28 Sept 2000

Public-Private Partnerships for Reducing Seismic Risk Losses*

Howard Kunreuther**
Center for Risk Management and Decision Processes
The Wharton School
University of Pennsylvania
Philadelphia, PA 19107

Paper Presented at
Second EuroConference

on

Global Change and Catastrophe Risk Management
Earthquake Risks in Europe
International Institute of Applied Systems Analysis
A-2361 Laxenburg, Austria

July 6-9, 2000

*Support from NSF Grant CMS 97-14401 to the University of Pennsylvania and from the Wharton Risk Management and Decision Processes Center Managing Catastrophic Risk project is gratefully acknowledged. Helpful comments were received from participants at the Wharton Managing Catastrophic Risk Sponsors Meeting in Bermuda on May 15-16, 2000. Special thanks to Applied Insurance Research, EQE and Risk Management Solutions for constructing exceedance probability curves for the model cities and for their help in analyzing the impact of parameterized indexed cat bonds on the losses to insurers. Jaideep Hebbar, with the assistance of Pooja Goyal, Patricia Grossi and Vikram Prasad, spent many hours analyzing the data from Oakland and helped construct the relevant tables and figures in the paper.

** Cecilia Yen Koo Professor of Decision Sciences and Public Policy, Chair of Department of Operations and Information Management, The Wharton School, University of Pennsylvania

1. INTRODUCTION

The importance of public-private partnerships for disaster management has been stimulated by losses from catastrophes in the United States and other parts of the world. Hurricane Andrew which created damage to Miami and Dade/County, Florida in September 1992 and California's Northridge earthquake together cost the insurance industry (US$28 billion) and the government an additional US$17.6 billion. The Kocaeli earthquake in Turkey in August 1999, which caused over 17,000 confirmed fatalities with massive disruptions to the economy of Western Turkey, has led to a recognition by the Turkish government, industry and the public of the urgent need to develop and enforce better building standards (Wilczynski and Kalavakonda 2000).

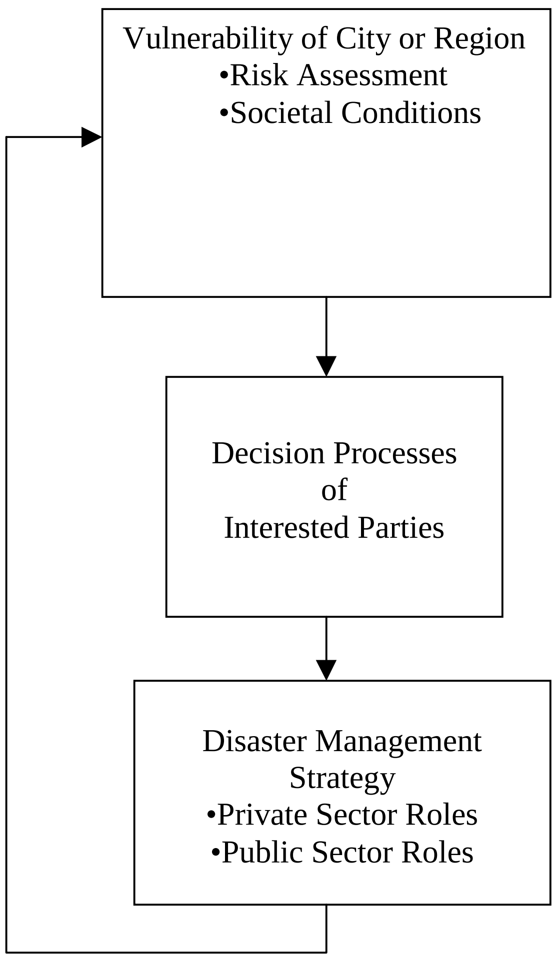
This paper explores risk management strategies for reducing losses from natural disasters and providing financial resources to victims of these devastating events in both developing countries and emerging economies. More specifically, it will examine programs that involve the private sector such as insurance and capital market instruments (e.g. Act of God bonds) in combination with public sector programs such as regulations and standards (e.g. well-enforced building codes). The focus of attention will be on the earthquake problem but the concepts are relevant to other natural and technological disasters as well.

Figure 1 depicts a framework for analyzing this problem. It builds on concepts developed in a report by the Heinz Center (1999) and by Kleindorfer and Kunreuther (1999). The vulnerability of a community or region includes the potential for direct damage to residential, commercial and industrial property, other facilities such as schools, hospitals, and government buildings as well as infrastructure damage to highways, water, gas, electricity and other lifelines. Any disruption of infrastructure such as loss of the water supply or electric power can cause indirect losses by interrupting business activity, forcing families to evacuate their homes and causing emotional stress to families. One also has to consider the exposure of the population to the hazard and potential number of fatalities and injuries to different socioeconomic groups.

The ingredients for evaluating the vulnerability of a city or region to natural hazards are risk assessment and societal conditions. Ideally a *risk assessment* specifies the probability of events of different intensities or magnitudes occurring and the impact of the direct and indirect impacts of these events to the affected interested parties. *Societal conditions* include human settlement patterns, the built environment , day-to-day activities and the institutions established to deal with natural hazards.

Before developing a disaster management strategy one needs to understand the decision processes of the key stakeholders. The term decision processes refers to the type of information and data collected by individuals, groups and organizations (either private or public) and how they are utilized in making choices. For example, if a family is considering whether to bolt its home to a foundation to reduce future losses from a severe earthquake, what information does it collect on both the hazard itself and the potential damage with and without this mitigation measure? What type of decision rule(s) does the family utilize in determining whether or not to invest in this mitigation measure? What type of data and decision rules do insurers, financial institutions and public sector agencies utilize in evaluating the cost-effectiveness of different mitigation measure? Unless we understand the nature of the decision processes of these different interested parties, we will have a difficult time recommending specific programs or policies.

Figure 1: Framework for Analysis



Based on an understanding of the vulnerability of the city or region and the decision processes of the key interested parties, one needs to develop a strategy for reducing losses and providing financial protection to victims of future disasters. This strategy will normally involve a combination of private and public sector initiatives which include insurance and new financial instruments as well as well-enforced building codes and land-use regulations. These measures will differ from country to country depending on the current institutional arrangements and existing legislation and laws.

