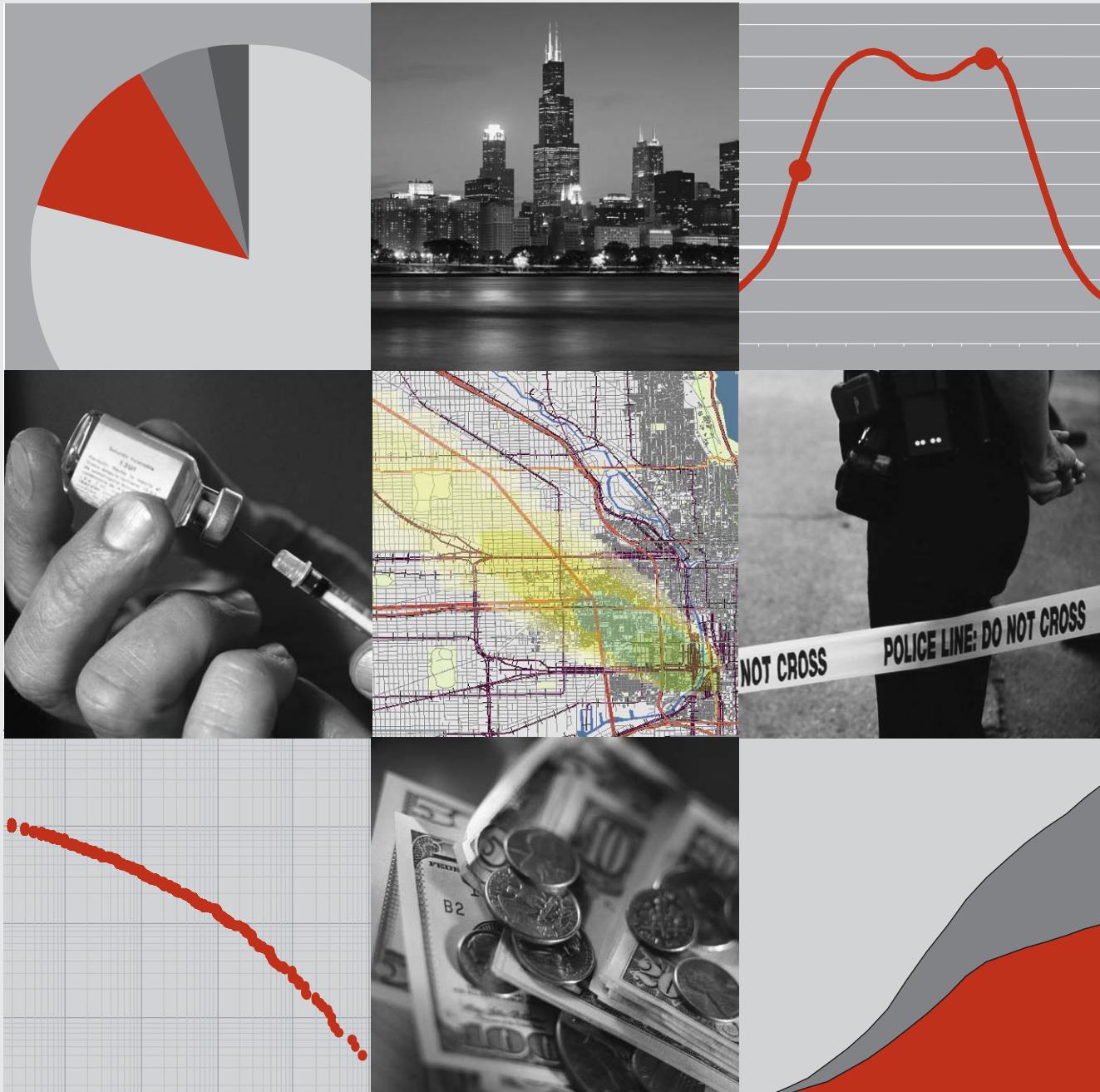


CATASTROPHE, INJURY, AND INSURANCE

The Impact of Catastrophes on Workers Compensation, Life, and Health Insurance

https://support.rms.com/Publications/Catastrophe_Injury_Insurance.pdf



INTRODUCTION

Throughout our 15-year history, Risk Management Solutions (RMS) has focused our energy on helping clients, associates, and community leaders understand the potentially devastating damage from catastrophic events such as earthquakes, hurricanes, and floods. The insurance industry in particular relies upon our technology to quantify the impact of these events on their portfolio of risk, and in turn take steps to manage that risk.

Until recently, the primary focus of modeling catastrophic events has been on the potential damage to property: personal residences and contents, commercial and industrial buildings, along with business interruption. However, the events of September 11, 2001 have made it clear that not only does the United States have a new catastrophic peril to deal with in terrorism, but the U.S. population also faces grave danger from extreme natural events.

The purpose of this study is to utilize cutting-edge modeling techniques to provide workers compensation, life, and health insurance writers with key benchmarks for the potential risk of human casualties from a range of possible catastrophic events including earthquakes, terrorist attacks, industrial accidents, and infectious diseases. Since catastrophe modeling is fairly new to the life and health industry, RMS has provided some background material on how catastrophe models work, the input data required, and how the results are used to manage risk.

There are a number of challenges inherent to the modeling of catastrophic risk to humans. Unlike property risk, where buildings stay in a fixed location, people represent 'mobile' exposures that are likely to be in different places depending on the time of day and day of the week. Modeling mobile exposures has required the development of detailed databases on the movements, demographics, and insurance coverages of the U.S. population.

To assist in the development of this report, RMS enlisted the help of a number of leading experts from the life and health insurance industry. We would like to thank these companies for their assistance, without which this study would not have been possible.

Our hope is that this study will improve the industry's understanding of the potential level of risk from human casualty, and lead to the reduction of casualties from major catastrophic events in the future through increased awareness, preparedness, and risk mitigation.

Hemant Shah



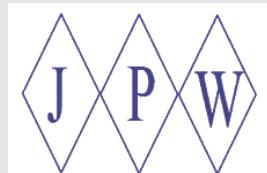
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The views and analysis in this report are those of Risk Management Solutions. We are grateful for the comments, advice, and review of our steering committee members from the sponsoring clients.



GUY CARPENTER



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1 SUMMARY

Although our society has made itself significantly safer than previous generations with regard to everyday threats, the potential exists for rare catastrophic events to overwhelm societal defenses and cause large numbers of deaths and injuries. The risk from a massive catastrophe is increasing. Populations are growing rapidly and are now more geographically concentrated. Cities have reached unprecedented size and density. Urban centers are filled with growing numbers of buildings that hold thousands of people in one structure. And the volume of social interactions and extent of travel are such that diseases can spread rapidly through the world's population.

1.1 SEPTEMBER 11: A WORST-CASE SCENARIO?

The World Trade Center (WTC) disaster is viewed by many in the insurance industry as a worst-case scenario for mass casualties, but in reality there are numerous events that would generate higher losses for life insurance and injury-related claims. This report shows that events capable of causing tens of thousands or even hundreds of thousands of fatalities are possible in the U.S., and that their financial impact can be quantified. Losses are estimated for several segments of the insurance industry including workers compensation, individual life, group life, accidental death and dismemberment (AD&D), and health insurance.

The analysis considers the risk of mass casualties due to terrorism, earthquake, industrial accident, and contagious disease. The risk posed by these perils is illustrated through a detailed analysis of seven extreme but plausible scenarios. The city of Chicago was chosen for illustrative purposes in five of the seven cases, to allow for extensive local research on human exposure patterns, the built environment, and insurance penetration. But Chicago is just one of numerous cities exposed to each peril. It should not be construed that Chicago is at greater likelihood of sustaining losses than other locations.

Other natural perils such as hurricanes, tornadoes and floods can wreak enormous damage on property, but thanks to modern-day warning systems, they rarely pose catastrophic risk to human life. Therefore, they are not considered in this study.

The scenarios selected for this study are extreme, but not worst-case events. The losses to the insurance indus-



Figure 1.1 After the events of September 11, emergency services groups began routinely practicing for mass casualty events, as in this Seattle, Washington TOPOFF drill in May 2003 (Image: Associated Press)

try in each case could be significantly higher depending on a number of factors including event magnitude, time of day, and location. A brief description of each event follows:

- Earthquake: M7.1 during peak work hours (early afternoon) in Los Angeles
- Earthquake: M6.0 during late night hours in Chicago
- Terrorism: synchronized attack deploying 2-ton truck bombs at three different locations in downtown Chicago during peak work hours
- Terrorism: medium-sized anthrax attack during peak work hours in downtown Chicago
- Terrorism: major anthrax attack during peak work hours in downtown Chicago
- Industrial accident: rail accident causing 90 tons of chlorine to spill during Chicago morning commute
- Infectious disease: nationwide impact of a flu pandemic resulting from a new strain of the influenza virus

1.2 LOSSES ACROSS MULTIPLE LINES OF INSURANCE

The resulting injuries, fatalities, and losses to each line of business under the seven scenarios are shown in Table 1.1. In addition to loss correlation among different lines of business, many of these events would also cause large losses to property lines, increasing the total impact on the insurance industry.

The potential for losses on this scale is a relatively recent phenomenon, caused by increasing densities of

Scenario	Fatalities	Total Casualties	Group Life	Individual Life	AD&D	Workers Comp	Health	Total
5 Terrorism Anthrax Large	106,700	942,900	\$8,930	\$7,240	\$4,230	\$32,320	\$2,040	\$54,760
7 Influenza Pandemic	200,000	10,000,000	\$2,680	\$6,430	\$0	\$250	\$30,520	\$39,880
4 Terrorism Anthrax	26,600	238,500	\$2,710	\$2,115	\$1,290	\$10,270	\$140	\$16,520
1 LA Earthquake M7.1	4,500	100,400	\$270	\$270	\$160	\$9,240	\$170	\$10,110
6 Industrial Accident	10,200	42,600	\$580	\$590	\$230	\$4,530	\$1,150	\$7,080
3 Terrorism Triple Truckbombs	5,300	87,600	\$550	\$430	\$300	\$4,020	\$70	\$5,370
2 Chicago Earthquake M6.0	2,100	66,300	\$70	\$70	\$40	\$190	\$1,920	\$2,290

Table 1.1 Losses by line of business for the seven scenarios in this report; scenarios are sorted by total insured loss (\$ Millions)

people and buildings within cities. Because these hazards occur infrequently, there are few historical events or statistical records of mass casualties that can be used to validate probabilities or loss assumptions for the most extreme scenarios. However, the analysis is derived from and tested against known phenomena and observations.

The occurrence of each peril is verifiable and most of the events in these scenarios are replays of real events that have occurred somewhere at sometime, but projected onto locations where they would affect many more people. The exceptions to this are the anthrax attacks, which mercifully have never occurred on a mass scale, but are known from research and testing to have these types of potential effects. RMS believes that these scenarios represent credible catastrophic events.

1.2.1 Impacts Differ by Peril and Line of Business

The scenarios show that the total number of deaths or injuries from an event does not completely predict the costs to the insurance industry or to different lines of insurance coverage. The penetration of insurance products among people affected, the severity of their injuries, and the time of day the event occurs are important factors determining the loss experienced by different lines of business.

The total number of fatalities is largest in the influenza pandemic, but the loss to life insurers is greatest from the large anthrax attack. This is because the people affected most by the anthrax event are working age, employed people with high benefits, while the flu pandemic would cause more deaths among the elderly and children, who have lower life insurance benefits.

Across all lines, the Los Angeles earthquake is more costly than the industrial accident, but the industrial

accident is more than twice as costly to the group life insurers. This is because the industrial accident scenario would cause more fatalities than the earthquake, even though the earthquake leads to a larger number of total casualties. Losses from the industrial accident and both of the earthquake scenarios are considerably less severe than the bio-terrorism attacks and the influenza pandemic.

The time of day an event occurs can have a dramatic impact on losses. Terrorist attacks typically occur in concentrated urban areas during times of peak exposure. Earthquakes on the other hand, are random events and can occur at any time of day, and any day of the week. An earthquake occurring on a weekend will cause minimal workers compensation loss, but significant loss to health insurance. Conversely, if the earthquake occurs during peak work hours, much of the health care cost will be “transferred” from health insurance to workers compensation. The potential for mass casualties is heightened during work hours when people are concentrated in urban areas, exposing populations to potential collapse of high-rise buildings that house hundreds or even thousands of workers.

Of the lines analyzed in this study, only workers compensation is able to recover funds from the government under the Terrorism Risk Insurance Act (TRIA) in the event of a foreign terrorist attack. Such recoveries have not been considered in this study, but would be significant in an event the magnitude of the large anthrax attack.

1.3 ASSESSING EVENT FREQUENCY

In order to manage catastrophic risk, insurers must understand not only the severity of events, but also their frequency. Following September 11, the price of catastrophe reinsurance skyrocketed. At the time, most life

Annual Probability	Return Period	Terrorism		Earthquake	
		Fatalities	Total Casualties	Fatalities	Total Casualties
0.01	100	8,400	133,000	1,700	45,000
0.004	250	14,000	259,000	3,900	91,000
0.002	500	19,000	360,000	7,000	159,000
0.001	1,000	34,000	520,000	12,000	259,000
0.0002	5,000	115,000	1,748,000	46,000	798,000
Average Annual		500	9,500	100	2,500

Table 1.2 Probability of number of deaths and total casualties resulting from terrorist attacks and earthquakes in the U.S.

and health writers had no way of assessing the magnitude of their catastrophe risk, and were unable to make informed decisions about the cost/benefit tradeoffs of proposed reinsurance structures. Table 1.2 displays probabilistic loss results for the industry from the perils of earthquake and terrorism, including the likelihood of the industry sustaining various loss levels. Similar output for an individual company portfolio allows management to quantitatively assess the effectiveness of risk transfer options.

1.4 THE NEED FOR IMPROVED EXPOSURE DATA

This study shows that the threat of catastrophic events to workers compensation, life, and health lines is real. The risk, however, is manageable. For members of the life and health industry, the challenge is analogous to the one

faced by the property insurance industry in the mid-1990s following catastrophic losses from Hurricane Andrew and the Northridge Earthquake. These events made it painfully clear that companies had to manage catastrophe risk proactively to survive and succeed.

Managing these risks within an insurance enterprise requires analyzing the potential impacts to each company's unique book of business. Collecting complete and accurate portfolio data is the essential, but sometimes difficult, first step. Following this investment in data capture, an accurate risk assessment can be used to make informed portfolio management decisions regarding geographic diversification, correlation across multiple lines of business, underwriting, risk transfer, and pricing.

2 BACKGROUND

This report explores the plausible financial impact for workers compensation, health, group and individual life, and AD&D insurers from excess mortality and morbidity caused by catastrophe events. A general range of causes and trends of mass casualty events are discussed, but the main focus of the report is on modeling the frequency and severity of losses from earthquake and terrorism, and exploring detailed scenarios of losses caused by industrial accidents and influenza.

2.1 ROUTINE PAYOUTS IN LIFE AND HEALTH

Approximately 2.5 million people die each year in the U.S. About 40% of those deaths result in approximately \$40 billion in insurance payouts under life policies. An average of 5,000 work-related fatalities occur and several million people become injured or ill in the workplace each year, receiving compensation and benefits under workers compensation insurance amounting to billions of dollars. The health insurance industry covers approximately 70% of the people treated in hospitals, with medical treatment costs totaling \$1.2 trillion.

The impact of a catastrophe that kills hundreds or even thousands of people, tragic though it may be in human terms, may be only a marginal event in terms of the additional financial costs to the insurance industry.

However, variations from the mean would be significant for the insurance industry if hundreds of thousands of additional casualties were caused by extreme events. Events on the level of a pandemic disease or a terrorist attack using weapons of mass destruction are possible and could cause catastrophic casualty levels, and are considered later in this report.

2.2 CORRELATED LOSSES IN CATASTROPHES

The aspect of catastrophes that is of most concern to individual insurers is the fact that clusters of people are affected, correlated in the same geographical location and time. This correlation affects some insurance companies more than others. A building collapse in an earthquake or in a terrorist attack may injure a lot of people employed by a single company occupying that building. The insurance company that provides the workers compensation insurance or the group life coverage for that company will experience a very large loss.

Individual insurance companies can also experience correlated losses where they have a higher than average penetration of insureds. One insurance company may take a higher loss than others if the catastrophe occurs near a location where they have concentrations of business. The regional history of life insurance, and the way

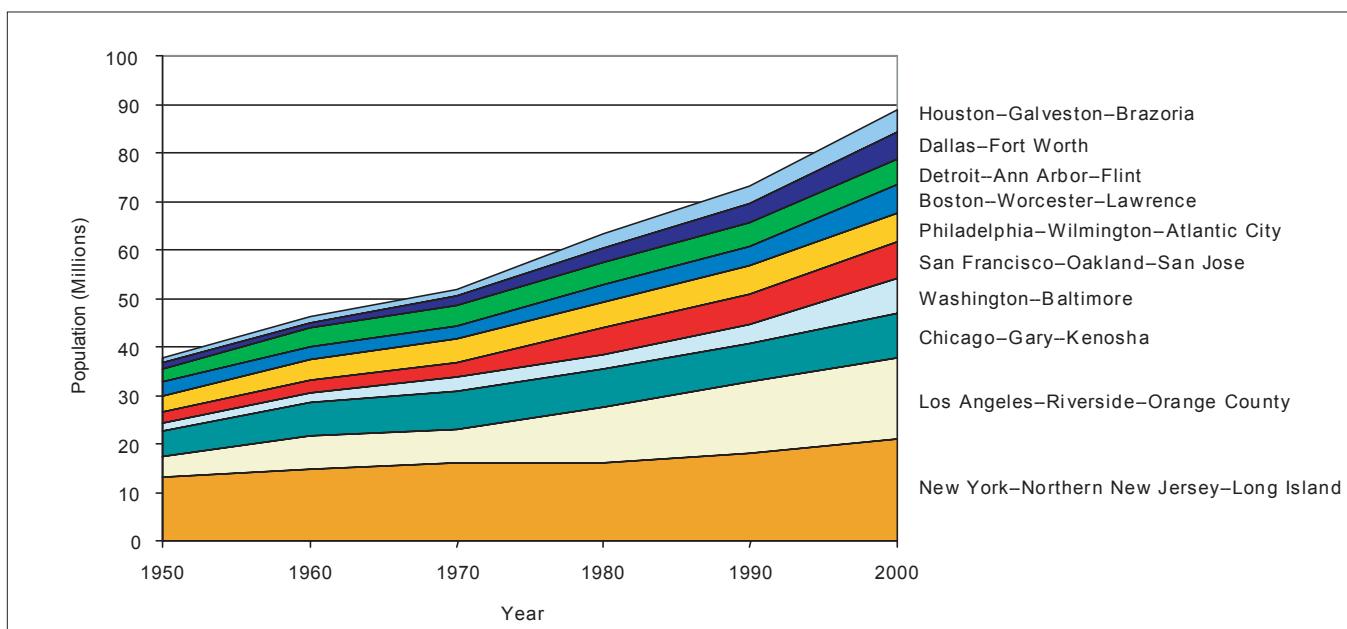


Figure 2.1 The rapid growth of large metropolitan areas has led to greater concentrations of population at risk from localized catastrophes

life insurance is sold to individuals means that some companies have strong portfolios in certain cities. Those cities concentrate the risk for that company. Insurance products sold through affinity groups and other schemes may increase the amount of correlated loss that an insurance company experiences when a catastrophe occurs.

The economies of scale that operate with the purchasing of health care provision also means that health insurance providers tend to build strong market shares in certain regions.

2.3 AN INCREASING RISK?

There are reasons to believe that the risk of catastrophe injury losses are increasing. New threats have emerged and existing ones have become more defined. Increasing population and, more importantly, growing concentrations of people raise the chances for mass casualties.

2.3.1 Increasing Threats

Since September 11, 2001 the image of mass casualties caused by terrorist attacks in the U.S. has been very real. The spread of severe acute respiratory syndrome (SARS), avian flu, and other diseases has demonstrated that growing globalization and international travel are rapidly increasing the transmission of contagious diseases around the globe. Natural catastrophes also continue to demonstrate the potential for causing many casualties.

2.3.2 Increasing Concentrations of People in Cities

Population growth trends have increased the amount of people and insurance in any one place. The metropolitan population of the U.S. has almost tripled since 1950 and now half of the nation lives in cities with a population of more than one million.¹ A dozen urban areas of about one hundred square miles contain increasing numbers of people, enabling a catastrophe or disease that hits a big city to easily affect a large population pool.

Within these metropolitan areas, the pattern of population distribution has shifted. Residential densities of city centers decreased towards the end of the 20th century, in contrast to the suburbs, which have become considerably denser. Although these increasing populations choose to live in the suburbs, large numbers of them travel to work each day in the city centers. The growth of large urban populations is most marked in the daily concentrations of workforce in city centers.

2.3.3 Growing Workforce in City Centers During the Day

Growing suburbs have increased the number of people traveling into and working within city centers. Although there has been a short-term decline over the past three years, the long-term trend has shown a steady increase in the number of working people concentrated in city centers during the day. On weekdays, over 2 million work-

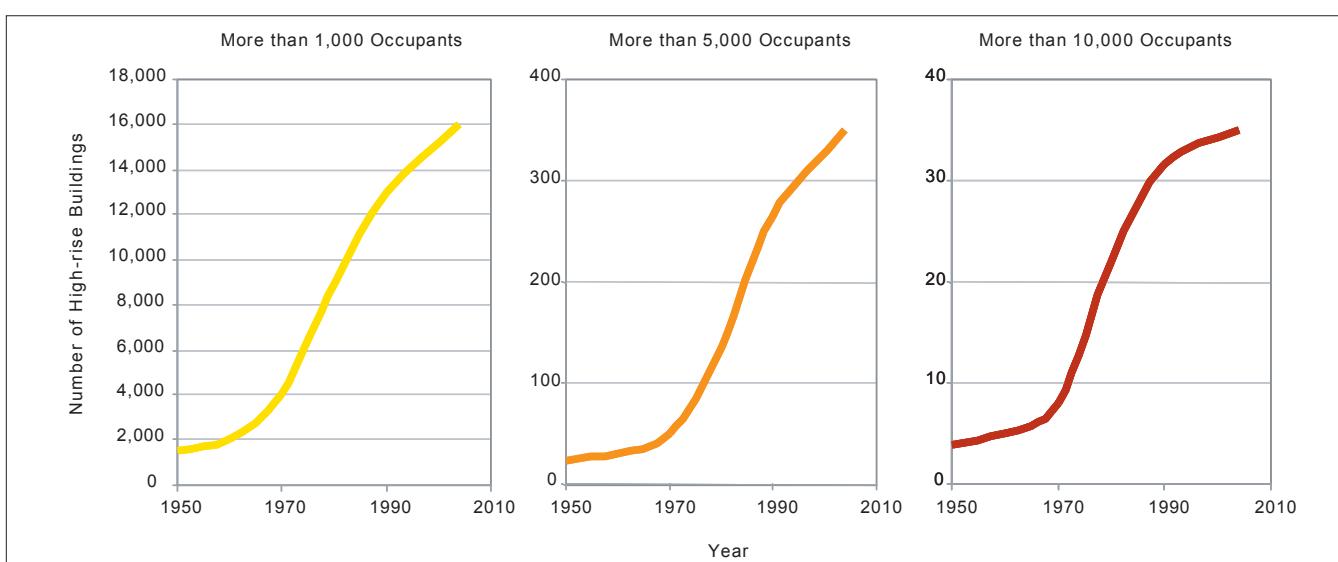


Figure 2.2 The number of large occupancy, high-rise buildings in U.S. cities has increased rapidly, putting more people at risk from a catastrophe affecting an individual building

¹ "Demographic Trends in the 20th Century," U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau.

ers inhabit the 23 square miles (60 square km) of Manhattan. On September 11, 2001 over 300,000 people were working within 1 mile (1.16 km) of the World Trade Center. A decade earlier, the number of people working in that area was less than 250,000. Many other city centers have been increasing their workforce even more rapidly—Younger cities like Houston and Dallas have grown their city center workforces at annual rates of over 5%. Over the past 25 years, the total number of people working in urban centers has increased by more than 50%.

The increasing concentration of people in urban areas means that any lethal events that do occur in a city center are likely to have a bigger impact on insurance claims.

2.3.4 Increasing Numbers of People in a Single Location

The number of people at risk in a single location (a building or a public gathering) is also increasing. More than three times as many people work in high-rise structures (above 12 stories) compared to 20 years ago. Land prices in city centers, favorable urban authorities, and the demand for prestigious buildings has encouraged a building boom for skyscrapers. Even the graphic impact of September 11—once thought by commentators to be “the death of the skyscraper”—has not blunted the appetite for high-rise buildings; some 140 new skyscrapers are currently under construction in New York and Chicago alone.²

More people are congregating at major gatherings, such as large shows, sports events, and entertainment centers. Of the 209 non-college stadiums in the U.S. capable of seating more than 30,000 over 50 of them were built post 1990.³ Sports stadiums are also occupied more frequently, hosting a broader range of entertainment events, and have higher attendance rates than in previous decades.

Attendance at amusement parks has increased by one third since 1990, to the point that 330 million people a year visit more than 600 mega-theme park attractions, many having more than 10,000 visitors on the grounds at a time. Disneyland in California holds more than 60,000 visitors on peak days such as July 4.

Some of the more frequent events causing hundreds of casualties are accidents affecting travelers. Travel is also a time when concentrations of people are potential-

ly at risk in aircraft, cars, trains, or boats. Despite a slowdown in air travel since 2001, the number of people traveling in large aircraft has increased by more than 50% over the last 10 years, and long range forecasts anticipate a renewed increase in demand.⁴ Traffic on the roads is denser and rush hour traffic persists for longer—commuter volumes into the central urban cities from the suburbs have increased by about 15% in a decade, and the average travel time to work in large cities has jumped from 20 minutes to nearly 30 minutes.⁵

2.4 MASS CASUALTY CATASTROPHES IN THE U.S.

Table 2.1 provides some examples of historical mass casualty events in the U.S. This is not a comprehensive catalog, but illustrates the numbers of deaths that have occurred from different types of events.

A wide range of event types have caused multiple casualties. It is worth noting that some of the most memorable, destructive, and costly natural catastrophes that caused



Figure 2.3 Cities in the U.S. have grown rapidly in the past half-century—the San Francisco Bay area now contains ten times as many people as it did during the 1906 Earthquake (Image: USGS)

² Skyscrapers.com catalogs major high-rise buildings under construction. New York, Chicago, and Seattle are in the top 10 cities worldwide for new skyscraper development.

³ Worldstadiums.com, stadium listings. Construction since 1990 also includes two stadiums of more than 100,000 capacity and six stadiums of over 75,000 capacity in the U.S.

⁴ Federal Aviation Administration. December 2003. “FAA, Administrator’s Fact Book,” Washington D.C.

⁵ U.S. Census Bureau. “2003 Commuter Patterns in Top 10 Metropolitan Areas.”



Figure 2.4 Workers in dense city centers tend to be concentrated in high occupancy buildings (Image: Getty Images)

many billions of dollars in property damage, like the 1906 San Francisco Earthquake, Hurricane Andrew, and the Northridge Earthquake, caused relatively few casualties.

This catalog provides examples and indications of the scenarios that could result in numerous claims for insurers of U.S. populations. They do not, by themselves, provide an accurate picture of the frequency and severity of likely events in the future. The population, circumstances, building stock, safety standards, emergency services, and many other factors have changed during the century. As with the following two examples, some types of events that caused high death rates in the past are less likely to do so today.

Heat waves cause deaths in major cities, particularly for older people and the very young. However, this risk has been largely reduced with air conditioning, mechanically assisted cooling, and better standards of insulation and ventilation in modern homes in the areas prone to hot summers.

The storm surge that crushed the wooden houses of Galveston, Texas and drowned 6,000 people in 1900 would today be forecast from hurricane observations several days in advance, enabling evacuations to take place. The rising waters would also now meet sizeable flood protection barriers that have been built to protect many of the coastal communities at risk.

To measure the risk of mass casualty events in the U.S., RMS models the physical processes of occurrence of different hazards and analyzes their likely effects on

today's population under current conditions. A small number of hazard types have been selected to model in this way, and the process of prioritizing the hazards for modeling will be discussed. In addition to the U.S. events, the experiences of other countries are considered to offer relevant lessons from the broadest possible sources of information.

2.5 MASS CASUALTIES IN OTHER COUNTRIES

The U.S. has never suffered the scale of life loss experienced in accidents and natural disasters in many other countries. Over the past century there have been six natural catastrophes worldwide that have caused more than 100,000 fatalities, and more than 50 events have caused 10,000 or more deaths. About half of these mass casualty disasters have been floods or cyclonic storm surges, a third are earthquakes, and the remainder are eruptions, mudflows, fires, and other natural hazards.⁶

A world catalog of lethal earthquakes that occurred in the last century shows the frequency with which vari-

Date	Event	Location	Fatalities
1918	Influenza pandemic	Nationally	500,000
1957	Influenza pandemic	Nationally	70,000
1968	Influenza pandemic	Nationally	40,000
1900	Hurricane storm surge	Galveston, TX	6,000
2001	September 11 terrorist attack	DC, NY, PA	3,031
1889	Dam burst in heavy rain	Johnstown, PA	2,209
1928	Hurricane	Florida	1,836
1904	Ferry boat fire	New York City, NY	1,030
1955	Heat wave	Los Angeles, CA	946
1995	Heat wave	Chicago, IL	700
1906	Earthquake and fire	San Francisco, CA	700
1939	Hurricane	New England	600
1925	Tornado storms	Illinois, Indiana, Missouri	589
1947	Accidental explosion	Texas City, TX	576
1903	Fire in the Iroquois Theater	Chicago, IL	575
1918	Wildfire	Cloquet, MN	400
1927	River flood	Mississippi River	313
1979	Air crash, DC10	Chicago O'Hare Airport	273
1993	Winter storm	East Coast	270
1946	Tsunami tidal wave	Hawaii	173
1992	Hurricane Andrew	Florida	61
1994	Northridge Earthquake	Southern California	51

Table 2.1 Examples of historical death tolls from different types of U.S. catastrophes

⁶ Munich Re. 2001. "Natural Catastrophes—The Current Position," Topics 2000.

ous death tolls have resulted.⁷ Figure 2.6 shows the distribution of the number of earthquakes that exceeded certain death tolls. Thirty earthquakes caused more than 10,000 fatalities, with three causing more than 100,000 fatalities.

