Issues and Approaches in Financial Management of NATURAL DISASTERS

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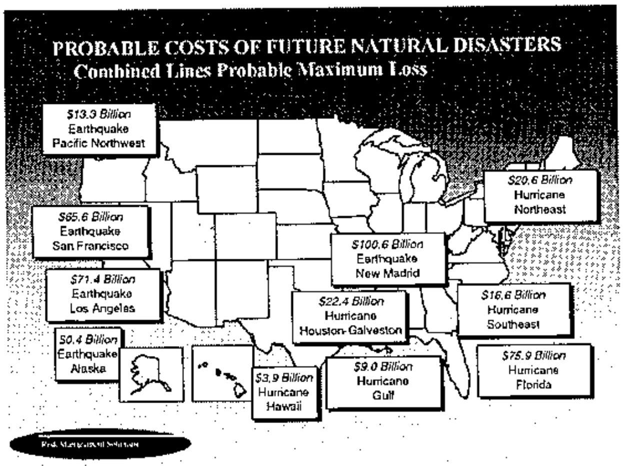
Introduction

The primary focus of this paper is to improve the understanding of how the technical expertise provided by engineers and other risk reduction professionals is used in the process of managing financial risk associated with natural disasters. The technical expert plays an important role in providing both the information used in decisions and in creating and using the analytical tools needed to interpret the information. This paper provides an overview of how financial risk is managed by various sectors (who bears risk, how risk can be reduced, transferred or avoided) and how engineering expertise fits into this process. The discussion is intended to be helpful for engineering professionals in gaining a better understanding of how the financial and insurance communities manage risk, and in understanding how the information they provide to various clients is part of the larger process of financial risk management.

Economic Loss from Natural Disasters is escalating

Catastrophic economic losses associated with disasters in the U.S. and the world are increasing. In the U.S. seven of the ten most costly disasters in history, based on dollar losses, occurred between 1989 and 1994, such as Hurricane Andrew in 1992 and 1994 Northridge earthquakes. Globally there was the $120 billion earthquake in Kobe, Japan, and most recently the $30 (estimated) billion earthquake in Izmit, Turkey and $ 10 billion earthquake in Taiwan. Fig. 1 shows the potential costs of future natural disasters in USA. Over the 5 year period from 1995 to 1999, the average annual cost to The Federal Emergency Management Agency (FEMA) alone has been more than 1 billion dollars, excluding the cost of the Northridge earthquake. This is very heavy burden to the government. For Northridge earthquake, thanks to insurance social function, the most of reconstruction funds were provided by



insurance (See Fig. 2). The recognition that these devastating economic losses are increasing has propelled some segments of the financial community as well as the government to carefully evaluate and identify options for managing risk. Given the enormous costs associated with recent U.S.

Fig. 1 Probable Costs of Future Natural Disasters

disasters, government at all levels has been re-evaluating policies for providing disaster assistance and the need to encourage risk reduction through mitigation. FEMA is promoting a much larger focus on mitigation and local resilience through programs such as Project Impact. Governments at all levels recognize that the next major urban disaster (earthquake or hurricane) could have economic and fiscal consequences that the public monies that have traditionally been available after such disasters may no longer exist.

Characteristics and Issues with Catastrophic Disasters

There are three characters with respect to catastrophic disasters:

1 They are uncertain. No one knows when, where and what size of disasters will occur;
2 They are rare. The chance to have these kinds of events may be one of hundreds of years;
3 They have tremendous impact on all walks of live and result in huge losses.

Due to uncertain and rareness in nature, it is difficult to justify economically proper actions such as retrofit, enhancement of building code, etc. to be taken. Decision-makers don't have clear picture what is the consequence should a disaster occur and usually mitigation measures have been put at the end of to-do list. There is urgent need to understand how to manage these kinds of catastrophe risks.