We apply this framework to Oakland, California, one of three cities that the Wharton Managing Catastrophic Risk project has been studying. [1] In particular, we examine the potential losses to either a private sector entity (e.g. an insurance company) or a public sector agency providing financial protection against losses from an earthquake in Oakland. This analysis illustrates how we can combine risk management tools with mitigation for dealing with these issues.

The next portion of the paper examines the different components of the above framework. Section 2 provides a perspective on the vulnerability of a city or region. We then focus in Sections 3 and 4 on the decision processes of the homeowners and insurers—two key stakeholders affected by natural disasters. Section 5 turns to the ways that mitigation and financial risk management policy tools can work together in reducing losses and addressing post-disaster needs of victims. Section 6 illustrates how these policy tools apply to Oakland, CA. The concluding section outlines a set of future research questions that need to be addressed for dealing with the problem by focusing on a proposed comparative study of Los Angeles, California and Istanbul, Turkey.

2.VULNERABILITY OF A CITY OR REGION

In determining the vulnerability of a city or region one needs to know the design of each structure (e.g. residential, commercial, public sector) and infrastructure, whether specific mitigation measures are in place or could be utilized, and their location in relation to the hazard. (e.g., distance from an earthquake fault line or proximity to the coast in a hurricane-prone area) as well as other risk-related factors.

Constructing an Exceedance Probability Curve Based on this information one can construct an exceedance probability curve which depicts the annual probability that the losses from a series of different disasters will exceed a certain magnitude. The EP curve is the key element for evaluating a set of risk management tools. The accuracy of the EP curve depends upon the ability of scientific experts and engineers to estimate the impact of disasters of different magnitudes on different structures.

With respect to the earthquake hazard, scientists have been working to reduce the ambiguity and uncertainty in predicting the location, severity, frequency of occurrence, and physical effects of earthquakes by examining geologic records, looking at actual events, and conducting experiments on how the ground responds to earthquake processes. However, scientists are still uncertain as to how different factors interact with each other and their relative importance (Hanks and Cornell, 1994).

Engineers have focused on the nature, distribution, and level of damage from earthquakes. Such investigations have increased our understanding of the performance of various types of buildings and structures in earthquakes of different magnitudes. Hazard

[1] The three cities, their associated modeling firm and hazard in parentheses are: Miami/Dade County, FLA (Applied Insurance Research,-hurricanes); Long Beach, CA (EQE, earthquakes); Oakland, CA (Risk Management Solutions, earthquakes).

risk maps have been drawn for earthquakes, but they only provide rough guidelines as to the likelihood and potential damage from specific events.[2] The recent use of geographic information systems (GIS) for incorporating geologic and structural information for a region has enabled scientists to estimate potential damage and losses from different earthquake scenarios. The data for the region are stored in the form of GIS maps of ground shaking estimation, maps secondary seismic hazards such as liquefaction, landslide and fault rupture and maps of damage to structures in the region. (King and Kiremidjian in press).

Application to Oakland We illustrate these concepts by developing an EP curve for a hypothetical insurance company that is providing financial protection to residential houses in Oakland, CA. This approach can be used in constructing an EP curve for any other community or region that faces potential losses from earthquakes or other disasters (e.g. Istanbul, Turkey). The losses could include residential structures, commercial and other buildings as well as infrastructure. As an alternative to viewing the EP curve through the eyes of an insurance company, one could take the position of the federal government who is concerned with the chances that an event will cause financial losses to the region greater than a certain amount.

The Alpha Insurance Company has a book of business (BOB) which consists of a set of wood-frame homes in different parts of the city. Homes constructed prior to 1940 are assumed **not** to have crippled walls and **not** to be bolted to the foundations. The damage to these homes from an earthquake can be reduced if this risk mitigation measure (RMM) were adopted in the future. The distribution of structures for the Alpha Company is given below in Table 1. Structures whose age was unknown are assumed to fall into the Pre-1940 or Post-1940 era with the same likelihood as for the known structures.[3]

Table 1: Composition of Books of Business for Alpha Insurance Company

‘

Don’t Know	259
Pre-1940	3,091
Post-1940	1,650
Total	5,000

[2] The last major published study undertaken by structural engineers to estimate damage ratios was ATC-13, published by the Applied Technology Council in 1985. In view of the extensive building damage experienced during the 1994 Northridge earthquake, the insurance industry would welcome a confirmation or update of that study by the structural engineering profession.

[3] Thus, 169 of the 259 unknown structures in Company S’s book of business (BOB) were assumed to be constructed prior to 1940 reflecting the ratio of pre-1940 to all known structures (3091/(1650+3091) in their BOB. These 169 were therefore eligible for mitigation.

The EP curve for the Alpha Insurance Company with a 95% and 5% confidence intervals is depicted in Figure 2. For Oakland, we begin with a mean loss (the middle curve), the best estimate for all the parameters used in the loss estimation process. The mean loss curve is defined as the most likely scenario of events.

The two parameters, frequency (F) and vulnerability (V), are varied in two ways relative to the mean loss, either high (H) or low (L). Based on the assumption that the two curves for F and V are on the high side and the two curves for F and V are on the low side with the other parameters at their base case, a 90% confidence interval using the joint distribution for F and V were generated. In other words, these estimates will cover the true estimate of the model parameter(s) with probability 0.90. The 95% confidence curve is a conservative estimate of more damage and the 5% confidence curve is an optimistic estimate of less damage.

Specifically, for the combination of parameters F and V, the 5% confidence curve is constructed by finding a pair of values (F05, V05), such that there is only a 5% chance that the true value of both parameters will be less than (F05, V05). Assuming that F and V are independently distributed, the required joint probability is:

$$P\{F < F05 \text{ and } V < V05\} = P\{F < F05\} \times P\{V < V05\} = 0.05$$

There are, of course, an infinite number of ways to pick F05 and V05 to make this equality true. We arbitrarily picked F05 and V05 so that each component had roughly the same marginal probability (i.e. F05=V05=.224)[4]. A similar analysis to construct the the 95% confidence curve. (Grossi et al 1999).