The statistical distribution of the sizes of death tolls from natural hazards of all types has been the source of a number of studies and shown to be useful in the analysis of the probability of natural hazard mortality.⁸

2.5.1 Hazards More Deadly Elsewhere

Some of the mass casualty catastrophes seen elsewhere in the world could not physically occur in the U.S. Floods on the scale of those seen in Bangladesh and China or the mudflows that enveloped towns in Peru came from steep glacial mountain ranges far different from those that exist anywhere in the U.S. Other types of natural hazards that do occur in the U.S., earthquakes for example, tend to kill fewer people than those in developing countries because the quality of engineering and building construction in the U.S. is more robust and survives with less damage. Healthcare in the U.S. is more advanced and emergency care is more effective in treating injured

people, and coping with more of them, to save lives. Safety standards in U.S. public transportation and industrial plant operation are among the most stringent in the world, so the large scale accidents seen in other countries are much less likely in the U.S.

2.5.2 Lessons for the U.S.

There are important lessons for the U.S. to learn from the mass casualty events that occur in other countries. By their very nature, catastrophe events are rare; no single country experiences all the possible permutations of hazards and circumstances that give rise to catastrophes. However, looking across the experience of many other countries, the patterns and circumstances of mass casualty disasters can be seen more clearly. Examples of extreme natural phenomena demonstrate that the power that can be unleashed by nature can easily overwhelm man-made defenses. Very often, and almost by definition, the catastrophe is a surprise—it has unexpected features or circumstances that compound to produce a scale of loss that was beyond the experience or expectation of the officials in that country.



Figure 2.5 Historical mass casualty events would cause greater casualties today—the 1906 San Francisco Earthquake killed more than 700 but a repeat of this event today could kill 6,500 people (Image: NISEE)

⁷ Coburn, A.W., Spence, R.J.S. 2002. "Earthquake Protection." John Wiley & Sons Ltd.

⁸ Woo, G. 2000. "The Mathematics of Natural Catastrophe," pp. 262-267. Imperial College Press, London.

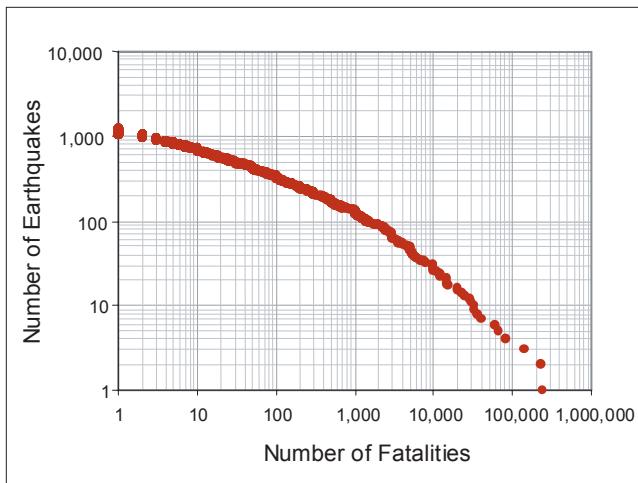


Figure 2.6 Lethal earthquakes during the 20th century were recorded in 80 countries, reflecting a wide range of buildings and seismic conditions

2.5.3 Catastrophes are Cascades of Failures

Catastrophes result from sequences of things failing and causing cascades of events that compound losses. For example, emergency systems fail, power is lost, organizational procedures fall apart, secondary catastrophes break out, and people panic. In events where large numbers of people are injured, the scale of the event overwhelms local resources from containing it and the psychological and sociological incapacitation of the affected community leads to an escalation of casualties. Responses that are normal in small scale events such as emergency activities, search and rescue, and treatment of the wounded fail to occur.

2.5.4 Catastrophes are Nonlinear

Hazards like hurricanes and earthquakes are not linear, in that small scale losses that have occurred previously do not prepare the community for the scale of loss that can still occur. In the early 1990s, Japan was commended and cited by the international community for having solved its earthquake problem. After a disastrous earthquake history in the first half of the 20th century (nine earthquakes had caused many thousands of deaths including one in which 140,000 people died), Japan introduced seismic building codes, developed world-class engineering, and invested in emergency preparedness. For practically all of the last half of the 20th century, its earthquake experience was far less severe; of the 35 strong earthquakes that occurred in Japan from 1949 to 1994, none caused more than a few hundred fatalities and the average death toll per event was 24. It was therefore beyond expectations when the 1995 Kobe Earthquake killed

5,400 and injured 35,000 people. The Kobe disaster was the result of a large magnitude earthquake impacting a major modern city and testing buildings and emergency systems well beyond any previous level. In the U.S., our earthquake experience is similar to Japan's in the second half of the 20th century—a catalog of low casualty events that do not include a large magnitude earthquake occurring close to a major city.

2.5.5 Lessons from International Experience

Examples of catastrophes, accidents, and technology failures in other countries demonstrate the ways that mass casualties can occur and the scale of loss that is possible. While similar events may be less likely in the U.S., or possibly would cause fewer casualties if they occurred, many of the processes are likely to be similar. Industrial accidents for example, or failures of emergency systems in natural disasters seen in other countries may arguably be less likely to occur. The additional precautions, training of personnel, and legislative standards in the U.S. may make accidents and failures less probable, but the processes by which their destructive forces kill and injure people when they do occur would probably be similar.

2.6 POTENTIAL MASS CASUALTY EVENTS

This study considers events that are likely to be of significance to the life, health, and workers compensation insurance industries. Events that cause more than a thousand deaths, not to mention additional injuries, form the threshold of events under consideration. The study does not include transportation accidents or large scale fires to individual buildings, as mortality levels in these types of events reach several hundreds.

2.6.1 Probability Range 1% to 0.02%

The analysis also considers the likelihood of events. The assignment of probabilities to events is an important element of risk analysis. Some events are feasible but the chances of them occurring are so low that they are beyond the consideration of most insurance companies and risk managers. Catastrophe insurers are usually concerned with managing the risks of events that generate a loss that is likely to occur within an annual probability range of 1 in 100 (1% probability per year) and 1 in 5,000 (0.02%). Events that occur less frequently than this are termed ‘improbable.’ This does not necessarily mean that these events are impossible—there are some

very large-scale loss events that could occur but best assessments suggest that the chance of these occurring is beyond the improbability threshold. These are not included in this report but insurers may need to be aware of the possibility, even if they choose not to manage their risk to this eventuality.

2.6.2 Plausible But Improbable Events

Scenarios that fall into these plausible mass casualty events but are improbable include a large-scale accidental release of radioactivity from a nuclear power station. Estimates suggest that such an event could affect several million people and make many hundreds of thousands sick. Operating safety standards for nuclear power stations require that the chances of a major radioactivity release are maintained at below 1 in 10,000.

A tsunami or coastal tidal wave affecting a major stretch of coastline on either the Atlantic seaboard or the Pacific coast could be destructive and deadly for populations living along the coast. Large-scale tidal waves could potentially be caused by an ocean floor earthquake, a submarine landslide, or a meteorite in mid-ocean, but estimates of the return periods of these types of events are measured in many thousands of years.

A meteorite impact on a major city could be highly destructive, but again the chances are extremely slight. A 50-foot (15-meter) diameter meteorite hits the earth once or twice each century and causes an area of destruction with a radius of half a mile (0.8 km). Larger meteorites, exceeding 300 feet (90 meters) in diameter, land on average every thousand years and cause craters several miles wide. The chances of one randomly striking a city in the U.S. has a probability of less than 1 in a million per year.

Other types of mass casualty events can be similarly constructed—an aircraft crashing onto a public gathering, a fire trapping a crowd, a massive and sudden land failure—but the probabilities of these occurring needs to be estimated for their importance. In this study, the main types of casualty causing events are examined within the framework of likelihood of occurrence.

2.6.3 Slow Onset Perils Pose Less Risk

Flood, hurricane, tornado, and wildfire are not explicitly modeled in this study. Tornados, although highly destructive, rarely threaten large numbers of people. Hazards like major floods and hurricane-related threats that have caused high casualties in the past, are today mitigated by sophisticated forecasting systems that can predict rising tides and incoming hurricanes, and evacuation systems are in place to move large populations in advance. Similarly, large wildfires that can burn thousands of buildings generally give people enough time to evacuate and generally do not cause large numbers of casualties. If prediction or evacuation procedures were to fail, then large casualties could still occur. It is possible for fires to trap large numbers of people unexpectedly. It is also possible that floods could occur in ways that would overcome defenses and surprise populations, with deadly results. These probabilities could be considered in a future report refining casualty risk.

2.6.4 Heat Wave Casualties

Heat wave deaths are not assessed in this report. Unusually hot spells in major cities have resulted in excess mortality in the past, including as recently as 1995. In a normal year, 175 Americans die from summer heat. This number can rise into the thousands during peak events.⁹ Deaths occur in inner-city areas and disproportionately among older, infirm residents on the top floors of apartments without air conditioning. Cities where domestic air conditioning is not common are more at risk. Various heat index measures have been proposed that correlate with the incidence of heat stroke and physical injury through heat cramps and exhaustion.¹⁰

The wide scale adoption of air conditioning and cooling technologies, and improved standards of thermal insulation and ventilation in many homes in the hotter climatic areas of the country has considerably reduced the risk of heat wave deaths in the main insured populations. Low income communities with lower penetrations

⁹ National Oceanographic and Atmospheric Administration. 1995 Natural Disaster Survey Report—July 1995 Heat Wave. U.S. Dept. of Commerce.

¹⁰ Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division. CBS 1996 study. “Urban Heat Catastrophes.”

of insurance coverage are still at risk. There remains the possibility of sizeable insurance losses if extreme events affect more of the population. This risk could be assessed in more detail with future analysis.

2.7 PERILS OF GREATEST CONCERN

Perils likely to cause thousands of fatalities and occur within the probability range are relatively few, but they pose a significant threat to the insurance industry.

These are:

1. Earthquake
2. Terrorist Attack
3. Industrial Accident
4. Influenza Pandemic

For each of these perils, a general context and the estimated effects of one or more scenarios are presented. Where possible, the probabilities of different levels of loss are discussed.

3 STUDY METHODOLOGY

3.1 SCENARIO STUDIES

3.1.1 Human Insurance Exposure Database

To study the impact to the insurance industry from injuries caused by catastrophes, RMS created a high resolution, dynamic human insurance exposure database. This database provides information on the geographic distribution of the population at any time of the day, the demographics, and most importantly, the insurance coverages of that population. It covers the entire U.S. at ZIP Code level and a considerably higher resolution for estimated occupancies of individual buildings for large parts of the commercial business districts of major cities. The construction of this exposure database is described in the next chapter.

RMS has well-established catastrophe models for earthquake and terrorism risk. The models have been adapted for this study to examine their impact on human exposure. They use a detailed understanding of the physical process of the events to construct the geographical extent and severity ‘footprint’ of destructive forces. By overlaying the footprint of a particular event on top of detailed property databases, and understanding the vulnerability of buildings to the destructive forces, it is possible to analyze the damage likely to be caused to the property. By adding the human occupancy of the structures and other people in the streets, the consequences of building damage and other harmful effects of the event



Figure 3.1 The study area, Chicago, is the second most densely populated city in the U.S. and has a large commuting population (Image: Associated Press)

on the exposed population can be analyzed to estimate the numbers of people injured or killed.

3.1.2 Chicago Area Study

The human exposure database covers the entire U.S. A case study area was used to assess events in detail and to understand the granularity of an event. The Chicago metropolitan area was selected as the location for five of the seven catastrophe scenarios. The buildings in the commercial city center have been individually mapped, and detailed studies made of the commuting patterns, demographics, and insurance penetration for the Chicago population. This has made it possible to assess the insurance claims that will affect the insurance losses by coverage.

The depiction of five different catastrophe scenarios in Chicago is not to suggest that Chicago is necessarily more catastrophe-prone than other cities. However, the fact that it is the second most densely populated city in the U.S. means that any events that do occur there are capable of causing more severe life loss than many other places. Chicago, like any sizeable city, has had its share of disasters, with a long history of accidents, health incidents, and civil disturbances that have caused clusters of casualties.¹ These include the 1871 Great Chicago Fire, the 1918 influenza epidemic (8,500 deaths), severe winters in 1967 and 1979, and various heat waves. The concentrations of people in a major city like Chicago exacerbate the death toll from accidents.

The scenarios included in this study are credible examples of hazardous events that could occur in Chicago, or any other major city.

3.2 INSURANCE COVERAGES

This study is an overview of the main lines of insurance covering human deaths and injuries at any time of the day. The specific insurance lines covered in this analysis are:

- Life: encompassing group, individual, and AD&D
- Workers Compensation
- Health

Although the analysis included disability coverages, the losses were relatively small and were excluded from this report. Results for health insurance include private insurance, but not public health care plans. Other lines of

¹ O'Brien, E., and Benedict, L. “Deaths, Disturbances, Disasters and Disorders in Chicago.” Chicago Public Library.

personal accident, including travel insurance, executive coverage, and others have not been analyzed in this study but would be amenable to a similar approach in modeling their risk. Annuities are also not taken into account.

The specific detail about how each of these lines is modeled and how coverages are represented in the human exposure dataset are described in the next section.

3.3 ESTIMATING THE COST OF INJURIES

3.3.1 Cost Severity Modeling

RMS has developed cost severities for use in estimating the insured loss for people with specific injury types.

For workers compensation, average costs vary by injury level and state, based on statutory regulations, average medical costs, and other payments such as legal and vocational rehabilitation costs. Given a number of casualties, the appropriate cost severities are applied to each injury level to estimate the insured loss associated with the injuries and deaths. The total loss is the sum of costs across all injury levels.

For group life insurance, the benefit payment upon death is a multiple of the policyholder's salary level. Average salary levels vary by occupation and ZIP Code, which would both be used to determine benefits. The benefits would be paid out as one lump sum.

For individual life insurance, a specific coverage amount is purchased by the policyholder. The amount of coverage purchased depends on the needs of those being provided for in the event of death. The average amount of coverage purchased varies according to number of dependents, profession, and other factors.

AD&D covers severe injuries and death according to a detailed schedule of injuries. Different types of injuries pay different percentages of the maximum benefit according to this schedule. The schedule of injuries has been simplified for the analysis by assuming that the benefit for death represents the full coverage, permanent total injury represents 50%, and permanent partial major injury represents 25% of the death benefit.

3.3.2 Multiple Coverages on One Person

One injury can result in multiple claims for each type of insurance coverage. An example would be a person killed

while at work who has workers compensation coverage, a group life insurance policy with the employer that includes an AD&D add-on, and a separate individual life policy. All four of these coverages would apply.

3.4 INDUSTRY LOSS CURVES

The scenarios in the Chicago area study and in Los Angeles also illustrate the potential for large losses in other major cities. However, the probability that an earthquake or a terrorist attack will occur varies considerably from city to city, and the effects are likely to be different with the urban conditions of each city—construction types, density, and occupational patterns affect the numbers of casualties that would result. The RMS® U.S. Earthquake Model simulates earthquakes of different magnitudes, locations, and probabilities of occurrence with a comprehensive representation of the seismicity of the U.S. Each of these events has been modeled against the human insurance exposure to assess casualties and insurance losses. The analysis is used to identify the largest losses that can result and the probability that different levels of losses could occur. This is summarized as an aggregate exceedance probability (AEP) curve, to show the probability of exceeding a certain level of loss. The inverse of the probability of a loss occurring in a given year is the 'return period' of a loss from that severity, and is a notional indication of probability, rather than an estimate of the elapsed time interval between losses of that severity. There is potential for multiple events in one year and for the aggregate losses in that year to exceed some threshold. The AEP curve is a measure of this probability.

The analysis of losses resulting from each of the 42,000 modeled earthquakes can be used to identify where the largest losses might occur with the highest probabilities. It enables the probability of loss for each city and region to be identified and can be used to estimate the probabilities of losses arising to each of the various insurance coverages and lines of business.

The RMS® U.S. Terrorism Risk Model is also a probabilistic model, with a catalog of 78,000 terrorist attacks at a variety of targets in different cities, representing the likely chances of attacks depending on type and location. The locations and types of events giving rise to the worst

casualties can be identified and the probabilities can be assessed for different numbers of casualties and losses to different insurance lines. These results are presented in this report.

3.4.1 Company Specific Analysis

This study analyzes the insurance industry as a whole and has not assessed the market share of any particular insurance companies or how market share is distributed between players in different regions. A company with a large market share in a particular city will take a large share of the loss from any catastrophe that occurs there. The Chicago scenarios will not be as meaningful to an insurer that has no market share there. For each company, the most important losses will be from those events in the regions where they have heavy concentrations. The probabilistic industry losses described here are unlikely to scale exactly for an individual company—the loss probability for a company will depend on where its portfolio is relative to the risk. Analyzing the portfolio of a company by comparing its regional or city penetration with industry losses will provide an indication of that company's catastrophe risk profile. The industry loss curves (the database of each event and its loss for each insurance coverage) resulting from this study are available for a company to analyze against their portfolio and derive their own loss probability.

Chapter 9 deals with data quality and the types and resolutions of information that a company should use to analyze its risk using a catastrophe model.

3.5 EVENT MODELING

3.5.1 Earthquake Modeling

Earthquakes are modeled by considering the moment magnitude of the seismic source and the severity of ground shaking at each distance from the fault rupture. The characteristics of each type of earthquake and the geological strata through which the energy disperses determines how strongly the earthquake is experienced at a location. The local surface geology also affects the severity of the ground shaking, with softer soils generally amplifying ground motion and harder soils dampening it. The frequency content of the earthquake is important—longer period vibrations affect taller buildings more, and shorter periods have more effect on stiff, low-rise buildings. The spectral acceleration of the earthquake ground motion is modeled at each location affected by the earthquake.

The damage caused to a building by spectral acceleration depends on type of construction, height, and resilience of the engineering design. Building stock across the country has been analyzed to produce a database of the construction type and vulnerability of buildings in each district. In some cases, the individual buildings have been plotted and assessed.

The earthquake ground motion is translated into estimates of damage by assessing the vulnerability of the buildings affected. These damage levels are then related to the numbers of people injured and killed by building damage or collapse. Four main classes of injury severity are derived: death, permanent total, serious, and medical only. The human exposure database determines the insurance coverage for those affected to each degree of severity and the compensation levels incurred by each coverage is quantified.

In this study, the possible effects of fire-following earthquake are incorporated in the casualty assessment, but not modeled separately. Historically, the casualties from the fires that follow earthquakes in the U.S. have not been significant.

3.5.2 Terrorism Modeling

A range of different types of terrorist attack are modeled in the RMS terrorism risk model, including bomb blasts, sabotage attacks, aircraft impact attacks, and chemical, biological, radiological, and nuclear (CBRN) weapons. The effects of each attack type and magnitude are modeled as a geographical footprint around the attack target.

For vehicle bombs, a detonation pressure-wave footprint, in pounds per square inch (PSI) is derived from blasts of different explosive yields, measured in equivalent mass of TNT. The injury rates to people caused by pressure and debris are related to their proximity to the bomb, as measured by the pressure wave. Building damage caused by the bomb is related to the numbers of people injured and killed by the damage or structural collapse of the building.

Anthrax attacks are analyzed by simulating spore dispersal patterns over an urban area using computational fluid dynamics. Wind direction, speed, and the quantity of spores released determines the density of spores in an event footprint. Infiltration rates of spores inside buildings are estimated. The dosage of spores received by populations indoors and outdoors is estimated from the spore densities and likely duration of the population breathing in the spore agent. The numbers of people that

die or are injured from the dosage they receive incorporates assumptions about the speed of detection of the attack, and the treatment the population receives after the attack.

3.5.3 Chlorine Dispersal

In order to examine the impact of industrial accidents, RMS has added the analysis of a major chlorine spill in a populated area, using a well established fluid dynamics model to simulate the dispersion of the specific chemistry and physical properties of chlorine. A footprint of chlorine gas concentration levels, in terms of parts per million (PPM) is estimated using the volume of liquid chlorine released, and the wind direction and speed. The concentration of the chlorine gas is the primary determinant of the injury levels suffered, assuming that people are exposed to it for many minutes. The numbers of people that die or are injured are estimated from medical data on injury levels related to chlorine concentrations.

3.5.4 Influenza Scenario

To assess the impact of influenza, modeled data from the Centers for Disease Control and Prevention² (CDC) was used as a baseline scenario. This modeling estimates the base caseloads of influenza for different scales of epidemic and pandemic, and differentiates numbers of people dead, seriously ill, and hospitalized. The pandemic is assumed to affect the entire population of the U.S., and although infection rates could be regionally diverse, and would almost certainly be higher in cities than in rural

areas, the event is assumed to be uniform geographically. Insurance impacts are derived from assessing the numbers of people with different coverages and the losses from different severities of illness to each affected coverage.

3.6 REPORT CONVENTIONS

- Time of Occurrence: Earthquakes are shown for three time scenarios: 2:00 pm weekday, 2:00 am (representing non-working hours), and random occurrence. The random occurrence scenario uses a weighted average of losses resulting from exposure distributions at different times of the day. Earthquake results are shown for random occurrence unless otherwise noted.
- Terrorist attacks are assumed to occur at peak occupancy (2:00 pm weekday).
- The AEP of a level of loss in a year is expressed as an annual probability and also as its reciprocal—a loss ‘return period.’
- The average annual loss (AAL) is the integral of all AEP levels, representing the average rate (sometimes referred to as the “burning rate”) of all losses if averaged over a long enough period of time.

The scenarios illustrate potential ways that large numbers of fatalities can come about. These are fictitious examples and not intended to be predictive or to imply a knowledge of a safety defect in any particular facility. Each example is provided to illustrate the type and scale of damage that would result, and its effect on life and health insurers in the vicinity.

² Meltzer, M.I., Cox, N.J., Fukuda, K. 2001. "The Economic Impact of Pandemic Influenza in the United States: Priorities for Intervention." *Emerging Infectious Diseases*, Vol. 5, No. 5. Centers for Disease Control and Prevention, Department of Health and Human Services.

4 POPULATION AT RISK

4.1 BUILDING THE HUMAN EXPOSURE DATA MODEL

Life, health, and workers compensation insurers are subject to claims from millions of insured people. These people move around, changing the buildings they occupy hour to hour, traveling to and from work, visiting shops and cinemas, going on vacation, business trips, and staying at home. Individual coverage depends on a person's location, type of injury, the particular event that occurs, and the carrier that supplies the coverage.

In order to analyze the potential losses from catastrophe events on this exposure, a dynamic human exposure database was developed. This database provides an estimate for populated locations, demographics, employment characteristics, and insurance coverages for every hour of the day.

The database does not model the location and activity of every person, but tracks the activities and locations of groups of people with similar characteristics. Time patterns and movement characteristics are captured for each of these statistical groups.

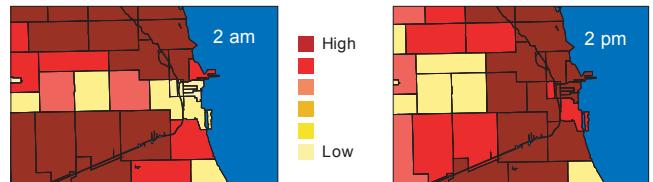


Figure 4.1 Location of Chicago population by day and night

4.1.1 Data Sources

The human exposure database was built from the compilation of a large number of primary sources, including population census data collected by the U.S. Census Bureau, employment statistics, economic data produced by the Bureau of Labor Statistics, and various locational surveys including the National Household Travel Survey and journey-to-work trends. Insurance penetration analysis was taken from a range of insurance market data and research from insurance bodies such as LIMRA, the American Council of Life Insurers (ACLI), and the Medical Expenditure Panel Survey (MEPS). RMS is also grateful for the information and inputs provided by its clients and sponsors of this study in the creation of the exposure database.

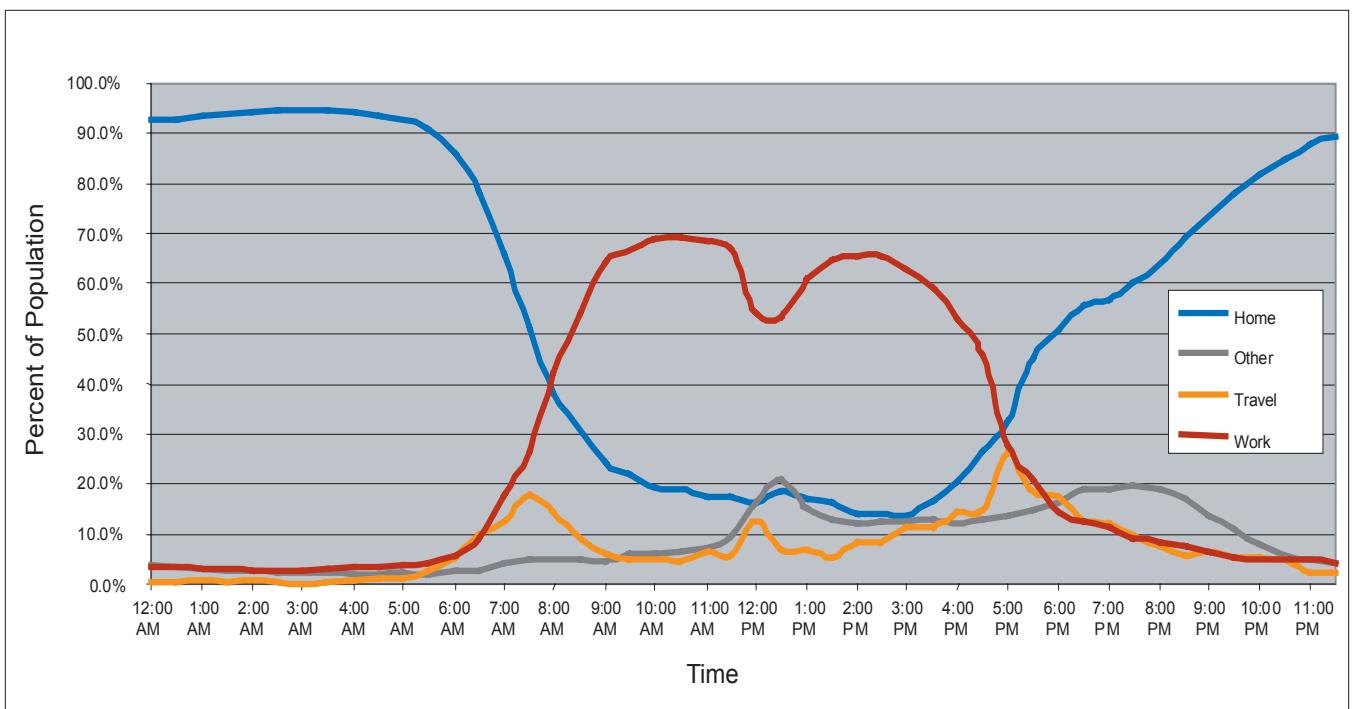


Figure 4.2 Activity patterns of working age, professional females during a normal work day—each demographic segment has its own activity patterns over time

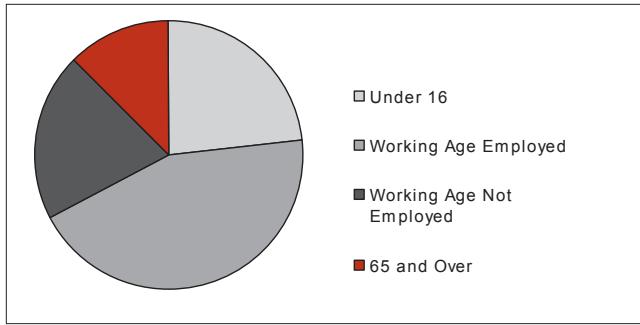


Figure 4.3 Distribution of population by age bracket for the U.S.

4.1.2 Demographic Segmentation

The population is segmented into the following primary demographic groups:

- By gender: male, female
- By age: working age (16 to 64), pre-working age (under 16), post-working age (65 & over)
- By occupation: professional, manual or non-professional, not employed

4.1.3 Location

The geographical basis of the mapping is a variable resolution grid (VRG) where grid cells are sized according to the density of population. At its finest resolution, the data exists for a specific building, related to the mapping of individual buildings in major city centers. Grid cells holding human exposure data vary from 164-foot (50-meter) cells to about a third of a mile (500-meter) in cities and up to 6.2 mile (10 km) cells in lesser populated rural areas. The data can be thought of as residing at ‘neighborhood’ level, or for a small part of a town, and can be aggregated for each ZIP Code. The population residing in each neighborhood is segmented into each of the key demographic groups. The whereabouts of working age people that reside in a particular neighborhood are related to the parts of town (or other location) that they work in. The people that work in each part of town can be traced back to the neighborhoods in which they live.

The demographics that can be examined with this information can be as general as patterns by sex or age and as specific as patterns by 19 year-old part-time working females living in New York.

4.1.4 Time Dimensions

The data is held for each hour of the day and a separate 24-hour cycle is derived for work days and non-work days. Non-work days are comprised of weekends and public holidays.

4.1.5 Insurance Coverage Rule-base

Some insurance lines, such as life insurance, provide continuous coverage. Others, like workers compensation, are conditional—if you are at work or engaged in work activities, you are covered, but outside the workplace you are not. Some insurance lines include compensation for injury, others only apply if the policyholder is killed.

While life insurers may be liable for claims occurring at any time during the day, workers compensation and health insurers may be liable for portions of time, depending on the location and activity of the exposed person. An injury that is covered under workers compensation is not also covered by health insurance—they are mutually exclusive. Other coverages may apply in conjunction with each other—if a policyholder is injured at work and has both workers compensation and disability insurance, the disability insurance will pay the portion of salary that is outside the bounds of the workers compensation coverage.

Life insurance policy benefits are paid irrespective of other coverages. A group life policy, one or more individual life policies, and an AD&D policy will all be paid out in the event of death. If the death occurs at work, dependants would also receive benefits from the workers compensation insurer.