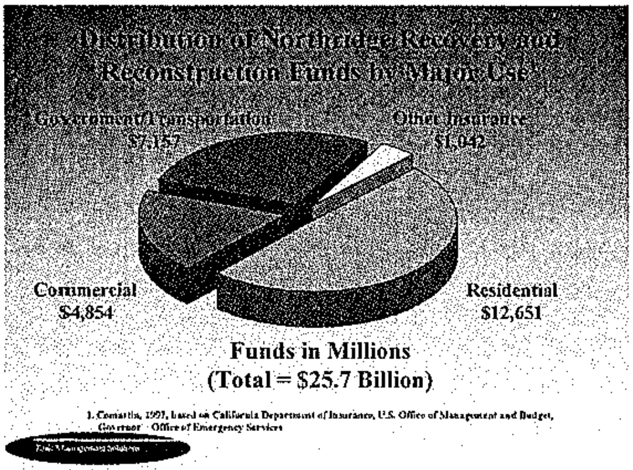


Fig. 2 Distribution of Northridge Recovery and Reconstruction Funds

Understanding Risk Management

The risk management process can be defined as the process for making and carrying out decisions that will minimize the adverse effects of accidental loss, involving five steps: identifying and analyzing loss exposures (also referred to as risk assessment); examining the feasibility of alternative risk management techniques; selecting the best technique(s); implementing the techniques; and monitoring the program. Measuring the potential frequency and severity of loss must use sound scientific and engineering methods, so engineers play a large role in conducting such risk assessments or analyses. Typically these assessments include identifying the asset or property at risk; evaluating the natural hazard at the site; estimating damage; and assessing monetary loss. These analyses then form the foundation from which other decisions can be made, including the selection of alternative risk management techniques (to eliminate loss exposures, control loss exposures that are not eliminated; or finance losses that occur despite the controls).

Technological Change

Technology is changing rapidly, and with these changes come increased opportunities for better understanding risk, and therefore better management of the risk. With the advance of science and engineering, we will be able to estimate the potential losses for future disasters with decent confidence. Many tools that have been developed in the last decade use the various loss estimation methodologies. Millions of dollars have been invested in developing these tools that allow for a more thorough understanding of expected losses associated with various events. These tools are changing how decisions are made regarding the management of financial risks associated with natural disasters. Tools such as Geographic Information Systems enable better mapping and more precise understanding of the risk. Communications changes including e-mail and the use of cellular phones are changing how business is conducted, as are changes in information technology, such as the use of the Internet to conduct financial transactions and make risk management decisions.

The need for engineering model

Estimating losses due to future catastrophe events based on actuarial (historic) data only, is inadequate for the following reasons. First, catastrophes are rare events so that the time window for which data have been collected is short compared with the return period of catastrophes. In particular, major earthquakes and extreme storms have average return period of the order of hundreds of years. The data time window is simply too short for the data to be used as the basis of an accurate estimator of the average loss. Missing an extreme loss will result in a much lower estimate of the average annual loss. Conversely, including a big one in a short time interval will overestimate the annual loss.

For illustration, Tables 1 and 2 are two tabulations of income/loss histories in California with regard to earthquakes since 1970. The tables are identical except that the Northridge event of 1994 is included in the second table but not the first. By comparing the two tables, it is obvious that a single modern event can alter the actuarial estimates significantly. In particular, according to the actuarial approach, the average loss ratio for the period 1970-1993 is 0.26, but increases to 2.07 when 1994 is included. The Northridge earthquake is only a moderate one. The loss would be much greater should an earthquake occur at the Newport Inglewood fault or should a repeat of the 1906 San Francisco earthquake take place (see Refs.1 and 2).

Another difficulty in using the actuarial approach is that, to be useful for contemporary times, historic data must be properly adjusted to account for factors that affect the ultimate loss, including:

- Inflation
- Increase in exposure
- Changes in vulnerability (updated building codes)
- Deeper insurance market penetration
- Changes in policy structures.

Table 1. Underwriting Experience, 1970-1993, Earthquake (in Million US$) (Ref. 3)

Year	Earthquake Event	Premium	Losses

1970		5.9	0
1971	San Fernando (6.6)	4.6	.8
1972		9.0	2.1
1973		10.9	.1
1974		13.0	.4
1975	Oroville	13.8	0
1976		17.1	.1
1977		19.8	.1
1978	Santa Barbara	23.2	.4
1979	Imperial Valley (6.6)	29.0	.6
1980		38.5	3.5
1981		50.2	.5
1982		58.9	0
1983	Coalinga (6.7)	70.4	2.0
1984	Morgan Hill (6.2)	79.4	4.0
1985		132.9	1.7
1986	Southern California	180.0	16.7
1987	Whittier (5.9)	208.4	47.6
1988		277.8	31.8
1989	Loma Prieta (7.1)	333.6	433.0
1990	Southern California	384.6	180.9
1991	Northern California	427.4	73.7
1992		479.9	87.7
1993		521.0	13.2
Total		**3,389.4**	**880.9**

Average loss ratio 0.26

The adjustment process is tortuous because the data reflect the time and socio-economic conditions at which they are collected. To adjust their values to modern times properly, the companion data (exposure, market penetration, policy changes) associated with each event must be collected, compiled and compared with their current counterparts. Since data on these items exist only in fragmentary form, it is difficult if not impossible to reconstruct the complete demographic and socio-economic environment in past years.