INSERT FIGURE 2 HERE

3. HOMEOWNER DECISION PROCESSES

In order to evaluate alternative risk management strategies for an insurance company, it is important to understand when homeowners are willing to invest in a cost-effective risk mitigation measure (RMM) voluntarily. The definition of cost-effective utilized here is related to the damage to the structure itself. In other words, we are interested in whether the expected discounted benefits with respect to loss reduction from the house exceed the cost of the measure itself. If a mitigation measure meets this criterion then it will certainly be viewed as desirable from a broader perspective when one takes into account other direct and indirect benefits, such as saving lives and the joys of not being forced to leave one's home.

There is a growing empirical literature which provides insight into the typical individual in an earthquake-prone who has to determine whether or not to invest in a protective

[4] In other words F05=.224 times V05=.224 =.05

measure. In a 1989 survey of 3,500 homeowners in four California counties subject to earthquake damage, only between 5 and 9 percent of the respondents in each of these counties reported adopting any LRMs (Palm et. al. 1990). A follow-up survey of residents affected by the October 1989 Loma Prieta earthquake and the Northridge earthquake of 1994 revealed that only 10 percent of homeowners invested in any type of structural loss-reduction measure whether or not they were affected by recent earthquakes in the State (Palm 1995). Measures such reinforcing crippled walls and bolting a house to a foundation may cost $1,000 to $3,000 but yield sufficient expected benefits to be justified for many existing homes in earthquake prone areas.

Factors Influencing Mitigation Adoption Decisions There are five principal reasons why homeowners do not appear to want to invest in cost-effective mitigation measures:

Short Time Horizons Individuals may have relatively short time horizons over which they want to recoup their investment in an RMM. Even if the expected life of the house is 25 or 30 years, the person may only look at the potential benefits from the mitigation measure over the next 3 to 5 years. They may reason that they will not be residing in the property for longer than this period of time and/or that they want a quick return on their investment.

High Discount Rates The need for a quick return is also consistent with having a high discount rate regarding future payoffs. Loewenstein and Prelec (1992) propose a behavioral model of choice whereby the discount function is hyperbolic, rather than exponential. Their model appears to explain the reluctance of individuals to incur the high immediate cost of energy-efficient appliances in return for reduced electricity charges over time (Hausman, 1979; Kempton and Neiman, 1987).

Underestimation of Probability Some individuals may perceive the probability of a disaster causing damage to their property as being sufficiently low that the investment in the protective measure will not be justified. For example they may relate their perceived probability of a disaster (p) to a threshold level (p*), which they may unconsciously set, below which they do not worry about the consequences at all. If they estimate $p < p^*$, then they assume that the event "will not happen to me" and take no protective actions

Aversion to Upfront Costs If people have budget constraints then they will be averse to investing in the upfront costs associated with protective measures simply because they feel they cannot afford these measures. It is not unusual for one to hear the phrase “ We live from payday to payday” when asked why a household has not invested in protective measures. (Kunreuther et al. 1978).

Truncated Loss Distribution Individuals may have little interest in investing in protective measures if they believe that they will be financially responsible for only a small portion of their losses should a disaster occur. If their assets are relatively limited in relation to their estimated potential loss, then these individuals may feel they that they can walk away from their destroyed home without being financially responsible. Similarly if residents anticipate liberal disaster relief from the government should they suffer damage, then they would have less reason to invest in a cost-effective mitigation measure.

Application to Oakland Homeowners who are residing in pre-1940 structures in Oakland can consider bracing their crippled wall and bolting the house to the foundation. Mitigation costs are based on 1.2% times the cost of the structure. Thus for a $200,000 home in Berkeley, it would cost $2400 to brace the crippled wall and bolt the house to the foundation.

In this analysis of decision processes with respect to homeowners adoption of mitigation measures we focus here on the impact of the first two factors---short time horizons and high discount rates and the homeowners' decision processes. Three scenarios will be considered to determine the cost-effectiveness of mitigation. Scenario 1 reflects a homeowner who has a long time horizon with low discount rate (20 years, 7%). Scenario 2 has a short time horizon and a low annual discount rate (5 years and 7%) while Scenario 3 has a short time horizon and high annual discount rate (5 years and 20%).

For each ZIP code in the Oakland the cost effectiveness of these RMMs was determined by asking the following question: If every pre-1940 home were required by law to adopt the RMM, would the aggregate reduction in expected losses across the ZIP code be greater than the total annualized mitigation costs of all properties in the ZIP code which had been mitigated?

Using Scenario 1 all ZIP codes in Oakland would satisfy this cost effectiveness condition. By reducing the time horizon to 5 years, as in Scenario 2, then 68.8% of the ZIP codes in Oakland satisfied this cost effectiveness condition. For Scenario 3, where the discount rate is 20% and the time horizon is 5 years, only 37.5% of the ZIP codes in Oakland satisfied this cost effectiveness condition.

This analysis implies that if the decision to implement a building code in a zip code was based on an analysis of benefits and costs, using short time horizons and/or high discount rates (Scenario 3), then the percentage of pre-1940 homes in Oakland that would have braced crippled walls and be bolted to its foundation would be only 37.5% of those that should have adopted this RMM.

4. INSURER DECISION PROCESSES

A literature has developed in recent years which suggests that insurers and other firms are risk averse and hence they must be concerned with non-diversifiable risks such as the possibility of catastrophic losses from disasters [Mayers and Smith (1982)]. Insurers are also likely to be ambiguity averse in that they are concerned with the uncertainty regarding the probability of a loss occurring [Kunreuther, Hogarth and Meszaros (1993)].

Importance of Safety First Constraint Actuaries and underwriters both utilize heuristics that reflect these concerns. Actuaries normally determine a premium based on expected value by assuming that the probability and loss are known. They then increase this value to reflect the amount of perceived ambiguity in the probability and/or uncertainty in the loss. One commonly used formula for determining a premium is $z=(1+\lambda)\mu$ where μ= expected loss (i.e. p x L) and $\lambda>0$ is a factor reflecting ambiguity and uncertainty independent of any adjustment to cover administrative costs [Lemaire (1986)].