	Group Life	Individual Life	AD&D	Workers Comp	Health Comp
Location Covered					
At home	•	•	•	•	•
At work	•	•	•	•	•
Commuting to work	•	•	•	•	•
Work travel	•	•	•	•	•
Other	•	•	•	•	•
Casualty Level Covered					
Death	•	•	•	•	•
Severe injury			•	•	•
Injury				•	•
Individual Covered					
Policyholder	•	•	•	•	•
Spouse	•				
Dependant (child)	•				

Table 4.1 Examples of the insurance coverage rule-base of the human exposure database

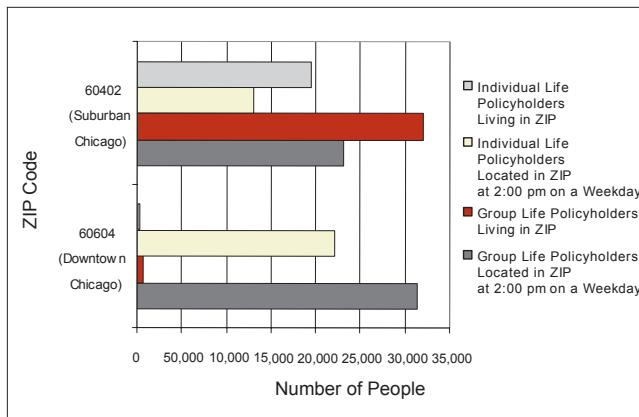


Figure 4.4 The number of people with different coverages varies by geography and time of day

For these reasons, certain perils show varied loss distributions to different lines of insurance, depending on the time of day, location, and activities of the insureds. These patterns are explained later in greater detail for the various scenarios and perils modeled in this study. In the case of earthquake, the scenarios consider different times of occurrence and the benefits of corresponding insurance coverages that would apply.

4.2 POPULATION EXPOSED TO CATASTROPHES

4.2.1 Demographics of Exposure

The total population of the U.S. is about 291 million. Approximately forty-four percent of the population



Figure 4.5 Residential, factory, and office buildings cluster in New York—the densest human mix in the U.S. (Image: Getty Images)

(130 million) are working adults, excluding members of the armed forces, with the rest split between non-working adults, children, and retirees. The percentage of each group varies geographically from one region to the next. The demographic characteristics of the population, such as age, also vary geographically. There are higher proportions of older people in Florida, and a younger average age in California. Certain neighborhoods around cities tend to have more families with children, other areas have higher proportions of young, single people.

Mapping the demographics of the population geographically shows a complex pattern of economic activity, migration, and social trends. Key factors of demographics for insured risk are employment type, earnings,

	Population within 2 miles of center		Population within 4 miles of center	
	Work hours (2:00 pm)	Home hours (2:00 am)	Work hours (2:00 pm)	Home hours (2:00 am)
1 New York, NY	2,216,000	923,000	3,757,000	2,334,000
2 Chicago, IL	1,037,000	368,000	4,109,000	2,406,000
3 Bronx, NY	714,000	845,000	1,331,000	545,000
4 Washington, DC	710,000	232,000	1,658,000	1,923,000
5 San Francisco, CA	689,000	411,000	1,119,000	519,000
6 Boston, MA	637,000	168,000	2,194,000	1,698,000
7 Brooklyn, NY	627,000	746,000	797,000	535,000
8 Philadelphia, PA	553,000	270,000	972,000	634,000
9 Los Angeles, CA	441,000	367,000	959,000	689,000
10 Baltimore, MD	421,000	225,000	660,000	493,000
11 Atlanta, GA	376,000	159,000	523,000	298,000
12 Seattle, WA	365,000	260,000	1,006,000	859,000
13 Newark, NJ	336,000	134,000	540,000	268,000
14 Houston, TX	321,000	120,000	550,000	295,000
15 Dallas, TX	316,000	145,000	533,000	272,000
16 Minneapolis, MN	285,000	120,000	601,000	552,000
17 Denver, CO	243,000	198,000	468,000	338,000
18 San Diego, CA	238,000	100,000	483,000	335,000
19 St. Louis, MO	223,000	100,000	394,000	268,000
20 Portland, OR	213,000	100,000	383,000	263,000

Table 4.2 Concentrations of populations drive catastrophe risk—an analysis of the human exposure database identifies the 20 locations of densest population, ranked by their 2 mile population concentration at 2:00 pm

and population density. These relate to the insurance penetration (how many people have insurance coverage) and values at risk (values of the coverage held) that determine insured exposure. In addition to the size and location of the event, the population density determines how many people can be affected.

Major cities have the densest populations. Table 4.2 shows the densest cities by time of the day and proximity to city center. The center of New York is the most densely populated location in the U.S., with over 2 million people located in a 2-mile (3.2-km) radius at 2:00 pm on an average work day. The next densest city is Chicago with about half of the workday density of New York.

The pattern of density changes over time, with evening population densities being very different. The area of greatest population density is still New York, but Chicago's density reduces considerably—the city center contains fewer people than San Francisco at night. Chicago has one of the biggest differences between daytime and nighttime densities, with nearly two-thirds of its occupants commuting out of the center at night. By contrast, the Bronx and Brooklyn are denser at night than during the day.

4.2.2 Visiting Population

Visitors are a small but significant part of the population in any one place. This consists of tourists, business travelers, and others that come to a city for an overnight stay or are just passing through. New York has 35 million visitors a year; Chicago has 30 million. Other cities that receive large numbers of visitors include Los Angeles (22 million), Washington D.C. (19 million), San Francisco (14 million), and the greater Boston area (13 million).



Figure 4.6 Chicago is a top U.S. tourist destination (Image: Getty Images)

About 10% of visitors to these major cities are international. They are assumed not to be insured, or at least not part of a U.S. insurer's domestic book, for the purposes of this study. The rest are visitors from other parts of the U.S. and are assumed to have insurance coverage in proportion to the rest of the population, with that insurance in the policyholder's home town. The origin of insurance coverage for the visiting population is not currently captured in the human exposure database.

Vacationing visitors are highly seasonal, but business travelers are only marginally seasonal. At night, visitors are mainly located in hotels and houses throughout the city. During the day, the visiting population is assumed to be distributed around the city, and more likely to be present at known tourist attractions and sites. Business travelers are likely to mirror the local working population.

4.3 POPULATION ON THE MOVE

4.3.1 Demographic Movement

Snapshots of where the population is at different times of the day shows changing patterns of exposure. A person that is in one location engaged in a certain activity at one time can be 20 miles (32 km) away doing a completely different activity an hour later. Most lawyers are in their offices at 2:00 pm on a Tuesday and a very high percentage of children are at home in bed at 4:00 am on a Thursday. Surveys of activities by time for different demographic groups enable a picture of their activity and location to be derived. For any particular business or neighborhood, a time distribution is obtained for the numbers and occupations of people.

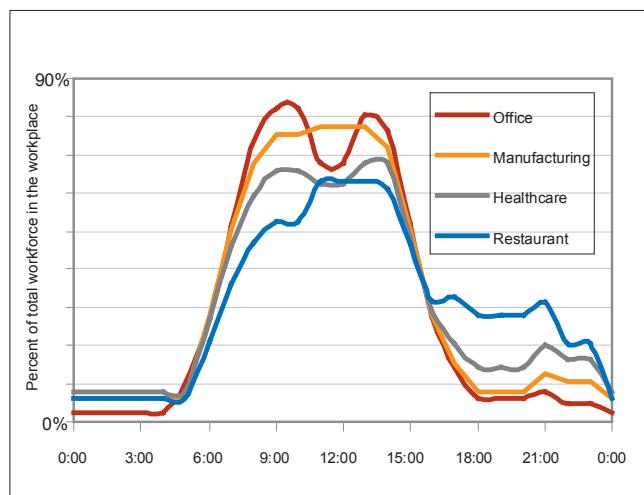


Figure 4.7 Occupancy by time for different types of businesses



Figure 4.8 Rush hour commuters are one example of the mobile nature of exposure

The occupancy patterns throughout the day vary for different types of businesses. The modern reality of the “nine-to-five” routine of office workers is that more than 50% are at their workplace from 7:30 am-4:00 pm, and even during lunch hours, two-thirds of the workforce stay in their office. Intensive manufacturing businesses may have their workforces operating in shifts, with almost equally as many people working throughout the night. Catering and hospitality businesses have high staff rates in the late evening.

4.3.2 Commuting Patterns

About 3% of the 130 million people employed in the U.S. usually work at home and 7% of the workforce spend at least one day a week working at home. The rest of the workforce travels from their home to the work place. The average worker lives more than 10 miles away from their workplace and spends 24 minutes commuting to work, although this is a skewed distribution with two-thirds of commuters having a commute less than the national average. Some people spend long periods and travel long distances to get to work. Eighty-six percent of people travel to work by car (73% drive alone) and 5% use public transportation.

The daytime occupants of city centers can live many miles away. The typical pattern is for people to live in suburban areas a few miles outside a major city, but travel in to the city each day. People in different occupations have different commute patterns. People in professional occupations tend to travel a longer distance. Those working in service industries often work much closer to their homes.

As most people realize, the balance between where they choose to live and where they work is a complex

mixture of economics, living standards, amenities, and quality of life. Demographers have sophisticated models of the interrelationship between real estate prices, amenity provision, transportation infrastructure, and population that are used to plan urban development needs.

4.3.3 Non-working People

Those who do not commute to work still travel outside their home. Children go to school for a portion of the day. Non-working people shop and spend time at leisure facilities and other locations. The non-working population tends to travel to locations closer to their home, and spends the majority of their time within the county or ZIP Code of their residence.

4.4 BUILDING TYPES

The location of the population is one factor that affects the impact of a hazardous event. The type of building (e.g. construction material and height) that people occupy when an event occurs is another important factor affecting the likelihood of injury in a catastrophic event.

People who spend their work hours in a strong building and go home to a weak building would be more at risk during home hours and vice versa. In earthquake areas, the weakest buildings are unreinforced masonry, and the safest buildings are wood frame or highly engineered steel buildings. If a terrorist attack used a poisonous agent in the air, people occupying buildings with air treatment and filtering may be less vulnerable than those in naturally ventilated buildings.

4.4.1 RMS Building Stock Database

Building construction types and the quality of building stock are an important component of the RMS exposure dataset. RMS has maintained a database of the U.S. building stock for several years, providing information on the number of buildings with different construction types and heights by geographic region. The database was enhanced in 2003 with the addition of datasets on indi-

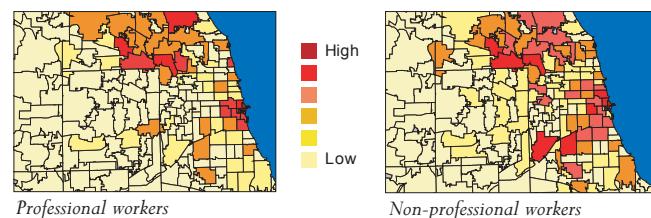


Figure 4.9 The commuting patterns of workers varies by occupation—professional employees tend to work in larger cities while non professional employees may work closer to home

vidual buildings in major city centers, in partnership with The Sanborn Map Company. This has enabled the commercial building stock of the major cities in the U.S. to be analyzed in unprecedented detail.

4.4.2 Human Vulnerability by Building Type

The human exposure database can be analyzed to ascertain the likely casualties from catastrophic events which are derived in part from the damages sustained by buildings occupied by those people at the time of the events. Damage to buildings forecast from the hazard severity of an event, an earthquake or a terrorist bomb blast for example, provides an estimate of the injury rate for their occupants. The differences in vulnerability between different construction types can be incorporated in injury estimates.

The people that occupy highly engineered commercial buildings at the time an event occurs, have different rates and types of injury than those that are inside their



Figure 4.10 Partial building collapses can be responsible for a range of injury types (Image: Associated Press)

wood frame family home. People that are inside an unreinforced brick masonry building or a pre-code reinforced concrete frame structure have different casualty rates than those working inside tilt-up concrete structures or portal framed warehouses.

4.5 INSURANCE COVERAGES

Most of the population is covered by some type of insurance to protect them in the event of a medical emergency. Insurance coverages range from Medicaid entitlement for poorer recipients, to the Preferred Provider Organization healthcare plans providing premium benefits to higher income individuals. Death benefits from a range of different life insurance products are similarly broad in scope.

4.5.1 Group Life

Most professional companies offer group life insurance as a benefit to their full-time employees. Group life policies generally provide coverage at a multiple of the employee's annual salary to be paid in the event of their death. Many group life policies will also include a small death provision for the spouse and children of an employee to help pay for child care and funeral expenses. Among non-professional employers with a large percentage of hourly employees, the penetration of group life coverage is smaller, but still significant. These employers also provide coverage as a multiple of salary, but at a smaller multiple.

All employees at a company with a group life policy tend to be covered by a single insurer, which means that the group life insurer has a highly correlated risk—if a catastrophe causes a large number of deaths in a workplace, that insurer takes all of the loss. Insurers covering several major companies with employees in offices in the central business district of a city are likely to find major concentrations of insured policyholders in their portfolio within a few square miles. A single catastrophic event is capable of causing large numbers of casualties for a company that has group life coverage.

4.5.2 Individual Life

Individual life policies are more varied in their values, terms, and conditions. The demographics of the policyholders are broader than those with group life, including a high percentage of people above working age.

Individuals purchase life insurance policies through many different channels, including agents, branches, telephone sales, direct retail, banks and lenders, and other sales methods. More people have an individual life policy than a group life policy, and the average individual life policy value is higher than the average group policy. The population with individual life coverage is more diffused across the population, so the risk tends to be more geographically diversified. Individual clusters where branches have been successful or local market conditions have enabled a company to sell into a particular area. Individual life policies cover more non-working people than group life, particularly older people. People can have multiple individual policies. Injuries that do not result in death are not compensated. The benefit of a policy may vary from one person to another and is usually related to their income and lifestyle.

4.5.3 Accidental Death and Dismemberment

Employers usually offer AD&D policies as an optional add-on to a group life policy. These policies provide additional benefits in the event that a severe injury or death is caused by an accident. Most AD&D policies will pay a flat sum in the event of death, and percentages of the total coverage in the event of severe injury, with the percentage of coverage based on the level of injury.

4.5.4 Workers Compensation Insurance

Almost all employees are eligible to receive workers compensation benefits. Workers compensation insurance covers medical costs, wage replacement costs, and in some states, vocational rehabilitation and legal costs, for all injuries sustained while at work. A wide range of illness and injuries are covered, including psychological injury, minor injuries, permanent disability, and death. The regulations, legal obligations, and benefits vary significantly from state to state. This study uses average benefit levels and regulations for each state to analyze the workers compensation loss from each catastrophe.

Compensation is limited to the employee; injuries to dependants are not covered. The location and timing of injuries is important in determining whether an injury is compensated under workers compensation insurance. An injury has to be sustained in the workplace or in the course of undertaking work. General illness in the population is not normally eligible for compensation (so flu is assumed not covered in the pandemic scenario) but under some circumstances, compensation may be possible.

People sustaining an injury while commuting to work are not eligible. People traveling on a business trip are usually covered the entire time they are on that trip, but are not covered while on vacation or paid time off.

4.5.5 Health Insurance

Approximately 70% of the U.S. population has private health insurance to cover their medical expenses, although this percentage varies by age. Most employed people get their health insurance through their employer—about two-thirds of companies administer health insurance plans (fewer in smaller companies). Although employers may offer a choice of health insurers and products to employees, a majority of employees at a company tend to be covered by a single insurer. As with group life insurance, this can lead to concentration problems for health insurers. If one company suffers multiple casualties, all the resulting loss will be carried by a single insurer.

Health insurance is also sold through many distribution channels and to a wider demographic range than the working population. Older people, children, and the non-working population may be covered by their health insurance. Although this study accounted for Medicaid and Medicare coverage in the population, results presented here only include private health coverage.

If an employed person is injured at work, their treatment is covered by their workers compensation insurance, and there is no cost to their health insurer. Health insurance applies if an injury is not covered by workers compensation.

Health insurance costs for treatment are generally marginally lower than the costs incurred by workers compensation insurers for similar treatments. This is because many healthcare providers are often able to purchase greater capacity of healthcare provision, and obtain lower treatment costs. The advantage to health insurers in building up their purchasing power however, leads to greater concentrations of policyholders in certain areas. If a mass casualty event occurs in these areas, a high percentage of the victims are likely to be covered by that health insurer and their loss will be disproportionate. The economics of health insurance tend to work against the diversification of risk followed by other lines of insurance.

4.6 CORRELATION WITH PERILS

The geography of catastrophe perils also varies considerably. For natural catastrophes, like earthquakes, this is largely independent of the population and the combina-

tion of dense populations with seismic hazard is the major concern. For man-made accidents, the threat is highly correlated with the population, so that wherever there are more people, there are more industrial plants located nearby and transportation activities serving that population that pose potential dangers to them.

Terrorism is even more highly correlated to population density. The major cities represent the primary targets seen by terrorists as causing the greatest impact. In the next chapters, the losses likely to be caused by different catastrophes are explored.

5 EARTHQUAKE

Small but damaging earthquakes can occur almost anywhere in the U.S. Large magnitude earthquakes mainly occur in the seismic zones of California, Alaska, and the Western coastal states. There are also rare, damaging earthquakes in the Central U.S. and occasional significant events in the East have the potential to cause sizeable losses.

5.1 GREATER EARTHQUAKE EXPOSURE

Major earthquakes can affect very large areas—a M7.0 event can shake an area of 800 square miles (2,072 square km) with an intensity capable of destroying buildings. It is the size of the footprint of large earthquakes that makes them so catastrophic.

Population movements have shown that California and other areas of high seismic risk have grown in population by 50% since the 1970s. As the populations of cities increase, and the density of populations grow, the potential for greater losses also increases. The 1906 San Francisco Earthquake was one of the most destructive earthquakes in the U.S. It killed at least 700 people (some estimates suggest more than 3,000) and injured thousands. But in 1906, San Francisco was a city of around 340,000 people and just over half a million people were likely within the area strongly shaken by the event. Today, the San Francisco Bay Area is the fourth largest metropolitan area in the U.S., with a population of over 7 million. The area affected by the 1906 earthquake contains nine times as many people today as it did in 1906. If the casualties from the event were scaled by population growth, over 8,300 would be killed.

5.1.1 Safer Buildings

The buildings and infrastructure in California today are very different from the artisan-built wood and brick houses that formed San Francisco in 1906. Several decades of seismic building codes and advances in engineering have made successive generations of buildings more resilient and safer against earthquake shaking. Fire awareness and improvements in fire-fighting systems have decreased the likelihood of fires, making containment much easier than in 1906.

But even with these very significant advances, earthquakes remain a serious hazard to inhabitants of seismic areas. The energy unleashed in an earthquake is one of

the largest natural forces—a M8.3 earthquake, like the 1906 event, releases approximately 1,013 kilojoules of energy, equivalent to more than 400 nuclear bombs detonated underground. The vibrational energy tests buildings to their limits, and often beyond their limits, causing structural failures and collapse before the occupants can get out. Design and construction faults that are invisible in normal building usage are suddenly revealed under the massive stress that an earthquake imposes.



Figure 5.1 Collapse of major engineered facilities in an earthquake can cause deaths as is seen in the damage to Interstate 880 from the 1989 Loma Prieta Earthquake (Image: Associated Press)

5.1.2 The Acid Test

Almost every large earthquake reveals new patterns of defects in design and construction that were not well understood in previous building codes or construction practice. In the 1994 Northridge California Earthquake, steel moment frame buildings revealed construction defects that resulted in much higher damage than was expected, leading to a major overhaul of the building codes for this construction type. In the 1995 Kobe Japan Earthquake many unexpected collapses occurred in modern steel and concrete frame buildings thought to have been designed to safely withstand the forces they experienced. Earthquakes causing the collapse of modern buildings in Mexico and Turkey showed that systems of building inspection and quality control can be secretly bypassed and only revealed after a strong earthquake.

Modern building stock in U.S. city centers remains largely untested against the strong ground motions generated by a large magnitude earthquake. U.S. engineering design, construction quality, and building inspection standards are generally considered to be among the best in the world. Design standards require that buildings withstand strong earthquake forces without collapse. But even the best quality construction contains some defects, and if a large population of buildings is shaken strongly enough, a small number of them will fail. The financial cost required to make buildings safe under any ground-shaking conditions may be too cost-prohibitive or economically impractical.

RMS analyzes earthquake events around the world and its engineers assess the vulnerability of different types of buildings from statistical damage surveys of past earthquakes. Masonry buildings are generally more vulnerable and injure more of their occupants than wood frame buildings. Engineered buildings, particularly those conforming to the seismic design codes required for the most earthquake-prone areas, have lower failure rates and are usually designed to sustain damage without endangering their occupants, but small percentages of them still fail under extreme loads.

5.1.3 *Collapse Rates*

Building collapse rates in earthquakes are a critical component in the estimation of casualties, and the modeling is very sensitive to the assumptions made. This is also an area of considerable uncertainty. Of particular sensitivity is the probability of collapse of large high-rise buildings with high occupancies. These buildings have been engineered to withstand high earthquake loads, so estimating collapse rates means estimating the construction errors or material failures they could experience. This is done by extrapolating from rates of ‘light damage’ levels observed under low intensities to ‘likely collapse’ levels at the high intensities generated by a large magnitude earthquake. In a city of several thousand engineered buildings with large numbers of occupants, collapse rates are likely to be low and variations in the collapse rates could make a large difference to the casualty estimates from the event.

5.2 INJURIES IN EARTHQUAKE

Earthquakes cause death and injury in many different ways. Epidemiological studies report causes of death from a wide variety of accidents induced by the earthquake, including road traffic accidents, and incidents with overturning items like heavy furniture or equipment. Lacerations from broken glass are a common injury. Earthquake vibrations cause people to fall, and also to panic. People are injured by jumping from windows or falling as they try to run down stairs. Some people suffer cardiac arrests from the shock of the earthquake. There are cases of epidemics in populations due to the lack of safe drinking water and sanitation. Most of the injuries treated after an earthquake are soft-tissue injuries, wounds, contusions, and blunt trauma.

5.2.1 *Injuries in Building Collapse*

The major cause of injury from earthquakes is due to building collapse or damage. When damaged, different types of buildings inflict injuries in different ways and to different degrees of severity. Huge amounts of dust are generated from a damaged building and asphyxia from obstruction of the air passages to the lungs is a primary cause of death in many building collapse victims. Suffocation can also occur from extreme pressures of materials on the chest preventing breathing (traumatic asphyxia).



Figure 5.2 Building collapse injured occupants in this Paso Robles store during the 2003 San Simeon, California Earthquake (Image: Associated Press)

Many victims inside a damaged building suffer traumatic injuries from the impact of building materials or other hard objects, and of these the most common appear to be skull or thorax injuries. Extreme injuries that occur in a small number of victims include head injuries, severe crushing of the thorax and abdomen, or the amputation of limbs by extreme pressure. Multiple fractures of the spinal column are commonly reported in victims of concrete slab buildings who were either standing or lying down when the collapse occurred. Most victims who are trapped in collapsed buildings suffer multiple and often extensive injuries, and those that are rescued after being trapped for some time have low survival rates or face permanent disability.

Fire is a common threat in earthquakes, causing large numbers of ignitions that stretch fire-fighting resources to their limits. Most fires in domestic or commercial buildings break out after buildings have been abandoned and do not pose an immediate threat to occupants. Burn victims are usually seen where collapses have trapped people. Burning collapses tend to have high mortality rates.

Industrial fires are also caused by earthquakes, and these can be deadly, particularly if emergency water supplies or fire-fighting resources are affected by the earthquake. The spillage of flammable or toxic materials in the workplace by an earthquake is a hazard that has the potential to cause injury to employees.

5.3 EARTHQUAKE RISK MODELING

RMS first developed a catastrophe model for earthquake loss in 1988, and has continued to update the model over subsequent years. The RMS® U.S. Earthquake Model is now used by hundreds of insurance and reinsurance

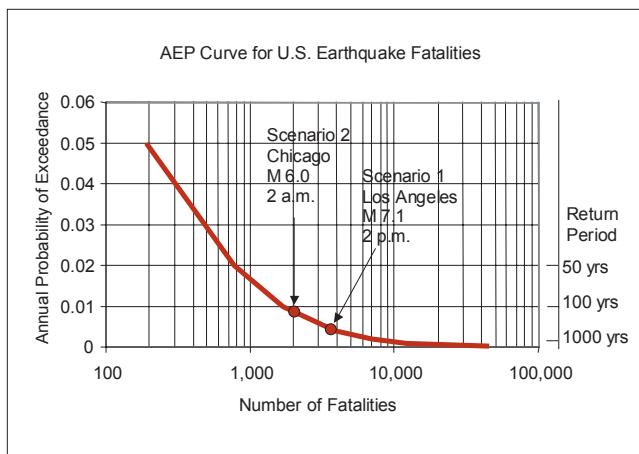


Figure 5.3 The annual exceedance probability for earthquake fatalities in the U.S. for current population and building stock

companies, as well as financial managers and consultants to assess the risk of earthquake loss in the U.S. The model simulates 42,000 earthquakes that represent the frequency and severity of earthquakes likely to cause significant loss. It also incorporates the latest view of seismic hazard published by the United States Geological Survey (USGS).

The RMS model has been used to assess the probability of loss to different lines of insurance occurring from earthquake injury. The probability of an earthquake causing a loss of specific size in a particular year is calculated by simulating the occurrence probabilities of earthquakes on seismic sources throughout the U.S., and modeling how each event could impact the cities, building stock, and populations in their vicinity.

The model shows that with current population and building stock, there is an annual probability of 1.14% (a return period of 87 years) that an earthquake could cause 1,000 or more fatalities in the U.S., and a probability of 0.14% (a return period of 718 years) that an earthquake could cause more than 10,000 deaths.

5.4 EARTHQUAKE SCENARIOS

To explore the impact of earthquake casualties on various insurance coverages, two scenarios were selected from the thousands available in the model. Casualty levels of 2,000 fatalities and 5,000 fatalities were chosen to illustrate losses for different insurance coverages in large earthquake events, within the probability range of concern to insurers.

- Scenario 1: 5,000 fatalities, (0.4% probability, 250-year return period)
- Scenario 2: 2,000 fatalities, (0.8% probability, 125-year return period)

The number of fatalities could occur in different ways—from a moderate earthquake causing a “direct hit” close to a big city of vulnerable buildings, or from a larger magnitude event affecting a large area of population. Time of day is also an important variable in the number of resulting casualties. Earthquakes of varying sizes in different regions and times of day could cause these levels of loss.

The scenario events were chosen to illustrate differences in the way earthquakes cause casualties and how they might affect insurance claims under different coverages.

The most frequent destructive earthquakes occur in California, and the first scenario describes how a large magnitude earthquake could impact Los Angeles. The

impact of the large magnitude is mitigated by the seismic engineering of California building stock. The potential for the less frequent earthquakes that can occur east of the Rockies is often overlooked. The second scenario is a rare but deadly earthquake affecting a city in the Midwest.

5.4.1 Scenario 1: Los Angeles Earthquake, M7.1

California is well-known as a seismic region with documented major fault systems than run close to highly populated areas like San Francisco and Los Angeles. Seismic sources in these regions are capable of large magnitudes and can be very destructive. Faults, such as the San Andreas and Hayward faults in northern California and the Newport-Inglewood fault that runs through Los Angeles and offshore to San Diego, have segments that are capable of rupturing with a M7.0 or more. Even larger magnitude events are possible if several sections of fault systems rupture simultaneously.

Over the last two decades, a number of new seismic sources (blind thrust faults) have been identified running near and within the Los Angeles metropolitan area. The activity rates associated with these sub-surface faults and the exact locations and extents have been debated within the seismological community. A newly-delineated feature, the Puente Hills Thrust, has been identified as a potential major source of seismic risk in the region and was added to the seismic source model for California by the USGS in conjunction with the California Geological Survey in 2002. It is believed to be an active structure in the Los Angeles basin, and partially ruptured during the 1987 Whittier Narrows Earthquake (M6.0).

The Puente Hills Thrust consists of three sections that could rupture independently, but if they ruptured together would produce an earthquake characteristic of a M7.1 event.

Because the Puente Hills Thrust runs through the center of downtown Los Angeles, it is a significant threat to the high-rise and high occupancy commercial buildings in the city. Scenario 1 examines the potential injuries resulting from this earthquake.

5.4.2 Scenario 2: Chicago Earthquake, M6.0

Chicago is in a stable region of North America that is far from the active tectonic plate boundaries found in Western North America. Seismicity in this region is evi-

dence of slow rates of geological deformation. Earthquakes occur infrequently and old earthquake fault surface ruptures are obscured by geological weathering processes, so the exact locations of faults where earthquakes may recur are not well-known. Epicenter maps show that seismicity is ubiquitous across the continental region of North America—earthquakes of moderate size can be expected almost anywhere. The cities in the Eastern U.S. are at risk from these types of low frequency, moderate magnitude earthquakes.

Earthquakes in the Central and Eastern U.S., although less frequent than in the Western U.S., are typically felt over a much broader region. An earthquake occurring east of the Rockies can cause shaking over an area as much as ten times larger than a similar magnitude earthquake on the West Coast.

A cluster of seismicity in northern Illinois has been identified as the Northwest Kankakee Arch, part of the New Madrid seismic zone. Five events greater than M4.0 were recorded in this region in the 20th century, including the 1909 Aurora Earthquake (M5.1), located some 30 miles (48.2 km) southwest of the present center of Chicago. The Aurora Earthquake caused the collapse of masonry chimneys, cracked walls and chimneys in Chicago, severed gas lines, and caused panic over a wide area. Events of up to M6.5 are feasible in this seismic zone, but for the purposes of illustrating a realistic event a M6.0 earthquake was selected and located in a region close to the epicenter of the Aurora Earthquake.