For these reasons, the use of historic data only and an empirical approach to forecast catastrophe losses is unsatisfactory; such estimates contain large uncertainties. The uncertainties can only be checked by an independent source of estimate, such as with the engineering modeling approach described below. Note that while engineering models are based on physics of the phenomenology and processes involved, they are not devoid of data. Most models are calibrated by their corresponding databases when available, e.g., building vulnerability, seismicity, attenuation functions, and so on. But the fundamental difference is that data are used to substantiate the models for the individual processes and phenomenology, so they may reflect the state of knowledge and current conditions. The models are then combined in making the loss estimates.

Table 2. Underwriting Experience (1970-1994, including Northridge), Earthquake (in Million US$) (Ref. 3)

Year	Earthquake Event	Premium	Losses
1970		5.9	0
1971	San Fernando (6.6)	4.6	.8
1972		9.0	2.1
1973		10.9	.1
1974		13.0	.4
1975	Oroville	13.8	0
1976		17.1	.1
1977		19.8	.1
1978	Santa Barbara	23.2	.4
1979	Imperial Valley (6.6)	29.0	.6
1980		38.5	3.5
1981		50.2	.5
1982		58.9	0
1983	Coalinga (6.7)	70.4	2.0
1984	Morgan Hill (6.2)	79.5	4.0
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1991	Northern Cálifornia	427.4	73.7
1992		479.9	87.7
1993		521.0	13.2
1994	Northridge (6.9)	619.4	7414.1
Total		**4008.7**	**8295.0**

Average loss ratio 2.07

Engineering Model for Loss Estimation

In general, a complete engineering model for catastrophe impacts has four components or modules:

1. A hazard module which predicts a series of events with various sizes, locations, and frequencies.
2. An attenuation module which generates the local severity (ground shaking intensity or peak wind gust) from the source given the size and location of the event.
3. A vulnerability module which estimates the loss given the local severity.
4. A financial module which allocates loss to different owners of risk

Hazard Source

The starting point in the engineering modeling approach is the source of the disturbance. For example, for earthquake hazards, the source is the rupture of a particular fault (Fig.3). A credible scenario is postulated, which is consistent with the seismicity database on frequency, magnitude and rupture length.

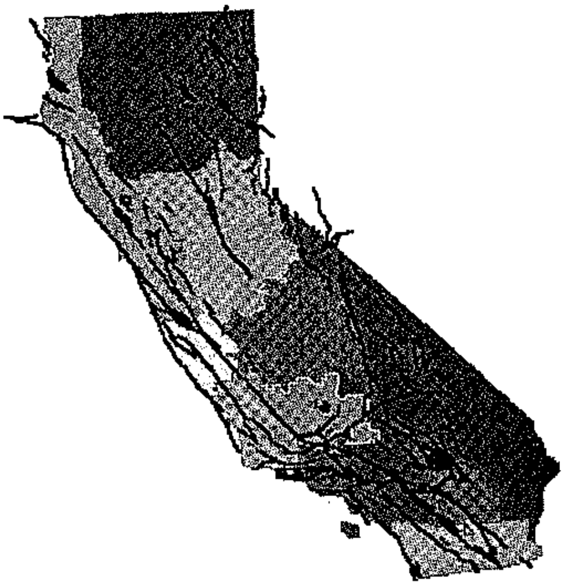

Figure 3. Sample source models: major faults in California

Attenuation

The energy released at the source manifests itself in the form of physical hazards such as ground shaking or wind velocity. These hazards are propagated from the source region, and attenuate and disperse as they propagate. The degree of attenuation is important as it affects the severity of hazards felt at the site of interest and the extent of influence of the event. The governing physical laws are summarized in the form of attenuation functions, which very often rely on empirical data for calibration. Figure 4 is a typical attenuation relation commonly used for propagating ground shaking in rock materials, and the uncertainty bands shown are representative of the uncertainty associated with this part of the modeling.

