THE COMPLEMENTARY ROLES OF MITIGATION AND INSURANCE IN MANAGING CATASTROPHIC RISKS[1]

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ABSTRACT

This paper examines the impact that specific risk mitigation measures (RMMs) could have on reducing losses from hurricanes and earthquakes as well as improving the solvency position of insurers who provide coverage against these hazards. We first explore why relatively few individuals adopt cost-effective RMMs by reporting on the results of empirical studies and controlled laboratory studies. We then investigate the impact that an RMM has on both the expected losses and those from a worst case scenario in two model cities---Oakland (an earthquake-prone area) and Miami/Dade County (a hurricane-prone area) which were constructed respectively with the assistance of two modeling firms—Risk Management Solutions and Applied Insurance Research .

The paper then explores three programs for forging a meaningful public-private sector partnership: well-enforced building codes, insurance premium reductions linked with long-term loans, and lower deductibles on insurance policies tied to mitigation. We conclude by briefly examining four issues for future research on linking mitigation with insurance: regulatory issues facing insurers, uncertainty issues in estimating risks, tradeoffs between reinsurance and mitigation and the impact of mitigation on capital market instruments.

1. OBJECTIVES OF PAPER

In December 1995 the Federal Emergency Management Agency (FEMA) introduced a National Mitigation Strategy to increase public awareness of natural hazard risks and to reduce significantly the risk of loss of life, injury and economic losses from natural hazards. FEMA's strategy was also designed to strengthen the partnership between the public and private sectors in ensuring safer communities. (FEMA 1997)

This paper examines the impact that specific risk mitigation measures (RMMs) could have on reducing losses from hurricanes and earthquakes as well as improving the solvency position of insurers who provide coverage against these hazards. An RMM is an action that reduces or eliminates the losses to individuals and their property from natural hazards. It normally involves an upfront investment cost in exchange for a stream of benefits accruing over time in the form of reduced expected losses from natural disasters. For example, if a property owner were to bolt the structure to its foundation, it might cost the property owner $1500. Should a severe earthquake occur in the vicinity of the property, the damage might be reduced by $20,000 if the house is prevented from toppling off its foundation. These mitigation benefits would continue to accrue over the lifetime of the property.

Of special interest for economics and public policy are cost-effective RMMs. These are any mitigation measures for which the discounted expected benefits over the life of the property are greater than the upfront investment expenses and other costs associated with the measure. In theory all of the interested parties concerned with natural disaster losses should view such a measure favorably. The **property owner** should see this as an attractive investment which will increase the value of his residence or business. The **insurer** knows that losses will be reduced should a disaster strike the area The **contractor and developer** should find it easier to sell a property which is better designed against hazards even if it costs more than one which is relatively unsafe. Public sector agencies at the state, local and federal levels should celebrate the lower need for disaster assistance due to the reduced losses from future disasters.

The reality of the situation is quite different. Few property owners voluntarily adopt mitigation measures nor do insurers provide incentives for these investments through premium reductions reflecting the decreased losses associated with the property. Housing values do not appear to reflect the benefits of mitigation measures, perhaps because people don't want to be reminded that they live in a hazard-prone area. As a result, developers and contractors have no economic incentive to build safer structures since it means incurring costs that they feel will hurt them competitively because the RMMs are undervalued by the potential buyers.[4] Hence the public sector has to bear a larger portion of the disaster losses than if these measures had been adopted.

This paper explores three interrelated issues associated with risk mitigation measures (RMMs). We first want to better understand why relatively few individuals adopt cost-effective RMMs. This issue is explored in the next section where we report on the results of empirical studies and controlled laboratory studies. Second we want to better understand the impact that RMMs have on the performance of insurance firms. We investigate this question in Section 3 by examining the impact that an RMM has on the expected losses and those from a worst case scenario in two model cities we have constructed---Oakland (an earthquake-prone area) and Miami/Dade County (a hurricane-prone area). The third area of interest is the role of the public and private sectors in developing a strategy for reducing losses from natural hazards. The types of policy instruments for a meaningful public-private sector partnership are examined in Section 4. The final section of the paper raises a set of additional questions regarding future research in evaluating the role that cost-effective mitigation measures can play in reducing losses from future natural disasters.

2. WHY IS THERE LIMITED INTEREST IN MITIGATION?

The empirical data on studies of mitigation adoption in hazard-prone areas of the United States suggest that individuals are not willing to invest in mitigation measures despite the rather large damage that either they and/or their friends and neighbors suffered from recent disasters. For example, after Hurricane Andrew in Florida in 1992, in terms of economic losses the most severe disaster in the United States, most residents in hurricane-prone areas appear not to have made improvements to existing dwellings that could reduce

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[4] Interviews with structural engineers concerned with the performance of earthquake-resistant structures indicate that they have **no** incentive to build structures that exceed existing codes because they have to justify these expenses to their clients and would lose out to other engineers who did not include these features in the design (May and Stark 1992).

the amount of damage from another storm.