Underwriters make their decision regarding whether a risk is insurable by utilizing the actuary's recommended premium z as a reference point and then focus on the impact of a major disaster on the probability of insolvency. In other words, underwriters are first concerned with the firm's safety and then with profit maximization. Stone (1973) formalized these concepts by suggesting that an underwriter who wants to determine the conditions for a specific risk to be insurable will first focus on keeping the probability of insolvency below some threshold level (q*). More specifically, suppose that the insurer expects to sell m policies, each of which can create a loss L. Then the underwriter will recommend a premium z* so that the probability of insolvency is no greater than q*. Risks with more uncertain losses or greater ambiguity will cause underwriters to want to charge higher premiums for a given portfolio of risks. The situation will be most pronounced for highly correlated losses, such as earthquake policies sold in one region of California.

The empirical evidence based on surveys of underwriters supports the hypothesis that insurers will set higher premiums when faced with ambiguous probabilities and uncertain losses rather than a well-specified risk. In a survey of underwriters pricing the earthquake insurance, Kunreuther et al. (1995) showed that for the case where both the probability of a loss was ambiguous and the resulting loss uncertain, the premiums were between 1.43 to 1.77 times higher than if underwriters priced a non ambiguous risk.

Application to Oakland Table 2 specifies the base case parameters for the Alpha insurance company providing coverage to homeowners in Oakland. We assume that full insurance coverage against damage from the disaster is available, with a 10 percent deductible. The (annual) premium charged is proportional to the expected loss (per year) for the property covered[5] and then multiplied by a loading factor (in this case 1.0) to reflect the administrative costs associated with marketing and claims settlement. In other words, for this analysis, property owners are charged premiums that are twice the expected losses to the insurer. A fixed cost of $300,000 reflects payments such as rent which are independent of the number of insurance policies that are sold.

[5] Expected loss to the insurer is defined as the probabilities of disasters of different magnitudes, each multiplied by the damage sustained minus the deductible and then summed.

Table 2: Base Case Alpha Insurance Company Parameters

Parameter	Base Case Value
Company Assets	$ 15 Million
Deductible %: (expressed as a fraction of the value of property)	10%
Insurance loading factor:	1.0
Fixed Costs	$300,000

Insurers are concerned with insolvency and focus on worst case scenarios in determining their portfolio of risks. A worst case loss (WCL) is defined as a disaster where the probability of exceeding this dollar amount is some predetermined target ruin probability. For example, if an insurer sets a “target ruin probability” at .01, this implies that it would like to limit its book of business (BOB) so as to have at least a 99 percent chance of being able to pay insured losses from assets and premiums. If it has sufficient assets and/or premiums, then the insurer’s actual probability of insolvency may be less than the this target level. Insurers who are more risk averse and hence have a greater concern with insolvency would reduce their target level probability to a lower level, say .002 (e.g. 1 in 500) which would imply a smaller BOB for a given asset base.

5. DEVELOPING A PLAN FOR DISASTER MANAGEMENT

There are several different strategies for reducing future losses from natural disasters and providing protection for victims of natural disasters that complement each other. This section briefly describes several policy tools for achieving these objectives and examines their implications in the context of Oakland, CA.

Specific Policy Tools We will be examining three policy tools as part of a disaster management strategy: building codes, indemnity contracts such as reinsurance and indexed catastrophe bonds. These options involve a number of different interested parties each of whom has their own values and objectives. The challenge is to develop a strategy for implementation which has enough positive returns to these different stakeholders for them to want to play the game:

Well-Enforced Building Codes Building codes mandate that property owners adopt mitigation measures. Such codes may be desirable when property owners would otherwise **not** adopt cost-effective RMMs because they either misperceive the benefits from adopting the RMM and/or underestimate the probability of a disaster occurring. For example, suppose the property owner believes that the losses from an earthquake to the structure is $20,000 and the developer knows that it is $25,000 because it is not well constructed. There is no incentive for the developer to relay the correct information to the property owner because the developer is **not** held liable should a quake cause damage to the building. If the insurer is unaware of how well the building is constructed, then this information cannot be conveyed to the potential property owner through a premium based on risk.

There are many other players who are involved with implementing building codes. Banks and financial institutions could require an inspection of the property to see that it meets code before issuing a mortgage. Similarly insurers may want to limit coverage only to those structures that meet the building code. Either banks or insurers can provide a seal of approval to each structure that meets or exceeds building code standards. Inspecting the building to see that it meets code and then providing it with a seal of approval provides accurate information to the property owner on the condition of the house. It also signals to others that the structure is disaster resistant. This new information might then be translated into higher property values if prospective buyers took the earthquake risk into consideration when making their purchase decisions.

One way for communities to encourage well-enforced building codes is to provide tax incentives for more disaster-resistant homes. For example, if a homeowner reduces the chances of damage from an earthquake by installing a mitigation measure, then this taxpayer would get a rebate on state taxes to reflect the lower costs for disaster relief. Alternatively, property taxes could be reduced for the same reason. In practice, communities often create a monetary disincentive to invest in mitigation. A property owner who improves a home by making it safer is likely to have the property reassessed at a *higher* value and, hence, have to pay higher taxes. California has recognized this problem, and in 1990 voters passed Proposition 127, which exempts seismic rehabilitation improvements to buildings from reassessments that would increase property taxes.

The city of Berkeley has taken an additional step to encourage homebuyers to retrofit newly purchased homes by instituting a transfer tax rebate. The city has a 1.5 percent tax levied on property transfer transactions; up to one-third of this amount can be applied to seismic upgrades during the sale of property. Qualifying upgrades include foundation repairs or replacement, wall bracing in basements, shear wall installation, water heater anchoring, and securing of chimneys. Since 1993, these rebates have been applied to 6,300 houses, representing approximately $ 4.4 million in foregone revenues to the city (Earthquake Engineering Research Institute, 1998).

Indemnity Contracts One way for private insurers to obtain protection against catastrophic losses is for them to purchase an indemnity contract against claim payments above a certain amount. A common indemnity contract is excess-of-loss reinsurance that provides coverage against unforeseen or extraordinary losses to the insurer. Specifically, the reinsurer charges a premium to indemnify the insurance company against all or part of the loss it may sustain under its policy or policies of insurance above a certain level.

For all but the largest primary insurers, a reinsurance-tied strategy is a prerequisite for offering insurance against hazards where there is the potential for catastrophic damage. An unusually severe set of claim payments can make even a well-capitalized insurer insolvent even if the insurer is, on average, profitable. A natural disaster with intense local effects, such as an earthquake, thus raises problems for insurers who cover multiple customers in a given geographic area because of the high correlation among the losses in their portfolio.