Asset Vulnerability and Damage

The site hazards are applied against the vulnerability of the assets in order to determine the damage incurred in the asset. While this process entails complex physical phenomenology and engineering development, the concept can be illustrated with reference to the loss ratio curve of Fig.5 used by Steinbrugge (Ref. 4). The figure gives the extent of damage to a particular class of structures when they are subjected to various levels of ground shaking. Uncertainties in the estimate of damage, due to inherent variability in the details of the structure as well as the state of knowledge, are also noted. These curves have since been greatly extended

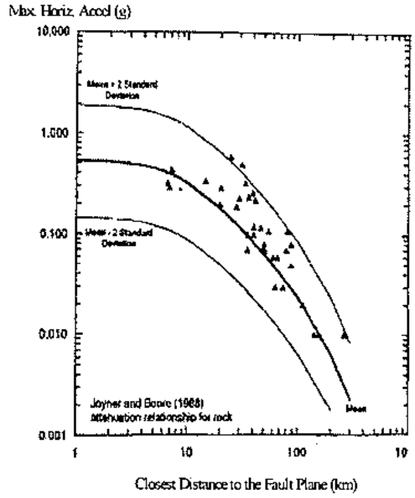

Figure 4. Attenuation of ground shaking with distance for rock sites.

and refined based on damage and insurance claim data collected in recent events.

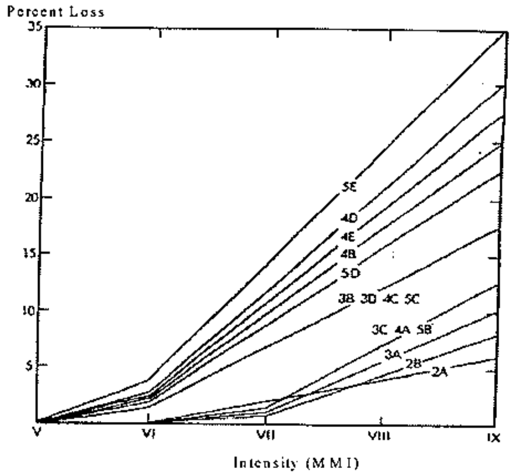

Figure 5. Loss ratio of building classes to ground shaking

Financial Module

Financial module will allocate loss incurred to all risk bearers based on insurance or other contract.

In the following, we will briefly discuss how various sectors manage financial risk . For more detailed information, refer to EERI White Paper (Ref. 5).

Public Policy

Government plays an important role in setting policies and regulations that affect risk bearing and risk transfer. Some government regulations (building codes, standards, land use regulations) and policy incentives (tax breaks, low cost loans, lower insurance costs) can reduce potential catastrophic risk. Other government policies have been used to transfer risk, such as the California Earthquake Authority. Other government policies also affect how insurers, lenders and the capital markets can develop and use new financial instruments.

Overview of the Risk Bearing Sectors

The Residential Sector

The residential sector includes homeowners as well as renters and owners of multifamily residential buildings. Homeowners include the owners of any residential property that could be damaged in disaster. For most people homeownership is probably the largest investment in one's life and with the investment the owner assumes the risk. The financial decisions a homeowner faces include: do nothing; risk reduction with retrofit or risk transfer through diversification of ownership, insurance or mortgage. Most of homeowners are reluctant to put up money at front to do retrofit to reduce the potential loss, which is so remote and may not happen at all. As a result, the burden of recovery after a disaster will be put on the shoulder of the government. Renters usually bear risk even more directly since they would have fewer options for mitigation and can only transfer risk via insurance.

The Small Business Sector

There are several characteristics that define the way in which a small business owner manages risk. Typically small business owners are sole or majority owners. Any loans are likely personal loans or collateralized with personal assets. They rent rather than own the premise of business; thus they are not at liberty to implement any physical measures related to the structure of the premise without the landlord's consent even if they are willing to pay for the expenses. They have little discretionary income to invest in preventive measures, and no staff dedicated to risk management. They do not have the leverage in negotiating insurance coverage that big businesses have. Their diversification options are very limited. Consequently, the risk borne by small businesses is primarily indirect and related to business interruption.

