CATASTROPHE MODELING: A NEW APPROACH TO MANAGING RISK

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CATASTROPHE MODELING: A NEW APPROACH TO MANAGING RISK

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Preface and Acknowledgments

This book had its genesis in June 1996 when the Wharton Risk Management and Decision Processes Center (Wharton Risk Center) co-hosted a conference on "Information Technology and Its Impact on Catastrophic Risks". It was one of the events that year celebrating the 50th Anniversary of the first computer (ENIAC) at the University of Pennsylvania. The focus of the conference was on the challenges in dealing with natural disasters. There had been two catastrophic events several years before — Hurricane Andrew in 1992 and the Northridge earthquake in 1994 — that had raised grave concerns within the private and public sectors as to what steps should be taken to deal with future losses from these and other natural hazards. The conference featured presentations by scientific experts on assessing these risks, three leading firms [AIR Worldwide, EQECAT and Risk Management Solutions (RMS)] on modeling the risks using information technology, and the development of new strategies by insurers, reinsurers and financial institutions for managing catastrophic risks.

Over the past 8 years, representatives from all these constituencies have worked together as part of the Wharton Managing Catastrophic Risks project to examine the role of catastrophe modeling in assessing and managing natural disaster risk. This book is truly a joint effort with the modeling firms and reflects the critical commentary and evaluations from key individuals in insurance and reinsurance companies as well as financial institutions who provided funds for the research activities.

From 1996 through 2001, the project was a joint venture between the Wharton Financial Institutions Center (WFIC) and the Wharton Risk Center. We want to express our deep appreciation to Anthony Santomero, director of the WFIC during the first five years of the project, Peter Burns, project manager, and Steve Levy, project coordinator, during this period. Thanks also go to Franklin Allen, Richard Herring and Carol Leisenring who assumed leadership positions at the WFIC after Anthony Santomero and Peter Burns moved on from the Wharton School in 2000.

From the outset, our goal was to undertake state-of the-art research on the role of risk assessment in developing meaningful strategies for managing catastrophic risks. Although our focus was on natural hazards, we viewed the project as one that could be applied to a wide variety of extreme events. In fact, since 2002 the Managing Catastrophic Risks project has morphed into the Managing Extreme Events project, which is one of the major ongoing activities at the Wharton Risk Center.

To ensure the highest scientific standards, we formed a Technical Advisory Committee (TAC) whose role was to provide detailed commentary on the models developed by AIR Worldwide, EQECAT and Risk

Management Solutions. For the first few years of the project, this committee met at least once a year and several members attended the semi-annual project meetings. The TAC provided insightful comments on the use of the models as a linkage between risk assessment and risk management and urged the modeling firms to coordinate their efforts to the highest extent possible. They were principally responsible for convincing the three firms that it would be beneficial to all if a comparative study of earthquake risk were completed. As a result, a study in Charleston, South Carolina presented in this book illustrates the opportunities of utilizing these models for estimating risks, while at the same time demonstrating the degrees of uncertainty surrounding loss estimates.

Each of the three firms permitted members of the TAC to examine their models. Subsets of the TAC visited AIR Worldwide, EQECAT and Risk Management Solutions for a full day for this purpose. These TAC members then wrote up reports on the technical accuracy of the models that they shared with each firm as well as with the Wharton team. Through this process and without revealing any confidential information, the TAC members were convinced that all three firms base their models on the best scientific information available. Without this assurance from the TAC we would not be writing this book.

Most of the TAC members also commented on earlier drafts of the chapters in the book. In particular, we want to thank Roger Borcherdt (USGS), William Holmes (Rutherford & Chekene), William Iwan (Cal Tech), and Robert Whitman (MIT), who spent considerable time in going over the material on the book and writing up extensive comments for us. The other members of the TAC who provided us with advice and guidance on the project and to whom we owe a debt of gratitude are: Joe Golden (NOAA), Mark Johnson (University of Central Florida), Ralph Keeney (Duke University), Peter Sparks (University of South Carolina), Kathleen Tierney (University of Colorado, Boulder), and Susan Tubbesing (EERI).