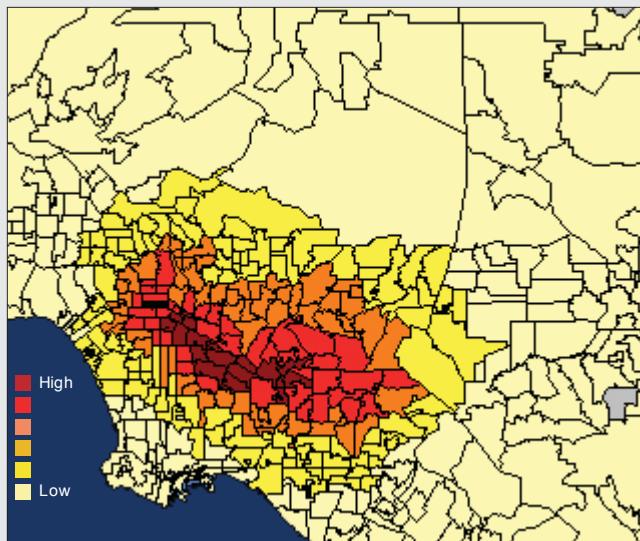
Because earthquakes are less frequent in these areas, building code requirements are less strict than in other seismic zones. Chicago is in zone 1 of the 0-4 grade U.S. Seismic Code Zonation, where zone 4 requires the highest level of design strength. The city includes many old buildings and a large proportion of unreinforced masonry buildings, one of the weakest types of construction against earthquake forces. Many of the houses in the towns and suburbs around the city are brick. This contrasts with California, where most residential construction is wood frame, which suffers very little damage in an earthquake.

Earthquake casualties are lower when they occur at night, but in Eastern U.S. earthquakes, the difference between casualty numbers at night and during the day is not large. A nighttime event was selected to contrast the California event, which occurs during peak work hours.

HYPOTHETICAL SCENARIO 1: M7.1 EARTHQUAKE IN LOS ANGELES

Killer Quake Brings Down High-rise Buildings in Los Angeles

A M7.1 earthquake is recorded in downtown Los Angeles in the early afternoon



Urban search and rescue is likely to be a major component of future large magnitude earthquakes (Image: Associated Press)

An hour after lunch on a Wednesday, 16 million people across the urban metropolis of Los Angeles feel a vibration underfoot that they recognize immediately as a major earthquake.

Killer Quake Hits Los Angeles

High-rise offices sway severely and workers brace themselves against their desks. Computer monitors bounce off desks and shatter on the floor. Bookshelves shower their contents onto the floor and a part of the suspended ceiling gives way and falls onto the cubicles. Lights flicker and glass shatters. Those standing near the windows see buildings across the street swaying. A 15-story building a few blocks away sags and then folds in on itself in a cloud of dust.

On the roads, drivers struggle to control their swerving cars. Most pull off safely, but there are some shunts and a series of high-impact accidents on freeways throughout the city. A seismically-retrofitted section of a highway overpass collapses and 60 vehicles vanish with it.

In homes across the city, people run outdoors as furniture jolts and decorations are thrown off the walls. Wood frame houses shake from their foundations, twisting and distorting with the vibrations, but they do not

collapse. Some masonry chimneys disintegrate and fall through the roof into homes.

Search and Rescue Teams Comb Rubble for Survivors

After the shaking, there is a short silence. Lights flicker and die. People rush for the stairs and join an exodus of others that emerge from buildings and stand in crowds on sidewalks littered with broken glass, trying to get reception on their cell phones. Initially, the helicopter news crews report that most of the city appears okay—shaken but apparently only superficially damaged. Then, crews spot people milling around a dusty vacant lot in one of the downtown blocks. They radio in that a building is down in the city center. Reports come in of other buildings that have collapsed—only one or two in every few thousand buildings, but this adds up to several hundred buildings. Some are only partially collapsed, but there are many people under the twisted concrete and steel. Police set up barriers around each site and teams of volunteers work with improvised tools to pull free anyone in the rubble they can reach. Many people are pulled out from light rubble. Fire-fighters bring in power saws, crowbars, and expander jacks but they make slow

progress cutting through reinforced concrete slabs. Mechanical diggers are ordered, but fire chiefs do not use them for fear of killing survivors.

Fires are reported burning across four blocks of the dense wooden houses in Brentwood. In the industrial areas of southwest Los Angeles county, large tanks and pipe runs are distorted and emergency teams are dealing with a number of minor fires, hampered by smoke and chemicals. One fire causes a major explosion engulfing a team of employees as they attempt to control the blaze.

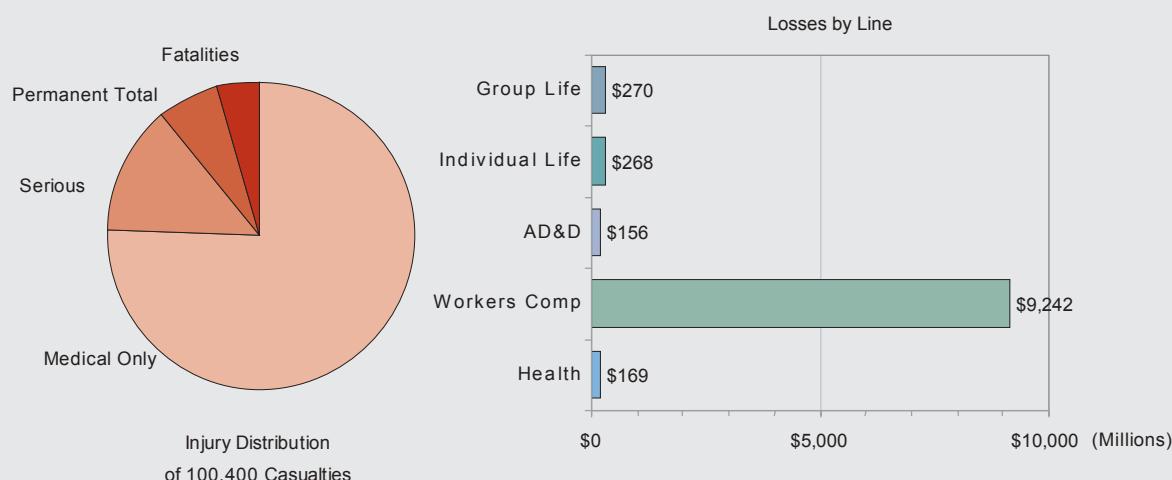
Hope Not Lost for Survivors on Third Day

By nightfall, many hundreds of individuals have been pulled out from under the rubble of the collapsed buildings. Most have suffered serious injuries. The work continues through the night under construction floodlights. Professional search and rescue teams have now taken charge, and bring in specialized equipment. They tunnel into the rubble and look for routes through in order to

find survivors. Each survivor is given emergency treatment inside the rubble by a rescue physician and secured to a body harness to protect possible spinal injuries before being dragged out. Victims pulled out in the first 24 hours stand a reasonable chance of survival with intensive medical attention. As time goes by, the number of survivors rescued diminishes rapidly. After three days, the search gradually shifts emphasis to the removal of bodies. There are thousands of people reported missing. A quarter of them will never be found, although many unidentifiable body parts are recovered. Occasionally a survivor is found, each heralded as "miraculous" by the world's media, but all are weak, dehydrated, and injured—several of them die later at the hospital. The last survivor is found on the ninth day, the surprise discovery of a woman trapped in an air pocket in a basement room. The victims of the earthquake are treated in over 2,000 hospitals across California and neighboring states.

	Fatalities	Total No. of Casualties	Total Industry Loss (Millions)
All Population	4,500	100,400	
Population with Group Life Coverage	3,000	3,000	\$270
Population with Individual Life Coverage	2,100	2,100	\$268
Population with AD&D Coverage	1,600	4,000	\$156
Population with Workers Compensation Coverage	4,300	91,400	\$9,242
Population with Health Coverage*	100	5,700	\$169
Population with No Health Coverage	100	3,400	
			\$10,105

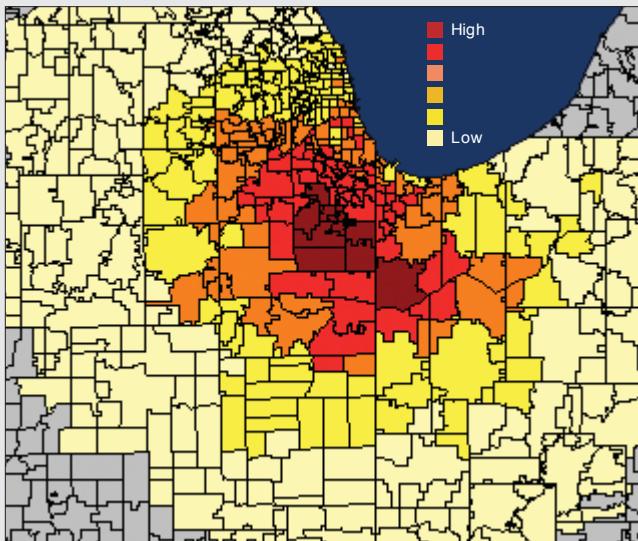
* Health coverage if not covered by workers compensation



HYPOTHETICAL SCENARIO 2: M6.0 EARTHQUAKE IN CHICAGO

Earthquake in Southern Chicago Injures Thousands

A M6.0 earthquake destroys buildings in the middle of the night



A large number of the injuries in an earthquake in the Midwest would be sustained from falling brick buildings (Image: Getty Images)

In the middle of the night in early spring, 9 million residents of the Chicago metropolis are woken by an unfamiliar jolting. Thousands of people are thrown out of their beds by the short, violent shaking of a strong earthquake. Roof tiles cascade into yards, and house ornaments are scattered. Walls are wrenched and split, and in 10,000 homes the brick chimneys disintegrate and fall through the roof into the house below. In 3,000 homes walls collapse and roofs fall in, burying the occupants.

A dazed homeowner reaches for a light switch but the power is out. Stumbling through dust and darkness, he and his wife find a flashlight, gather their frightened daughter, and make their way outside into the cold night. The houses on the block are all severely cracked and it is safer outdoors. The streets are full of shivering neighbors. A bad head wound on an elderly man caused by falling bricks is dressed by a neighbor. Several people are in need of medical attention. A few blocks away an old masonry grocery store has collapsed. Under car headlights, a crowd of people comb through the bricks and dust, until they locate and bring out the bodies of the shop owners.

Phones still work but most lines are busy, 911 callers are put on hold. The elderly man and a woman with a

broken arm are put into a neighbor's car and he drives them to the nearest hospital. The car radio brings news of the damage extent, which is reported to affect a 100-mile (161-km) area of southern Chicago and parts of Indiana. Casualties are in the thousands.

Chicago Area Hospitals Call on Public for Blood Donations

The drive to the hospital is difficult. There are no city or road lights, some of the roads and bridges are damaged and there are many cars driving quickly. Approaches to the hospitals are jammed with cars. He reaches a police roadblock. Only cars carrying the severely injured are allowed through, so he escorts his wounded neighbors to the hospital on foot.

This hospital is one of eight in the city that has been damaged by the quake and evacuated until its safety can be assessed. There are hundreds of casualties standing and lying outside the hospital grounds. Patients from inside the damaged hospital are set up in tents. Dim light comes from the windows of an emergency operating station set up in a tent. The three join a long line of emergency patients as they reach a triage area in the hospital's forecourt. Teams of paramedics give the woman a green

tag and the semi-conscious elderly man a red tag—a triage for prioritization of treatment. The red tag puts the elderly man in line for surgery—he will die without treatment. The elderly man is in the operating room for less than half an hour, he is now stabilized, but will need more thorough treatment later. The woman waits several hours for treatment on her non-urgent fracture. Finally, her arm is bound in a splint, there is no time for the conventional x-ray and cast. In a day or two the medical staff may have time to reset her arm. Wound dressings, fracture settings, intravenous fluids, and surgical supplies are running short. The blood bank is nearly exhausted. The situation is critical. The driver and the injured woman go to a blood donation area to give blood.

Emergency Health Care Staffing Adds to Disaster Cost

It is daybreak and the lines of casualties are still increasing. Large numbers of injured wait patiently while para-

medics check them. All available medevac helicopters are in use, ground transportation is the only way in or out. A van arrives with National Guard physicians from Indiana. The elderly man is being transported to an undamaged hospital in Bloomington, he could die on the way, but must go because the facilities here are not adequate. Over the next two days, many patients requiring bed care or specialist treatment will be shuttled to other hospitals in Illinois, Indiana, and surrounding states. Sixty-six thousand patients are treated. Increased staffing is needed for the hospitals over the next three weeks, which are brought in by the healthcare companies at a considerable cost. All emergency treatments need to be retreated, and much of the initial emergency surgery is revisited with follow-up operations. The medical treatment for earthquake victims continues for many weeks.

	Fatalities	Total No. of Casualties	Total Industry Loss (Millions)
All Population	2,100	66,300	
Population with Group Life Coverage	1,100	1,100	\$71
Population with Individual Life Coverage	700	700	\$73
Population with AD&D Coverage	300	1,000	\$43
Population with Workers Compensation Coverage	100	2,300	\$192
Population with Health Coverage*	1,500	47,400	\$1,918
Population with No Health Coverage	500	16,700	
			\$2,297

* Health coverage if not covered by workers compensation

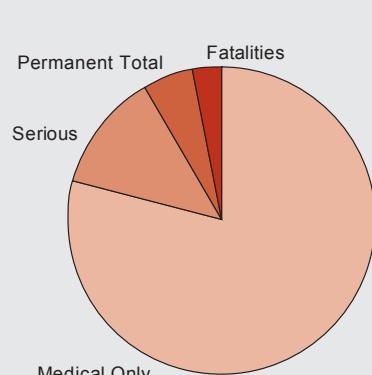




Figure 5.4 Search for victims trapped in the rubble of a building collapse in the 2003 San Simeon, California Earthquake (Image: Associated Press)

5.5 LOS ANGELES VS. CHICAGO

These two scenarios illustrate some key factors about earthquake casualties. The earthquake in Chicago is a magnitude size smaller (M6.0 vs. M7.1) than the event in Los Angeles, and yet has a casualty rate two-thirds the size.

The Chicago event hits buildings, that are older and not built to strong seismic building codes. The brunt of the impact is taken by residential buildings over a wide area of Chicago, a large number of which are older, masonry buildings. These buildings are moderately damaged, causing injuries through partial collapse, falling building elements, and earthquake-induced accidents. Minor injuries comprise 80% of the total injuries, close to the total for the larger Los Angeles event: nearly 60,000 minor injuries in Chicago and 75,000 minor injuries in Los Angeles.

5.5.1 Los Angeles High-rise Commercial Collapses

In the Los Angeles event, the damage and injury pattern is significantly different. The high intensities generated by the large magnitude event occurring in the city center has its main impact on the commercial building stock. In general, the building stock, built to some of the most stringent seismic building codes in the world, performs very well—hundreds of thousands of buildings are relatively unscathed, despite the massive stress of a strong earthquake. However, a very small number that fail, do so catastrophically and collapse without time for occupants to escape. Casualties in collapsed buildings are badly injured, higher proportions die, and there are

many people that will suffer permanent total disability as a result of their injuries. In the Los Angeles event, more than 6,000 people face permanent total disability.

5.6 TIME OF DAY

Casualties can vary significantly, based on where the population is at the time of the earthquake and the relative vulnerability of the residential and commercial building stock. Earthquakes at night mainly catch people at home and casualty rates depend on how resilient the residential building stock is. Earthquakes during work hours catch a large number of people at their workplace, and the casualty outcomes heavily depend on the performance of the commercial building stock.

The RMS exposure database captures the location of each segment of the population by where they are at each hour during the day. Analyzing the impact of the earthquake on the population at particular locations during different times of the day shows how casualty patterns change by time.

In Los Angeles, the difference between seismic performance of residential and commercial buildings is more marked, particularly with the high intensity generated by a great earthquake. In the wood frame buildings that form the large majority of houses in California, death and injury rates are generally low, even at high intensities. In the reinforced concrete and other types of structures that form a large proportion of commercial buildings, they tend to be highly resilient, especially at low intensities, but a small proportion of them can fail with strong ground shaking, leading to high injury rates for their occupants.

	Chicago M6.0		Los Angeles M7.1	
	Peak Home Occupancy 2:00 am	Peak Work Occupancy 2:00 pm	Peak Home Occupancy 2:00 am	Peak Work Occupancy 2:00 pm
Fatalities	2,100	3,300	500	4,500
Total No. of Casualties	66,300	92,500	16,800	100,400
Group Life (\$M)	\$71	\$160	\$18	\$270
Individual Life (\$M)	\$73	\$155	\$19	\$268
AD&D (\$M)	\$43	\$95	\$10	\$156
Workers Comp (\$M)	\$192	\$4,308	\$421	\$9,242
Health (\$M)	\$1,918	\$1,223	\$240	\$169
Total Loss (\$M)	\$2,297	\$5,941	\$708	\$10,105

Table 5.1 If the earthquake had occurred at a different time of day losses and casualties would be significantly different

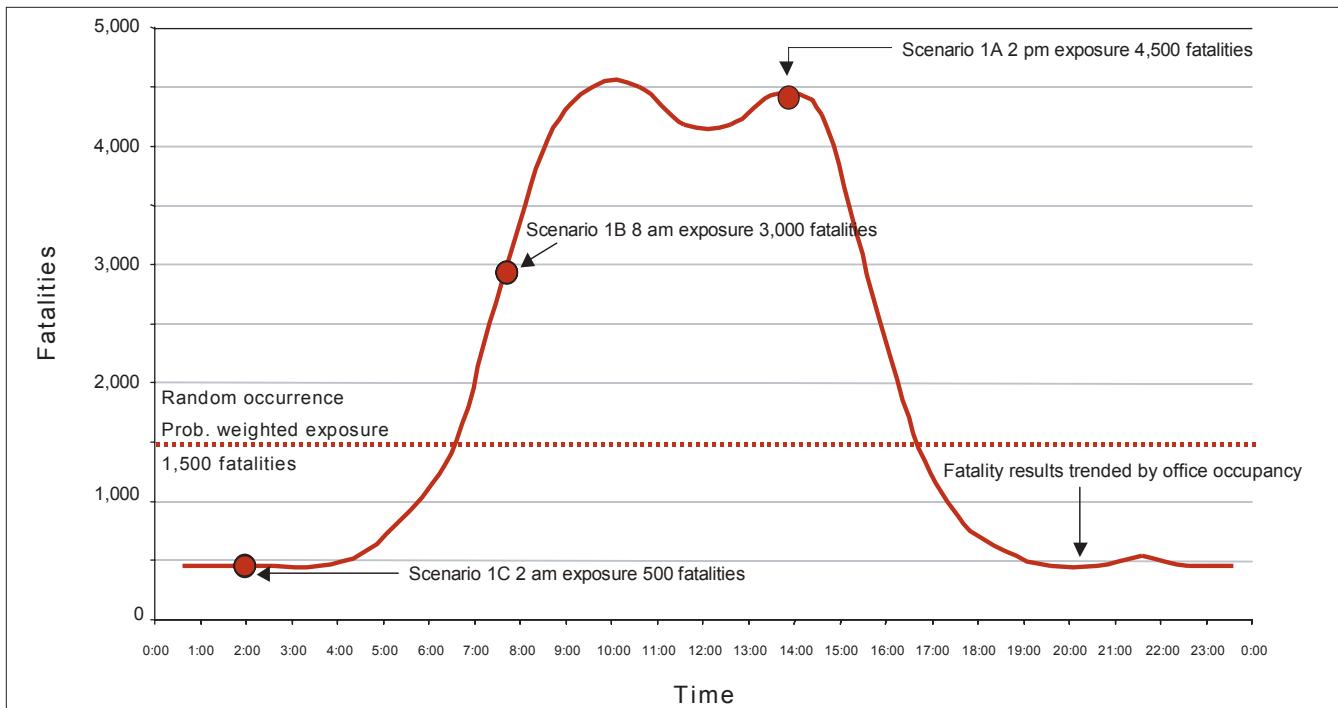


Figure 5.5 The variation of fatalities during time of day for the Los Angeles M7.1 earthquake

In Chicago there is less difference between casualty rates at different times of day, because the performance of residential buildings is closer to that of commercial structures. Both contain a high proportion of loadbearing brick masonry and many of them are older, with half of the building stock at more than 40 years old.

Earthquakes that occur during work hours cause more injuries and cause more insurance loss. Health insurance pays out less for an earthquake during work hours because workers compensation insurance covers the treatment costs of those injured at work. Only treatment not covered by workers compensation is paid by the health insurers.

Earthquakes occurring during work hours may not always cause more loss than those that occur at night. In other parts of the country where commercial building stock is stronger than residential, injuries will be higher and costlier during at-home hours.

To aid in the analysis of this important variable, Table 5.1 shows results for working hours (2:00 pm), and home hours (2:00 am).

5.7 It COULD HAVE BEEN WORSE...

These two scenarios illustrate how an earthquake could cause significant human injury and insured losses. The Chicago scenario shows how a city that is not expecting an earthquake could suffer from a M6.0 event, and the

Los Angeles scenario shows how a large event could affect a major city. In both of these examples, the magnitude chosen was near the top of the range likely in these areas, but not the most extreme event possible.

5.7.1 Losses From Larger Magnitude Earthquakes

In Los Angeles there are several seismic sources in the basin that could give rise to earthquakes greater than M7.0 and there are some that could generate larger magnitude ruptures. The Puente Hills Thrust Fault runs right through the center of Los Angeles and although its characteristic intensity is assessed as M7.1, uncertainty on the magnitude means that earthquakes of up to M7.5 are possible. There are other large magnitude faults, such as the Newport-Inglewood Fault that runs along the coastline of Los Angeles, that are capable of triggering events of M7.5. There is also increasing evidence that multiple segments of earthquake faults could rupture in a single earthquake, in which case this could generate very large earthquakes of up to M7.9.

Modeling the impact of these kinds and magnitudes of earthquakes shows that a M7.9 earthquake on a rupture originating on the Newport-Inglewood Fault in Los Angeles could cause losses and casualties nearly 50% higher than those in the modeled scenario (more than 7,000 fatalities and 150,000 total casualties if it occurred during working hours).

Larger events than the M6.0 scenario are also possible in Chicago and the stable continental region of North America. The upper end magnitudes in the Northwest Kankakee Arch (the seismic zone that poses the main seismic threat to Chicago) is approximately a M6.5. An event of this magnitude, although very improbable, could cause losses five or more times that cited in the scenario (more than 10,000 fatalities and several hundred thousand total casualties), depending on its exact location and time of day.

5.7.2 Other Locations

These scenarios were located in two major cities of the U.S. for illustrative purposes. The threat of earthquakes is present in many—all to some degree—of the major cities in the U.S. For example, large magnitude earthquakes are possible in Seattle, San Francisco, and San Diego. Moderate magnitude earthquakes are possible in almost all cities from New York to Honolulu. It is also possible that moderate to large magnitude earthquakes could hit many of the other less-prepared cities in the Eastern and Midwestern states.

One of the largest seismic events to have occurred in the U.S. happened outside of California, in the region known as New Madrid, Missouri in 1811-1812. This triple earthquake event has been estimated at M8.0 or greater. This scale of event would be devastating to any region that it occurred in.

Earthquakes also pose a significant threat to the large populations in Massachusetts, Connecticut, New York, Pennsylvania, and other Eastern states. Events of greater than M6.0 are possible in the seismic source zones identified as New England, Adirondack, the New York—Philadelphia—Wilmington Urban Corridor, and the

Washington-Baltimore Urban Corridor. Some of the largest casualty events from earthquakes in the U.S. could occur from large magnitude events (above M7.0) in the Connecticut region.

5.8 PROBABILISTIC ASSESSMENT OF EARTHQUAKE LOSS

The probability of occurrence of any of these catastrophic earthquake events is small. Damaging earthquakes are rare events, and for any given segment of fault, or a particular area of a seismic source zone, a destructive magnitude earthquake may have a return period measured in hundreds of years. By looking at all the various potential sources of earthquakes and the different ways they could cause loss, a complete assessment of the likelihood of different levels of loss can be obtained.

The RMS® U.S. Earthquake Model consists of a complete representation of the seismicity in the U.S. Using the best assessments of USGS local geological science and independent research, the model provides the magnitude probabilities for all important seismic sources. The effects of each potential earthquake, in terms of magnitude, location, and other seismic source characteristics, is used to assess the amount of damage and the number of casualties it causes. The probability of each event occurring, together with the loss that it would cause, is summed up for all events in the catalog across the entire country. This enables the probability of loss to be assessed. It is possible for a particular insurance company to assess their own probability of loss by calculating the losses to their own portfolio from the catalog of potential earthquakes. In this report, the portfolio represents the total insurance industry in each of a number of lines of business: group life, individual life, AD&D, workers compensation, and health.

5.8.1 Working Hours vs. Home Hours

The analysis assumes a particular exposure at a particular time. To incorporate the time of occurrence differences in the analysis, the earthquake exposure is divided into two groups, working hours (2:00 pm) and home hours (2:00 am). The exposure is assumed to be at its maximum occupancy for that mode. The working population is near maximum at 2:00 pm and the residential population is near maximum at 2:00 am. A set of probabilistic analyses is derived for both of these occupancies. Earthquakes occur randomly and the probability of experiencing a loss is a mix of these two loss probability



Figure 5.6 Although fires after earthquakes are not major causes of earthquake injury, they can contribute to it (Image: Associated Press)

Annual Probability	Return Period	Fatalities	Total Casualties
0.01	100	1,700	45,000
0.004	250	3,900	91,000
0.002	500	7,000	159,000
0.001	1,000	12,000	259,000
0.0002	5,000	46,000	798,000
Average Annual		100	2,500

Table 5.2 Return period of deaths and total casualties in earthquakes in the U.S., assuming random occurrence

results. Working hours represent about a quarter of the time, and home hours represent most of the remaining three quarters.

5.8.2 Casualty Return Periods

Loss return periods for death and injury in earthquakes are given in Table 5.2.

The AEP curve for earthquake injuries shows that losses escalate after the 500-year return period, but begin to top out at return periods beyond the 5,000-year return period. As shown in Table 5.3, the AEP curves for different times of the day show the large variation in casualties that can occur depending on the time of day that an event occurs. Because an earthquake can occur at any time, looking at the 2:00 am and 2:00 pm casualties provides a range of possible outcomes.

5.9 LOSSES BY INSURANCE COVERAGE

Across the lines of insurance business, earthquake loss is most significant to workers compensation. The workers compensation industry each year faces a 1% probability

Annual Probability	Return Period	2:00 am		2:00 pm	
		Fatalities	Total Casualties	Fatalities	Total Casualties
0.01	100	700	26,000	5,000	104,000
0.004	250	1,900	61,000	10,000	189,000
0.002	500	4,000	120,000	16,000	279,000
0.001	1,000	9,000	225,000	24,000	409,000
0.0002	5,000	41,000	749,000	66,178	1,000,000
Average Annual		60	1,600	230	5,400

Table 5.3 Return period of deaths and total casualties in earthquakes in the U.S., if occurrences were restricted to specific time windows

of suffering a loss of \$2.4 billion or more. There is a 0.1% probability, or one in 1,000, of suffering a \$9.1 billion loss. The AAL for workers compensation is \$120 million.

The health insurance industry faces considerably lower losses than workers compensation, particularly at the shorter return periods, and its catastrophe losses are relatively small in comparison to its routine costs each year. But for the very rare, extreme events the health insurer's losses exceed those of the workers compensation writers, by a considerable margin (\$26.5 billion compared to \$18.4 billion at the 5,000-year return period).

Group life and individual life face very similar earthquake losses, despite there being fewer people in the population with group life coverage. The disproportionately higher group life losses occur as a result of the more dense concentrations of these exposures. Many of these exposures exist in high-rise buildings that could cause many fatalities if they were to collapse. Individual life exposures, on the other hand, are more geographically diverse and often in buildings of better construction, thus minimizing the potential for large numbers of fatalities from individual structural failures. AD&D loss levels are notable, particularly in comparison to group life, and are due to the nature of earthquake injury, with significant numbers of severe injuries among the victims.

Annual Probability	Return Period	Group Life	Individual Life	AD&D	Workers Comp	Health
0.05	20	\$10	\$10	\$10	\$500	\$50
0.02	50	\$40	\$40	\$30	\$1,300	\$200
0.01	100	\$80	\$90	\$50	\$2,400	\$500
0.004	250	\$200	\$200	\$100	\$4,300	\$1,600
0.002	500	\$300	\$300	\$200	\$6,400	\$3,900
0.001	1,000	\$500	\$500	\$300	\$9,100	\$7,700
0.0002	5,000	\$1,600	\$1,600	\$800	\$18,400	\$26,500
Average Annual: (Millions)		\$5	\$5	\$3	\$120	\$40

Table 5.4 Losses to different lines of insurance coverage from earthquakes

6 TERRORISM

On September 11, 2001, terrorist attacks on American symbols killed at least 3,031 people and caused economic losses well in excess of \$100 billion. Despite a major war on terrorism and massive expenditure on homeland security, the threat of Islamic militants and other extremist groups remains a palpable threat to the U.S.

Prior to 2001, the U.S. had suffered only minor levels of terrorist activity, compared to other western countries like Israel, the United Kingdom, and Spain. The U.S. had experienced the occasional massive attack, like the 1995 bombing of the Murrah Federal building in Oklahoma City by right wing extremists. But most domestic terrorism incidents were on a relatively small-scale using primarily small yield bombs, assassinations, arson attacks, and other acts that resulted in only moderate losses.

Since September 11, the idea of more large-scale terror attacks being perpetrated on American cities has been a major focus of domestic and foreign policy. Despite the disruption of its Afghanistan base and the loss of many of its senior membership, Al Qaeda and its associated Islamic militant groups have succeeded in carrying out major terror attacks in many other countries, including Saudi Arabia, Turkey, Indonesia, and Kenya. The U.S. has been placed on Orange (High) alert on average every four months. The FBI claims that there have been more than 30 planned attacks within the U.S. that have been interdicted since September 11.

6.1 MODELING TERRORISM RISK

Assessing the likelihood of a major terrorist attack is complex and requires an understanding of the motivation, psychology, and capabilities of organizations that are highly secretive by nature. The chances of an attack are affected by the security levels in place, counterterrorism actions taken by government agencies, and the quality of protection at potential targets. RMS has developed a U.S. terrorism risk model that enables the frequencies and losses of potential terrorist attacks to be estimated.¹ The model is used to analyze the probability of losses to life, health, and workers compensation insurance from a terrorist attack in the U.S. This model is used by many leading insurance and reinsurance companies to quantify and manage their terrorism risk. The

RAND Corporation, a leading military think tank, was involved in developing the model for public policy and strategy applications and performed an independent peer review of the model.

