Catastrophe Mortality in Japan

The Impact of Catastrophes on Life and Personal Accident Insurance

RMS™

INTRODUCTION | はじめに

Risk Management Solutions (RMS) assists clients, associates, and community leaders in understanding the potentially devastating damage, casualties, and economic consequences from catastrophic events such as earthquakes, floods, and terrorist attacks. The insurance industry in particular relies upon our modeling technology to quantify and manage these risks.

Japan has the largest life insurance industry in the world. While it has rarely faced losses on the catastrophic scale confronted by property insurers, large losses are clearly possible and, as some argue, inevitable in the longer term. New threats such as the avian flu and the rise of global terrorism combine with changing demographics and the growth of cities to create more vulnerable populations and increase the potential for mass-casualty events.

This report uses cutting edge modeling techniques to provide life and personal accident insurers with key benchmarks for the potential risk of human casualties from a range of possible catastrophic events including earthquakes, tsunamis, terrorist attacks, and infectious diseases. Since catastrophe modeling is fairly new to the life insurance industry, RMS has produced some background material on how catastrophe models can be used to manage risk, the input data required, and how the results are applied.

Modeling catastrophic risk to human life is a challenging process that requires an account of the 'mobile' exposure of people. Modeling the spread of infectious diseases entails analyzing social interaction and forecasting the epidemiology within a modern, highly-informed population. Modeling the impact of a geographical peril like a tsunami involves forecasting the location of millions of people and estimating the effectiveness of their likely evacuation attempts. Modeling the impact of an earthquake or terrorist attack requires estimating how many people will be in different types of buildings at certain times of the day. Understanding and modeling 'mobile' exposure of people holding life and personal accident insurance policies requires the development of detailed databases on the movements, demographics, and building stock occupied by the population of Japan.

We are grateful for the assistance received during the development of this report from various experts in life and health insurance and in Japanese catastrophe and insurance business. It would not have been possible without their contributions.

Our hope is that this study will improve the understanding of the potential risk from human casualty in Japan and lead to the reduction of casualties from future catastrophes through increased awareness, preparedness, and mitigation.

Hemant Shah

President and CEO, Risk Management Solutions

ヘマント・シャー
社長兼最高経営責任者
リスク・マネージメント・ソリューションズ

リスク・マネージメント・ソリューションズ（RMS）は、地震や風災、洪水などの巨大災害による壊滅的被害の可能性を理解する際にお役に立てるよう、創設以来エネルギーを注いできました。特に保険業界の皆様には、これらの災害がポートフォリオに与える影響を定量化し、そしてそのリスクを管理するために、私たちの技術を広くご利用いただいております。

日本の生命保険は世界最大の規模がありますが、財物保険を扱う保険会社が直面したような巨大損害に見舞われたことはありません。しかしながら、大規模な損害の可能性が存在することは明らかであり、そして、長い期間の中では避けることが出来ないとも言われています。鳥インフルエンザや世界的テロの勃発のような新しい脅威は、実態的人口統計の変化や都市の発展と相俟って、人口集団をより脆弱なものにし、大規模な死傷事故の可能性を増大させています。

この報告書では、地震、津波、テロ攻撃および伝染病などの巨大災害について、想定される範囲における人的損害リスクの可能性に関する主要なベンチマークを、生命保険および傷害保険を扱う保険会社に提供するために、最先端のモデリング技法が使われています。特に生命保険分野にとってカタストロフィー・モデルは新しいものなので、RMSはリスク管理のためのモデルの使用方法、必要な入力データや結果の適用方法等に関して、バックグラウンドとなる資料を作成しました。

人命に対する巨大リスクのモデル化には困難なプロセスがあり、リスクに曝されている人々を"動的"に数値化することが必要となります。伝染病の流布をモデル化するにあたっては、現代の高度な情報をもつ人々の中での社会的交流の分析と疫学的な予測が必要です。津波のような地理的危険の影響のモデル化には、何百万人もの人々の所在地の予測と、さらに彼らが試みるであろう避難行動の効果に対する評価も含まれています。また、地震やテロ攻撃の場合には、一日のうちの一定の時間帯に、どのくらいの人々がそれぞれ異なったタイプの建物の中にいるかを見積もらなくてはなりません。生命保険や傷害保険の証券を持つ人々の"動的"なリスク量の把握とモデル化においては、日本人の行動パターン、実態的人口統計および人々が居住・使用する建物の分布や構造等に関する詳細なデータベースの構築が不可欠です。