There are numerous other individuals and firms who played a key role in this effort. Jim Tilley from Morgan Stanley and Jerry Isom from CIGNA (now ACE) convinced their organizations to provide initial seed funding for the project. Other sponsors included American Re, General Re, Goldman Sachs, Japan Property and Casualty Association, State Farm, Swiss Re, and Tokio Marine. A number of individuals from these organizations provided us with extremely helpful comments at various stages of the project. They include: James Ament (State Farm), David Durbin (Swiss Re), Carl Hedde (American Re), Robert Irvan (CIGNA/ACE), Jeff Warren (General Re), Gordon Woo (Risk Management Solutions), Yuichi Takeda (Tokio Marine). American Re (Carl Hedde, Mark Bove, and Hjortur Thraisson) provided key information on historic losses. Goldman Sachs (Vivek Bantwal and Ohi Akhigbe) also provided helpful comments on the current state of catastrophe

bonds and other new financial instruments.

Special thanks go to the leadership in all three modeling firms for agreeing to share their software with the Wharton team and to open their doors to a dialog with academia: Karen Clark from AIR Worldwide; Dennis Kuzak from EQECAT; and Tom Hutton, Haresh Shah, and Terry van Gilder, who were at Risk Management Solutions when the project started.

The research on this book occurred over a span of almost 9 years, so there have been a number of individuals who have played a key role in helping to undertake the research that forms the basis for each of the chapters. At the beginning of each chapter, we list the principal authors who took the lead in writing the material, but there are others who played a role in providing data for the various chapters. In particular, we want to thank Vivek Bantwal, Jessica Binder and Jaideep Hebbar, three remarkable undergraduate students at Wharton, who were indefatigable in their efforts working with the modeling groups. Without their assistance, Chapters 8 and 9 in the book could not have been written. Paul Kleindorfer, co-director of the Wharton Risk Center, played a key role in providing inputs and guidance on the project from its very outset. He participated in all the meetings of the project and provided invaluable comments and suggests on all aspects of the research. We would also like to thank Neil Doherty and Dave Cummins from Wharton for their helpful comments and suggestions at various stages of the project. Both Neil and Dave were undertaking complementary studies of risk transfer instruments and insurance as part of the Managing Catastrophic Risks project and were also involved in the meetings with the sponsors of the project. We also had helpful discussions with Daigee Shaw of Academia Sinica in Taipei, Taiwan. Erwann Michel-Kerjan of the Wharton Risk Center has reviewed the entire book and provided insightful comments as to how the material on natural hazards linked to other extreme events, notably terrorism.

We both had a wonderful time working with our co-conspirators from the modeling companies, without whose active involvement this book would never have been written: David Lalonde, Beverly Porter, and Mehrdad Mahdyiar from AIR Worldwide, Dennis Kuzak and Tom Larsen from EQECAT, Weimin Dong and Don Windeler from Risk Management Solutions.

Chandu Patel from the Casualty Actuarial Society volunteered to play the role of editor and has gone through every chapter with a fine tooth comb, making a number of extremely helpful suggestions for improving the flow of material. We want to thank Cathy Giordano from ACE and Tara Newman from the Wharton Risk Center for their help in coordinating this effort. We were also fortunate to have Ann Perch from the Wharton School and Hannah Chervitz from the Wharton Risk Center go through the entire book to make sure it was readable to a more general audience and was in final camera-ready form for the publisher.

This has been a long journey that has taken Patricia Grossi through her doctoral dissertation at the University of Pennsylvania, to an Assistant Professor at Southern Methodist University and finally to her current position at Risk Management Solutions. On September 3, 2001, Howard Kunreuther began a one-year sabbatical at the Earth Institute (Columbia University) and has been involved in terrorism research ever since September 11th. The last chapter of the book reflects the broader objectives of catastrophe modeling by applying the concepts from natural hazards to this risk.

Our families have been part of the process from the very beginning and our spouses, Mohan Balachandran and Gail Loeb Kunreuther, deserve special thanks for their encouragement and understanding.