Reinsurers have similar concerns to those of the insurers and hence will limit their exposure in catastrophe-prone areas. A typical excess loss reinsurance contract requires the primary insurer to retain a specified level of risk and then covers all losses between an attachment point (L_A) and exhaustion point (L_E). In other words, the indemnity contract is of the following form: the reinsurer pays all losses in the interval L_A to L_E with a maximum payment of $L_E – L_A$.

If insurers were allowed to charge higher premiums on their own policies, many would need less reinsurance and would accept a higher attachment point L_A. However, regulatory constraints, such as obtaining prior approval by the State Insurance Commissioner on rate changes, limit insurers ability to raise premiums to levels that they feel reflect the risk. For example, in Florida following Hurricane Andrew in 1992 there were restrictions placed on rates that could be charged on homeowners coverage (which covers wind damage) in areas of the State affected by hurricanes (Lecomte and Gahagan 1998).

Catastrophe Bonds As an alternative or complement to reinsurance, the insurer may want to utilize catastrophe-linked bonds (henceforth referred to as *cat bonds*) for protection. A cat bond requires the investor to put money up front, which could be used to pay for claims if some type of triggering event were to occur.

This process is called *securiitization* which simply means converting a financial contract into a security that can be traded in the secondary market. In practice, Alpha would begin the securitization process by meeting with investment banks who would provide Alpha with their estimates of the current market price of a cat bond. The investment bank would use risk assessment data from modeling firms to determine the expected losses from the specific cat bond that Alpha is interested in issuing. The expected losses along with spreads for comparable risks in the credit markets will determine the price of the cat bond. (Kuzak 2000)

In contrast to reinsurance where the reinsurer can become insolvent if it suffers catastrophic losses, the insurer does not face any credit risk from the cat bond. The money to pay for the losses is already in hand (usually deposited in escrow, and invested in short-term liquid securities). The first cat bond was issued by USAA in June 1997 to protect itself against cat losses from hurricanes in Florida. In this cat bond, USAA offered two tranches, geared towards different types of investors. Tranche one paid only a modest interest-rate premium above the risk-free rate (LIBOR), but investors would lose only their interest payments if USAA suffered hurricane losses during a 15-month period that exceeded $1 billion. Tranche 2 offered a higher premium over LIBOR but the investors' entire principal was at risk in case of severe hurricane losses by USAA.[6]

Most of the cat bonds which have been issued since the USAA offering are tied to a loss index (e.g., total insured losses from an earthquake in California) or to a disaster severity index (e.g., paying amounts for earthquake damages based on the Richter-scale measurements at specific locations in Japan) rather than to the insurer's losses.[7] If the index is independent of actual losses (as in the case of a disaster severity index), the insurer cannot manipulate the claims. Hence claims to insurers can be made immediately after the disaster rather than being subject to a time delay as in the case of reinsurance.

On the other hand, such a cat bond may create **basis risk**. Basis risk refers to an imperfect correlation between the actual losses caused to the insurer and the payments received from the cat bond. Traditional excess-of-loss reinsurance has zero basis risk because there is a direct relationship between the loss and the payment delivered by the reinsurance instrument. Even a cat bond based on some verifiable, non-manipulable index (e.g., aggregate insurance industry losses, the Richter or Saffir-Simpson scales, total rainfall in Rangoon during August) is subject to basis risk. In other words, the insurer's book of business may not be accurately represented by the index, and therefore the insurer's losses will not be perfectly correlated with the actual payments from the cat bond triggered by the index.[8]

6. A RISK MANAGEMENT STRATEGY FOR OAKLAND, CALIFORNIA

The model city of Oakland, CA offers an opportunity to examine the impact of alternative disaster management strategies on the performance of the insurer. More specifically we will be examining the role of building codes, reinsurance and indexed catastrophe bonds on the performance of the Alpha Insurance Company.

Specific Policy Tools The following policy tools will be examined:

***Building codes*-----**We will compare the losses to Alpha for two polar cases: (1) when there are no building codes in place so that all pre-1940 homes are not mitigated and (2) all homes have crippled walls and their foundations braced.

***Indemnity Contracts* ---**Alpha will purchase an excess of loss reinsurance contract that has an attachment point (L_A) where there is a 4 percent chance that the losses will exceeding this amount when there is no mitigation in place . The exhaustion point (L_E) is determined so that the chances of Alpha's losses exceeding this amount is 3 percent when no pre-1940 homes are mitigated. More specifically Alpha's reinsurance contract has a

[6] For more detail about USAA's financing decision, see Froot and Seasholes (1997)..
[7] For more details on the structure of recent cat bonds see Insurance Services Office (1999).
[8] See Major (1999) for a more detailed description of basis risk, and the effect of basis risk on insurers' ability to address catastrophic losses.

value of L_A = $5.93 million and L_E = $8.27 million. Alpha must pay a premium that reflects the risks that the reinsurer faces plus a loading factor of 100 percent. Thus if the expected losses to the reinsurer over the interval $L_E - L_A$ was $40,000 then Alpha would pay the reinsurer $80,000 in premiums.

Catastrophe Bonds--- Insurers can issue a parameterized indexed cat bond where they would receive payments according to a predetermined measurement schedule. More specifically Alpha issues a catastrophe bond that pays investors an interest premium in exchange for guaranteed funds based on the occurrence of a disaster of a given intensity or magnitude. The amount of funds given to the insurer is based on an index (e.g. an earthquake of 7.5 on the Moment Magnitude scale) so it likely will not be perfectly correlated to actual claim payments.