A July 1994 telephone survey of 1241 residents in six hurricane-prone areas along the Atlantic and Gulf Coasts revealed that 62 percent indicated that they had **not** installed hurricane shutters, used laminated glass in windows, installed roof bracing and/or made sure that side walls were bolted to the foundation either before or after Hurricane Andrew. (Insurance Institute for Property Loss Reduction 1995). Studies of the added costs of materials and labor for hurricane-resistant designs indicate that this will add no more than 4-5 percent to the cost of a new home and that the additional expense is not substantial relative to the added benefits of safety and security (Unnewehr 1994). A recent do-it-yourself guide to hurricane retrofit by the Institute for Building and Home Safety (IBHS) recommends home improvements that individuals can make themselves or can share with the contractor doing the work for them. (Institute for Building and Home Safety 1997).

With respect to investing in RMMs to reduce quake damage, a 1989 survey of 3,500 homeowners in four California counties subject to the hazard reported that only between 5 and 9 percent of the respondents in each of these counties reported adopting any loss reduction measures (Palm et al. 1990). A follow-up survey by Palm and her colleagues in 1993 revealed that between 20 to 25 percent of the homes in the two counties affected by the 1989 Loma Prieta earthquake (Santa Clara and Contra Costa) had bolted their house to the foundation; less than 10 percent of homeowners in the two southern counties in the survey (Los Angeles and San Bernadino) had undertaken this measure (Palm 1995).

Measures such as strapping a water heater cost relatively little (e.g. $75) and can significantly reduce damage by preventing the heater from toppling during an earthquake and causing a fire. The expected benefits from such a measure greatly exceed the costs in quake-prone regions and yet these and other loss reduction investments are not being adopted. This behavior suggests that individuals do **not** believe that investing in the RMM will increase their residence's property value or that they have either short time horizons and/or severe budget constraints which either reduce their perceived net benefits from RMMs or simply prevent them from making the investment.

To determine how much an individual is willing to pay for an RMM, a set of controlled experiments were conducted in Pennsylvania and California (Kunreuther, Onculer, and Slovic 1997). Subjects were asked to specify the maximum they were willing to pay (WTP) for bolting the structure to its foundation of their house if they planned to reside in it for exactly 5 years and the expected annual reduction in damage from the RMM was approximately $500.[5] They were then asked to specify a maximum WTP if they expected to live in the house for exactly 10 years. In other words their time horizon (T) for residing in their house was doubled. Table 1 presents the distribution of these WTP figures for 84 students at the University of Pennsylvania. Half of these students were not

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[5] The expected annual reduction in damage was specified in the following manner. The reduction in damage from preventing the house from toppling off its foundation is $20,000. The risk mitigation measure (RMM) is assumed to reduce the annual probability of an earthquake causing the structure to topple off its foundation from 1/20 to 1/40. Hence the expected annual benefits of the RMM are approximately (1/20-1/40) $20,000 = $500.

told what the RMM cost to install and the other half were told that the price of installing the RMM was $1500.

INSERT TABLE 1 HERE

The data reveal that only 12 percent of the individuals would be willing to pay over $2000 for the measure if the price was not given and they expected to live in the house for 5 years. The proportion in this category increases to 18% for the group who were given a price of $1500. In other words, a relatively small proportion of subjects behaved as if they made decisions based on benefit-cost comparisons using a reasonable discount rate. More specifically, a risk-neutral person should be willing to pay as much as $2,085 if their annual discount rate was 10% and they expected to live in their house for 5 years. When the time horizon is lengthened to 10 years the maximum WTP for a risk-neutral investor facing an annual cost of capital of 10% increases to $3,380. Yet only 7% of the subjects who were **not** given the price chose to spend more than $3,000; the percentage increases to 17% for this group when the price was specified to be $1,500. These results suggest that RMMs may need to be very cost effective indeed if they are to be adopted through normal private choice without regulation.

Similar findings emerged from a survey of 252 individuals visiting the Exploratorium Museum in San Francisco. Now three different time horizons (T) for residing in the house were utilized: 5 years, 10 years and 20 years for obtaining the maximum WTP when the price of the quake RMM was given at $1500. As in the earlier experiment, a significant proportion of the respondents had either high effective discount rates (the mean value varied between 67% and 74% depending on the values of T)[6] or did not change their maximum WTP as the time horizon for residing in the house was increased. For the case where the length of time in the house was extended from 5 to 10 years, 45% of the subjects did not change their expressed WTP for the protective measure (Kunreuther, Onculer and Slovic 1997). The large group of individuals who maintain the same WTP as the time horizon changes may be because these individuals cannot afford to pay more and/or they believe that the cost of the RMM is fully capitalized in the selling price of the property value.

Taken together with earlier studies on individuals behavior with respect to low probability high consequence events (e.g., See Camerer and Kunreuther, 1989 for a summary of these studies), these results suggest that some property owners are reluctant to invest in cost-effective RMMs because they do not make the implied tradeoffs between spending money now in return for potential benefits over time. Such non-adoption behavior may be further exacerbated by developers who may believe (perhaps correctly) that they are unable to recover the costs of RMMs in increased selling prices for the structures. Insurers and regulators may need to provide additional incentives and/or building codes so that these cost-effective measures will be adopted. We next explore why insurers might be interested in providing such incentives through premium

[6] These high discount rates are consistent with empirical findings on 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).

reductions or lower deductibles.