Patricia Grossi
Howard Kunreuther

Prelude

The aftermath of a natural disaster, such as an earthquake, flood, hurricane, can be devastating. There is a tremendous sense of personal as well as economic loss. Immediately following the disaster, the actual devastation as well as media coverage related to the event causes the affected individuals as well the general public to be keenly aware of the risk of catastrophes. Unfortunately, this awareness often fades with time and the importance of being prepared is often forgotten. There are, however, a large number of individuals who spend a great deal of time and energy modeling natural disasters and enlightening others on ways in which their impact can be managed.

The goal of this book is to bring the reader up to date on recent developments in the nature and application of catastrophe models used to manage risk from natural disasters. It describes current and potential future uses of such models. The book emphasizes natural disasters, but also discusses application of the models to the terrorist attacks of September 11, 2001. The book is targeted to individuals concerned with monitoring and managing the impact of catastrophe risks. For example:

- Senior insurance and reinsurance managers can gain insight into the policy implications of competing hazard management strategies.
- Actuaries and underwriters can learn how catastrophe modeling, in its current form of user-friendly software, can facilitate their portfolio analyses.
- Federal, state and local government employees can learn to expand their definition of risk management to include the role that insurance can play in protecting their organizations against loss.
- Structural engineers, proficient in seismic and wind resistant design, can examine the latest approaches to modeling the fragility of a building system.
- Other experts interested in catastrophe modeling, including earth scientists, computer scientists, economists, and geographers, can discover their role in creating the next generation of models.

Roadmap of the Book

Part I of this book provides an introduction to risk management and catastrophe models. Chapter 1 indicates the need to manage risk and describes the key stakeholders involved in the process. Chapter 2 provides an introduction to catastrophe models and insurance. It introduces the components of a catastrophe model and how catastrophe models aid insurers in assessing their portfolio risk. The chapter concludes by introducing a framework for integrating risk assessment with risk management strategies via catastrophe modeling.

Part II of the book delves more deeply into the complex process of linking the science of natural hazards to the output from catastrophe models. Chapter 3 discusses the components of catastrophe modeling in more detail, including the hazard, inventory, vulnerability, and loss modules. This chapter clarifies how data are incorporated into catastrophe models and how modeling techniques facilitate the assessment of earthquake and hurricane risk.

Chapter 4 discusses the treatment of uncertainty in a catastrophe model. Catastrophe modeling is an evolving science; there are assorted interpretations and approaches to the modeling process. Differences in the output from competing catastrophe models are presented for hurricane and earthquake risk. Using the Charleston, South Carolina region as an example, the chapter highlights how uncertainty in modeling risks affects estimates of future losses.

Part III examines how catastrophe modeling currently aids insurers and other stakeholders in managing the risks from natural hazards. After a general overview of current practices used by insurers, specific examples of risk management strategies are discussed in Chapters 5 though 7. Chapter 5 focuses on the actuarial principles for insurance rate making. Special emphasis is given to the role of catastrophe modeling in earthquake risk classification and rate setting for residential structures in the state of California.

Chapter 6 focuses on the role of catastrophe modeling in quantifying an insurer's portfolio risk. One of an insurer's principal concerns when constructing a portfolio of risks is to reduce the possibility of unusually large losses. Special attention is given to ways that models can address uncertainty issues and reduce the chances of highly correlated losses in an insurer's portfolio.

Chapter 7 provides a comprehensive discussion of risk financing for an organization and the regulatory basis for the design of risk transfer instruments. The chapter illustrates the role that catastrophe modeling plays in evaluating these financing schemes and discusses the reasons why there has been limited interest by investors in utilizing new financial instruments.

Part IV illustrates how catastrophe models can be utilized in developing risk management strategies for natural disasters and terrorism. In Chapter 8, insurers consider a specific risk management strategy – requiring homeowners to adopt specific mitigation measures – in determining the pricing of a policy and the amount of coverage to offer. Utilizing data provided by the three leading modeling firms (AIR Worldwide, EQECAT, and Risk Management Solutions), three hypothetical insurance companies are formed to provide earthquake or hurricane coverage to homeowners in Oakland, California, Long Beach, California and Miami/Dade County, Florida. The analyses illustrate the impact of loss reduction measures and catastrophe modeling uncertainty on an insurer's profitability and likelihood of insolvency.