Suppose that Alpha issues a $10 million Total Face Value cat with a 10% annual coupon. If the risk-free interest rate (LIBOR) is 5.5% then the spread above this rate for this cat bond is 4.5% (10%-5.5%). At the beginning of the year Alpha will receive $10 million from investors and immediately reinvest this amount in a risk free investment earning $550,000 (i.e., 5.5% x $10 million). Insurers will pay investors guaranteed coupon payments of $1 million (i.e., 10% x $10million) so that the price to the insurer for interest rates over LIBOR is $450,000 ($ 1million-$550,000)

In return for a higher return the investor does face the possibility of losing some or all of its principal if a severe enough earthquake occurs in Oakland. The amount paid out to the insurer depends on how the cat bond is constructed. The cat bond was designed to protect insurer from losses greater than the reinsurance exhaustion point (L_E). We constructed the cat bond by first computing the expected losses generated by earthquakes of different intensities in Oakland. For example, if one specified all earthquakes of magnitude 7.0 to 7.5 that would impact residential homes in Oakland, CA we could determine the probability of each of these events i ($p_{i\,(7.0\text{-}7.5)}$) occurring and the damage that each event ($L_{i\,(7.0\text{-}7.5)}$) would create. The expected loss for earthquakes of this magnitude would be

$$E(L_{i\,(7.0\text{-}7.5)}) = [\sum_i p_{i\,(7.0\text{-}7.5)})\,(L_{i\,(7.0\text{-}7.5)})] / [\sum_i p_{i\,(7.0\text{-}7.5)}]$$

In the above equation, we only used losses in excess of L_E since we wanted to model the cat bond to protect the insurer from losses in the far right tail of the distribution. We did this same type of calculation for each earthquake in Oakland within specified intervals (e.g. 7.0-7.5 MMI). We then set these expected losses equal to the actual payout of the cat bond to the insurer for acceptable ranges of magnitudes. More specifically, cat bonds paid the insurer for earthquakes greater than 7.0 in Oakland. These payouts for cat bonds will create basis risk since there will be some events in the interval that will produce insurer claims (net of reinsurance payments) larger than the amount provided by the cat bonds (positive basis risk) and those that are smaller than the cat bond amount (negative basis risk).

Table 3 depicts the structure of two different cat bonds for Oakland depending on whether or not a building code was in place. When there were no pre-1940 homes mitigated, then the total face value of the cat bond was $30 million and the price to the insurer for a higher interest rate than LIBOR was $1.342 million. When homes were mitigated then the insurer only required a cat bond with face value of $18.5 million, since catastrophic losses were reduced. As shown in the payout schedule for the cat bonds, when there was no mitigation in place insurers would receive $29.196 million if an earthquake occurred in Oakland that had a magnitude between 7.0 and 7.5 on the MMI scale. Interestingly enough the payout was only $1.058 million when earthquakes greater than 7.5 registered on the scale. The smaller figure was due to the relatively few residential structures in those portions of Oakland where earthquakes of this magnitude or greater could occur.

Table 3: Structure of Cat Bond:

Oakland

(All Dollar Amounts in $ Thousands)

Parameters:	**0% Mitigation**	**100% Mitigation**
Total Face Value	$30,000	$18,500
Cat Bond Return to Investor	9.97%	10.00%
Price to Insurer over LIBOR	$1,342	$832

		0% Mitigation	**100% Mitigation**
Magnitude	*Probability*	*Payout to Insurer*	*Payout to Insurer*
< 7.0	98.0%	$0	$0
[7.0,7.5)	1.8%	$29,196	$18,279
[7.5,max)	0.2%	$1,058	$203

Performance of Alternative Risk Management Strategies There are eight different strategies which could be undertaken by Alpha using the above three policy tools depending on whether or not one had well-enforced building codes, reinsurance and cat bonds in place.[9] Building codes and cat bonds will lower the exceedance probability curves for Alpha from the strategy of no building code and no available cat bonds.

[9] These eight strategies reflect the eight possible combinations of the 3 different policy tools (building codes/no building codes; reinsurance/no reinsurance; cat bonds/ no cat bonds). For example one strategy would be Building codes, reinsurance, no cat bonds.

Building codes reduce the damage to pre-1940 homes from earthquakes. Cat bonds provide insurers with pre-determined payments as a function of the magnitude of the earthquake and independent of the actual damage. Hence they will reduce the losses over what they otherwise might have been. Insurers have to pay for this protection in the form of interest rates substantially above LIBOR. Figure 3a depicts the EP curves with and without cat bonds when **no** mitigation is in place for pre-1940 homes. Figure 3b examines the EP curves with and without cat bonds when a building code is in place for pre-1940 homes.

Figure 3a: EP Curves Without Mitigation, With and Without Cat Bond, 10% Deductible Oakland: Alpha Insurance Company

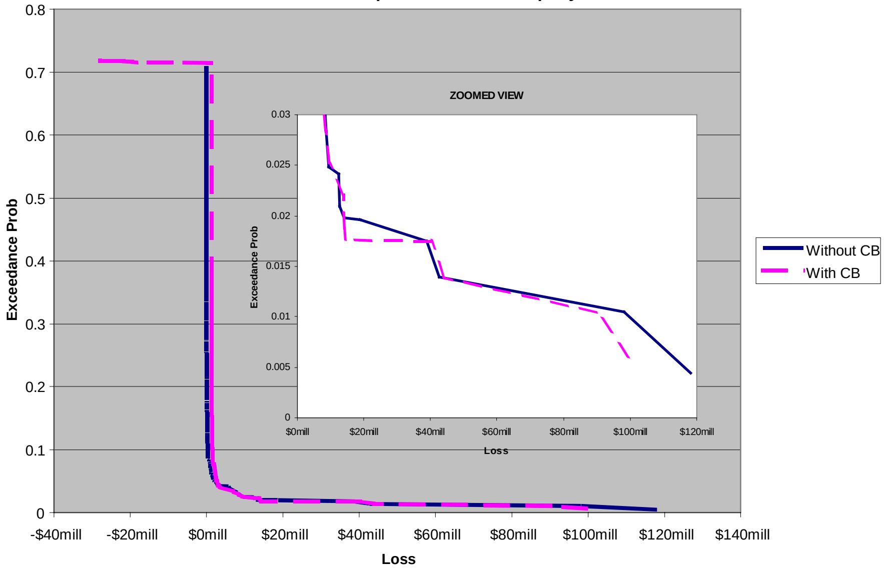
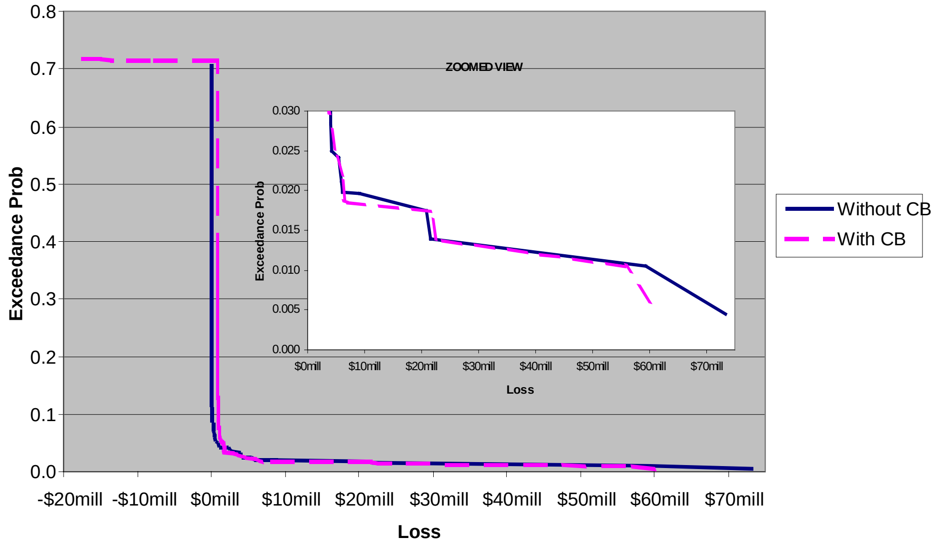