3. IMPACT OF MITIGATION ON DISASTER LOSSES

To provide insight on the interaction of policy instruments and outcomes, we have worked with three prominent natural hazard modeling firms, Applied Insurance Research (AIR), EQECAT, and Risk Management Solutions (RMS), in evaluating the impact of mitigation in several “model cities” which are subject to earthquake and hurricane damage. Here we report on the impact that mitigation would have on two of the model cities---Oakland (which is subject to earthquakes) and Miami/Dade County (which is subject to hurricanes). The data for Oakland (referred to below as Model City 1 or MC1) was provided by RMS and the Miami/Dade County (referred to as MC2) data was provided by AIR.[7]

Constructing the Model Cities and Their Protective Activities

The principal policy question addressed in this analysis is the effect that adoption of mitigation measures by property owners has on their own welfare and the solvency of insurers. We consider two prototypical insurance companies, one Small (Company S) and the other Large (Company LG), which provide coverage to residential property owners in each of the model cities. All residents would like to purchase hazard insurance, but not everyone can obtain coverage. If the insurer is concerned with the possibility of insolvency, then it will limit the amount of coverage it provides and some property owners will be unprotected. Below we describe in more detail the composition of the model cities and the nature of the insurance companies. We then indicate the types of analyses which can be undertaken for examining the impact of different mitigation policies on the costs to property owners and insurers. We begin with a general description of the overall structure of the models and the economic agents in this analysis.[8]

General Model Structure: The structure of the prototype analysis is depicted in Figure 1. First, the Model City is specified after which scenario variables are set which describe the set of hazard events and their probabilities which may occur in a “typical year” as well as the impact that mitigation measures have on the losses from different hazards. These variables together with a model characterizing the hazard (either the RMS Model for MC1 and the AIR Model for MC2) give rise to a loss distribution ($F(L) = \Pr\{Loss \leq L\}$) and the associated exceedance probability (EP) function ($EP(L) = \Pr\{Loss > L\} = 1 - F(L)$). For a given insurance company, the EP function is, of course, a function of the policy types and premium (specified as part of the Scenario Variables Set), the properties insured, mitigation levels, coverage limits, amount of reinsurance and the

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[7] We have also been examining the impact of mitigation measures on Long Beach using data provided by EQECAT and these analyses will be reported in a subsequent paper.

[8] We only sketch the model structure here. For additional details on these models, see our earlier paper Kleindorfer and Kunreuther (in press).

events (location, number and severity of earthquakes or hurricanes) that are used to generate loss exposures.

The EP functions for all insurance companies and for uninsured properties provide the foundation for evaluating expected and worst case consequences of the above scenario as well as the shares of the losses borne by each stakeholder. Let us consider each of the elements of the model in more detail.

INSERT FIGURE 1 HERE

Books of Business for the Insurance Companies: For both MC1 and MC2 we randomly picked 5,000 and 10,000 residential structures to constitute the maximum books of business which Company S and Company LG respectively can write. Companies may choose to insure a smaller number of structures to protect themselves against insolvency should a major disaster occur in the region where they are providing coverage. Detailed information on the Insurance Companies' initial books of business follow:

Model City 1: All structures are wood frame, single-family residences. The distribution of structures for Company S and LG by year of construction is given below in Table 2. All pre-1940 structures are considered appropriate for the RMM in question. 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.[9]

Table 2: Composition of Books of Business in MC1 by Year Built

	Company S	**Company LG**
Don't Know	259	599
Pre-1940	3,091	6,196
Post-1940	1,650	3,205
Total	5,000	10,000

Model City 2: The properties of interest in MC2 are also single-family residences. The type of structures in the books of business for companies S and LG, shown in Table 3, mirror the general distribution of structure types in MC2. All structures were considered appropriate for the RMM of interest, and all structure types were assumed to have similar mean damage reduction ratios from mitigation.

[9] Thus 172 of the 259 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 172 were therefore eligible for mitigation.

Table 3: Composition of Books of Business in MC2

	Company S	Company LG
Wood Frame	496	993
Masonry Veneer	1,005	1,802
Masonry	3,117	5,910
Semi-Wind Resistive	260	248
Wind Resistive	122	1,047
Total	5,000	10,000

Levels and Costs of Mitigation: The RMM used in MC1 was bracing the cripple wall and bolting the structure to the foundation. This only applied to pre-1940 wood frame single family residences. The RMM used in MC2 was partial roof mitigation which means improving the uplift resistance and strength of the roof without removing the roof covering. This RMM assumes that the roof covering is in good, wind resistant condition. Partial roof mitigation includes bracing roof trusses and gable end walls, applying wood adhesive where the roof decking and roof supports meet, and installing hurricane straps or clips where the roof framing meets the top of the studs. The proportion of structures in each model city that adopted a mitigation measure were assumed to vary from 0 to 100%. In the analysis which follows we examined three levels: 100%, 50% and 0%. Full (100%) mitigation assumes that every applicable structure in the Model City (all pre-1940 houses in MC1 and all houses in MC2) utilizes installs the RMM, with lower levels of mitigation (e.g., 50%) having costs proportional to the full mitigation costs (e.g., 50% of these full costs). In MC1 mitigation costs are based on 1.2% times the cost of the structure. This represents an estimate based on structural engineering estimates obtained from RMS. In MC2 the mitigation costs are $3,000 for the typical single family dwelling in the Miami metropolitan area, an engineering estimate provided by AIR.