Chapter 9 builds on the analyses presented in Chapter 8 by examining the role of risk transfer instruments in providing protection to insurers against losses from natural disasters. The chapter examines the impact of reinsurance and catastrophe bonds on the profitability of an insurer and the return on assets to investors in the insurance company.

Chapter 10 concludes the book by focusing on how catastrophe modeling can be utilized in dealing with terrorism. The chapter examines the challenges faced by the U.S. in providing terrorism coverage after the September 11th attacks. Given the uncertainties associated with this risk and the potential for catastrophic losses, there is a need for public-private partnerships to reduce future losses and provide financial assistance after a terrorist attack.

A Glossary at the end of the book provides definitions of scientific, engineering and economic terms used throughout the book. This should aid the reader in understanding key words that are often used to characterize and analyze risks.

PART I

FRAMEWORK FOR RISK MANAGEMENT USING CATASTROPHE MODELS

Part I of this book is an introduction to natural hazards and catastrophe risk management. Chapter 1 discusses the history of natural disaster loss and introduces the stakeholders who manage catastrophe risk, along with their motivations and relationships to one another. The chapter also discusses the role of the public and private sectors in managing risk. Chapter 2 turns to the development of catastrophe models and the use of insurance in managing catastrophe risk. The concept of an exceedance probability curve is introduced. This is a key element used throughout the book for communicating risk to a stakeholder. Finally, a conceptual framework is presented that illustrates the critical role that catastrophe modeling plays in managing risk.

San Francisco, California, Earthquake April 18, 1906. Fault trace 2 miles north of the Skinner Ranch at Olema. View is north. Plate 10, U.S. Geological Survey Folio 193; Plate 3-A, U.S. Geological Survey Bulletin 324.

Chapter 1 – Introduction: Needs, Stakeholders, and Government Initiatives

Major Contributors:
Patricia Grossi
Howard Kunreuther

1.1 Need to Manage Risk

The problem of preparing for a natural disaster is not a new one. Around the world and particularly in the more-developed countries, governments, individuals and corporations know they should prepare for a "big earthquake" or a "large hurricane" or an "extensive flood." Yet, they often do not take the necessary steps to prepare for a disaster. Only after a disaster occurs do they recognize the importance of preparing for these types of extreme events.

A major earthquake or hurricane can result in loss of life and serious damage to buildings and their contents. Bridges and roads can be damaged and closed for repair over long periods of time. Disaster victims may need to be relocated to temporary shelters or reside with friends or relatives for days or weeks. Businesses may have their activities interrupted due to facility damage or lack of utility service. For some businesses, this may result in insolvency. In August and September 2004, these challenges were obvious when Florida and other states as far north as New Jersey and Pennsylvania were deluged by Hurricanes Charley, Frances, Ivan, and Jeanne.

The need to prepare for these types of extreme events is evident when evaluating the economic consequences of natural disasters. Figure 1.1(a) and Figure 1.1(b) depict the losses due to great natural catastrophes from 1950 to 2002 throughout the world. A great natural catastrophe is defined as one where the affected region is "distinctly overtaxed, making interregional or international assistance necessary. This is usually the case when thousands of people are killed, hundreds of thousands are made homeless, or when a country suffers substantial economic losses, depending on the economic circumstances generally prevailing in that country" (Munich Re, 2002). These

figures include data on the overall economic and insured losses worldwide (in 2002 dollars) from earthquakes, floods, windstorms, volcanic eruptions, droughts, heat waves, freezes, and cold waves.

