruption experience, orientation toward scientific knowledge, management approach, and leadership.

Gary Hart
3: Time Frame for Engineering and Political Decisions

Perhaps it will help if I relay my Kaiser Hospital Experience. The two key parts of the decision process were: (1) What can possible happen during my(i.e. the leaders) span of being the boss, and (2) What can possible happen after my span of being the boss but before I die. The first requires the impact of the earthquake in all aspects(damage, loss of business, office closure time etc.) typically in a 5 to 7 year time frame. The second requires the same impact but now for a longer time frame of about 20 years. I think this is important not only for the leaders of large companies but also the politicians.

Peter J. May
3: Code Enforcement/Compliance in Performance Based Design

See also Olson, French, Hall

A variety of evidence points to noteworthy gaps in enforcement and compliance with seismic provisions of building codes. As the introduction of performance-based provisions adds to code complexity, these gaps will be exacerbated. Research needs to be undertaken to investigate: (a) the capacity of and approach to code enforcement by local governments, and (b) factors affecting the willingness and ability of design and construction professions to comply with performance-based code provisions.

Paul Fratessa
3: Alternate Strategy to Codes

Building Codes have been a deterrent to determining and assigning responsibility for risk management. A broad strategy involving the financial, insurance and real estate development industries, working with owners, needs to be developed which will bridge the gaps of defining acceptable risk, acceptance of responsibility, levels of mitigation and the insuring of probable losses with acknowledgment of mitigation programs.

Tom Tobin
3: Business Perspectives on Acceptable Risk

Acceptable risk remains as a seminal and illusive issue at the root of earthquake risk reduction and management policy. In practice acceptance has resulted largely from ad hoc decisions by engineers and code writers, but an increasing number of decisions are now shared by state and local government in regards to public health, safety and welfare, and by owners, lenders, insurers, tenants and utility and transportation systems providers in regards to business and investment security. Arriving at acceptable risk is a complex, multi headed, dynamic process influenced by changing knowledge of hazards and risk, awareness of responsibilities, emergency of new tools to understand and control building performance and estimate community-wide losses, and newly recognized business opportunities. Research from business perspectives, but involving earthquake community expertise, is needed to improve the understanding of business decisions to manage earthquake risk in general and the arrival at earthquake risk acceptability. Investments risk, liability, risk perception and aversion, cross discipline communications, marketing, business vulnerability to facility and customer disruption are some of the factors involved.

Steve French
3:Implementing Plans for Seismic Safety

See also May, Olson

Local governments in California are required to address seismic safety as part of their comprehensive plans, but it appears these plans are not always implemented. This piece of cross-sectional research would investigate how local plans are implemented and what factors lead to aggressive implementation.

Arietta Chakos
3: Local Government Implementation

See also May, Willson, Mittler

A useful study for local officials might be an examination of how municipal governments bridge the seismic hazards information gap. What sources of hazards information truly affect policy and budget decisions? Are academic and technical resources (studies, papers) used as guides for policy and program development? Do elected officials and community members respond primarily to disaster events and the resultant media coverage as the catalysts for mitigation.

Another potential study would be a survey of existing mitigation incentive programs at the local government level. Do they work? Do voluntary programs provide enough incentive for change; do mandatory approaches with less stringent performance standards provide adequate seismic protection? What can the earthquake community learn from hurricane and flood communities in the quest for effective programs.

Dwight Jaffee and Tom Russell
Analyze the CEA

We propose to analyze the structure of the CEA. Our analysis will include at least the following:

We will develop a simple model of the structure and workings of a public insurance agency such as the CEA (there are similar agencies in Florida, Hawaii, and Texas for hurricane risks).

We will analyze the demand for incomplete insurance (as is now offered by the CEA), both from a rational and from a behavioral perspective. For example, a large deductible (as under the current CEA policy) both reduces the premium costs and the loss payouts. Would consumers prefer high premiums and payouts (i.e. low deductibles)?

We will study the actual sales results of the CEA to understand what is determining consumer choices.

We will exchange changes in the CEA contract and in the CEA premium structure that would create a more beneficial institution.

We will examine the incentives for loss mitigation built into the CEA contract and will attempt to measure their effectiveness.

We will examine new tax proposals that would maximize the potential for a return to a functioning private market in earthquake insurance.

Louise K. Comfort
Inter-organizational Coordination

While much attention has been given to the design and construction of the built infrastructure to mitigate seismic risk, little attention has been given to the design and implementation of an information infrastructure to support policy and planning among organizations, jurisdictions and disciplines. Current uses of information technology now enable us to monitor the direction, content, timing and exchange of information among organizations with legal responsibilities for protection of life and property in disaster. This possibility enables us to measure coordination of action among organizations and jurisdictions participating in mitigation and response operations, and what combination of search, exchange, and feedback of information among these actors will increase the capacity of the community to reduce seismic risk?

Cliff Marks
Link Urban Planning and Seismic Hazards

First, I think that it would be helpful to create a typology relating the appropriateness of different tools (geotechnical investigations, structural requirements, retrofit requirement, zonig designations, etc.) to different seismic hazards (ground shaking, liquefaction, fault movement, landslides, etc.). Which tools can really be applied to the different hazards? C with an eye out on how far we can go wtih respect to urban planning (zoning) designations of land use type and intensity.

Second, with this typology in mind, it would be useful to document how much in the realm of urban planning has actually been done C to see how far we have gone, in fact, beyond building codes. I know of the Geology and Planning publication by Spangle and Associates dealing with Portola Valley, and Planning and Earthquakes by Berke and Beatley, and some other publications, but I still think that more research needs to be carried out. Portola Valley has slope density regulations, and many places have hillside regulations, but this seems a little different than just seismic issues. And what about the biggest and most wide spread hazard: groundshaking? There has been some talk about relating building height to soil depth (periodic vibration?) But I don't think this has ever taken place. We have liquefaction and landslide regulations in Seattle, but all we require are studies and adequate engineering design; we don't regulate the type or intensity of land use based on these hazards. Portland has done some work but I don't think that it has been translated into actual land use regulations.

Richard Bernknopf
Questions and Analyses

What are the appropriate levels of detail and resolution of geologic hazards to be used in community mitigation decisions?

The research is to compare the benefits and costs of the appropriate levels of detail and resolution of geologic hazards information to be used in a community mitigation strategy. This map based risk assessment can be evaluated by considering the threshold value of the probability of earthquake-triggered hazards on a grid. The value of the information is the difference in the cost of increments of additional scientific data added to each grid cell to improve the resolution of the hazard and the incremental benefit (expected losses avoided) with the improved hazard resolution.

Can scarce public resources be used in an optimal way to mitigate a variety of public infrastructure services including schools, hospitals, other public buildings, and transportation facilities?

This question can be approached by developing an analytical tool to identify the most cost-effective mitigation applications given the public funds available. This spatial optimization problem combines GIS-based hazard maps with cost and public infrastructure data. The objective is to minimize expected losses from earthquake-triggered hazards sub-

ject to site specific hazard conditions and limited budget. Once solved, this information can be used to make decisions regarding allocations in an optimal scheme for mitigation.