The Corporate Sector

The big corporations face more serious risk from natural disasters not only their properties expose to the hazard also business interruption will bear profound consequences. Some multinational firms might cause chaos in global economy. their financial risk management decisions have to be based on a thorough study of potential risk. Many corporations will request engineering firm to evaluate their risk and to choose from the following: strengthening the existing facilities, providing redundant system such as multi-location data centers, relocation, risk transfer through insurance. The risk to businesses include not only the buildings but the contents or inventory, and the possibility of business interruption due to damage to a building, damage to the surrounding area or region, or damage to a supplier or to clients. The possibility of business interruption is a major consideration in evaluating financial risk due to an earthquake. The impacts of ChiChi Earthquake to corporations in the Hsinzhu scientific park are a vivid example of consequence due to business interruption.

The Lifeline Sector

Lifelines are infrastructure systems, such as power, transportation, telecommunications, water and waste, gas and liquid fuel. They are vulnerable to natural and manmade hazards; their performance can be degraded; their ability to function can be disrupted due to damage to components of the system and to the support systems. They are risk-bearers, however their assets are different from a home or office building. They are massive networks consisting of myriad of components that are dispersed in space and function, yet linked to perform together as a system. They also are constrained in terms of location, i.e. they must be where they are, so certain diversification methods of risk management are not an option. Mitigation and transfer are typically the two primary methods of managing financial risk for the lifeline sector.

The Government Sector

In addition to its role as a policymaker and regulator, government at all levels is a major property owner. The federal government, for example, is the largest single property owner in the state of California, and the state government is the second largest owner. In the U.S. there are more than 78,000 different local government units, most of which own or manage property. Damage to public buildings in an disaster typically results in four types of losses to the government sector: life loss; economic loss; loss of function; and loss of cultural heritage. The three typical options for managing the risk include risk reduction (retrofit), risk transfer (typically through insurance) and risk retention. The choice of which technique to adopt is generally governed by the cost of the technique and the intended goal.

Overview of Risk Transfer Sectors

Insurance

Insurance is a risk transfer mechanism that allows a property owner to transfer the risk of loss to the insurance company. Typically, insurance is based on the Law of Large Numbers (insured events are seen as independent of each other; the probability of many occurring at once is low). However, catastrophe insurance, such as earthquake or hurricane insurance, acknowledges that the loss of many properties over a large area is no longer independent. Rather, those losses are seen as correlated. This loss concentration caused 14 local insurance companies in Florida and Hawaii went to insolvent in 1997 as results of hurricanes Andrew and Iniki. The less correlated the hazards, the lower the risk for a particular company. Insurance companies use the re-insurance industry to help transfer and manage their own risk. A reinsurance company will write policies for different parts of the world, spreading the risk geographically.

Mortgage

The mortgage sector, along with insurance and capital markets, provides a mechanism for transferring risk. Property owners, including individuals, large corporations and governments, use mortgage as mechanisms to lay off their financial risk associated with natural disasters. Different types of financial institutions offer mortgages, and each approach the financial risk associated with disasters differently. Mortgage banks typically do not retain much risk as they sell most of their loans. Depository institutions retain only the risk based on the loans they keep in their portfolios. The government-sponsored enterprises, Fannie Mae and Freddie Mac buy many of the residential mortgages, and therefore assume risk on much of their portfolios. The secondary mortgage market retains much of the risk associated with disasters, since these are the financial institutions that buy most of the mortgages.

The Capital Markets

Capital markets have a newly emerging role in catastrophic risk transfer. A basic feature of market-based economies such as found in the U.S. is the existence of a well-developed capital market system. This system allocates savings and investment capital to various economic sectors, with allocation rules based on risk and return. In practice, financial risk is packaged and transferred to investors via financial instruments, either through equities (such as common stocks), debt securities (loans, bonds, promissory notes) or derivatives (stock options, interest rate futures, foreign exchange, and commodities futures). The possibility thus exists to transfer risk from the risk-bearing sectors (the property owners broadly defined) to the capital markets.

Conclusion

This paper links together a number of disciplines by discussing how engineering is important to the various sectors of society that manage financial risk associated with natural disasters. By gaining a better understanding of how this risk is managed by each of the individual sectors the engineer should be able to more effectively play a role in the provision and analysis of technical information. Catastrophic risk management options can vary from complete retention to transfer of the risk to another sector, yet each option relies on information that comes from the engineer. Understanding the importance of this role in the context of how financial risk is managed is the subject of the paper. The interaction is iterative and evolutionary: the financial sectors pull the engineering community to provide information and develop more sophisticated tools, and the engineering community pushes the financial sectors to make decisions based on scientific and technical expertise. The paper aims to provide an overview of ALL issues, with an emphasis on those where the engineering professional has a role.

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