Figure 1.1(a) suggests a good deal of variation in losses with time. The figure illustrates that in certain years, such as 1976, 1988, 1995, and 1999, there are peaks in the amount of loss. Furthermore, the amplitude of the peaks seems to be increasing over time. This trend is expected to continue as higher concentrations of population and built environment develop in areas susceptible to natural hazards worldwide. Additionally, worldwide losses during the 1990's exceeded $40 billion dollars each year with the exception of 1997. Losses were as high as $170 billion in 1995, primarily due to the large-scale earthquake that destroyed portions of Kobe in Japan in January of that year. Insured losses matched this growth during the same timeframe.

The volatility and trend in losses can be seen in the United States as well. Figure 1.2(a) and Figure 1.2(b) show the economic and insured losses from significant United States catastrophes from 1950 through 2002 with losses adjusted to 2002 dollars. U.S. catastrophes are deemed significant when there is an adjusted economic loss of at least $1 billion and/or over 50 deaths attributed to the event (American Re, 2002).

There are peaks in losses due to catastrophic events, as in worldwide losses (most prominently in 1989, 1992, and 1994), and the upward trend over the past 50 years is evident when broken down by decade, as seen in Figure 1.2(b). The losses from individual disasters during the past 15 years are an order of magnitude above what they were over the previous 35 years. Furthermore, prior to Hurricane Hugo in 1989, the insurance industry in the United States had never suffered a loss of over $1 billion from a single disaster. Since 1989, numerous disasters have exceeded $1 billion in insured losses. Hurricane Andrew devastated the coastal areas of southern Florida in August 1992, as well as damaging parts of south-central Louisiana causing $15.5 billion in insured losses. Similarly, on the west coast of the United States, insured losses from the Northridge earthquake of January 1994 amounted to $12.5 billion.

Residential and commercial development along coastlines and areas with high seismic hazard indicate that the potential for large insured losses in the future is substantial. The ten largest insured property losses in the United States, including the loss from 9/11, are tabulated in Table 1.1 adjusted to 2001 dollars (Insurance Information Institute, 2001). The increasing trend for catastrophe losses over the last two decades provides compelling evidence for the need to manage risks both on a national, as well as on a global scale.