Figure 3b: **EP Curves With Mitigation, With and Without Cat Bond, 10% Deductible**
Oakland: Alpha Insurance Company



The analyses of the performance of the impact of mitigation, reinsurance and cat bonds on the Alpha Insurance Company in Oakland reveals some interesting findings as shown in Table 4

Table 4: Summary of Results:

Oakland

	0% Mitigation			
	w/o Reinsurance		**w/ Reinsurance**	
	w/o Cat Bond	*w/ Cat Bond*	*w/o Cat Bond*	*w/ Cat Bond*
Insolvency Prob	3.19%	2.87%	2.44%	2.22%
Expected Profit	$1,680	$898	$1,604	$822
Worst Case Loss	($114,660)	($96,173)	($112,468)	($93,981)

	100% Mitigation			
	w/o Reinsurance		**w/ Reinsurance**	
	w/o Cat Bond	*w/ Cat Bond*	*w/o Cat Bond*	*w/ Cat Bond*
Insolvency Prob	1.98%	1.89%	1.98%	1.76%
Expected Profit	$954	$473	$905	$424
Worst Case Loss	($71,449)	($58,254)	($69,990)	($56,794)

Impact of Mitigation An analysis of the expected loss reduction for Oakland reveals that bracing the crippled wall and bolting pre-1940 houses to their foundation is a cost-effective RMM. For very severe earthquakes in Oakland this mitigation measure reduces the worst case losses (WCL) by approximately 40% whether Alpha purchases reinsurance and/or cat bonds.

Impact of Reinsurance As expected, reinsurance reduces the insolvency probability of Alpha but its expected profits are also reduced because Alpha is assumed to have 100 percent BOB. If the insurer were able to write more coverage because it had reinsurance, then profits could actually be higher. In other words, the reinsurance would expand the insurer's capacity.

Impact of Cat Bonds Turning to the impact of cat bonds on the insolvency and profitability of Alpha, we obtain the following results, Cat bonds reduce the insolvency probability by almost 0.2 percent when there is no reinsurance or mitigation in place and reduced the insolvency probability by 0.1 percent when both reinsurance is purchased and mitigation is in place. Cat bonds reduced WCLs by about $20 million with no mitigation and by about $10 million with mitigation.

Conclusions In summary, a combination of building codes, reinsurance and indexed cat bonds can form a useful strategy for reducing losses to property owners as well as insurers and the investment community. The implementation of this strategy requires a concerted effort by both the public and private sectors. For example, building codes require inspections by certified personnel. Banks and financial institutions can help enforce these building codes by making loans conditional on such an audit. Insurers can offer lower premiums for those adopting cost-effective mitigation measures.

With new sources of capital from the Bermuda market, there is an opportunity for reinsurance to provide more protection against insurers' potential losses if the premiums are attractive enough to them. With respect to new financial instruments, the interest rate on cat bonds has to be sufficiently low so that insurers will want to issue them but high enough for investors to want to purchase them.[10] One needs to determine what the appropriate role of the public sector is in providing financial protection against large losses. The reluctance of the insurance industry to cover losses from earthquakes in California led to the formation of the California Earthquake Authority which is a state-run insurance company funded by the insurance and reinsurance industry will limited liability.[11]

The potential for developing an effective disaster management strategy has been made possible by the new advances in information technology (IT) and risk assessment over the past ten years. More sophisticated catastrophe models have provided far more accurate estimates of the likelihood and potential losses from future natural disasters than

[10] See Bantwal and Kunreuther (2000) for some of the reasons why cat bonds are priced as high as they are today.

[11] See Roth, Jr. (1998) for a more detailed discussion on the formation and status of the California Earthquake Authority.

we have had in the past. These models coupled with user-friendly software have paved the way for an analysis of the cost-effective of mitigation measures as well as the emergence of new capital market instruments. Our own work on the Wharton Catastrophic Risk project would not have been possible without the aid of these models.

5. Issues and Questions for Future Research

To conclude the paper here are a set of issues and questions designed to stimulate discussion among the panelists in this session:

Relationship Between Insurers and Reinsurers Both the insurer and reinsurer traditionally have viewed reinsurance as a long-term relationship with elements of trust between the two parties. Can one view this relationship today in the same manner? For example, if reinsurers suffer large losses following a major disaster are they still willing to provide insurers with protection in the future? What is likely to happen to the price of future reinsurance after a catastrophic event?

Long-Term Guaranteed Protection Can one establish long-term guarantees with new financial instruments after the contractual period is reached? For example, if an insurer purchases an indexed cat bond for 15 months, how certain is the insurer as to what price he will have to pay for another cat bond? How does this long-term uncertainty with capital market instruments compare with the reinsurance market today?

Attractiveness of Cat Bonds Today there is not a large investor appetite for indexed cat bonds and there appears to be a risk premium that needs to be attached to these financial instruments to attract investors? Does this risk premium hold for all type of cat bonds or are there certain classes of cat bonds that raise special concerns for investors? In other words, what aspects of the bonds themselves and the risk quantification process underlying them are more attractive or less attractive to institutional investors?