Estimates can vary considerably around the probabilities and severities of a terrorist attack in any given year. RMS has derived estimates of the likelihood of a terrorist attack in the U.S. from data on historical attack frequencies, recent unsuccessful attacks, and insight from some of the world's foremost experts on Islamic militant terrorist groups. The current probability of a significant U.S. terrorist attack over the next year by Al Qaeda or associated groups is estimated at less than 25%.

6.2 SELECTING SCENARIOS

If there were a terrorist attack, the types of weapons that would most likely be used and the targets that would most likely be chosen are derived from studies of historical patterns of attacks and recent intelligence. The magnitude of a potential attack is constrained by the capability of the terrorist organization in terms of the number of well-placed operatives, and the access to weapons. Al Qaeda and its acolytes have been adept at using conventional weapons, such as bombs and aircraft hijackings, but have scaled up their impact through multiple synchronized attacks and ruthless targeting to cause mass casualties and economic disruption. Large-scale, synchronous attacks using conventional weapons are complex to plan and require major resources, including a sizeable team of skilled, disciplined operatives, lengthy reconnaissance and preparation time, and the ability to procure the equipment and material they need.

Three scenarios illustrate the likely impact on the insurance industry from injuries resulting from terrorist attacks. Each represents realistic but increasingly lower probability events. They are:

- Scenario 3: Multiple Truck Bomb
- Scenario 4: Anthrax Attack
- Scenario 5: Major Anthrax Attack

6.3 TRUCK BOMBS

The first chosen scenario features three simultaneous truck bombs in Chicago, the third largest city in the U.S. Vehicle bombs, also known as improvised explosive

¹ Documentation on the RMS® U.S. Terrorism Risk Model is available from RMS. Public domain literature about the model can be obtained at <http://www.rms.com>.

devices (IEDs), are historically one of the methods most commonly used for large-scale terrorist attacks.

6.3.1 Favored Terrorist Attack Mode

During the past 25 years, there have been several thousand terrorist bombings worldwide. Large-scale vehicle bombs have been perpetrated by many different terrorist groups, including Palestinian militants, Bader Meinhoff, the Irish Republican Army, right-wing U.S. extremist groups, the Tamil Tigers, FARC, Hezbollah, Hamas, and others. Al Qaeda and its associated groups have developed the technique of using truck bombs as terrorist weapons over many years. The group first used a truck bomb in 1993 to attack the World Trade Center. Their signature technique, multiple synchronous bombings used to attack major cities, has been carried out in Riyadh, Casablanca, Istanbul, and Baghdad. Recent analysis has shown that many of the bombings carried out by militant Islamic terror groups in different countries around the world follow a similar design taught in the training camps in Afghanistan.

Explosives are relatively easy to acquire, and most people that have been through basic military training have some familiarity with this technology. Although the manufacture and priming of a large-scale bomb, particularly one assembled clandestinely, almost certainly requires advanced guerrilla expertise.



Figure 6.1 Casualty treatment from events like a terrorist bombing are taught to first responders (Image: Getty Images)

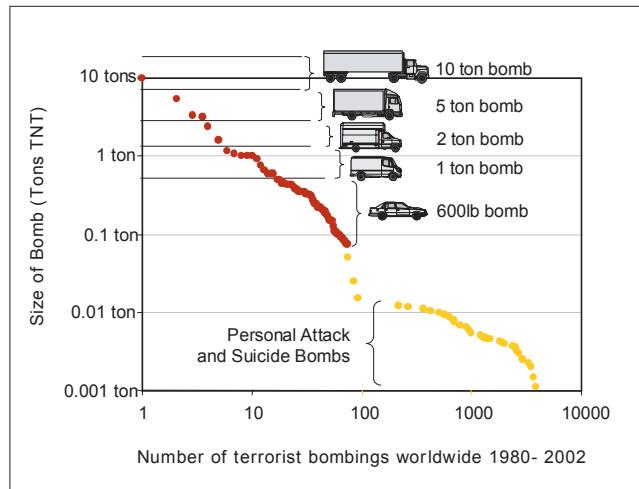


Figure 6.2 Relative frequency of occurrence of different sizes of bombs used in terrorist attacks, from a sample of events

6.3.2 Bomb Yield

The size of a bomb is determined by the amount of explosive that can be assembled, and is measured in terms of its explosive yield, as a TNT-equivalent. Yield can be estimated from the effects of the blast and crater size after an explosion. Larger bombs (1 ton and above) are very destructive but rare since they require a large amount of explosive to be amassed. Figure 6.2 shows how rare the larger bombs are. Of the terrorist bomb attacks in the historical database for which there is sufficient data to estimate the explosive yield used, there are more than five times as many car bombs, around 600 lbs (0.3 tons) of explosive yield, than there were truck bombs of 1 ton and above.

6.3.3 Bomb-related Casualties

Bombs are very deadly. The blast from a large bomb kills 95% of the people standing within 100 feet (30 meters) and a third of everyone within 200 feet (60 meters). People can be killed up to an 0.8 miles (201 meters) away. Blast pressures dismember bodies and cause severe trauma. Bombs generate a debris field of high velocity shrapnel and other material blown by the blast that is very damaging. The pressure impulse waves generated can also cause serious internal injuries, primarily to the ears and lungs.

6.3.4 Bomb-induced Building Collapse

Some of the most deadly bombs are those that have caused buildings to collapse. The truck bomb attack that collapsed the four-story U.S. Marine barracks in Beirut, Lebanon on October 23, 1983 killed 241 soldiers in the collapse. On the same day, another large truck bomb in West Beirut caused the collapse of an eight-story building housing the French paratrooper barracks, killing more than half of the 110 occupants. The most deadly bombing on U.S. soil killed 168, a quarter of the occupants, and injured many others when a truck bomb caused the collapse of a substantial portion of the eight-story Murrah Federal Building in Oklahoma City in 1995.

However, the collapse of large buildings by terrorist bombs is rare. Modern multi-story buildings are structurally resilient and although bombers may have tried to bring about the collapse of high-rise buildings such as in the 1993 World Trade Center bombing, the massive steel frames and design for strong wind and earthquake loads makes them less vulnerable to blast pressures. Older buildings are more vulnerable, and terrorists could seek these out. Precisely placed explosives, like demolition charges, could cause the collapse of a high-rise building (under the right circumstances), but terrorist bomb attacks have rarely been totally successful with this method.

6.3.5 Injuries Within Buildings

Bombs detonated outside buildings commonly cause injury to the occupants of nearby buildings even if the buildings do not collapse. The pressure waves usually pass through windows or wall cladding. Occupants of the lower floors of buildings, even those in the core of the building, experience injury from the high pressure impulse wave that passes through. Those close to the exterior wall also experience injuries from flying glass and metal.

6.3.6 Evolving Modus Operandi

The truck bombing scenario in this report is typical of an Al Qaeda inspired attack: multiple, synchronized detonations of large scale bombs, carefully planned, rehearsed, and resourced over many months of preparation. Al Qaeda has carried out attacks itself and also “franchises” its operational techniques to associated groups in different parts of the world like Islamic Jihad, Jemaah Islamiyah, Abu Sayyef, and Ansar al-Islam. In

these cases, Al Qaeda has had various degrees of involvement ranging from inspirational models and training, to lending operational assistance and financing.

Techniques for bomb attacks have developed over recent years. As likely targets, military bases, government buildings, and embassies have improved their defenses ('hardened' in counter-terrorism terminology) and attackers have increasingly switched to 'softer' targets. Hotels, commercial buildings, tourist attractions, and other potential locations for high-casualty outcomes now form the targets of choice. As defenses have improved, such as manned security guards, the techniques have been adapted. Recent attacks in Saudi Arabia, Indonesia, and Iraq for example have involved armed pre-emptive attacks on the security guards to clear the way for the bomb run. Terrorists have shown ingenuity in using disguise, deception, and guerrilla techniques to overcome security measures.

6.3.7 Security

In the U.S. today, counter-terrorism security is at an all-time high. It is difficult for terrorist operatives to enter the country, known sympathizers are closely watched, communications are monitored, and security services maintain a high degree of vigilance watching for any signs of attack planning. Explosives have been made more difficult to obtain, and ingredients used for bomb making such as ammonium nitrate and detonators are on restricted purchase lists.

Nevertheless, security specialists acknowledge that these precautions can be evaded with determination and ingenuity. Attacks remain possible and most security sce-



Figure 6.3 A terrorist attack targeted on producing mass casualties could overwhelm emergency room capacity, even in a major city (Image: Getty Images)

narios envision explosive devices as the most likely terrorist threat to be encountered.

6.3.8 Chosen Scenario

The scenario considers a terrorist selection of high-priority targets in the RMS target database—a landmark skyscraper in a central business district, a corporate headquarters building, and a major tourist attraction. These U.S. icons are likely targets, representing prosperity. Similar buildings have been the target of Al Qaeda attacks in the U.S. and internationally in the past.

It would take a team of 15-20 people and require considerable resources to perpetrate the scenario illustrated. This scale of team organization is not unprecedented; it would be difficult to assemble within the U.S. if all of these were foreign visitors, but if there were suf-

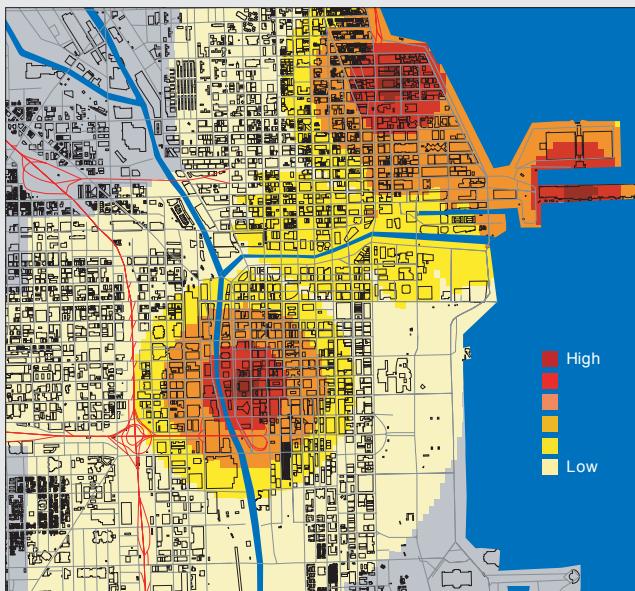
ficient volunteers among sympathetic U.S. residents, this could be accomplished. This scenario envisions that the operations leader and bomb-master is brought in from outside the country, but the rest of the team are sympathizers from within the U.S.

The attack entails three bombs, each with a 2-ton yield, which is at the upper end of the scale for a bomb attack. It requires over six tons of explosives, which is a considerable amount for a covert operation to amass without detection. However, it is not unprecedented. An interdicted Al Qaeda attack in Singapore in December 2001 reportedly discovered seven tons of explosives and a plan for up to six truck bombs to be used simultaneously. The attacks in Riyadh in 2002 involved three vehicle bombs and over 4 tons of explosives.

HYPOTHETICAL SCENARIO 3: TERRORIST TRUCK BOMBINGS IN CHICAGO

Terrorist Bombings Cripple Center of Chicago

Three truck bombs attack landmark buildings, killing staff and tourists in Chicago business district



Hazard levels for triple truck bomb in Chicago

At 9:00 am, a convoy of nine vehicles leaves a large warehouse in northern Chicago where for the past few weeks a team of 15 people has been assembling electronic components: weed killer, explosives, and commercially available chemicals. The operational commander has done this several times before in Indonesia, Iraq, and Saudi Arabia. The explosive mixture is now packed in 60 drums in three separate vehicles, each disguised for its own target. The interior of the trucks are caulked to minimize the chances of an alert security guard recognizing the pungent smell of the mixture. Rush hour is almost over but the vehicles will still take an hour to reach their destinations. Each truck bomb is accompanied by two other vehicles containing armed operatives and lookouts to maximize the mission's chances of success.

Terrorist Cell Suspected in Illinois

At 10:30 am, the building manager of one of the largest and best known skyscrapers in central Chicago receives an urgent call from the head of Current Intelligence at the Department of Homeland Security. Information has been received that there is a bomb in the building. It is



Following terrorist attacks, areas controlled by civil authorities will require a number of law enforcement personnel to maintain order (Image: Getty Images)

possibly a hoax, but the best assessment is to take it seriously. A bomb detection team is on its way and an immediate evacuation of the building's occupants is ordered. Over the next 20 minutes, 16,000 people work their way down and out of the building to rally points in streets around the plaza at the base of the building. At one end of the plaza, few people pay attention to the white truck parked on the street, disguised with the logo of a construction company. The plaza is crowded when the bomb goes off.

The second bomb detonates only a few minutes later. A delivery truck with a hidden explosive payload is driven unchallenged into the internal service bay of a 10-story historic building housing the regional headquarters of a large American company. The blast causes the partial collapse of the building and severe damage to surrounding buildings.

The third bomb is almost 10 minutes later. A car crashes through protective barriers at the approach to the Navy Pier, enabling a large SUV to drive through the security checkpoint. Guards at the checkpoint, already alerted by the distant explosions, open fire on the vehi-

cle, which explodes nearly 300 feet (91 meters) short of its intended target—the crowds in the Crystal Gardens complex of food and entertainment facilities on the Navy Pier.

Chicago Terror Attack Devastates City Center

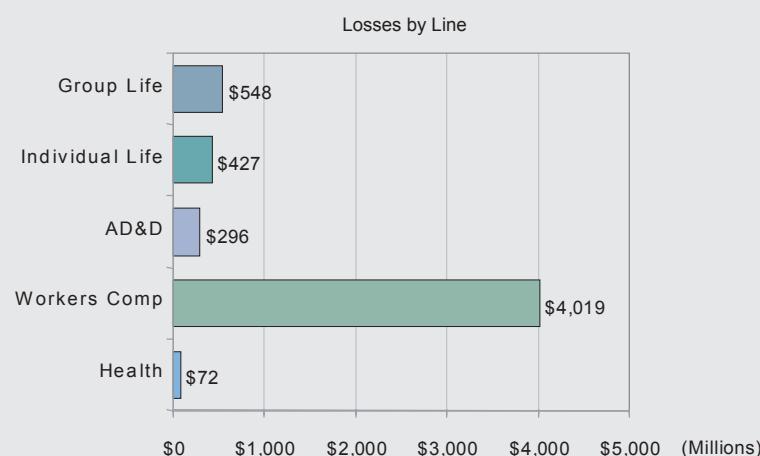
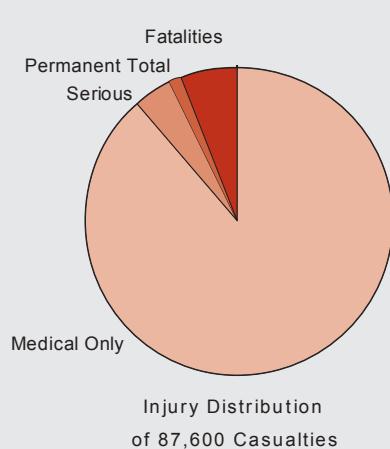
All three targets are located within 2 miles (3.2 km) of each other in downtown Chicago. The city center is badly damaged. Medical services are initially overwhelmed with the number of injuries, and doctors triage and treat the severely injured in the main plaza. Search and rescue teams dig into the rubble of the collapsed building for survivors. A civil authority zone is declared, sealing off nearly 100 blocks. Emergency services try to keep the occupants of buildings within the zone indoors while they check for more bombs. Geiger counters are brought in to check for dirty bombs (contaminated with radioactive sources), but to their relief, radioactivity is not present in the devastated area. Finally, occupants are released from their buildings and escorted out of the area. It will be many months before most of them return to their offices, and some will never come back.

Casualties Mount from Bomb Attacks

The bomb in the plaza kills over 3,000 people and severely injures 4,000. Others are killed inside buildings around the plaza. From the second bomb, 1,200 occupants are killed in the collapse of the 10-story building, and another 800 people are trapped in the rubble. Many thousands of people suffer injuries from bomb debris and flying glass. Apart from the six police and fire-fighters attending the hoax evacuation, nearly all of the dead and injured from the bombs are employees of companies in the target buildings or surrounding offices. The third bomb kills 400 people, including security guards. Had this bomb reached its intended target, casualties and damage would have been much higher.

	Fatalities	Total No. of Casualties	Total Industry Loss (Millions)
All Population	5,300	87,600	
Population with Group Life Coverage	4,100	4,100	\$548
Population with Individual Life Coverage	2,900	2,900	\$427
Population with AD&D Coverage	2,400	3,300	\$296
Population with Workers Compensation Coverage	5,000	80,600	\$4,019
Population with Health Coverage*	270	6,320	\$72
Population with No Health Coverage	30	680	
			\$5,362

* Health coverage if not covered by workers compensation



6.4 ANTHRAX ATTACKS

Anthrax has long been feared because it has a reputation of being relatively easy to produce. However, its production actually requires a high level of specialist skill, laboratory techniques that are not everyday practice, and the correct sterile equipment. It also requires initial cultures of the right strain of anthrax to produce bacteria that are harmful. Despite some of the best equipment and scientists, Aum Shinrikyo, perpetrator of the sarin attacks on the Tokyo subway, abandoned its anthrax development program in 1993 after two years of unsuccessful attempts to carry out effective attacks.

Anthrax is one of several ‘category A’ agents identified by the CDC as a potential terrorist bioweapon. Even a small quantity used effectively can be fatal. People who inhale anthrax spores are killed or injured. Some may become ill from cutaneous anthrax exposure if it touches the skin, or gastrointestinal anthrax if it is ingested. The deadliness of anthrax has long been known and has been developed into biological weapons by many different countries, including the U.S. and the Soviet Union. The deadly potential for releasing anthrax spores on the population was demonstrated when a few milligrams of anthrax spores were accidentally released from a Soviet military bioweapons facility at Sverdlovsk in 1979, which affected a narrow zone downwind for 2.5 miles (4 km), killing 66 people and affecting many others.

6.4.1 2001 Anthrax Letters

The lethal potential of anthrax as a terrorist weapon in the U.S. became highlighted in the months following the September 11 attacks with a series of letters containing anthrax spores sent anonymously to government officials and news organizations in the U.S. In September and October of 2001, four letters containing a few grams of anthrax spores caused 23 people to contract anthrax, five of which died. No one has ever been charged with sending the letters, but some believe that the perpetrator was from the biological warfare research world drawing attention to the ease of manufacturing anthrax and its potential use as a terrorist weapon.

6.4.2 Aum Shinrikyo Anthrax Attempts

Anthrax was explored by Aum Shinrikyo in incidents that predated the 1995 sarin gas attacks on the Tokyo subway. In 1993, a strain of veterinary anthrax was tested on unsuspecting people in the streets of Kameido, Japan-

through a release of anthrax spores from its mid-rise office-building laboratory in Tokyo. The anthrax strain used was fortunately not very damaging to humans.

6.4.3 Anthrax and Injuries

Anthrax is a bacterium (*bacillus anthracis*) with spores, only microns in diameter, that replicate in the blood and produce toxins that cause severe illness and death. The bacteria can get into the body through the skin if touched or handled (cutaneous anthrax, mortality rate of about 30%), through the intestine if swallowed (gastrointestinal anthrax, mortality rate of about 50%), or through the lungs if inhaled (inhalation anthrax, mortality rate of over 90%).

Once infected, the onset of illness is gradual. Victims show no symptoms for the first 1-6 days. This is known as the pre-symptomatic incubation stage. The symptoms are flu-like, including fever, chest discomfort, fatigue, and coughing. These symptoms are known as the prodromal stage and may last several days. This stage can culminate in a temporary period of improvement in the patient’s condition. The final stage of the illness is known as the fulminant stage, when the patient becomes severely ill and develops serious respiratory difficulties with obstruction to the upper airways. In most cases, death follows very quickly. Those that recover from developing an anthrax infection may be ill for a very long period of time. Some of the 2001 anthrax victims were hospitalized for over two years.

Anthrax infection rates are driven by the number of spores someone may be exposed to. Chances of developing the infection also increase significantly with age; if a person inhales 10,000 spores, the chances of infection at 15 years-old are about 33%; at 75 years-old they are over 95%.

6.4.4 Treatment of Anthrax

It is possible for people that have inhaled anthrax spores to avoid developing the infection if they take oral antibiotics before they start exhibiting symptoms. If a large number of people exposed to anthrax are given antibiotics within the first day or two, the infection rate could be substantially reduced. The issue is one of logistics—a method to get antibiotics to hundreds of thousands, possibly millions, of people within a few hours of an attack that might not be initially known.² In scenario 4, the attack is a surprise and antibiotics are given to symptomatic patients and then to higher risk (old or very young) people who may have been affected. In scenario 5, the attack is anticipated and results in a massive and rapid antibiotic distribution to the whole population.

The antibiotic course is long, 90 days is recommended, and can cause unpleasant side effects. Studies show that the efficacy of the treatment can be reduced as a result of people not completing the full course. It is possible to improve the chances of survival if somebody who has developed the initial anthrax symptoms, in their prodromal stage, takes a combination of antibiotics and has aggressive hospital support care. This is resource-intensive, requiring special ventilator equipment and high numbers of staff per patient. In a large-scale attack, there would be an insufficient amount of medical staff to provide this level of intensive hospital care for large numbers of patients. Once someone has reached the fulminant stage, death is almost inevitable.

6.4.5 Dispersal of Anthrax

The reason anthrax is highlighted as a bio-terrorism weapon is because of the ease with which it can be disseminated and the large area that can be affected with lethal dosages. The microscopic spores are easily airborne and stay airborne for a long time, like plant pollen. A cloud of dry spores or a mist of wet slurry can be carried for miles in a light wind. Just 2 lbs (1 kg) of pure anthrax can contain 10^{15} spores. If anthrax was to be sprayed or dispersed into the air with the right conditions of mild, steady winds, these spores could be carried in ground level air that would eventually spread into thousands of spores per cubic yard over many square miles. A person breathing at a normal rate for an hour in these conditions would inhale enough anthrax to become infected. It is theoretically possible to infect millions of people by dispersing anthrax over a densely populated city. In reality, a mass of anthrax is unlikely to be perfectly distributed and weather conditions, even if the timing is carefully chosen, are never ideal. High or turbulent winds would create an uneven distribution of anthrax, rain would wash it to the ground, and a significant proportion of the spores would harmlessly escape. Estimating the spread of anthrax spores from a release involves using sophisticated dispersion models that attempt to account for these effects in mapping out the geographical footprint.

6.4.6 Spore Infiltration into Buildings

Most of the population with the potential of being affected by an anthrax strike are inside buildings. A high percentage of modern commercial buildings have air handling which will filter out a proportion of anthrax spores from the air. The degree of protection may depend on the sophistication of the attack carried out.

In scenario 4, a crude culture of anthrax slurry is made by biomedical students. This slurry consists of about 2% spores and is likely to contain clumps of spores and vegetative cells that flocculate into droplets of at least 10 microns and possibly much larger. Air intake filters of MERV standard 11, common in high grade office buildings will take out 85% of particles greater than 10 microns. Even lower grade MERV 6 filters remove 50% of them. The highest quality buildings use HEPA filters, which remove 99.97%.

In scenario 5 however, the attack is much more sophisticated. The attackers have ‘weaponized’ the anthrax: they have dried and filtered the material to remove dead cells and to make the spores as fine a material as possible. The common MERV 11 air intake filters will catch fewer (65%) of these finer spores. The attack will be more effective in penetrating air conditioned buildings.

6.4.7 Potential Anthrax Users

The relative ease of creating a weapon that in theory has the potential to kill tens of thousands of people is an obvious concern. The technologies involved, although complex, are simpler than the large-scale manufacturing of deadly chemical weapons, the procurement of a nuclear bomb, or other attack modes that could kill thousands.

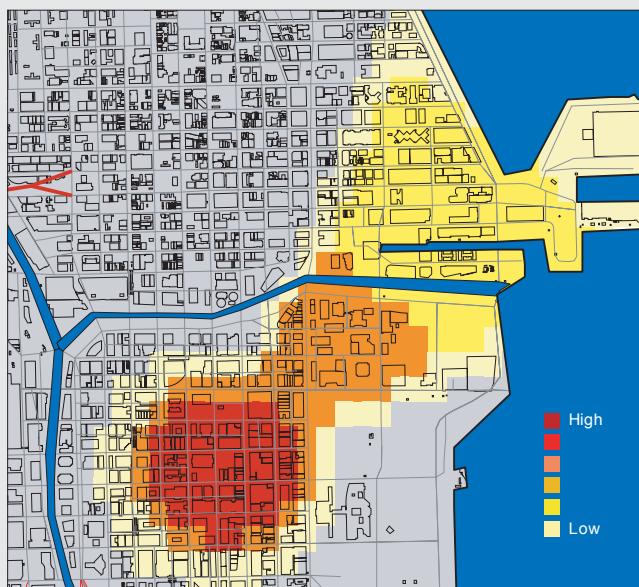
However, the primary determinant of the likelihood of an anthrax attack is not the ease of its manufacturing, it is how many people would have the motivation to rationally choose to use it to kill thousands of people. Those we call terrorists have developed a mindset far removed from our social norms. Terrorist organizations reinforce this different value system within their membership and enable individuals to carry out atrocities. The number of people who are capable of crossing that barrier are few, but significant. There have also been lone perpetrators and small groups capable of rational acts of mass murder. The Unibomber, the anthrax letters mastermind(s), Timothy McVeigh and Terry Nichols, and perhaps the Washington snipers fall into this category. Driven by a perceived cause, these individuals could be capable of mass casualty attacks.

² Wein, L.M., Craft, D.L., and Kaplan, E.H. 2003. Emergency response to an anthrax attack, *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*. April 1, 2003, Vol. 100, No. 7.

HYPOTHETICAL SCENARIO 4: TERRORIST ANTHRAX ATTACK

Thousands Infected in Anthrax Attack in City Center

Security agents track terrorists who dispersed an estimated 2 lbs of crude anthrax slurry from a building top



Bag Used for the Disposal of Biohazardous Materials (Image: Getty Images)

Three young naturalized U.S. citizens studying at a technical college in Chicago share a house. One is a post-graduate student doing biomedical research. Over time the three have built a close friendship and rivalry. They are not particularly religious, but feel alienated from mainstream society and are taken with some of the radical Islamic messages espoused by youth movements on campus. It is the start of a psychological journey for the solitary group that sees them reinforcing and justifying their pathological but highly rational activities. Although inspired by Al Qaeda rhetoric, they act alone.

Radical Writings Blamed for Anti-U.S. Sentiments on Campus

The 2001 anthrax letters are debated, and press articles on biological weapons are ridiculed. They experiment with culturing bacterium, first with bacillus cereus, associated with food poisoning, and then they try anthrax. Over a period of many months, and with several failures, they achieve a successful culture of bacillus anthracis and grow it, collecting it as a thick liquid in a 30-oz (0.9-liter) glass pickle jar, within an airtight cooler box, kept in a deep tank of water in the basement of their house.

When the jar is full they decide to use it to strike and cripple the hated society that surrounds them.

The youngest member of the group volunteers to carry out the attack, knowing he will die from releasing the anthrax. The three have chosen their spot with care. They watch the weather forecast and then check the volunteer in to the penthouse suite in one of the 10 downtown Chicago hotels that are more than 25 stories high. There they help him break a window. They assemble a power air pump and take the jar of anthrax slurry from the cooler box. In the hours before dawn, the volunteer sprays the slurry out through the hole in the window. He dismantles and packs the equipment and checks out, taking a cab to the airport to die in the care of his friends, already a city away.

Doctors Suspect Anthrax Cases in City

The fine spray of the aerosol is carried through the morning air. The tiny droplets containing the spores float in the wind, and larger drops begin to fall 300 feet (91 meters) to the ground, slowly drifting as they go. Parts of the aerosol reach ground level at about 8:00 am. Drivers and pedestrians in the streets below do not

notice that they are inhaling microscopic particles. The rest of the fine spray cloud drifts in the air, floating between the high-rise office buildings in the city. The air intake grills of the skyscrapers suck in air from inlets at different heights of the building. Air passes through intake filters, air-cleaning units, and cooling treatment plants before it is pumped through the building air supply system. The intake cleaning in most buildings removes about 85% of the anthrax spores. The spores are only the size of a micron, but this crude student-made culture contains clumps and droplets of 10 microns or more. In the highest quality buildings 99.97% of the spores are filtered out. But the aerosol is fairly dense and even a small percentage getting through the filters means billions of spores circulating in the air system. On the lower floors of many of the office buildings, most of the occupants unwittingly breathe in at least 8,000 spores, a lethal dose.

Mass Antibiotic Distribution to Halt Anthrax Spread

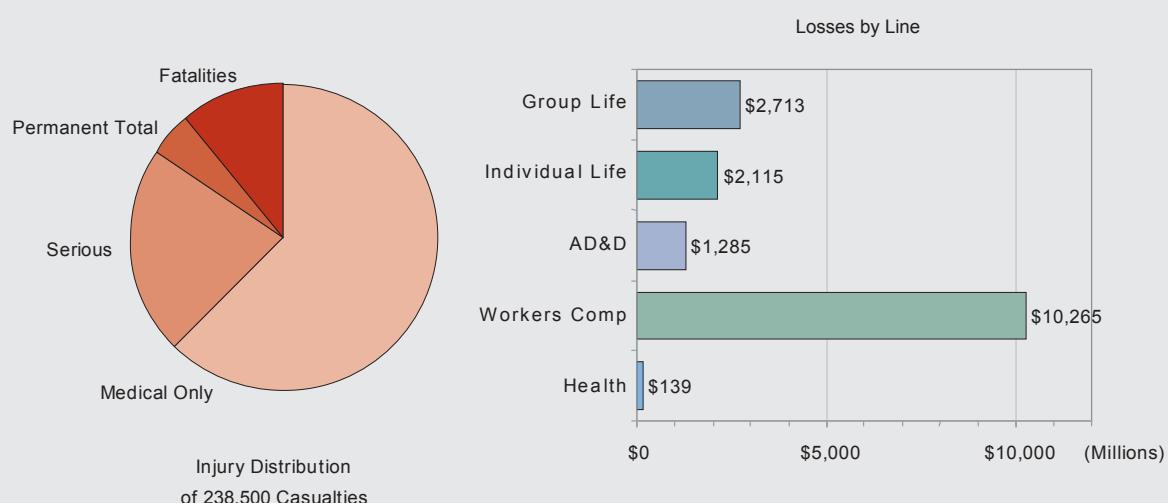
The first patients arrive at their doctor's office (complaining of stomach pains) the morning of the second day

after the attack. Physicians are suspicious and notify the Centers for Disease Control. Blood tests take eight hours and reveal gastrointestinal anthrax. The main wave of patients starts on the third day, with an unusual number of flu-like cases, caused by inhalation anthrax. Emergency plans are executed, clearing wards for the expected influx and distributing Cipro antibiotics to patients. Chicago does not have sufficient antibiotic supplies to provide for everyone that may be affected, but supplies are rushed from other parts of the country and a program of mass prophylaxis is instigated. Medical facilities are quickly overwhelmed.