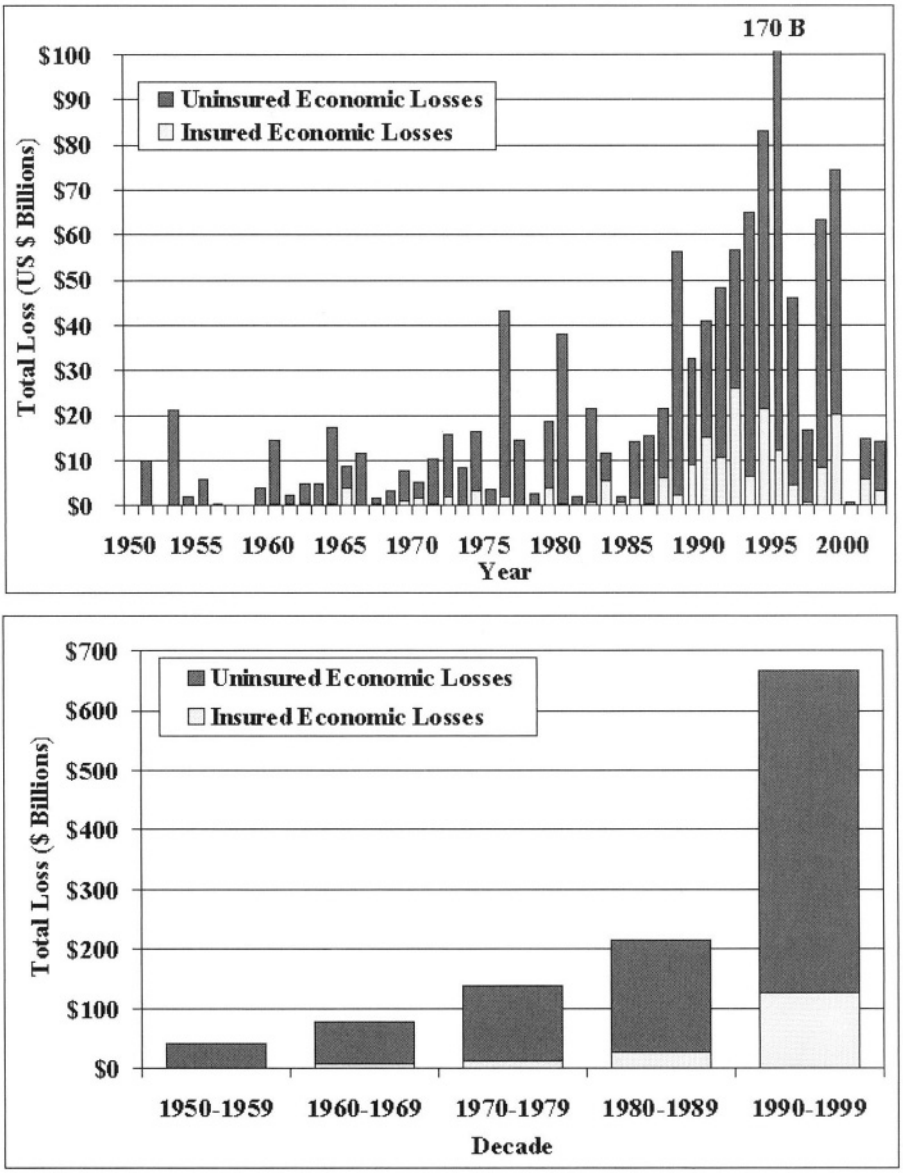
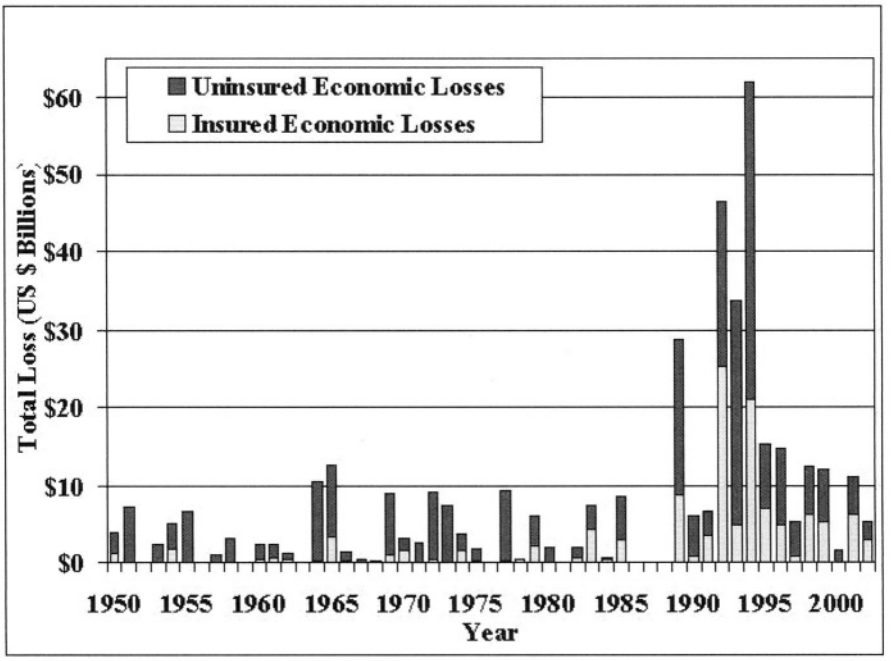


Figure 1.1. Losses due to great natural catastrophes worldwide: (a) by year; and (b) by decade (developed by the Geoscience Division of Munich Re).