Cost effectiveness of Mitigation: For each ZIP code in the two Model Cities the cost effectiveness of these RMMs was determined by asking the following question: If every property owner for which the RMM was applicable (only pre-1940 construction in MC1 and all construction in MC2) 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? If the answer to this question is "yes", then this ZIP code would be a candidate for a building code requiring such mitigation. Using an interest rate of 7% and a time horizon of 20 years, we found that all ZIP codes in MC1 and that 93.1% of the ZIP codes in MC2 satisfied this cost effectiveness condition.[10]

Insurance Company Premium and Asset Levels: Table 4 specifies the base case parameters for the insurance companies. For simplicity we do not explicitly consider the

[10]Higher real interest rates or shorter time horizons would reduce the number of ZIP codes for which the cost-effectiveness condition would be satisfied.

impact of reinsurance on insurance company performance.[11] We assume that full insurance coverage against damage from the disaster is available, with a prespecified deductible. The premium charged is proportional to the expected loss of the property covered[12] and then multiplied by a loading factor (in this case 1) to reflect the administrative costs associated with marketing and claims settlement. In other words, for this analysis property owners are charged premiums which are twice their expected loss covered by insurance.

Table 4: Base Case Insurance Company Parameters

Parameter	**Base Case Value**	
	Model City 1	**Model City 2**
Company S Assets	$ 70,000,000	$32,000,000
Company LG Assets	$140,000,000	$82,000,000
Deductible %: (expressed as a fraction of the value of property or as a specific $ amount)	15%	$1000
Target Ruin Probability	.01	.01
Insurance loading factor:	1.0	1.0

Insurers are concerned with insolvency and focus on worst case scenarios in determining their portfolio of risks. For this analysis we define a worst case loss (WCL) as a disaster where the probability of exceeding this dollar amount is .01. Insurers are assumed to set a "target ruin probability" based on this definition of a WCL as shown in Table 4. This implies that they would like to limit their BOB so they have at least a 99 percent chance that they can pay insured losses from assets and premiums to avoid insolvency. If they have sufficient assets and/or premiums then their actual probability of insolvency may be less than the target 1% level.

Impact of Mitigation on Losses and Insurer Behavior

Let us now consider the effect of the level of mitigation on total losses. These results are shown for the full book of business (BOB) for each of our four insurance companies in Table 5 for levels of mitigation of 0%, 50% and 100%. To make mitigation costs comparable with insurance costs and losses (all of which are annual), we annuitize total mitigation costs, using an interest rate of 7% and assuming a time horizon for benefits from mitigation of 20 years. The "annual total cost to homeowners" is the sum of insurance premiums, expected deductible losses and the annual costs of mitigation. The

[11] Alternatively, the reader may consider the assets available to cover losses as including a pre-specified level of reinsurance (net of the premiums thereof). Explicit treatment of reinsurance would not fundamentally affect the conclusions here, but solvency and the scope of coverage offered would, of course, both be improved under reinsurance scenarios, as shown in Kleindorfer and Kunreuther (1996).

[12] 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.

“probability of insolvency” is the probability that the insurer’s losses will exceed the sum of its premiums and assets when it has a full BOB. The entries following “properties insured (%)” are the percent of the full BOB that each insurer can cover without having its probability of insolvency exceed 1%. Clearly as mitigation increases, the solvency-constrained book of business for each insurer can increase.

INSERT TABLE 5 HERE

Reduction of Expected Losses from Mitigation: The key finding from this analysis is that mitigation is beneficial in reducing losses to the insurer and the homeowner in MC1. For example, for Company LG there is a reduction in expected annual losses (for the LG pool) of 9.51 - 7.13 = $2.38 million, whereas annualized mitigation costs to the property owner is $0.94 million. Note also that this expected cost calculation does not account for the additional benefits resulting from reduced public sector involvement resulting from the reduction in worst case losses for Company LG in MC1 of 306.88 - 251.12 = $55.76 million. For MC2 mitigation significantly reduces worst case losses and the insolvency probability of insurers. Homeowners are slightly better off with mitigation.