Wards rapidly fill up with severe cases of bronchial failure; most die. Tens of thousands need respirators. Volunteer physicians from across the country bring the respirators in. Some pull through with intensive care, but remain hospitalized for many months. Some are permanently disabled. Most are either infected and die, or recover relatively quickly.

	Fatalities	Total No. of Casualties	Total Industry Loss (Millions)
All Population	26,600	238,500	
Population with Group Life Coverage	20,600	20,600	\$2,713
Population with Individual Life Coverage	14,500	14,500	\$2,115
Population with AD&D Coverage	11,900	11,900	\$1,285
Population with Workers Compensation Coverage	25,000	221,800	\$10,265
Population with Health Coverage*	1,560	4,760	\$139
Population with No Health Coverage	50	11,940	
			\$16,517

* Health coverage if not covered by workers compensation



6.5 MAJOR ANTHRAX ATTACK

6.5.1 Weapons of Mass Destruction

The potential for terrorists to acquire and deploy weapons of mass destruction (WMD) is an important part of the assessment of terrorism risk. The strikes on September 11 demonstrated that Islamic militants had no moral qualms or ideological constraints on mass killing. In June 2003, an internal assessment of the U.S. government concluded that there is a “high probability of a terrorist attack with weapons of mass destruction in the next two years.”³ Documents and materials discovered during the search of more than 40 sites used by Al Qaeda in Afghanistan in 2001 demonstrated “an appetite for weapons of mass destruction.”⁴ Statements made by members of the Al Qaeda network themselves have expounded a rhetoric of justification for using WMD on their enemies and threatened the death of up to 4 million Americans through the use of chemical and biological weapons.⁵

6.5.2 Al Qaeda and CBRN

Weapons of mass destruction are commonly referred to as CBRN technology, consisting of: chemical (deadly chemicals and poisons), biological (biological viruses and bacteriological agents), radiological (dispersal of radioactive materials), and nuclear (detonation of nuclear fission weapons). Al Qaeda has conducted research into all four of these. Evidence of research into chemical agents includes videotapes of nerve gas tests on dogs and formula for sarin gas were recovered in Afghanistan. Unverified reports have circulated about Al Qaeda and Chechyan agents enquiring about obtaining ex-Soviet nuclear weapons. In 1998, an unsuccessful attempt by Al Qaeda to purchase uranium from black-market sources suggested the development of at least a research interest in radiological weapons. A chapter in an Al Qaeda training manual “Encyclopedia of Jihad,” gives schematic instructions on building a radiological dispersal bomb, or dirty bomb.

Documents seized in Afghanistan training camps indicated a rudimentary understanding of nuclear fission devices. Asked in an interview in 1998 about allegations that Al Qaeda had acquired suitcase nuclear weapons,

Osama bin Laden said, “Acquiring weapons for the defense of Muslims is a religious duty. If I have indeed acquired these weapons, then I thank God for enabling me to do so.”

Leaders at the top of the Al Qaeda hierarchy completed plans and obtained the materials required to manufacture two biological toxins and the chemical poison cyanide. The most credible evidence however is of Al Qaeda making advances in a research and development program into biological weapons, specifically anthrax.

Despite their interest, research, and development activities, it is generally believed that Al Qaeda and its associated groups did not succeed in making or acquiring any functional CBRN weapons in Afghanistan before the U.S. invasion in 2001. Much of the war on terrorism carried out by the allies has been to disrupt the organizational capability of the terrorist groups to prevent them from acquiring WMD. The invasion of Iraq was justified on the basis of denying terrorists the opportunity to acquire weapons thought to be stockpiled in Iraq.

6.5.3 Al Qaeda’s Anthrax Program

Al Qaeda’s interest in anthrax is known from training materials and research data on anthrax production from a number of sources. Mohammed Atta, the Al Qaeda member who piloted one of the planes into the World Trade Center, made enquiries about a crop-duster aircraft in early 2001. A crop-duster aircraft could potentially be used to distribute anthrax spores on a city.

In Afghanistan, notes and documentation on anthrax production were found in the Al Qaeda sites. Prisoner interrogations from 2002-2003 revealed a clearer picture of Al Qaeda’s anthrax project and how the group had collaborated with associated regional terrorist groups, such as Jemaah Islamiah, to continue its research and development. Al Qaeda apparently relocated its anthrax research project from Khandahar to Indonesia when the bombing of Afghanistan began in October 2001. The management of the program was assumed by Jemaah Islamiah with newly recruited competent scientists, including a Pakistani microbiologist.

Evidence suggests that detailed components on the process of mass producing anthrax have been mastered by Al Qaeda. Equipment inventories have been seized, as alerted the cleanup op-

³ U.S. Government report to the United Nations Security Council. June 10, 2003.

⁴ Statement by Defense Secretary Donald H. Rumsfeld. 2002.

⁵ Evidence came from documents and computer hard drives seized during the capture on March 1, 2003 of Khalid Sheikh Mohammed, head of Al Qaeda’s military committee. Sheikh Mohammed was arrested at the home owned by Abdul Quddoos Khan, a bacteriologist with access to production materials and facilities. Further information came from Riduan Ismuddin, the terrorist known as Hambali, arrested in Thailand on August 11, 2003.

well as apparent laboratory logs for trial growths of pathogen seed stocks, and how to dry the resulting liquid slurry into a form suitable for aerosol. There is no evidence that specific manufacturing facilities exist or any details of actual or planned production.

The current status of the Al Qaeda anthrax program is unclear. It appears to have been dispersed to other countries but it is assumed in abeyance for now. A raid on a Jemaah Islamiyah safe house in Mindanao, Philippines on October 20, 2003 discovered unspecified manuals on bioterrorism. The suspicion remains that Jemaah Islamiyah has taken over the anthrax program, but probably lacks the skilled manpower to take it to the next level unless experienced microbiologists are recruited. Security services will continue to act on intelligence in order to disrupt future biological terrorist operations. Scenario 5 explores how an attack might play out if and when the Al Qaeda anthrax program were taken through to completion.

6.5.4 Scale of Anthrax Loss

There has never been a terrorist attack using anthrax on the population as envisioned in these scenarios. There have been experimental attempts and mailed anthrax, but no large-scale dispersal in a city. A small-scale accident in the Soviet Union has been the closest example of airborne anthrax spores traveling miles and causing inhalation anthrax deaths—the number of deaths is unknown, possibly hundreds from a few milligrams of spores.

There is considerable consensus in the research com-



The receipt of letters containing anthrax in October 2001 public to the hazards of biological materials., as seen in the ration for the American Media building in Florida (Image:

munity about the feasibility and lethality of an anthrax attack of this type. In a 2003 peer-reviewed study, university researchers predicted 123,000 deaths from an urban anthrax attack using 2 lbs (0.8 kg) of anthrax spores.⁶ A study by the World Health Organization (WHO) of a 110 lb (50 kg) anthrax attack on a population of 5 million concludes that 100,000 people would die. Another study, published by the CDC, analyzed the impact of 100,000 people dying in an anthrax attack.⁷ In the absence of historical precedent, it is difficult to be certain that an aerosol of anthrax spores would behave as expected and infect the number of people that appear likely, however the science has been independently calibrated by a body of literature.

It is often difficult for people to accept the scale of death and injury that specialists predict from an anthrax attack of this type. Government officials with access to classified military studies have no such doubts. The results of military anthrax tests in the 1940s and 1950s remain classified, but it is known that fine fluorescent powder simulations were used to cover tens of thousands of square miles and the live testing grounds for animals have remained off-limits for decades.⁸ In World War II, contingency plans existed for anthrax attacks on German cities: approximately 8,000 lbs (3,630 kg) of anthrax was proposed for a large town of 25 square miles (65 square km).⁹ Prior to the 1972 Biological and Toxins Weapons Convention, anthrax had been developed as a military weapon by an estimated 14 countries.

6.5.5 Hope For Protection From Vaccine

Given the extreme scale of potential death and injury, the U.S. National Institutes of Health (NIH) is collaborating with commercial immunotherapeutics companies to develop, as rapidly as possible, both injectable and rapid-acting oral vaccines against anthrax. The oral vaccine is in a preclinical stage of development, but the injectable vaccine is already in Phase I trials. When Phase II and Phase III trials are completed, and the vaccine is marketed for public protection, the anthrax casualty risk should be significantly reduced. However, these developments are sufficiently far off into the future, and do not impact the current risk assessment, but do provide hope for three, four, or five years in the future.

⁶ Wein, Craft, and Kaplan, *ibid*.

⁷ Lisa D Ritz, Ali S. Khan, Scott R. Lillbridge, Stephen M. Ostroff, and James M. Hughes. February 2002. *Public Health Assessment of Potential Biological Terrorism Agents*. CDC, Atlanta, GA, Report Summary in *Emerging Infectious Diseases*, Vol. 8, No. 2.

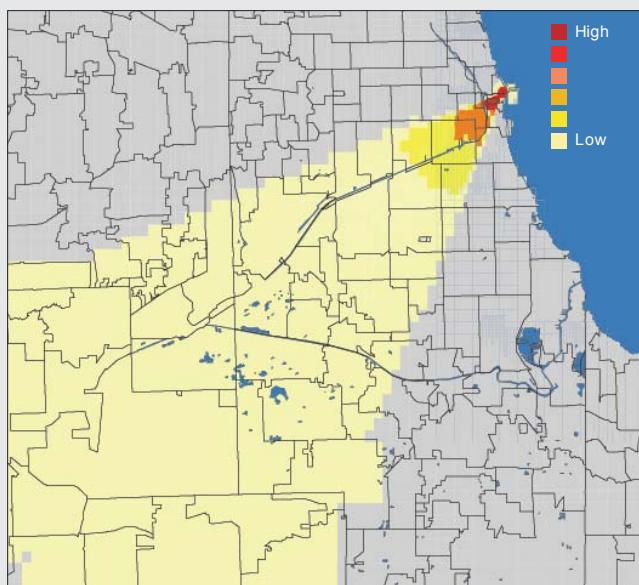
⁸ Mangold, T., Goldberg, J. 1999. "PlagueWars: A True Story of Biological Warfare." Pan Books.

⁹ Harris, R., Paxman, J. 1982. "A Higher Form of Killing: The Secret History of Chemical and Biological Warfare." Arrow Books, Random House Ltd. Study commissioned by Winston Churchill and delivered on July 27, 1944 included plans to deliver agent 'N' (code-name for anthrax) in 2,000 cluster bombs for a large town of 25 square miles. The report included an appendix of 60 target German cities.

HYPOTHETICAL SCENARIO 5: MAJOR TERRORIST ANTHRAX ATTACK

Al Qaeda Anthrax Strike: “Worst Fears Realized”

Large release of weaponized anthrax powder in Chicago prompts full emergency response



The orange “high” terrorism alert status in the U.S. runs into its third week. In Washington, a counter-terrorism briefing is given by a senior intelligence analyst. Email and cell phone intercepts have diminished. For three weeks, police and security personnel have been working overtime searching, checking, and guarding. If there is a terrorist cell within the U.S. they have not been found. The analyst recommends that intensive security activities continue, and emergency logistics be put into place, but the costly public alert can be downgraded to yellow “elevated.”

Security Finds Confirm Al Qaeda Bio-terror Program

At a secret meeting of Jemaah Islamiah in the Philippines, the leaders of a Shura council representing 12 militant Islamic groups review the project that has been in preparation for over five years: an unprecedented strike against the U.S. population.

The project leader presents the plan’s history to his team, showing how the materials and knowledge were transferred from Kandahar to Indonesia when the U.S. began bombing Afghanistan in October 2000. In 2003, the project was again relocated to Malaysia and now has



The affected area from the attack reaches far into the Chicago suburbs; teams are sent out to test for anthrax for hundreds of miles (Image: Getty Images)

been finalized in the camps of Mindanao, a Filipino island with a history of Islamic militancy. The project has suffered several setbacks. The arrest of two former project leaders, Khalid Sheikh Mohammed and Hambali, has provided the international security services with much information about the plan. Just as the plan has reached completion, the alert status in the U.S. has become elevated. It is a possibility that the current operation has been compromised. However, while U.S. intelligence now has a majority of information about the plan, it has failed to locate the team. By controlling the timing and location of the attack, the chance of a successful execution is still good. The project leader asks for permission to strike once the alert status is downgraded.

The weapon has been in place for a month. A large batch of fine-powdered anthrax was manufactured in a factory in the camp, tested and packed into an airtight steel ammunition case, 3 cubic feet (0.085 cubic meters) large. It was shipped into the U.S. using good credentials through container shipments via Taiwan to Oakland, CA among the 500,000 containers processed there this year. A team of dedicated operatives has been in the U.S. for six months and have carried out three practice runs.

Evacuation and Mass Drug Handout After Major Anthrax Attack

The call that the Department of Homeland Security has feared comes through at mid-day on a Wednesday. The bio-detector outside Chicago City Hall has tested positive for anthrax—high-grade weaponized spores have been distributed in the air from somewhere in the city. City officials, intelligence personnel, and bio-terrorism specialists coordinate actions from an emergency control center.

By 2:00 pm, the attack is only a few hours old and with swift action many lives can be saved. Large stockpiles of Cipro tablets are available and need to be issued to everyone affected within one or two days. If they get the treatment early enough, and complete the long course, survival rates will be greatly increased. Distribution centers are ordered for every community. A campaign will urge people to keep taking their tablets each day for three months.

The other priority is to get everyone out of the affected area to minimize the dosage of spores they

inhale. A mild southwest wind will spread the spore cloud several miles across the city center over about 36 hours. The current location of the cloud is unknown but analysts make rough estimates. Evacuating the city center is difficult—it takes a long time and creates panic and chaos. Vaccinated police and troops, some in full bio-protection suits, marshal frightened crowds out of the city. Cars are filled, trains rescheduled, and millions walk, heading into the wind. People are clearly terrified but are told that they will be fine if they get their Cipro allocation once they get home. Morale holds.

The full impact emerges over the next week. Hundreds of thousands fall sick with inhalation anthrax. Approximately 100,000 people die. Without the Cipro, casualties would have been much higher. There are too many people to treat with the intensive care needed, and many are hospiced at home until they die. Patients are treated in cities all across the U.S. Routine health care is postponed for millions as the nation's resources stretch to cope with the scale of the attack.

	Fatalities	Total No. of Casualties	Total Industry Loss (Millions)
All Population	106,700	942,900	
Population with Group Life Coverage	74,700	74,700	\$8,928
Population with Individual Life Coverage	51,000	51,000	\$7,235
Population with AD&D Coverage	39,500	39,500	\$4,229
Population with Workers Compensation Coverage	82,000	572,800	\$32,315
Population with Health Coverage*	19,100	239,400	\$2,041
Population with No Health Coverage	5,700	130,700	
			\$54,748

* Health coverage if not covered by workers compensation

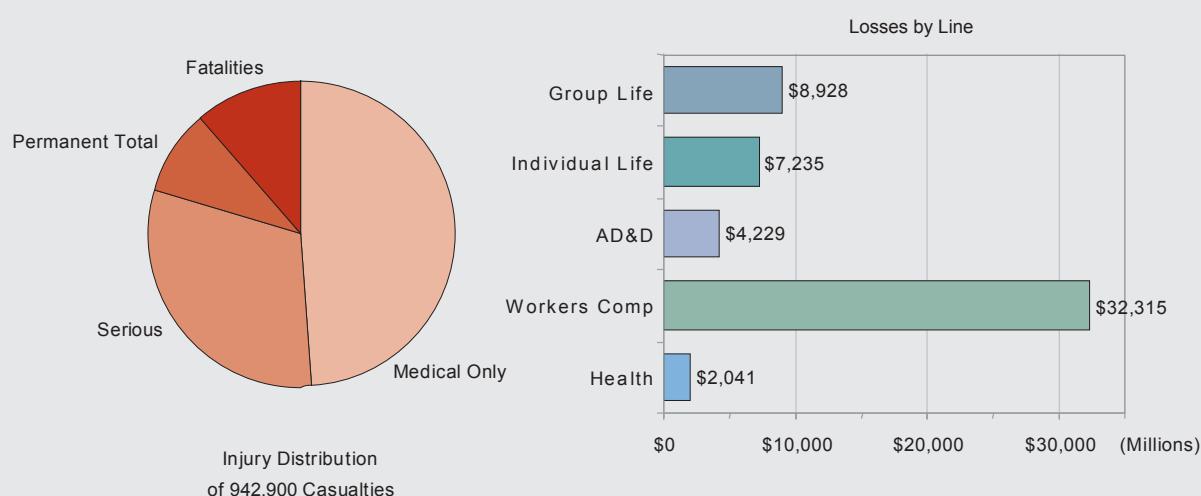




Figure 6.5 Emergency services practice their response to a bio-chemical terrorist attack in a drill in New York in October 2003 (Image: Associated Press)

6.6 LOSSES FROM TERRORISM

Attacks from terrorism can cause large numbers of casualties, and the examples chosen here, although low probability, are feasible and are among those that security services in the U.S. are actively working to prevent. The casualties are high because of the well-planned intent of the terrorists. Previous generations of terrorists, like the nationalists and left-wing terrorist organizations, generally considered mass casualty events counter-productive and their attacks were often of limited scale or accompanied by warnings to civilians. For the new generation of Islamic militant terrorist groups, mass casualty is an explicit objective.

The insurance penetration rates among the victims of terrorism attacks are higher than average across the population. The terrorists target the central business district of major cities in the U.S.—symbolic and prestigious buildings. The people in these areas, most of them working in commercial buildings, are high-income individuals, with more life and health insurance than elsewhere in the country. Workers compensation insurance bears a high proportion of the loss as these attacks happen during work hours, targeted at employees in their workplace, as was the case in the World Trade Center attack.

Health insurance lines are also impacted heavily by losses on this scale. The large scale of the attacks affects people at home and those visiting the area, which are generally not going to be covered by workers compensation.

6.7 WORSE CASE SCENARIOS

These scenarios could have resulted in even more casualties and larger losses. Scenario 5 assumes an efficient and

rapid distribution of Cipro to the affected population but if this were less timely or supplies were insufficient, many more people would die. Assumptions about the size of the area affected by the anthrax could also have been more pessimistic, traveling further under the wind conditions and affecting more people. The terrorists could have also attacked with a larger amount of anthrax agent, infecting a larger area.

Worse types of terrorist attacks are possible. Events such as sabotaging a nuclear power station or deliberately triggering an industrial accident that releases hazardous materials could cause mass casualties (as illustrated by the accidental release scenario in the next chapter), and some of these could be more severe. Different forms of biological attacks are possible. Modeling attacks using a contagious disease like smallpox suggests that in general, the losses would be comparable with or less than an anthrax attack, but the potential for the disease to spread nationwide means that in some circumstances many hundreds of thousands of smallpox cases could occur.

The specter of a nuclear bomb, procured from some failing Soviet stockpile or terrorist-allied nuclear state is one that has dominated the geo-political agenda for some time. A detonation of a 5 kiloton nuclear device, a small tactical weapon in terms of the modern military arsenal, in a U.S. city would cause over 300,000 deaths in the initial blast, and more would die later from radioactive fallout.

6.7.1 Terrorism Risk Insurance Act (TRIA)

Losses to workers compensation insurance from a major terrorism attack would qualify for government compensation to the insurance company under the terms of TRIA. If the event caused an insured loss of greater than \$5 million and is “certified” as having been instigated by a foreign source, then 90% of the losses above a deductible level are repaid by the government. The deductible level is different for each company (a proportion of its premium income), and the proportion increases each year from 2003-2005. TRIA is currently enacted until the end of 2005.

The workers compensation losses here are the gross loss and do not include any government repayment from TRIA, which would reduce the losses to individual insurers. The recoverables from TRIA can only be calculated on a company-by-company basis, assessing the deductible level for that company based on its assessed total premium income. This has not been attempted here but analysis could include this for a particular company.

The truck bombing and the large anthrax attack, as described here, would both likely be certified as a foreign-instigated attack. Scenario 4, carried out by U.S. nationals without foreign assistance, would technically be classified as a non-certified event, in which case workers compensation insurers would not receive Federal compensation. However, the Secretary of State has powers of discretion in determining whether or not an event is certified, and it could be that a large event of this type was eventually determined as a certified event.

6.8 PROBABILISTIC MODELING OF TERRORISM LOSSES

Many different types and severities of attacks are possible for terrorism. The cities that could be struck, and the targets that might be selected are numerous, but those that would cause the most loss can be identified from analysis. The RMS® U.S. Terrorism Risk Model considers a range of attack modes and targets that represent the most likely ways terrorists would choose to attack the U.S. that would result in the most significant losses. The prioritization of these, based on which types of attacks the terrorists would choose, and which targets they might select, depend on a number of factors that can change over time. For example, the targeting strategy of Al Qaeda has shifted over the past few years from military and political targets to commercial and mass casualty targets. Likely attack modes can change with evidence that Al Qaeda has acquired new capability or with security measures that make aircraft hijacking less likely.

6.8.1 2004 Risk Outlook

The probability of an attack occurring is also something that changes dynamically, as terrorist groups change

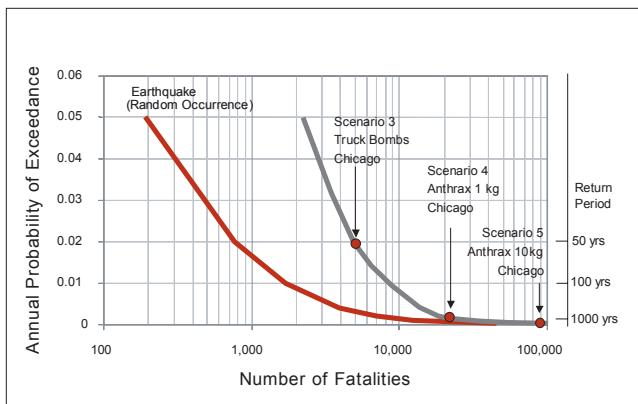


Figure 6.6 Exceedance probability for fatalities resulting from a terrorist attack in the U.S.

Annual Probability	Return Period	Fatalities	Total Casualties
0.01	100	8,400	133,000
0.004	250	14,000	259,000
0.002	500	19,000	360,000
0.001	1,000	34,000	520,000
0.0002	5,000	115,000	1,748,000
Average Annual		500	9,500

Table 6.1 Probability of number of deaths and total casualties resulting from terrorist attacks in the U.S.

their capabilities or counter-terrorist operations disrupt their activities and capture their operatives. RMS reassesses the capabilities and likely attack preferences of terrorist groups each year, using data on past attacks and observed trends. Some of the world's leading authorities on Islamic terrorist groups, terrorism academics, security specialists, and intelligence consultants provide RMS with input to calibrate the probabilities of the U.S. Terrorism Risk Model.

6.8.2 Casualty Return Periods

Loss return periods for death and total casualties from terrorism in the U.S. is given in table 6.1 and shown in figure 6.6.

The probability of experiencing a certain number of deaths from terrorist events shows that an event exceeding 3,000 fatalities, the official number killed in the September 11 attacks, could recur with a probability of about 3.4% (equivalent to a 30-year return period). This is in contrast to the scale of destruction of physical property that occurred in the September 11 attack, which the terrorism model assesses as approximately a 300-year return period (i.e. terrorist strikes are more likely to succeed in killing large numbers of people than to cause extreme amounts of property damage).

The scenarios selected have the following probabilities of exceedance:

- Scenario 3: Triple Truck Bombing, Chicago, 5,000 fatalities, return period 50 years, probability 2%
- Scenario 4: Anthrax Attack, Chicago, 25,000 fatalities, return period 700 years, probability 0.14%
- Scenario 5: Major Anthrax Attack, Chicago, 100,000 fatalities, return period 5,000 years, probability 0.02%

The probabilities of the most severe events are very low, but remain within the concerns of most insurers.

Annual Probability	Return Period	Group Life	Individual Life	AD&D	Workers Comp	Health
0.05	20	\$300	\$200	\$200	\$1,600	\$20
0.02	50	\$700	\$400	\$400	\$3,200	\$30
0.01	100	\$1,200	\$700	\$600	\$5,200	\$60
0.004	250	\$2,200	\$1,100	\$1,100	\$8,500	\$280
0.002	500	\$2,800	\$1,500	\$1,500	\$12,000	\$880
0.001	1,000	\$3,800	\$2,200	\$2,000	\$23,400	\$1,880
0.0002	5,000	\$14,100	\$8,300	\$8,200	\$76,300	\$6,130
Average Annual (\$Millions)		\$67	\$37	\$36	\$333	\$10

Table 6.2 Losses to different lines of insurance coverage from terrorist attacks

The other area of considerable concern is that the tail of the AEP curve is very long—events of several hundreds of thousands of fatalities are at the extremes of the AEP curve.

Relative to earthquake risk, the chances of large numbers of deaths and injury are much higher for terrorism. The 100-year return period event for an earthquake is 1,600 fatalities, but for terrorism it is more than 8,000 fatalities. This is the result of an earthquake being a random process, whereas a terrorist attack is one that is targeted and intentional.

6.9 LOSSES BY INSURANCE COVERAGE

The largest risk from terrorism is posed to workers compensation insurance coverages. The targeting of workers in city centers is reflected in the differential loads borne by these coverages for the victims. Compensation payments are many times larger for workers compensation than for health coverage.

Health risk is lower than workers compensation because terrorist targeting is focused on combining high casualties with a high economic impact. Losses from these are mainly from workers compensation and only those who are not covered by workers compensation (tourists, residents living in the city center, and other non-working people) incur costs to their health insurance. The losses to health coverages tend to mainly be driven by the large attacks that go beyond city centers to affect residential areas. These tend to be the larger magnitude attacks of lower probability, so the losses increase more rapidly at the longer return periods.

The high ratio of death to injuries seen in some of the larger events also increases the losses significantly at the longer return periods for the life insurance lines.

7 INDUSTRIAL ACCIDENT

An average of 5,000-6,000 work-related fatalities occur each year in the U.S. While the occupational mortality rate for ages 25-64 has declined by 57% since 1912, this remains a far lower reduction than in other areas of public safety, such as hurricane casualties or aircraft accidents. Mining and oil/gas extraction are the most dangerous industries, with the highest fatality rates per worker. It is in these same industries where the greatest potential for major incidents exists.

Explosions, transportation accidents, and chemical releases all pose a threat to people living, working, or traveling in the vicinity of the accident.

7.1 ACCIDENTAL EXPLOSIONS

When accidental explosions occur, either in an industrial setting or in the detonation of transported goods, the explosive yields can devastate very large areas, and have the potential to injure many people. A catastrophic industrial explosion occurs somewhere in the world every few years, as in 2001 at the Toulouse AZF fertilizer plant in France and 2003 at the LNG compression plant in Skikda, Algeria. Both of these explosions caused devastation to houses, schools, and other industries at more than a mile around the accident site, and blew out windows as far as 3 miles (5 km) away.

In the U.S. some of the largest historical accidents have been explosions of material and munitions in transit. On April 16, 1947 the S.S. Grandcamp, carrying ammonium nitrate fertilizer, exploded in the Texas City harbor. The explosion destroyed parts of the port, created a 15-foot (5-meter) tidal wave and was felt 75 miles (121 km) away in Port Arthur. A 1-ton turbine caught in the blast was thrown three quarters of a mile (1.2 km). The explosion brought down two small aircraft circling overhead and set fire to a second ship berthed nearby, which also exploded. The disaster killed 576 and injured several thousand people. The S.S. Grandcamp incident still counts as the most lethal industrial accident in the U.S.

7.2 TOXIC AGENT RELEASE

However, the most devastating of all industrial accidents, and those with the potential to injure the most people, involve the release of toxic agents, causing casualties well beyond the perimeter fence of the facility that houses



Figure 7.1 Hazardous Materials crews are specially equipped to tackle industrial accidents (Image: Associated Press)

them. Worldwide, the most deadly industrial accident on record occurred in Bhopal, India on December 2, 1984 when more than 3,000 people were killed and 500,000 injured by a toxic cloud of methyl isocyanate that leaked from holding tanks in a Union Carbide plant and rolled into a highly populated shantytown in the valley below.

Many industrial facilities store chemicals on site that would be toxic if released into the atmosphere. The list of officially classified “hazardous materials” (HAZMAT) is long, but some of the more common ones are sulfuric acid, ammonia, hydrochloric acid, chlorine, trichloroethane, and phosphoric acid. The toxicity, density, and other properties vary by chemical type. The effects would differ depending on how each chemical spreads once it is released into the atmosphere and how it affects the people that come into contact with it. Scenario 6 uses the example of chlorine to illustrate the potential lethality of HAZMAT releases.

The Environmental Protection Agency (EPA) maintains a record of U.S. facilities containing hazardous materials (the HAZMAT Register). This register contains several hundreds of thousands of facilities, 300 of which are plants that have a million or more people living within 10 miles (16 km) of them, and many others located in the industrial belts fringed around the major cities.

The scale of potential casualties from events like these is often not recognized. The amount of chemical agent being stored or transported can, if released, affect very large areas with lethal and debilitating concentrations of chemicals.

7.3 PRECEDENTS

Toxic releases endangering human life occur in the U.S. every few years. Most of them are relatively small and cause few deaths. Sometimes larger volumes of toxic substances are accidentally released, but the population nearby is low or rapidly evacuated. Examples like this include the accidental release of chlorine gas from the Honeywell chemical plant in Baton Rouge, Louisiana on July 20, 2003. Four people were hospitalized in that event, but casualties were reduced by the swift evacuation of the population in the vicinity.