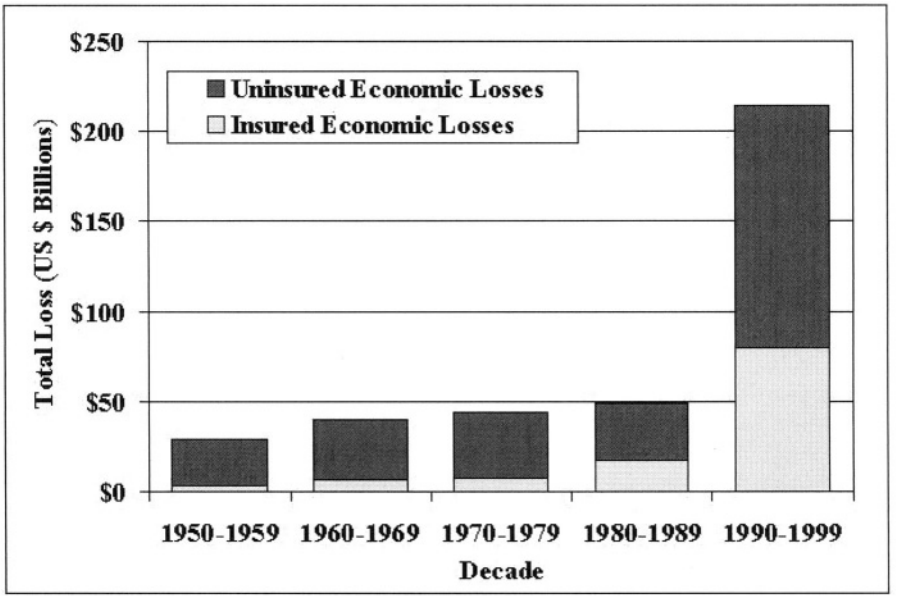


Figure 1.2. Losses due to significant U. S. natural catastrophes: (a) by year; and (b) by decade (developed by the Geoscience Division of American Re).

Table 1.1. Top 10 U.S. insured property losses (US $ billions)

Event	Dollars at year of occurrence	2001 dollars
World Trade Center (2001)	$20.3	$20.3[1]
Hurricane Andrew (1992)	$15.5	$19.6
Northridge Earthquake (1994)	$12.5	$14.9
Hurricane Hugo (1989)	$4.2	$6.0
Hurricane Georges (1998)	$2.9	$3.2
Tropical Storm Allison (2001)	$2.5	$2.5
Hurricane Opal (1995)	$2.1	$2.4
Hurricane Floyd (1999)	$2.0	$2.1
20-state winter storm (1993)	$1.8	$2.1
Oakland Firestorm (1991)	$1.7	$2.2

(Source: Insurance Information Institute)

1.2 Private Sector Stakeholders in the Management of Risk

The magnitude of economic and insured losses from natural disasters raises various questions. Who are the individuals affected by these events? What options are available to them to assess their risk? What factors influence their choices for dealing with these risks and actively managing their risk? By examining the perspectives of these individuals and groups, one can develop more effective risk management strategies for reducing potential losses from such disasters.

Figure 1.3 illustrates the key stakeholders in the management of risk that are discussed in this book. Each of the stakeholders' goals and perceptions of the risk lead them to view natural hazards from a unique perspective.

At the bottom of the pyramid are the property owners who are the primary victims of losses from natural disasters. They have to bear the brunt of the losses unless they take steps to protect themselves by mitigating or transferring some of the risk. Insurers form the next layer of the pyramid. They offer coverage to property owners against losses from natural disasters. Insurers themselves are concerned with the possibility of large claim payments from a catastrophe and turn to reinsurers, the next layer of the

[1] Some major claims are still in dispute; this does not include liability claims. Total insured losses due to the 9/11 attacks (including liability) are estimated around $35 billion as of July, 2004.

pyramid, to transfer some of their risk. At the top of the pyramid are the capital markets, which in recent years have provided financial protection to both insurers and reinsurers through financial instruments, such as catastrophe bonds. Of course, there are exceptions to this pyramid structure. For example, there have been two catastrophe bond issues (Concentric Re, covering Tokyo Disneyland, and Studio Re, covering Universal Studios) that offered direct protection to these property owners in place of traditional insurance arrangements.