Reduction in Probability and Associated Costs of Insolvency: A principal reason for investigating the impact of mitigation on the worst case loss (WCL) is to understand how RMMs impact on the insolvency probability of insurers. Insolvency risks are a major concern to regulators because of the significant cost to policy holders and shareholders of the company which follow insolvency. If mitigation can reduce the magnitude of the WCL, then the insurer has an added benefit from these measures by decreasing their chances of insolvency. The data from Table 5 provide evidence that this is exactly what will happen. To illustrate, consider Company S in MC1 where none of the pre-1940 structures are have adopted an RMM. In this case the chances of insolvency is 1.1% if S Company has a 100% book of business. Should mitigation be adopted on all these structures the probability of insolvency is reduced to 0.58%.

Increase in Scope of Coverage: Mitigation will also increase the percentage of structures for which the insurer can provide coverage and still maintain an annual probability of insolvency at .01. As shown in Table 5, when no mitigation is adopted the S companies in MC1 will only be able to provide coverage for 88.72 % of those properties who would like to buy a policy. As the percentage of homes adopting mitigation increases then the BOB increases. When 50% of the homes have adopted the RMM, then the insurer is willing to provide a full BOB and still have a probability of insolvency which is below 1%.

The above results suggest that the two mitigation measures studied here are cost-effective for a large range of values in mitigation expenses as well as the expected long-term benefits. To illustrate this point, consider the homeowners insured by the LG companies in MC2 . The total costs for mitigating all the homes in the model city by roof decking is $2.83 million. By taking this action the total costs to homeowners is reduced by $17.36 -15.90= $1.46 million. This implies that mitigation would be cost-effective to this group of homeowners even if the aggregate total increased to $2.83 + $1.46 = $4.29

million. Put another way even if the cost for roof decking increased by as much as 52% (i.e., 1.46/2.83), it would still be a cost-effective measure. Alternatively one could examine how sensitive the results are to estimates of the reduction in expected losses from mitigation and obtain similar qualitative results. By analyzing the other homeowners in MC2 as well as the residents in MC1 using the data from Table 5, it will be clear that these findings are general across the two insurance companies and the two model cities.

4. POLICY IMPLICATIONS: NEED FOR A PUBLIC-PRIVATE PARTNERSHIP

Suppose homeowners were to voluntarily adopt cost-effective mitigation measures and insurers were to set premiums which reflected the reduction in losses from RMM to their insured structures. Then we would be going a long way toward reducing disaster losses to those in hazard-prone areas as well as reducing the probability of insurer insolvencies.

As pointed out in Section 2, most property owners have limited interest in investing in these measures. Furthermore, insurers have little interest in encouraging mitigation in hazard-prone areas if they feel that the rates they are allowed to charge by state regulators are inadequate. Due to regulatory constraints on pricing, insurers will *not* voluntarily provide these incentives unless they are forced to provide coverage to individuals in hazard-prone areas They would prefer to charge the same rates with and without mitigation and hope that some policyholders decide not to renew their insurance policy. In fact, the insurer wants to do everything it can to make the policyholder leave them. If rates in hazard-prone areas are based on risk, then mitigation would be encouraged by insurers reducing premiums as implied by the analysis of MC1 and MC2.

In this section we turn to three types of public private partnership programs that can encourage mitigation: (1) building codes, (2) premium reductions linked with long-term loans for mitigation (3) insurers offering lower deductibles for those investing in mitigation. In evaluating these programs we are assuming that there has already been an attempt to use market-based mechanisms to encourage the different interested parties to take action.

Role of 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 misperceive the benefits from adopting the RMM and/or underestimate the probability of a disaster occurring. If these property owners were forced to cover their own disaster losses, then one might contend that they should be left to their own designs since they would have only themselves to blame for not taking preventive action. However, all taxpayers bear some of the costs of restoring damaged property through low-interest federal loans and grants. Hence there is an economic justification to all citizens to design structures to be safer.

Cohen and Noll (1981) provide an additional rationale for building codes. When a building collapses it may create externalities in the form of economic dislocations and other social costs that are beyond the economic loss suffered by the owners. These may not be taken into account when the owners evaluate the importance of adopting a specific mitigation measure. For example, if a building topples off its foundation after an earthquake, it could break a pipeline and cause a major fire which would damage other homes that were not affected by the earthquake in the first place. In other words, there may be an additional annual expected benefit from mitigation over and above the reduction in losses to the specific structure adopting this RMM. All financial institutions and insurers who are responsible for these other properties at risk would favor building codes to protect their investments and/or reduce the insurance premiums they charge for fire following earthquake .

If a family is forced to vacate their property because of damage which would have been obviated if a building code had been in place, then this is an additional cost which needs to taken into account when determining the benefits of mitigation. In addition to these temporary food and housing costs, the destruction of commercial property could cause business interruption losses and the eventual bankruptcy of many firms. The impact on the fabric of the community and its economic base from this destruction could be enormous (Britton 1989). In a study estimating the physical and human consequences of a major earthquake in the Shelby County/Memphis, Tennessee area, located near the New Madrid fault, Litan et al. (1992, pp. 65-66) found that the temporary losses in economic output stemming from damage to workplaces could be as much as $7.6 billion based on the magnitude of unemployment and the accompanying losses in wages, profits and indirect “multiplier” effects.