Larger spills give clues to what might occur in a populated area. In 1996, a train derailed in a sparsely populated stretch of line near Alberton, Montana. Tanker cars ruptured, venting at least 17,000 gallons (64,000 liters) of chlorine as a dangerous plume of gas, although some reports estimate up to 100,000 gallons (378,000 liters) were lost. This plume was mainly directed across the Clark Fork River. Fortunately, there was not a major town in the vicinity, but 352 people were hospitalized and one person died.

7.3.1 Higher Safety But More Activity

Industrial safety measures, improved engineering design, and legislative standards have made manufacturing and processing plants much safer over the years. Accident frequencies per plant are much lower than several decades ago. But at the same time, as the safety has improved, the number of industrial facilities around our cities have proliferated.

Accidents occurring while hazardous materials are being transported by road, rail, or seas are one of the most likely causes of an explosion or toxic release. General transportation and rail safety has improved, for example rail safety accidents per million train miles has decreased by over 10% since the 1990s.¹ However, the volumes of hazardous materials being transported is generally increasing.

7.4 PUBLIC SAFETY DEBATE

The safety of HAZMAT plants and the transportation of hazardous materials has been the topic of political debate since September 11, when the idea that terrorists could

cause massive casualties through an intentional toxic release became a real possibility. The degree of regulation of safety standards by the EPA is still being discussed and various attempts have been made to introduce legislation to reroute shipments and improve the safety of communities. Rail companies argue that the routes they use are the safest, with the highest quality track and quickest routing, and that rerouting shipments on detours around cities would make accidents more likely.

7.4.1 Nuclear Waste Transportation

Policymakers are disturbed by the possibility of transportation accidents causing a release of radioactive waste. Used nuclear fuel is transported to reprocessing and storage sites around the country. About 100 cross-country shipments per year are currently made. With new storage sites, this is planned to increase substantially to 580 (rail) or 2,870 (truck) shipments.² Trucks typically carry about 0.5-1 tons of material at a time, and rail shipments average about 10 tons. The steel and lead casks that carry the radioactive waste are designed to withstand strong impacts and high temperatures, but some accidents could exceed the design strengths of the containers. In July 2001 a train derailed and caught fire in the Baltimore rail tunnel, used as a route for nuclear waste shipments. Although there was no shipment of nuclear waste in the tunnel at the time, the duration and temperatures reached would have breached the casks.³ Accidents from nuclear shipments are controversial and



Figure 7.2 A train derailment in Chicago in 2003 illustrates the potential for hazardous accidents in the busiest rail hub in the U.S. (Image: Associated Press)

¹ Federal Railroad Administration, Office of Safety Analysis.

² Testimony of Robert J. Halstead, transportation advisor, Nevada Agency for Nuclear Projects, to Senate Committee hearing on proposed Yucca Mountain nuclear waste repository, Nevada, May 22, 2002.

views differ about likely effects. The Department of Energy's "worst case scenario" estimates 80 deaths from a year's exposure to radiation from a severe rail accident, and the state of Nevada estimates up to 2,900 latent cancer fatalities from a similar train wreck scenario.⁴

7.4.2 HAZMAT Shipment Routing

There are a number of locations identified by various communities protesting the shipments of hazardous materials through populated areas. Washington, D.C. is debating the banning of shipments of hazardous materials. As many as 4,000 HAZMAT rail cars pass within sight of the Capitol each year.⁵ Shipments of hazardous materials through the city are routinely suspended during VIP events, such as the gathering of Congress for the State of the Union address.

Baltimore, the scene of the 2001 train tunnel disaster, has been running an action campaign to ban hazardous waste shipments through its most populated areas.⁶

Chicago is another city debating the ban of chemical shipments through its center. Chicago is a major nexus for national rail and road transportation. Over 500 freight and 700 commuter trains travel each day through its rail network, making it the largest internodal hub in the U.S. Worldwide it is surpassed only by Hong Kong and Singapore. One-third of all transnational freight shipments also pass through Chicago. Certain sections of the railway network in Chicago have been the subject of local protests for years. One section known as the St. Charles Airline, is used for HAZMAT routing and runs through the downtown area and under McCormick Place, one of the largest convention and expo centers in the world. Another major section of line, the Union Street Interlocking is the location for the rail accident that causes a HAZMAT release in scenario 6.

7.4.3 Chlorine Cl₂

Chlorine is one of many industrial agents that are harmful, yet used extensively in processing and transported in bulk. Chlorine gas is so deadly that it was used as a chemical weapon in the trenches of World War I. Yet chemicals like chlorine are essential to modern life and supplies are needed in every city. Chlorine is used as a key disinfectant for the water supply in cities, and is com-

monly used in cleaning and bleaching agents, for paper production, and to manufacture plastic products. Chlorine ranks eighth in terms of the quantities of chemicals manufactured in the U.S., and is transported across the nation in more than 100,000 shipments each year.⁷ Chlorine shipments probably have no more or fewer accidents than other hazardous materials per mile of transportation, but a number of recent accidents have highlighted the danger chlorine poses when released near populated areas.

Scenario 6, described in detail on the following pages, uses chlorine to explore the impact of a major hazardous chemical release in the center of a large city.

7.5 DISCUSSION OF RESULTS

The chlorine spill scenario results in 42,600 total casualties, over 10,000 of which are fatal. Insurance claims covering these casualties would exceed \$7 billion. An accident of this magnitude would be unprecedented in U.S. history. Yet, the analysis shows that in an accidental release of chlorine on this scale, and under these credible conditions, the gas cloud would affect a dense population living and working nearby. The probability of a major accident occurring in a city center is low, but as past events and current political campaigns show, it is not impossible.

7.5.1 Similar Chlorine Scenario Studies

Similar studies of potential HAZMAT releases concur with this scale of disaster from chlorine leaks. The scenario of a major chlorine leak caused by a terrorist attack on a rail car passing through Washington, D.C. could produce a chlorine cloud covering a 14-mile (23-km) radius that would encompass the White House, the Capitol, and the Supreme Court, endangering nearly 2.5 million people, and killing 100 people per second.⁸ A study in the Groningen province of the Netherlands indicated that if an area of about 0.2 square miles (0.5 square km) was exposed to chlorine for 45 minutes it would cause 5,000 deaths and 17,800 other casualties.⁹

7.5.2 Who Pays for What?

This event occurs at a time when many people are on their way to work. The commuters caught in the accident

³ Report on the Baltimore Tunnel Fire, by Radioactive Waste Management Associates, commissioned by Nevada's Agency for Nuclear Projects.

⁴ Resnikoff, et al 2001. "Worst Case Credible Nuclear Transportation Accidents: Analysis for Urban and Rural Nevada."

⁵ Gallagher, J. February 23, 2004. "Hazardous Proposals." *Traffic World Magazine*.

⁶ A Greenpeace USA campaign has demonstrated that the fire in the rail tunnel that burned for three days released poisonous dioxins from the HAZMAT shipment.

⁷ Department of Transportation, 2003.

⁸ Scenario drawn from a Naval Research Laboratory study, cited by "Hazardous Proposals," *Traffic World Magazine*, February 23, 2004.

⁹ Study carried out by the Groningen Communities, *Hulpverleningsdienst Groningen*, <http://www.groenengeel.nl>.

are treated under their health insurance; since they have not reached their workplace, they are not covered under workers compensation policies. About half of all employees are estimated to be at work by 8:00 am, so these people are covered by their employer's workers compensation insurance.

In addition to the fatalities, there are many serious injuries. People that suffered lung damage are incapacitated for long periods of time. While most of the injured are eventually able to go back to work, there are people that will be disabled for the rest of their lives.

7.6 BIGGER EVENTS ARE POSSIBLE

This scenario used Chicago to illustrate how an industrial accident of this magnitude could cause human injury and insured losses on this scale. Chicago was chosen because it is a good example of a city with heavy commercial freight and hazardous materials traffic passing close to population centers and business areas. In reality, there are many cities with industrial facilities close to population centers and transportation routes that pass through city centers. A similar scenario could occur in any one of them.

This event could have been a lot less disastrous. If the tank was partially ruptured or not full of chlorine a smaller quantity would have been released. A wind blowing east could have blown the chlorine cloud relatively harmlessly out into Lake Michigan, or the spill could have occurred at midnight when fewer people were working or traveling in the vicinity. As well, it could have happened in warmer weather, evaporating the chlorine more quickly.

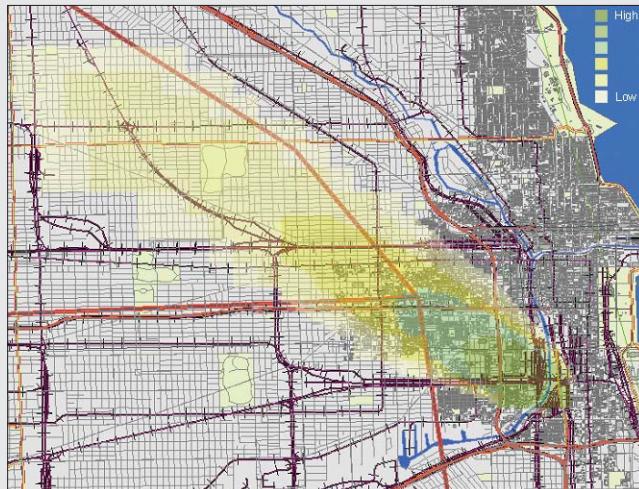
It also could have been worse. More than one tanker could have ruptured and multiple volumes of chlorine could have been released. More people would have been in the vicinity and in their offices if it had happened at 10:00 am. A wind blowing due north could have affected more of the city. A disorderly or panicked evacuation could have compounded the injuries.

As several studies have pointed out, there remains the possibility that this kind of event could occur not as the result of an accident, but deliberately targeted in a terrorist attack. The previous chapter of this report has explored terrorism risk, and these types of industrial sabotage scenarios are included within the probabilistic loss assessment.

HYPOTHETICAL SCENARIO 6: INDUSTRIAL ACCIDENT AND CHLORINE

Train Crash Causes Deadly Chlorine Cloud in City Center

Many thousands are feared dead from the 90-ton spill of chlorine during an early morning commute



Hazard levels for chlorine spill in Chicago

The thirty miles through the center of Chicago is the slowest leg of the monthly freight train from west Michigan to Minnesota. Industrial freight gets the night transit slots and is subject to constant checks and speed limits. Among the 40 cars carrying industrial raw materials are four tankers of chlorine destined for water treatment plants in Minneapolis. It is 6:30 am on Monday, snowing, and the train is already three hours late, delayed from coupling problems in Chicago's southern approach. The conductor hurries to get across the city before dawn. At 7:20 am he reaches the Union Street Interlocking, crossing 14 rail tracks. Visibility is poor in the snow. Without warning the train drags to a halt. Several rear cars have derailed, deflecting onto adjacent rails.

Worst Accident in U.S. History

The commuters on the 7:30 am METRA train from Chicago's western suburbs into Union Station have no warning. The impact as they hit the derailed cars is sudden and vicious. They are thrown the length of the train car. The derailed train ploughs into the tanker cars containing 90 tons of pressurized liquid chlorine, splitting one of them open and damaging a second one. A jet of



A June 2000 hazardous gas leak (nitric acid) in Chicago illustrates the potential for large accidents (Image: Associated Press)

chlorine gas explodes out through the rupture. It takes fifteen minutes for the tanker to empty. The sub-zero temperatures outside are 34 degrees warmer than chlorine's boiling point. A plume of yellow-green gas reaches 50 feet (15 meters) into the air. The billowing cloud fills the railway tracks. Three commuter trains are halted on the approaching tracks to the accident, each crowded with more than 400 people on board. Within minutes the trains are full of the lethal gas.

The Chicago rail junction is controlled from a huge communications center 750 miles (1,200 km) away in Fort Worth, Texas. Controllers have raised an incident alert, halted trains, and are performing an emergency assessment from an array of displays and instrument panels. Trains are being reversed out of the area. Emergency services are rushing to the scene.

A gentle wind carries snow and the chlorine northwest. In a major parcel dispatch center about half a mile from the crash, nearly half of the 1,200 strong workforce has arrived when the gas cloud, denser than 1,000 parts per million, envelops the building. Hundreds of workers choke to death in minutes as the dense chlorine pours in through the air heating system. Others suffer permanent

lung damage and skin burns. In a nine-story office building nearby, the chlorine fills the bottom two floors, killing many occupants, but workers who manage to get up above the third floor survive.

The cloud reaches a university campus 2 miles (3 km) from the site. By now it is less dense, around 200 parts per million. Students in their beds convulse with pulmonary edema – their lungs fill up with fluid. TV news channels are providing continuous coverage of the disaster, and broadcasting the pleas from Chicago city authorities for people to not commute into the city. The roads in the southwest of the city become choked with cars as people evacuate from the affected areas. Emergency crews in breathing apparatuses battle their way through the crowds to reach the disaster site. Officials move through the traffic jams encouraging people to pull their cars over and walk. Air conditioning systems in the cars provide no protection against the chlorine fumes. The cold weather keeps the chlorine in the air for several hours.

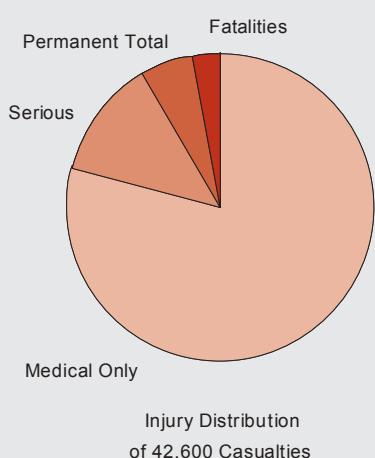
City Faces Long Clean-up After Chlorine Disaster

The acrid stench of chlorine in the air affects half the city. Many people are coughing and exhibiting serious breathing difficulties as they evacuate the area. Medical teams are treating thousands of people with respiratory problems, streaming eyes, and nasal or tracheal inflammation. Air quality monitoring shows that chlorine levels have stopped rising but the cloud still covers 10 square miles (16 square km). By mid afternoon, much of the chlorine gas has evaporated in the afternoon warmth and has been dissipated by breezes. More emergency teams are sent in to the disaster area to retrieve bodies and to search for survivors.

The city authorities seal off the emergency area for more than a week. People begin to return to their homes, but many complain of lingering chlorine smells and leave again to stay outside the city.

	Fatalities	Total No. of Casualties	Total Industry Loss (Millions)
All Population	10,200	42,600	
Population with Group Life Coverage	6,700	6,700	\$580
Population with Individual Life Coverage	4,500	4,500	\$592
Population with AD&D Coverage	3,000	4,400	\$232
Population with Workers Compensation Coverage	5,600	22,300	\$4,533
Population with Health Coverage*	3,400	14,900	\$1,148
Population with No Health Coverage	1,200	5,200	
			\$7,085

* Health coverage if not covered by workers compensation



8 INFECTIOUS DISEASE

Apart from the scenarios already considered, there are other potential causes of excess mortality and sickness. Illnesses that infected large numbers of people in the past have now largely been mitigated by modern medicine and public hygiene. However, there remain occasional modern diseases that defy our medical defenses.

The assumption that infectious diseases have been completely conquered by antibiotics and vaccines has been criticized by healthcare professionals, and virus experts have warned that the growth of world population, rapid international travel, and the development of drug-resistant microbes and pesticide-resistant insects make a worldwide spread of infectious disease more likely.

8.1 NOVEL DISEASES

8.1.1 AIDS

In the 1980s, a new disease became recognized after sudden increases in a rare cancer were discovered in otherwise healthy men. Acquired immunodeficiency syndrome (AIDS) soon became recognized as a killer, and was traced to the human immunodeficiency virus (HIV). Transmission of the virus through sex, communal drug use, and blood transfusion led to rapid increases of AIDS cases. The quick spread of the disease in many communities caught people by surprise, and nobody could have

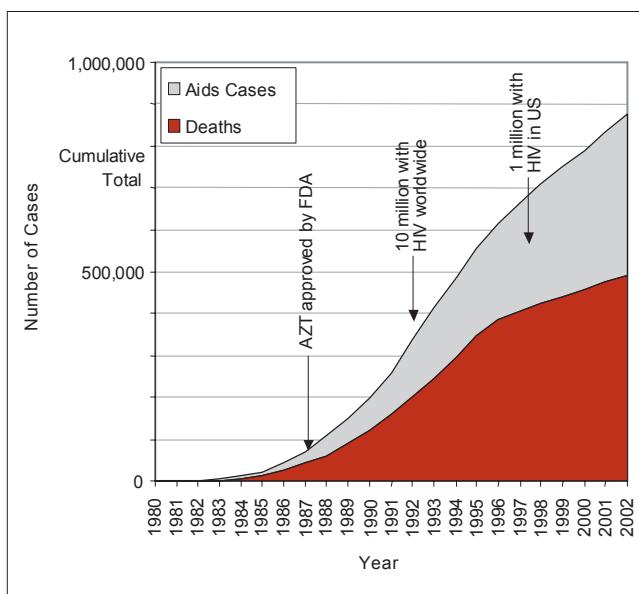


Figure 8.1 The rapid increase of AIDS cases showed how a new disease could spread through modern populations¹

known how extensive it was to become. The 1985 public health campaign recognized that there was a huge hidden case load, but predicted that 150,000 Americans were infected with AIDS, a considerable underestimate. The development of new drugs and lifestyle changes finally brought the disease and related deaths under a more manageable proportion. New AIDS cases began to decline in 1994 and deaths began declining two years later.

8.1.2 SARS

In 2003, an outbreak of another previously unknown disease spread around the world with alarming speed. SARS is a respiratory illness caused by a new type of coronavirus, for which there is no consistently effective medical treatment. It first appeared in China in 2002 and in an outbreak the following year over 8,000 people worldwide became sick with SARS, of which nearly 800 died. Its effects on the U.S. were limited—there were 156 reported cases. However, the speed at which the cases appeared in across Asia, and surfaced in other parts of the world, caused a global crisis. The ease of transmission (droplets spread through coughs and sneezes) and the mobility of the carriers, many of whom flew internationally and caused new outbreaks in the cities they visited, raised alarms about international disease spread. Treatments for SARS are in development, such as an antiviral drug treatment for hepatitis C which may reduce infectiousness, and studies are improving the understanding of the origin of this rare virus and its interaction with other conditions.

8.1.3 Virus Mutation

Virus mutation is a major cause of potential new diseases or strains of disease that are immune to standard treatments. Viruses with high mutation rates include HIV, influenza, hepatitis C, and polio. Mutation processes and rates of mutation are the subject of extensive medical research. By looking at mutagens that boost the mutation rates, scientists can find ways of combating the disease. The process of virus mutation may include jumping animal species, causing a greater threat to humans due to the increased degree of contagion and lethality.

¹ Centers for Disease Control and Prevention, Department of Health and Human Services. United States HIV and AIDS Statistics by Year.

The chances of a major outbreak or a resistant strain of a disease of a disease may be of concern to the life and health insurance industry. The quantification of this risk is in its infancy, but studies are progressing to understand the scale of this threat. Stochastic models of branching processes can simulate outbreaks such as the experience of SARS in 2003, and model hypothetical epidemics arising from a more contagious mutation of the coronavirus.

This chapter examines the threat to the insurance industry from new strains of disease by looking at an influenza scenario.

8.2 INFLUENZA

Influenza causes a notable source of variability in the annual mortality rate of the U.S. population. The main complication from the influenza virus is pneumonia, which accounts for a sizable portion of influenza deaths. Secondary bacterial pneumonia associated with influenza is most common among the chronically ill, who are more susceptible to complications. Occasionally, flu rates can reach pandemic proportions.

8.2.1 Historical Pandemics

Influenza epidemics cause an average of 20,000 excess deaths annually in the U.S., which is only about 10% of the deaths from all forms of respiratory disease. However, the death toll in pandemics is far greater. There have been three pandemics in the last century, in 1918, 1957, and 1968. Of these, the most disastrous was the 1918 global pandemic, which was more lethal than World War I. Around 700,000 Americans died in the 1918 pandemic, which was 0.67% of the population at that time (105 million). By comparison, the U.S. death tolls from the 1957 and 1968 pandemics were about 70,000 and 40,000, approximately 0.04% and 0.02% of their respective populations. In scenario 7, the death toll of 200,000 people represents 0.07% of today's population, one tenth of the population in 1918, but greater than those of 1957 and 1968.

8.2.2 Antigenic Variation

Antigenic variation is the process by which an influenza virus mutates to evade the immune systems. Every few years there is an antigenic drift which causes influenza

epidemics. On average, every 25 years a more serious antigenic shift occurs involving an exchange of gene segments between human and avian viruses. In these cases, a significant proportion of protective antibody levels are absent, and a pandemic results. Epidemiological models can replicate general patterns of sickness and mortality.

The main reservoirs for antigenic variation are the vast flocks of birds in China, which are in close contact with large human populations. In June 2001, and again in May 2002, a total of 4 million chickens were destroyed in Hong Kong as a precaution against the global spread of a new strain of avian influenza. Beyond China, international surveillance is headed by the WHO, which has developed an Internet application linking the global network of influenza centers (FluNet). A major objective of FluNet is the selection of strains included each year in influenza vaccines.

8.2.3 Defining the Scenario

Historical records since 1889 have shown that the average time interval between pandemics is approximately 25 years. The severity index varies from one pandemic to another. It is known that about 30% of the American population succumbed to the 1918 pandemic, and that this is the highest severity index for any of the four pandemics since 1889. By ranking the four severity index values, the probability of the 1918 index being exceeded is approximately 25%. However, progressive immunity loss or a long elapsed time since the previous mild pandemic could exacerbate the severity of the next pandemic. With three decades having passed since the last pandemic, which was relatively mild, there is now a 25% probability of the severity index being somewhat higher than that of 1918. This would have an annual exceedance probability of $(1/25)*(1/4) = 1/100$.

The CDC has published estimates of the possible effects of an influenza pandemic in the U.S.² Assuming that 35% of Americans become clinically ill in the next pandemic, the CDC mortality modeling indicates that 200,000 deaths would result, 750 million people would be hospitalized, and 40 million would require outpatient care. Monte Carlo simulation provides a pessimistic 95% confidence value of almost 300,000 deaths and a million hospitalizations. By contrast, optimistic 5% confidence values are found to be approximately 125,000 deaths and half a million hospitalizations.

² Meltzer, M.I., Cox, N.J., and Fukuda, K. Centers for Disease Control and Prevention, Department of Health and Human Services, 2001. "The Economic Impact of Pandemic Influenza in the United States: Priorities for Intervention," *Emerging Infectious Diseases*, Vol. 5, No. 5.

HYPOTHETICAL SCENARIO 7: INFLUENZA PANDEMIC

National Flu Outbreak Impacts U.S. Economy

State of emergency declared as one third of the country suffers from a new strain of influenza



Current medical and treatment facilities are not prepared to handle massive volumes of flu patients, as experienced in the 1918 pandemic (Image: National Museum of Health and Medicine)

Over several years, cluster cases of a deadly new strain of flu, designated A(H5N1), have been reported in Southeast Asia. The avian flu strain is spread through contact with fowl, and is particularly deadly, claiming more than one-third of its victims, mostly children. There are no recorded cases of this strain of the flu being transferred from person-to-person contact. The transmission path is from inhaling particles from infected birds, mainly chickens. Public health measures to contain the disease include the slaughter of infected flocks.

No Vaccine Available for New Strain of Flu

During the month of December, four cases are identified in a hospital in Southeast Asia that appear different. These are traced back to an older man that died from a more common strain of flu—A(H1N1). Tests show that the man had both forms of flu and that he infected others with a new strain: a combination of a rare H-9 avian flu virus and genetic material of the human flu virus. This virus, designated A(H10N3) is passed from person-to-person. More flu cases of this strain are found a week later. It is evident that the new virus is infecting the population.



Make-shift treatment centers will likely be required to medicate and treat the high case load (Image: Getty Images)

As case loads grow, epidemiologists establish that the lethality of the new virus (the proportion of people who die from the infection) is close to the more usual strains of human flu at 0.5%. It is fortunate that the strain is not as lethal (30% mortality rate) as the avian strain A(H5N1).

In the U.S., the first cases of the new flu are recorded in Los Angeles in mid-January from travelers returning from Southeast Asia. They are placed in isolation wards. Mass vaccinations of conventional flu vaccines are administered but this has little effect on the overall spread—the A(H10N3) flu strain is resistant to the less expensive class of the anti-influenza virus, including amantadine and rimantadine. This resistance is apparently the result of a change in just one of the many amino acids in the influenza virus itself. Several research laboratories worldwide race to develop a new vaccine. New techniques are needed to prepare a seed virus, which is finally ready in late January. The seed virus is then used to prepare batches of vaccine for testing, which entails fast-track trials on animals and then on human volunteers. Finally, the new vaccine is ready for production and certified by the Federal Drug Administration (FDA)

in mid-April. Production of over 100 million doses will be delivered in phases over the next eight months. Vaccinating the U.S. population against the new flu is at least assured for next year's flu season, but will not be possible this winter. Isolation of flu cases slows its initial spread in the U.S. population. The rate at which people exhibit flu symptoms increases generally, first across the West coast, then in urban populations across the country.

One-third of the U.S. Workforce Affected by Flu

Families with children have high illness rates as the flu spreads through schools, then through work colleagues, and social mixing. Even healthy people find themselves suffering from fever, fatigue, aches, and nasal congestion. Most sufferers take 3-4 days off work, but some are off for two or more weeks. About 2% of sufferers develop complications like pneumonia, bronchitis, and sinus and ear infections. Hospitals are quickly overloaded with cases of bronchial infections and other flu-exacerbated

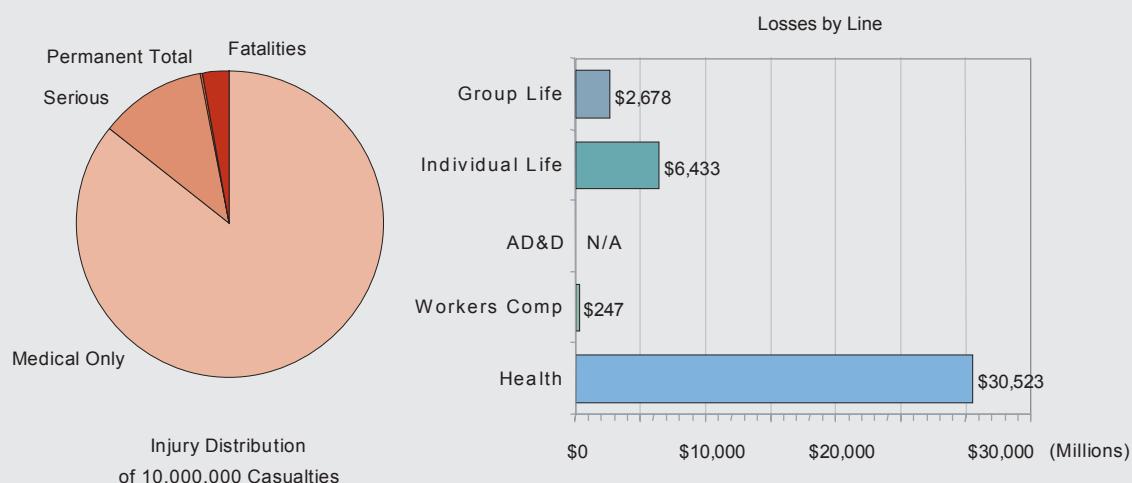
problems; many admitted to hospitals are elderly people and young children. Around one in every 200 flu victims develops complications from which they do not recover. The large majority of deaths are in patients who have a pre-existing medical condition made worse by the flu. Overall, about 35% of the U.S. population is struck by the flu during this winter season.

The pandemic runs its course over nearly four months, with caseloads peaking in late February and March and gradually trailing off into April and May. By June, flu cases have reduced significantly. In June, the new vaccine becomes available and is provided to high-risk groups. The crisis has prompted calls for increased funding of health expenditure, and political fall-out includes questions of free travel between countries with different standards of health care. Some bereaved victims try suing their spouse's employers for contracting the disease in the workplace.

	Fatalities	Total No. of Casualties	Total Industry Loss (Millions)
All Population	200,000	10,000,000	
Population with Group Life Coverage	69,300	69,300	\$2,678
Population with Individual Life Coverage	72,200	72,200	\$6,433
Population with AD&D Coverage*	N/A	N/A	N/A
Population with Workers Compensation Coverage	280	14,100	\$247
Population with Health Coverage**	140,100	7,152,700	\$30,523
Population with No Health Coverage	59,930	2,833,200	
			\$39,881

* Illness not covered by AD&D

** Health coverage if not covered by workers compensation



8.3 DISCUSSION

The ‘new flu’ just depicted is fictitious and strain A(H10N3) does not exist, but this scenario illustrates how a new strain could arise. The flu variant was chosen to illustrate one possible scenario for the way that mutations of a virus can occur and spread. Although the circumstances for the example are only illustrative, the outcome of a pandemic of this proportion in the U.S. and across the world is a very real concern to many health-care professionals. The CDC published estimates of 89,000 to 207,000 deaths and 20-47 million people infected from the next influenza pandemic in the U.S.³ The scenario is at the upper end but within the range of these estimates. The RMS scenario has fewer people (10 million) incurring physician costs compared to that of the CDC (18-42 million outpatient visits), although the healthcare losses are not very sensitive to the rates of minor illness.

This pandemic scenario would have considerable economic loss implications for the country as well as for insurers. Apart from the direct health costs, there is indirect economic loss resulting from the loss of productivity of those who fall ill. Many companies, faced with large numbers of their workforce out sick, would suspend operations for some period. The economic disruption caused by replacing those lost permanently to the workforce might add additional significant costs to the overall national economic loss.

8.3.1 Health Insurance Costs

Health insurers take the large majority of the insured losses from this scenario, paying \$30 billion of the \$41 billion total insured loss. Nearly \$13 billion of this comes from the large number of hospitalizations, expected to be between several days and three weeks, for an estimated 2.5 million people who will need special care and clinical tests. About \$8 billion is needed for the 200,000 people who become severely ill and develop pneumonia, bronchial injury, or other complications. The healthcare load is spread fairly uniformly geographically across the whole country, although there may be patches of localized severity. The scale of demand would place a severe strain on the current healthcare infrastructure and could

result in some patients not receiving the level of care they would otherwise receive. This could reduce the costs, but it could also increase costs by leading to more cases of severe illness for those who develop complications that were initially untreated. The heightened demand could also drive up losses through incurring higher costs of care in overtime, and additional personnel and equipment at a higher cost.