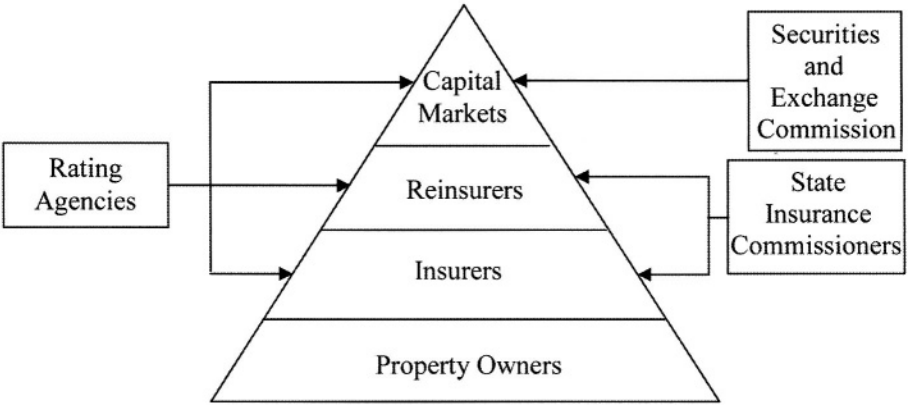


Figure 1.3. Key private sector stakeholders in the management of risk

The insurance rating agencies and state insurance commissioners are the two institutions that regulate the insurance industry. Rating agencies provide independent evaluations of the financial stability of the insurers and reinsurers. State insurance commissioners are primarily concerned that the rates charged by insurers are fair and that insurers in the market will remain solvent following a disaster. The Securities and Exchange Commission (SEC) regulates capital markets and catastrophe bonds are given bond ratings by organizations such as Fitch, Moody's Investor Service, and Standard & Poor's.

In the following sections, risk management strategies are discussed from the perspective of each stakeholder in the pyramid.

1.2.1 Property Owners

Owners of commercial and residential structures have a range of risk management strategies from which to choose. They can reduce their risk by retrofitting a structure to withstand wind or earthquake loading, transfer part of their risk by purchasing some form of insurance, and/or keep and finance their risk.

The ways in which particular individuals decide to manage risk is often a function of their perceptions. Despite a front-line position in facing the

financial impacts of natural disasters, the average homeowner is one of the least active stakeholders in the process. For most, the choices are whether or not to buy insurance – if this is an option – and whether to take actions that would make their home more resistant to damage. Many homeowners do not take action even when the risk is abundantly clear and loss-reducing measures are available. It is often the case that these homeowners feel that a disaster will not affect them.

A commercial property owner's risk perception and strategies to manage risk are different from those of residential owners. A commercial establishment must concern itself not only with life safety and insolvency issues, but also with the impact of a natural hazard on the operation of its business. Often, there are extra expenses as a business tries to remain viable after a catastrophe. The company is concerned about business interruption loss – the loss or reduction of income due to the suspension of operations resulting from a natural disaster. Business owners in hazard-prone regions are normally quite interested in purchasing coverage against this type of risk.

1.2.2 Insurers

An insurer provides protection to residential and commercial property owners for losses resulting from natural disasters. Losses due to damage from fires (resulting from lightning during thunderstorms) and wind (resulting from tornadoes and hurricanes) are covered by a homeowner's insurance policy, normally required by lenders as a condition for a mortgage. In the U.S., loss due to water damage (resulting from floods) is covered under the National Flood Insurance Program (NFIP), a public-private partnership between the government and the insurance industry established in 1968. Losses due to damage from ground movement (resulting from earthquakes and landslides) are covered by a policy endorsement or by a separate policy. This separate policy is issued either by the private sector or, in California, through a state-run, privately funded earthquake insurance company, the California Earthquake Authority (CEA) that was created in 1996.

Losses from natural disasters can have a severe impact on an insurer's financial condition. Insurers, therefore, want to limit the amount of coverage they provide to property owners in hazard-prone areas. An important concern for insurers is the concentration of risk. Those who cover a large number of properties in a single geographic area face the possibility of large losses should a natural disaster occur in the area. An insurer views a portfolio with this type of highly correlated (or interrelated) risks as undesirable. Subject to regulatory restrictions, an insurer limits coverage in any given area and/or charges higher premiums in order to keep the chances of insolvency at an acceptable level.