Premium Reductions Linked with Long-Term Loans

Premium reductions for undertaking loss prevention methods can be an important first step in encouraging property owners to adopt these measures. The basic rule in this case is a simple one: if the premium reduction is less than the savings in expected claim payments due to mitigation, it is a desirable action for the insurer to promote. If homeowners are reluctant to incur the upfront cost of mitigation due to budget constraints, then one way to make this measure financially attractive to the property owner is for the bank to provide funds for mitigation through a home improvement loan with a payback period identical to the life of the mortgage. For example, a 20-year loan for $1500 at an annual interest rate of 10% would result in payments of $145 per year. If the annual premium reduction from insurance reflected the expected benefits of the mitigation measure (e.g., $500 in the example in Section 2), then the insured homeowner would have lower total payments by investing in cost-effective mitigation than not doing so (Kunreuther 1997).

One way to encourage the adoption of cost-effective mitigation measures is for banks and financial institutions to provide a seal of approval to each structure that meets or exceeds building code standards. Under the IBHS Showcase Community Program structures that meet predefined criteria would receive a certificate of disaster resistance. Upon receipt of that certificate, there would be a set of incentives provided by banks (e.g. lower mortgage rates), contractors and insurers. (Personal Communication with Harvey Ryland, November

1997. The success of such a program requires the support of the building industry and a cadre of qualified inspectors to provide accurate information as to whether existing codes and standards are being met. Insurers may want to limit coverage only to those structures that are given a certificate of disaster resistance.[13]

Many poorly constructed homes are owned by low-income families who cannot afford the costs of mitigation measures on their existing structure nor the costs of reconstruction should their house suffer damage from a natural disaster. Equity considerations argue for providing this group with low interest loans and grants for the purpose of adopting cost-effective RRMs or for them to relocate to a safer area. Since low-income victims are likely to receive federal assistance after a disaster, subsidizing these mitigation measures can also be justified on efficiency grounds.

Lower Deductibles Tied to Mitigation

An alternative way to encourage consumers to adopt mitigation measures is to change the nature of their insurance coverage rather than reducing the premium. More specifically, the insurer could offer a lower deductible to those who adopt mitigation at the same or lower price than if they had decided not to invest in the RMM. Such a program is likely to be very attractive given the empirical and experimental evidence which suggests that consumers appear to dislike deductibles even though they offer considerable savings in premiums.

A graphic example of the aversion to higher deductibles is the outcry by consumers in Pennsylvania, when Herbert Denenberg, then the Insurance Commissioner of Pennsylvania, instituted a mandatory $100 deductible for automobile collision policies. Although the plan purportedly saved consumers millions of dollars, it was eventually rescinded (Cummins et al. 1978, p. 146). This attitude toward deductibles still prevails. Johnson et al. (1993) attribute the dislike for deductibles, in part, to loss aversion and provide evidence from controlled laboratory experiments to support this conjecture.

We examined the impact of lowering the deductible on insurance policies for earthquake and hurricane protection if the property owner adopted a cost-effective RMM on his property. Premiums would be based on their expected losses from future disasters. Table 6 provides the total expected costs to the homeowner who mitigated with those property owners who did not for two different levels of deductibles---15 percent and 10 percent for those in MC1 and $1000 and $0 for those in MC2.

The results are interesting in two ways. First, both homeowners and insurers tend to be better off when they mitigate and have a lower deductible than when they fail to adopt protective measures. Thus, homeowners insured by the LG company in MC1 had total costs of $12.12 million when they did not mitigate and had a 15% deductible compared to total costs of $10.52 million when they mitigated and were given a 10% deductible. Insurers insolvency probability fell from 1.10% to 1.07% when mitigation and the lower deductible was in place. Similar results apply to the small company in MC1 and the large

[13] For more details on ways to make communities disaster-resistant see CUSEC 1997.

and insurer in MC2. For the small insurer in MC2, homeowner cost increases slightly when comparing the $1000 deductible-no mitigation case to the no deductible-100% mitigation case. This result would change if a lower insurance loading factor were used (we used 1 for this analysis), since then the reduction in losses associated with mitigation would have an increased impact on premium reduction. In general, the effects of mitigation are sufficiently positive in these Model Cities so that insurers, looking for cost-effective ways of increasing solvency, and property owners, looking to reduce their costs of protection, can both profit from mitigation.

Secondly, both homeowners and insurers would be even better off in terms of their expected losses if they had chosen to maintain the higher deductible after they invested in a cost-effective RMM. Thus, residents in MC1 who bought insurance from the LG company would have had their expected losses reduced from $12.12 to $9.93 million had they mitigated and maintained the 15% deductible. Insurer insolvency probability would also have fallen from 1.10% to 0.57%. This result is not surprising since there was a loading cost associated with insurance premiums and insurance claims will decrease as the deductible is raised. As pointed out above, it may be difficult to convince property owners of the merit of the higher deductible because they may focus on their out-of-pocket expenses following a disaster which will be reduced as the deductible falls.