8.3.2 Life Insurance

Life insurers pay out an estimated \$9 billion in group and individual life claims in the scenario. Life policy losses might be hedged to some extent by gains on their annuity policies, especially if the pandemic takes a heavy toll on the elderly. As a fraction of average mortality, the annual increase in claims would be 8%. As a fraction of average hospitalization, the annual increase in health claims would be several percentage points. In this scenario it is assumed that AD&D policies do not cover illness, so no payouts are made.

8.3.3 Workers Compensation

To reflect current practice, this scenario assumes that workers compensation payments are not made to influenza victims. A few claims arise from nursing staff and healthcare workers that contract the flu while treating flu cases in their workplace. However, there could be significant losses under workers compensation insurance if employees were able to establish that they contracted the flu in their workplace or were clearly put at a higher risk because of specific circumstances related to their job.

The possibility of a claim is likely to vary depending on the wording of each state’s workers compensation statutes and case law. Some states rule that if a disease is general throughout the population, then workers compensation cannot be claimed. If a unique flu strain were responsible for the epidemic, as in this scenario, it might be possible to establish through tests and medical forensics that a victim caught it from a work colleague. In fatal cases it is more likely that compensation would be sought.

8.4 IT COULD HAVE BEEN WORSE...

This mutation of the influenza virus is assumed to have a mortality rate of 0.5%, close to the common strains of

³Meltzer et al. 2001, *ibid.*

human flu. It is possible that new mutations could have higher mortality rates. The nightmare scenario would be a vaccine-resistant mutation that spreads as easily as the common flu, but is as lethal as the avian flu strain with a mortality rate as high as 30%.

Infection rates could also be higher than this scenario. Although it has not been possible to produce a full probabilistic analysis for this scenario, an event that affects 35% of the population is estimated to have a 1% probability per year, or a 100-year return period. Lower probabilities (longer return periods) would give higher infection rates and higher losses to all lines of business.

There remains the possibility of other new diseases beyond influenza which are more contagious or for which there is currently no vaccine or treatment. The mutation of viruses to generate new diseases or new treatment-resistant strains remains a serious concern of

healthcare professionals. The nature of these potential novel diseases, the chances of them occurring and the likely impact on the population is the subject of continuing research.

8.5 MITIGATING THE RISK

Vaccination is an obvious mitigation measure for drastically reducing the pandemic risk. The current practice of vaccine production is too slow to respond to the emergence of an unfamiliar and unexpected virus. However, using a technique called reverse genetics, it may be possible to engineer the seed strain of a pandemic virus, and mass-produce it rapidly in mammalian cell cultures. The WHO is promoting clinical trials of a vaccine made using reverse genetics.

9 IMPACT OF DATA QUALITY

Insurance executives use the output of catastrophe models to support decisions that can have major financial implications for their business. Like all modeling, the quality of the output is only as good as the quality of the input data. The key input into catastrophe models is data about the exposure in an insurer's portfolio. The importance of the quality of this data cannot be underestimated, as the completeness, accuracy, and resolution of portfolio information has a direct impact on the magnitude of losses output by the model. While models have the ability to infer information to help compensate for missing data, these assumptions may not always provide the most accurate assessment of a company's risk.

Better quality data does not necessarily lead to lower modeled losses. However, it will result in more accurate model results for better decision making. This chapter identifies not only the key portfolio information needed, but also the benefits of capturing the appropriate data.

9.1 CATASTROPHIC EVENTS

It often takes a critical catastrophic event to prompt changes in practices for the insurance industry. For property insurers, the key events were Hurricane Andrew in 1992 (\$16.5 billion in insured loss¹) and the Northridge Earthquake in 1994 (\$12.5 billion in insured loss²). These and other large losses of the early 1990s forced many unprepared insurance companies and reinsurers out of business. Available capital reserves for large catastrophe losses were depleted and there were many changes in the industry, including a major consolidation, the arrival of new capital and the single line catastrophe reinsurer, exploration of alternative risk transfer mechanisms, and increasing emphasis on regulation, security, and rating.

9.1.1 The Need for Data

For property insurers, the ability to assess risk after these key benchmark events required significant reengineering of their data capture processes. Aggregated data by state or county was no longer adequate and more precise location information with construction and occupancy detail was required to analyze a company's exposures accurately. For some companies, the process of improving the quality of the data involved changing back-office systems and front-office data collection, and it took several years

to accomplish. Today, it is standard practice for property insurers to capture all important location information at a high level of resolution, and to manage and demonstrate capital adequacy through analytical models.

9.1.2 The World Trade Center Event

In 2001, the WTC attack resulted in more than \$40 billion³ of insured loss, and has caused many companies to reevaluate their practices of managing multi-line exposure, including workers compensation and other areas of potential human loss. Losses in many individual lines, particularly workers compensation, proved unprecedented. The potential impact of mass casualty events has registered with management, and many companies are looking for ways of assessing their risk from catastrophe loss to insurance lines such as life and health.

Workers compensation writers have embarked upon a similar process to improve the quality of the data they collect following the WTC event. Prior to September 11, the industry standard for data capture to fulfill regulatory reporting requirements was state aggregates by rating class. However, as many of the workers compensation insurers recognized the value of monitoring and managing catastrophe risk through the property side of their business, the process of improving data quality has been rapid, driven by senior management and reinsurers that have made data collection an important priority.

9.1.3 Assessing Life and Health Catastrophe Risk

If life and health insurance companies want to understand and manage their catastrophe risk, they will need to address the types of information they collect, and the resolution of that data.

The assessment of catastrophe risk requires understanding three main areas:

- How much is insured? It is important for a company to understand how much exposure (either number of people or limits) they have at risk. Understanding the level of exposure is the prerequisite for modeling. Exposure analysis should consider who is insured (how many, their occupations) and the coverage provided (limits, deductibles, and other financial information).
- Where are the insured people located? The magnitude of catastrophe risk varies dramatically with geographic

¹ In 1992 dollars, \$19.6 billion in 2001 inflation adjusted dollars.

² In 1994 dollars, \$14.9 billion in 2001 inflation adjusted dollars.

³ Insurance Information Institute estimate (September 6, 2002).

location. For a peril capable of destroying a building and its occupants, knowing which buildings you have insured personnel inside is important. Capturing an accurate street address for the company or individual will help identify where that exposure is located. As this report has illustrated, businesses that insure people face the additional problem that their insureds move, and they may need to capture both a work and home address to better understand their exposure.

- In what type of structure are the insureds located? The strength and resilience of the buildings that insureds occupy affects their risk. The characteristics of a structure affects its chances of collapsing in an earthquake or having its occupants injured in other types of events. Building type information such as construction material and height is useful to develop an accurate risk assessment.

While models are capable of capturing additional data fields, the information previously listed is the most important, and the potential impact of each is discussed below.

9.2 EXPOSURE INFORMATION

9.2.1 Market Share Information

A market share analysis can provide a useful assessment of the order of magnitude of a loss for a particular company from a particular scenario, by assuming that the loss for that company is proportional to its share of the industry exposure, premium, or other metric. By taking a company's market share region by region, or city by city, and assuming the appropriate proportion of the loss from each of the different events modeled in the RMS industry loss event set, a rough indication of the AEP of various levels of losses for that company can be obtained.

9.2.2 Locational Data

Better quality data will enable a more precise assessment of risk. A market share analysis can be misleading, because losses do not average out in the way a market share analysis assumes. A company that insures a large number of people in buildings that sustain casualties in an event will likely take a much higher proportion of losses than their market share would suggest.

A terrorist attack using conventional weapons, such as in the September 11 attack, results in concentrated

losses in an area of only a few urban blocks. Insurers that covered people in the affected buildings sustained very large losses and insurers that had no insureds in the affected buildings had minimal losses. A market share analysis of the industry average would be an inaccurate assessment for these types of insurance portfolios.

9.2.3 Geographic Resolution

Life and health insurers are challenged to improve the precision of locating the people they insure. Figure 9.1 illustrates the potential impact of address resolution using the example of terrorism risk assessment in Manhattan. In this example, risk has been assessed under three levels of resolution: county, ZIP Code and urban block. Averaging the threat of terrorism risk across a county masks the localized hotspots of risk. ZIP Code averaging is an improvement, but street addresses are needed for an insurer to know whether they have any exposure in the highest risk zones.

9.2.4 Company Addresses

It is common practice for companies to provide the address of their corporate headquarters in their insurance details and for insurers to log the address without a detailed schedule of employees at company branches. When insurers analyze their exposure, it will appear that all of the employees are located at a single location. This can materially distort the risk of loss for that company policy.

In this example, a company's headquarters are located in New York—an area of relatively low earthquake risk. However, they have a significant number of employees located in branch offices in San Francisco, Los Angeles,

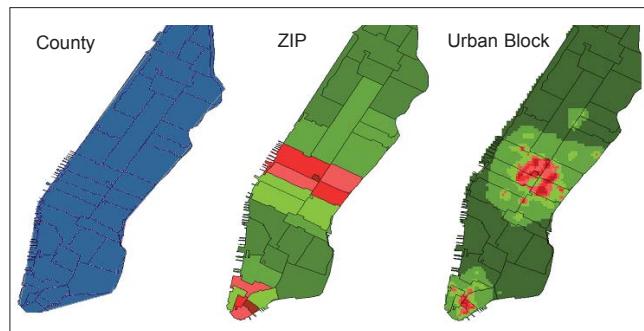


Figure 9.1 Differentiating a localized risk like terrorism using a coarse geographic resolution masks the specific hotspots of risk; street addresses are needed for an insurer to know whether they have any exposure in the highest risk zones

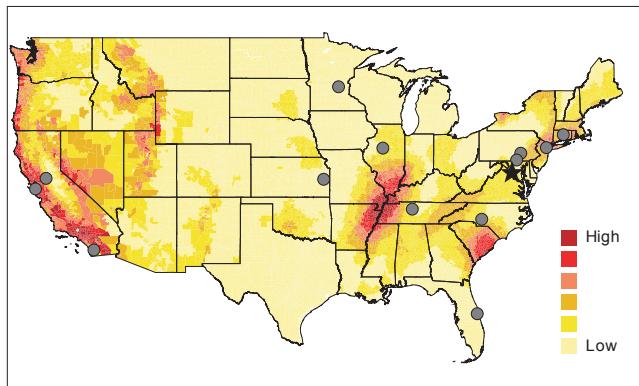


Figure 9.2 The risk of earthquake losses to a national company with its headquarters in New York would be underestimated if it declared all its employees at its New York address

and Seattle—areas of high seismic risk. This data coding leads to a material understating of the actual risk. Figure 9.2 quantifies the magnitude of the difference in modeled loss when the branch office employees are properly located—this single account is underestimated. For a book of business that contains many accounts, the total exposure of the insurer could be very different from the initial picture obtained when representing the total account exposure at the corporate headquarters. The only method of obtaining an accurate picture of an insurer's full exposure is to request schedules of employees by location from each of the major companies insured. Several large accounts often make up a high proportion of an insurer's total book, so prioritizing data collection for the largest accounts will make the biggest improvements in exposure accuracy.

9.2.5 Co-locational Exposure

In the aftermath of the WTC disaster, many insurance companies found that they had insured several tenants in the same physical structure that collapsed, even though each of the tenants had a different address. Buildings can have multiple valid addresses and insurers may not be aware that several accounts are located in the same building and at risk in the event of a single structure failure.

Counting the different shops on the lower floors, many skyscrapers can have more than 20 valid addresses. Street addresses are commonly duplicated with a well-known building, such as the Empire State Building, Sears Tower, and Transamerica Pyramid. Because of this, companies attempting to limit their exposure in any one building may be misled into exceeding their own limits by writing accounts at multiple addresses within the same building.

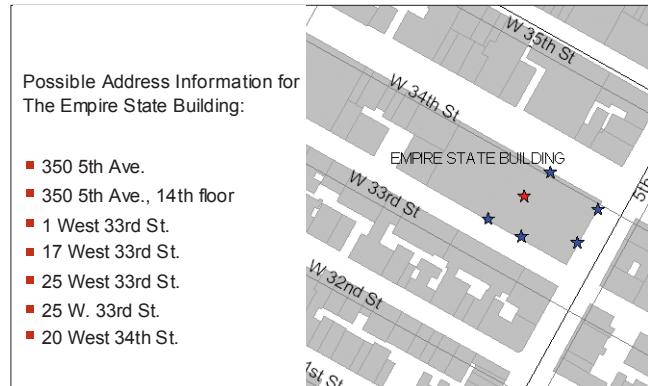


Figure 9.3 Businesses located in the Empire State Building in New York use many addresses—mapping all the addresses to one structure enables insurers identify their co-located risks

Insurers are increasingly running address checks to see if they map to buildings they already have exposure in. These insurers manage their exposure by a single building. RMS provides a unique building identification tag and multiple address-matching data for buildings in major urban centers to assist clients in managing their risk at a single building.

9.2.6 Building Characteristics

The number and severity of injuries in an earthquake or terrorist attack are affected by the likelihood and degree of building collapse at an insured location. The likelihood of building collapse is determined by the event severity combined with the construction type, number of stories and other data. Capturing data about the building where insureds are located will assist with risk assessment.

Different types of buildings cause different rates of injury and fatality when they collapse. Information about the building assists in assessing the risk of casualties.

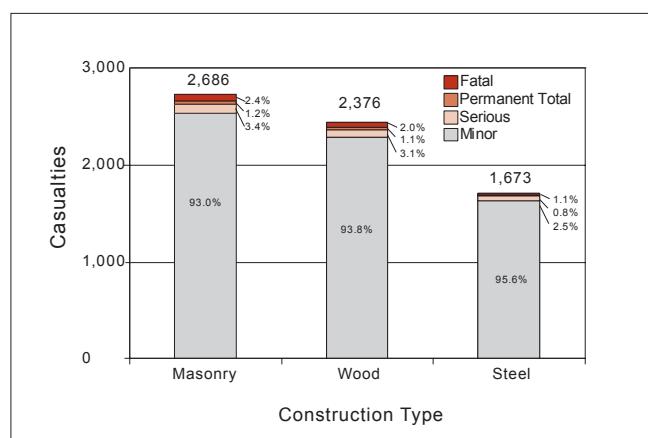


Figure 9.4 Effect of construction type from a 1-ton bomb detonated at a building containing 10,000 occupants

9.2.7 Building Occupancy

Life and health insurers face the complex task of managing the risk associated with mobile exposures. The type of business or the occupation of the insureds is an important piece of information. Different types of businesses vary in the typical patterns of occupancy of their employees. Figure 4.7 (chapter 4) showed the variation in occupying the premises for workers in different occupations.

Using typical occupancy patterns of this type, insurers can leverage the information they collect about the occupation of insureds to estimate their temporal exposure or the amount of time spent at a premises.

9.3 How Models Treat UNKNOWN DATA

Although a company may not have complete data, it is possible to estimate its risk using supplemental information to analyze the characteristics of that company's portfolio. To deal with the challenge of missing data, RMS builds "intelligent" assumptions into the model. These are inferences developed using industry averages to provide surrogate data for missing portfolio information. In many cases, these assumptions provide the best-available loss estimates, however they can be considerably improved with actual data.

Examples of ways the model can be used to augment coarse resolution data include:

- Work address: RMS has developed a database of the number of workers by occupancy type in each ZIP Code in the U.S. For exposure information aggregated by state or county, the model distributes the workers across ZIP Codes based on the overall industry distribution.
- Home address: RMS has built a database that approximates the commuting patterns of employees in a given ZIP Code. According to the work address or ZIP Code provided, the model distributes the employees to residential ZIP Codes based on the overall commuting distribution.
- Construction class: for urban areas believed to be at high risk of a terrorist attack, RMS has compiled a database of the exact location footprint of each building, all

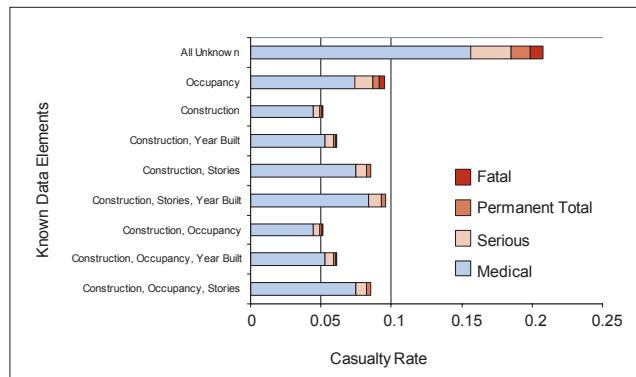


Figure 9.5 The effects on earthquake casualty rates for a sample building in San Francisco when modeling different combinations of known building characteristics

applicable addresses for the four-wall structure, construction type, and building height. For companies with incomplete construction class information, this database can be accessed and actual building characteristics can be used for a catastrophe analysis. For the rest of the U.S., a distribution of construction class by ZIP Code (or state for some areas) has been developed. Companies with incomplete data in these areas can apply an average vulnerability for construction that is the weighted average of each construction class present in that area.

- Occupancy class: RMS has compiled a database of how many workers fall into each of 10 general occupancy types in each ZIP Code in the U.S. If occupancy information is known, it is used to make a more informed assumption about unknown construction class information. For example, office workers are likely to be located in a high percentage of steel and reinforced concrete buildings, while heavy manufacturing is often located in warehouses made of brick, light metal, or tilt-up concrete.

Incomplete data can make a material impact on a company's understanding of risk. There is no perfect data, and it is inevitable that data will remain incomplete. However, assumptions based on industry averages rarely depict an accurate picture, as few if any companies closely match the industry average. Significant variations from industry averages can lead to material inaccuracies in risk assessment. Better quality data provides a more accurate assessment of the true risk.

10 MANAGING THE RISK

The events of September 11 have led the insurance industry to rethink catastrophe risk management. Despite the fact that losses were confined to several city blocks of New York, record levels of loss were incurred in virtually every line of business, highlighting several important lessons for the insurance industry:

- The geographically-focused nature of terrorism loss illustrates the need to understand the exact location of all insureds—as a result, insurance companies are taking a back-to-basics approach and collecting more complete portfolio information
- In extreme events, losses are highly correlated across lines of business—catastrophe risk must be managed across multiple lines simultaneously to properly manage risk for the total entity
- To avoid excessive concentration of exposure, underwriters must not only quantify the risk of a new account, but they must monitor the impact that it makes on the overall portfolio

These lessons have helped shape new risk management strategies. Rather than relying solely on probabilistic analyses, prudent risk managers now utilize multiple methods of risk quantification to triangulate on the magnitude and location of the risk. Specific analyses include:

- Multi-line exposure accumulation
- Deterministic loss modeling
- Probabilistic loss modeling

A discussion of each of these analyses and how companies are using the results to manage their risk is included below. This section focuses on terrorism risk management. Risk management for earthquake and other perils follow similar practices, but have a number of peril specific nuances. Contact RMS for a discussion of risk management for other perils.

10.1 MULTI-LINE EXPOSURE ACCUMULATION

The geographically-focused nature of potential mass casualty events highlights the need to identify and quantify any accumulations of exposure that could potentially lead to losses greater than the threshold set by management. The collection of detailed portfolio information for all lines of business potentially impacted the essential first step in performing exposure accumulation analyses.

10.1.1 Data Collection

In the previous chapter, the issue of data collection, address matching, and multiple addresses for individual buildings were described. Recommendations were made for collecting and managing improved portfolio data, ranging from more precise location determination to information about the buildings where policyholders spend their time.

10.1.2 Identifying Concentrations

After capturing a comprehensive set of portfolio exposure information, the next step is to identify and quantify any multi-line exposure concentrations. As part of this analysis process, three questions must be answered:

1. Where in the country do you search for exposure concentrations?
2. How large of an area do you use to quantify exposure accumulation areas?
3. At what point should an exposure accumulation area raise concerns?

It is valuable to know about all areas where multi-line exposure concentrations exist. However, extra attention should be paid to those exposure concentrations in areas of highest hazard, for example in highly seismic zones and around locations with a high likelihood of terrorist attack.

If, for example, a company identifies that its top two concentrations are in Omaha and Boise, and that its next three greatest concentrations are in midtown Manhattan, it probably makes sense to focus efforts on the concentrations in Manhattan due to the high risk of terrorist attack.

RMS recommends that companies perform a two-stage analysis of their exposure concentration. The first stage receives the greater attention and focuses primarily on high-risk targets of terrorist attack, such as those on the RMS target list. The second stage looks at all large concentrations in the company's portfolio and examines whether any of them might constitute a high risk, requiring further examination and possible monitoring.

10.1.3 Radius of Analysis

The question of how big an area in which to measure concentrations is answered through analysis of the ‘footprints’ of likely terrorist attack modes or other localized

perils. Conventional attack modes such as truck bombs or aircraft impacts can cause damage up to 1 mile (1.6 km) from the target, but over 90% of the damage typically occurs within the first 0.25 miles (0.5 kilometers). RMS recommends that exposure accumulations be performed through analysis of a 1,300 foot (400 meter) radius around chosen targets.

10.1.4 Managing Accumulation Limits

The level of exposure accumulation that raises concern is specific to each company, and should be addressed by senior management. A maximum threshold for multi-line exposures should be established by management and strictly adhered to by underwriters and portfolio managers. If exposure concentrations exceed management guidelines, an analysis of accounts driving the concentration should be made and addressed accordingly.

10.2 DETERMINISTIC LOSS MODELING

The second step of the risk management process is to look at modeled losses under one or more scenarios at key locations in the portfolio. For example, how much would the company lose on a multi-line basis if a truck bomb was detonated at a target like the Transamerica Pyramid in San Francisco?; or what losses would be suffered from a large magnitude earthquake in Los Angeles? This process requires management to select an event to serve as a benchmark, and to establish a loss threshold for multi-line losses in a single event.

10.2.1 Conventional Terrorist Attack

Terrorist attacks are severe events that usually target highly localized areas. Terrorists select from a myriad of possible attack modes, some of which are so severe that they could place the insurance industry in danger of insolvency (e.g. weapons of mass destruction). While these attacks are possible, the more likely events involve the use of conventional weapons such as truck bombs, and make a better choice for use as a benchmark event around which risk is managed. A 2-ton truck bomb, similar to the bomb detonated in Oklahoma City, is a weapon that terrorists are likely to build and deploy, and highly desirable from the terrorist's standpoint for its high damage potential, making this a good benchmark event for analysis.

10.2.2 Loss Limits

Selection of a threshold for each company under the benchmark scenario (the level which modeled multi-line losses should never exceed) is a management decision, which will depend on a variety of factors including surplus level, risk appetite, rating agency, and regulatory requirements. In terms of where the benchmark scenario should be modeled, the same process can be followed as with the exposure accumulation analyses. Foremost priority should be given to analyzing multi-line losses for attacks modeled at a list of high-risk targets. Secondary consideration should be given to all other possible locations to at least identify other, although less likely, large loss scenarios.

If benchmark scenario losses exceed management set thresholds, analyses should be performed to identify the account(s) and line(s) of business driving the losses. Appropriate remedies such as facultative reinsurance, non-renewal, or change of attachment point can also be determined.

10.3 PROBABILISTIC LOSS MODELING

The third step of the risk management process is to look at modeled losses on a probabilistic basis. This entails modeling a spectrum of potential events against the company's portfolio, and looking at the loss and associated probability of each event occurring to define a loss distribution or AEP. The RMS® U.S. Terrorism Risk Model, for example, models 32 attack modes ranging from conventional weapons to weapons of mass destruction at approximately 3,400 targets at high risk of terrorist attack. Altogether the attack modes and targets define 78,000 unique terrorist attacks. The output of the probabilistic model includes the modeled loss amount for each event, along with an associated probability of the event occurring.

10.3.1 An Evolving Risk

There is a great deal of uncertainty associated with modeling terrorism risk on a probabilistic basis. Insurance policies are typically enforced for one year or more. Terrorism is a constantly evolving threat with risk changing over the life of the policy. Therefore it is prudent to

analyze alternative risk outlooks to assess how the threat level might change over the course of the next 12 months. RMS regularly monitors the terrorism threat level and includes an expected risk outlook and a 12-month view on a possible increased or decreased threat level in the terrorism risk model. This allows companies to view portfolio risk under a range of scenarios.

10.3.2 AEP Output

Developing an AEP distribution allows a company to analyze risk and answer important questions including:

- From a macro-level, what is driving portfolio risk?

By looking at AAL from a variety of perspectives, information can be learned about the portfolio risk. Examples include AAL by line of business to determine which line drives risk, AAL by city to discover the region driving risk, AAL by attack type to highlight the benefit of possible coverage exclusions (i.e. CBRN exclusions), and AAL by target type to ascertain targets around which the company might want to consider limiting future writings.

- From a micro-level, what is driving portfolio risk?

Looking at AAL by account is possibly the most telling driver of portfolio risk. It is not uncommon for a handful of accounts to drive more than 50% of a company's catastrophe risk. Identification of these accounts may provide a road map for a company to reduce risk to an acceptable level.

- What is the most effective risk transfer option?

Using an AEP loss distribution, different reinsurance

treaty options can be evaluated. The amount of risk transferred can be weighed against the price to determine the most effective option.

10.4 PULLING IT ALL TOGETHER

Due to the human element, there is greater uncertainty in modeling terrorism risk than in modeling the risk of natural perils, such as earthquakes, where the models are based purely on scientific research. Instead of relying solely on probabilistic modeling, as is typically the case with natural perils, prudent risk managers will use the three different risk management methods described in this report to triangulate terrorism risk. The current best practices for managing terrorism risk within the insurance industry include bringing multi-line exposure concentrations to a manageable level, maintaining benchmark scenario losses below management-prescribed thresholds, using AEP loss distributions to analyze key drivers of loss, and making informed risk transfer decisions.

However, companies shouldn't stop with managing terrorism risk. The life and health insurance market faces risk from other types of catastrophes such as earthquakes and industrial explosions. To get a true picture of the catastrophe risk a company faces, these risks cannot be viewed in silos. An overall corporate view of catastrophe risk is one in which AEPs are combined for each line written and for each peril faced. Only then can the risk be fully understood and effectively managed.

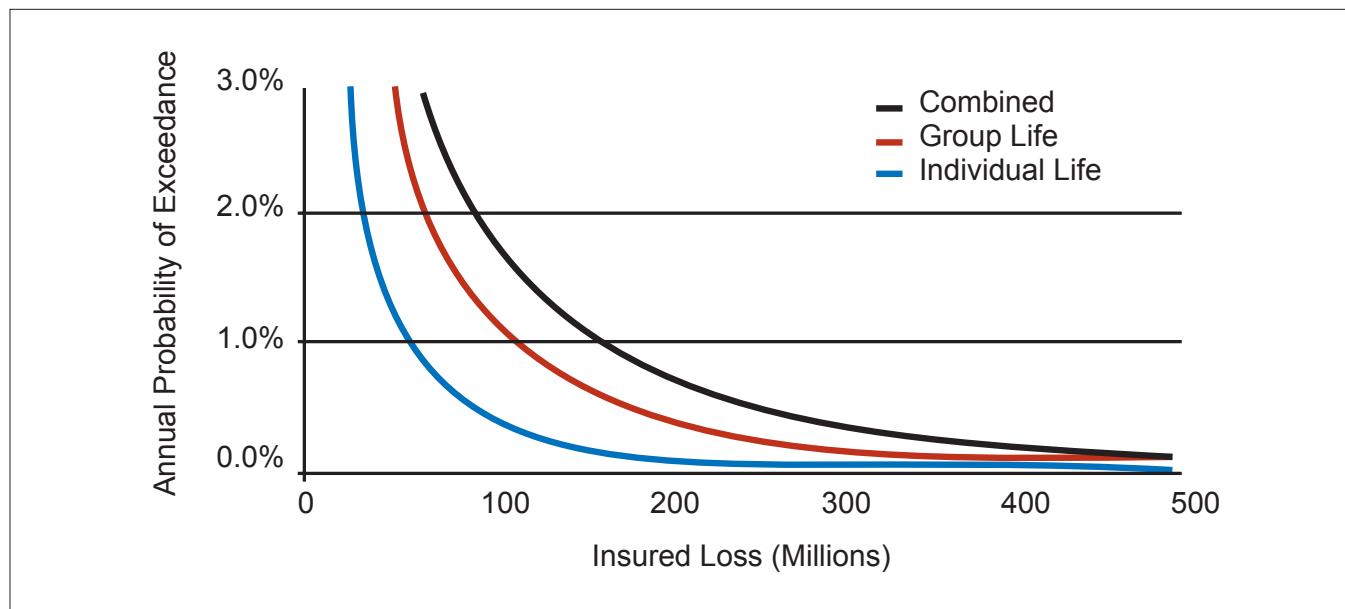


Figure 10.1 An AEP curve shows the overall risk of loss to a portfolio

11 THE FUTURE

Over the past decade, the capture of detailed portfolio information and active use of sophisticated catastrophe risk management tools has become standard operating procedure for all property and casualty writers exposed to catastrophe risk. These actions allow insurers to survive the threat of extreme catastrophic events, and thrive in an atmosphere where knowledge provides a competitive advantage.

The life and health industry can benefit from the lessons learned by the property and casualty industry in the 1990s. By providing an improved understanding of the magnitude, likelihood, and location of risk, investments in systems for data capture and risk quantification will readily pay dividends in the form of improved risk management decision-making.

The issue of catastrophe risk to the life and health industry has further ramifications. Increasing numbers of insurance companies are creating the role of chief risk officer whose responsibilities include the quantification of total catastrophe risk. A key lesson learned from the WTC disaster is that in extreme events there is a significant correlation across lines of business. For insurers that write multiple lines—property and casualty, life and health, or both—the chief risk officer needs to consider the aggregate catastrophe risk in order to completely understand the risk faced across the enterprise.

Individuals are limited in their capacity to prevent or mitigate catastrophes. Whether natural or man-made, the effects on the population can be disastrous. Insurers play an important role in making the financial consequences of inevitable injuries and fatalities more bearable. Only future experience will reveal the full dangers posed by events of unprecedented magnitude or unexpected origin. To act now, science and technology offer the best tools to manage risk and understand the relationship between catastrophe, injury, and insurance.



Figure 11.1 The risk of mass casualty events can be managed with preparation and planning—U.S. First Responders in preparedness training, Seattle, May 2003 (Image: Associated Press)

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