Pricing of Capital Market Instruments What are these prices of cat bonds likely to be relative to reinsurance prices in the next year or two if there is no major disaster or a catastrophic earthquake or hurricane occurs? How will this affect the tradeoffs insurers are willing to make between purchasing reinsurance and cat bonds?

Coverage of Cat Losses What type of layers is reinsurance most likely to cover with respect to losses? What about cat bonds and their coverage? Can these two layers complement each other?

Linkage of Mitigation Measures with Financial Protection What role are mitigation measures likely to play in the pricing of capital markete instruments and reinsurance? What impact are different types of mitigation measures likely to have on the different layers of reinsurance or payouts from cat bonds? Mitigation is likely to reduce the variance in future losses but we need to know where the impacts of mitigation are likely to be for earthquakes of different intensities and magnitudes.

Impact of Regulation What is the impact of solvency and premium regulation on the attractiveness of cat bonds for companies or groups of companies covered by such regulation?

There are a number of challenges associated with developing a disaster management plan which require interaction between researchers and practitioners. It is an exciting time to have these two groups address these issues in a systematic manner so as to increase the chance that a meaningful strategy can be implemented for reducing future losses and providing protection against future disaster.

REFERENCES

Bantwal, Vivek and Kunreuther, Howard 2000 "A Cat Bond Premium Puzzle?" *Journal of Psychology and Financial Markets* 1:76-91.

Croson, D. and A. Richter (1999) "Sovereign Cat Bonds and Infrastructure Project Financing." Working Paper 99-05-25, Wharton Risk Management and Decision Processes Center. University of Pennsylvania; Philadelphia, PA. Forthcoming, *Risk Analysis*.

Earthquake Engineering Research Institute (EERI). (1998) *Incentives and Impediments Improving the Seismic Performance of Buildings*. Oakland, CA: Earthquake Engineering Research Institute

Froot, K. and M. Seasholes (1997). "USAA: Catastrophic Risk Financing." Case 9-298-007; Harvard Graduate School of Business Administration; Boston, MA.

Grossi P., P. R. Kleindorfer and H. Kunreuther, 1999. " The Impact of Uncertainty in Managing Seismic Risk: The Case of Earthquake Frequency and Structural Vulnerability", WP 99-03-26, Risk Management and Decision Processes Center, Wharton, Philadelphia

Hanks, Thomas, and C. Allin Cornell. 1994. Probabilistic seismic hazard analysis: A beginner's guide. *Proceedings of the Fifth Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping.* Raleigh: North Carolina State University.

Hausman, Jerry (1979) " Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables", Bell Journal of Economics 10, pp.33-54.

Heinz Center for Science, Economics, and the Environment. 1999 The Hidden Costs of Coastal Hazards: Implications for Risk Assessment and Mitigation. Washington, DC: Island Press.

Hurriyet, October 21st, 1999, p. 14.

Insurance Services Office 1999. *Financing Catastrophe Risk: Capital Market Solutions* (New York, N.Y.: Insurance Services Office)

Kempton, Willett and Neiman, Max (ed.) (1987) Energy Efficiency: Perspectives on Individual Behavior, Washington, D.C.: American Council for an Energy Efficient Economy.

King, Stephanie, and Anne Kiremidjian. In press. Use of GIS for earthquake hazard and loss estimation. In *Geographic Information Research: Bridging the Atlantic*. London: Taylor & Francis.

Kleindorfer, P. R. and Kunreuther, H. 1999. "Challenges Facing the Insurance Industry in Managing Catastrophic Risks" in Kenneth Froot (ed) *The Financing of Property/Casualty Risks* (Chicago: University of Chicago Press).

Kunreuther, Howard, et al. 1978. *Disaster Insurance Protection: Public Policy Lessons.* New York: John Wiley and Sons.

Kunreuther, Howard, Jacqueline Meszaros, Robin Hogarth, and Mark Spranca. 1995. Ambiguity and underwriter decision processes. Journal of Economic Behavior and Organization 26:337—352.

Kuzak, Dennis (2000) "The Capital Markets" Chap. 10 in Earthquake Engineering Research Institute *Financial Management of Earthquake Risk* Oakland, CA: EERI.

Lecomte, Eugene and Gahagan, Karen (1998) "Hurricane Insurance Protection in Florida" Chap. 6 in Kunreuther, Howard and Roth, Richard, Sr. ed. (1998)_ *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States* Washington, D.C: Joseph Henry Press.

Lemaire, Jean. 1986. Theorie Mathematique des Assurances. Belgium: Presses Universitaires de Bruxelles.

Loewenstein George and Prelec, Drazen (1992) " Anomalies in Intertemporal Choice" *Quarterly Journal of Economics*, 107, pp. 573-597.

Major, John A. (1999) "Index Hedge Performance: Insurer Market Penetration and Basis Risk." in Kenneth Froot (ed.) (1999) *The Financing of Property/Casualty Risks* (Chicago: University of Chicago Press).

Mayers, David, and Clifford Smith. 1982. On corporate demand for insurance. *Journal of Business* 55:281—296.

Palm, Risa, Michael Hodgson, R. Denise Blanchard and Donald Lyons. 1990. *Earthquake Insurance in California: Environmental Policy and Individual Decision Making.* Boulder, Colo.: Westview Press.

Palm, Risa. 1995. *Earthquake Insurance: A Longitudinal Study of California Homeowners*. Boulder, Colo.: Westview Press.

Petak, W. and Atkisson, A. 1982 *Natural Hazard Risk Assessment and Public Policy: Anticipating the Unexpected* New York: Springer Verlag

Roth, R. Jr. "Earthquake Insurance Protection in California" Chap. 4 in Kunreuther, Howard and Roth, Richard, Sr. ed. (1998)_ *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States* Washington, D.C: Joseph Henry Press.

Stone, James 1973. A theory of capacity and the insurance of catastrophe risks: Part I and Part II. Journal of Risk and Insurance 40:231—243 (Part I) and 40:339—355 (Part II).

Wilczynsky, Piotr and Kalavakonda, Vijay 2000. "TURKEY: Strategy for Disaster Management and Mitigation" Paper presented at World Bank ProVention Consortium Seminar Washington,DC: February 2-4.

Figure 2: EP Curves with 5% and 95% Confidence Intervals: Oakland,