INSERT TABLE 6 HERE

5. SUGGESTIONS FOR FUTURE RESEARCH

The results from these studies just scratch the surface with respect to the impact that mitigation measures are likely to have on property owners, insurers and social welfare. The following areas will be examined in our future work with the modeling groups and other private and public sector groups concerned with more effective management of catastrophic risk

Regulatory Issues: The above analysis was undertaken under the assumptions that insurance premiums were based on the actual risk faced by homeowners. One could examine the impact of rate restrictions on the premiums that insurers are allowed to charge in hazard-prone areas such as hurricane-prone regions of Florida. Looked at qualitatively, insurers will be less likely to reward mitigation measures when forced to charge lower premiums than they feel are adequate to cover the risk. We plan to examine the implications of different types of regulatory restrictions placed on insurers as it affects the availability of coverage as well as the incentives for encouraging mitigation. These findings can then be contrasted with those reported here.

Uncertainty Issues: The above analysis assumed that there was no ambiguity in either the estimates of the probability of disaster of different magnitude occurring and the magnitude of the losses from these events if mitigation was or was not adopted. Despite considerable scientific advances in the prediction of earthquakes and hurricanes there is still considerable uncertainty on the estimates of the probabilities associated with these events. On the damage side, best engineering judgment informed by past data and controlled laboratory experiments (e.g. wind tunnel studies for hurricanes; shake tables for earthquakes) are used to estimate damages to structures from disasters of different magnitudes. But there is still considerable variation in the estimates provided by engineers for the same structure in the same location. Similarly the costs of mitigation measures can vary considerably. These uncertainties need to be taken into account in computing the range of expected damage as well as losses from worst case scenarios.

Tradeoffs Between Reinsurance and Mitigation: As an alternative to mitigation insurers can protect themselves against large losses through reinsurance and thus reduce their probability of insolvency. The price of reinsurance can be quite expensive particularly following a large-scale disaster, as was evidenced after Hurricane Andrew and the Northridge earthquake. It would be interesting to determine how much reinsurance would have to be purchased to provide sufficient protection to the insurer as a function of the amount of mitigation in place. Such an analysis should provide an additional rationale for insurers to want to encourage homeowners to adopt mitigation since they would then be able to reduce their expenditures on reinsurance.

Impact of Mitigation on Capital Market Instruments: As indicated by Doherty and Cummins in papers presented at this Conference, the insurance industry is concerned with their capacity to provide sufficient coverage to cover the losses from large scale natural hazards. Hence the capital markets are now beginning to provide coverage in the form of new instruments, such as Act of God Bonds. Since mitigation can reduce the losses from catastrophic events, it would be interesting to determine how this will impact on the ability of the insurance industry to provide coverage without relying extensively on other sources of funds. To the extent that mitigation also promises to reduce the uncertainty of future losses, financial instruments will be more easily marketed.

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Figure 1: General Structure of the Model

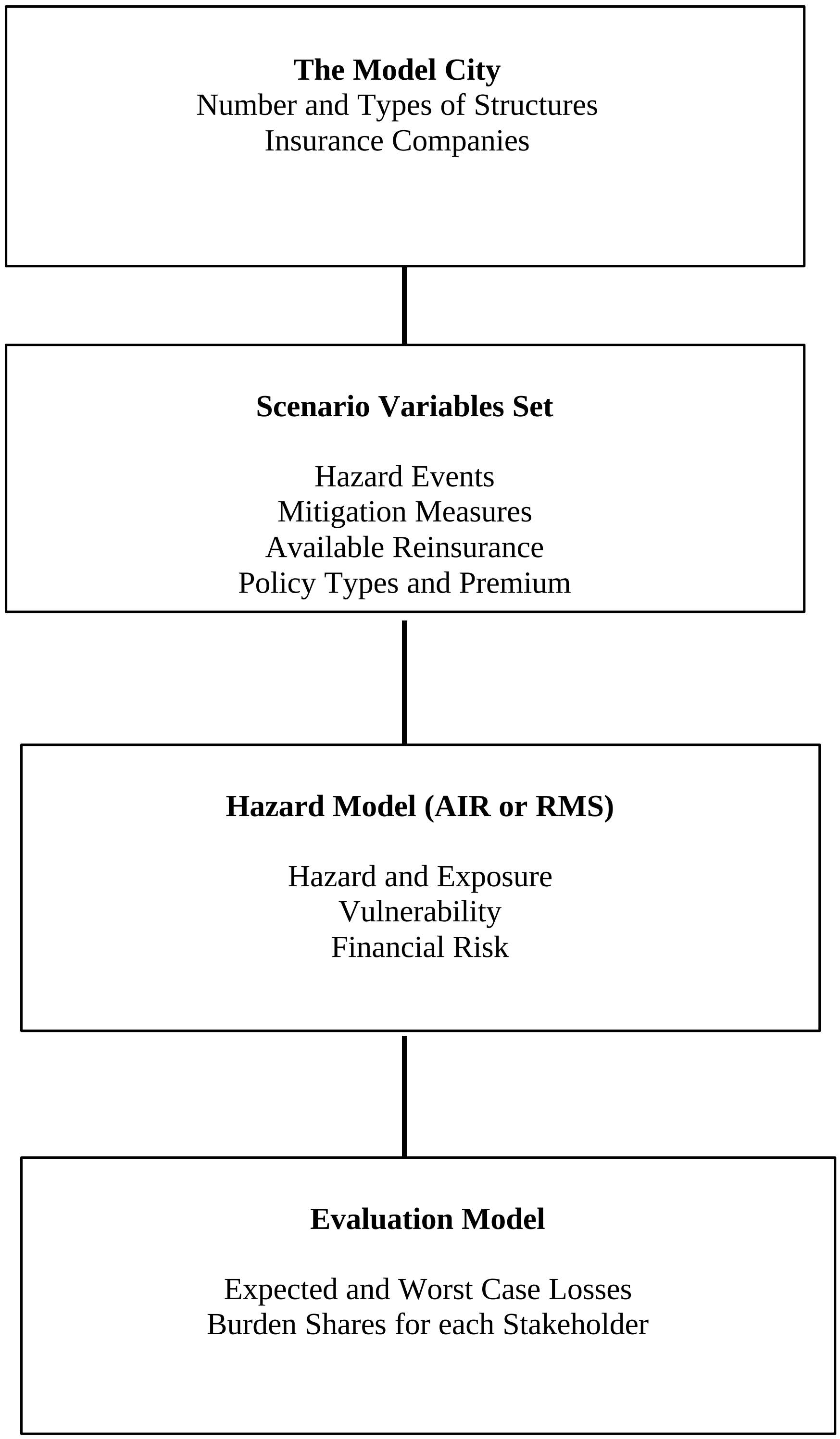

TABLE 1

DISTRIBUTION OF MAX WILLINGNESS TO PAY (WTP)

% Individuals in Each Category

	Price Not Given		**Price Given=$1,500**	
	5 Years	**10 Years**	**5 Years**	**10 Years**
$0-$500	5%	5%	7%	4%
$501-$1,000	7%	7%	16%	16%
$1,001-$1,500	45%	17%	43%	44%
$1,501-$2,000	31%	36%	16%	19%
$2,001-$2,500	5%	14%	3%	0%
$2,501-$3,000	5%	14%	3%	0%
$3,000 up	2%	7%	12%	17%
Number of Subjects = 42			Number of Subjects = 42	

Source: Kunreuther, Onculer and Slovic (1997)

TABLE 5

THE EFFECT OF MITIGATION LEVEL ON EXPECTED AND WORST CASE LOSSES ($ Millions)

	Mitigation Level		
	0%	50%	100%
Small Pool Losses MC1			
Expected Losses	4.76	4 .17	3.57
Worst Case Losses	153.64	139.74	125.76
Mitigation Costs	0.00	0.23	0.47
Probability of Insolvency (%)	1.10	0.97	0.58
Total Cost to Homeowners	6.08	5.52	4.98
Properties Insured **(%)**	88.72	100.00	100.00
Large Pool Losses MC1			
Expected Losses	9.51	8.33	7.13
Worst Case Losses	306.87	279.21	251.12
Mitigation Costs	0.00	0.47	0.94
Probability of Insolvency (%)	1.10	0.96	0.57
Total Cost to Homeowners	12.12	11.14	9.93
Properties Insured **(%)**	88.97	100.00	100.00
Small Pool Losses MC2			
Expected Losses	3.18	2.79	2.41
Worst Case Losses	61.05	50.36	38.28
Mitigation Costs	0.00	0.71	1.42
Probability of Insolvency (%)	1.63	1.35	0.94
Total Cost to Homeowners	6.15	6.10	6.06
Properties Insured **(%)**	61.89	77.21	100.00
Large Pool Losses MC2			
Expected Losses	9.01	7.92	6.83
Worst Case Losses	169.48	135.90	102.29
Mitigation Costs	0.00	1.42	2.83
Probability of Insolvency	1.74	1.39	0.99
Total Cost to Homeowners	17.36	16.63	15.90
Properties Insured **(%)**	58.25	73.09	100.00

TABLE 6

EFFECT OF DEDUCTIBLES AND MITIGATION ON HOMEOWNER COST (IN MILLIONS OF DOLLARS) AND CHANCE OF INSURER INSOLVENCY

	MC1		**MC2**	
	Deductible		**Deductible**	
	15%	**10%**	**$1000**	**$0**
Small Pool				
0% Mitigation				
Homeowner Cost	$6.08	$6.48	$6.15	$6.36
Probability of Insolvency	1.10%	1.20%	1.63%	1.76%
100% Mitigation				
Homeowner Cost	$4.98	$5.27	$6.06	$6.24
Probability of Insolvency	0.58%	1.07%	0.94%	1.07%
Large Pool				
0% Mitigation				
Homeowner Cost	$12.12	$12.92	$17.36	$18.02
Probability of Insolvency	1.10%	1.20%	1.74%	1.94%
100% Mitigation				
Homeowner Cost	$9.93	$10.52	$15.90	$16.49
Probability of Insolvency	0.57%	1.07%	0.99%	1.10%