この報告書をまとめるにあたり、人の生命や健康に関する保険、日本における巨大災害や保険業界についてのさまざまな専門知識をお持ちの皆様からいただきましたご支援に、心より感謝いたします。そのようなご協力がなければ、この報告書が完成することはなかったと思います。

私たちは、この研究が、日本における人的損害リスクの可能性をよりよく理解することに役立ち、そして、将来に起こるかもしれない巨大災害に対する意識が高まり、即応態勢とリスク軽減策が強化されることを通じて、死傷者数の減少につながっていくことを希望しております。

RMS is grateful for the contributions of sponsoring clients from the local Japan and Bermuda markets, as well as:

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1 SUMMARY

1.1 Variations in Insurance Loss

Life insurance companies and those offering personal accident coverage have typically used statistical and actuarial techniques to quantify likely levels of payouts each year. In an average year in Japan, about a million people die, and for most of these, one or more life insurance policies are paid out. Variations occur above and below this average, driven by natural randomness and various conditions, like an exceptionally cold winter or a cluster of deaths from a certain demographic within the insured population. Statistical and actuarial techniques make it possible for insurance companies to anticipate these normal variations and manage their reserves for the years of above-average payouts. The report examines the likelihood of events causing more than 10,000 fatalities, representing 1% excess mortality: i.e., an increase of 1% in the average annual number of one million deaths in Japan.

1.2 Catastrophe Models Enable Insurers to Manage Risk

Some events can cause losses far in excess of the expected variability of life and personal accident payouts. In addition, some insurers can suffer a disproportionate share of the loss if a particular town or locality where they have a concentration of their policy holders is impacted.

These events can be anticipated through the use of catastrophe modeling, a science that has developed since the late 1980s and been extensively adopted in the management of risk in property and casualty lines of insurance. In the United States, it is now standard practice to use catastrophe modeling to manage a portfolio of property insurance, as well as other lines of insurance business including life, health, and workers compensation. Insurers use catastrophe modeling to make reinsurance purchasing decisions, to allocate capital and manage a portfolio, as well as in underwriting to ensure that new accounts meet their strategic risk management guidelines.

1.3 Catastrophic Losses Are Increasingly Common

Events of catastrophic proportion have become increasingly common, and a year rarely goes by without a record-breaking disaster in some part of the world. The frequency of severe typhoons and extreme weather is increasing. Growing population densities in catastrophe-prone areas and certain building constructions add to the risk of extensive damage. The emergence of jihadist terrorism has demonstrated that a new generation of terrorists is capable of causing mass casualties and is intent on unleashing increasingly horrific attacks on the populations of Western democracies. Globalization and a rise in international travel have enabled infectious diseases to spread more rapidly around the world, and despite all the advances of modern medicine, new viruses pose a significant threat to society. These emerging and growing threats need to be anticipated in the management of modern insurance.

1.4 Mass-casualty Scenarios

This report illustrates the types of perils that can cause catastrophic loss to life and personal accident insurance in Japan and shows how modeling these events can help insurance companies manage their risk of extreme loss. The scenarios chosen to illustrate each peril are not most extreme cases possible but are illustrative examples of the types of events that are capable of causing large numbers of casualties. The scenarios show the ways in which deaths and injury can occur and the scale of the potential losses that can result. However, similar events can occur in other locations, at different times, or with many other variations and could be more severe than the scenarios chosen.

1.5 Human Exposure Database

To analyze the risk of mass-casualty catastrophes, RMS has created a database of human exposure that can be used to estimate the location and activities of people in Japan at different times of the day. This is used to analyze the effects and variations of different characteristics of catastrophes such as where they may occur, the types of people affected, and the affected exposure. A high-resolution database was built for the Tokyo area for detailed analysis of specific scenarios affecting the metropolis.

1.6 Earthquake Risk

Earthquakes are a major peril in Japan: there have been 87 lethal earthquakes causing over 168,000 deaths in Japan since 1900. The 1923 Great Kanto Earthquake alone killed 142,800 people. Low death tolls from earthquakes in the second half of the 20th century caused some people to think that better building standards in Japan had made mass casualties from earthquakes a thing of the past. However, the 1995 Kobe Earthquake that killed 5,502 people and injured 41,520 demonstrated that mass casualties were still possible.

Earthquake risk in Japan is evolving. The most likely cause of mass casualties is from the collapse of old post-and-beam houses that still comprise the residential areas of many cities. In particular, high density neighborhoods pose a significant risk of fueling a large-scale fire that can trap and kill occupants. These houses and neighborhoods are being replaced over time with new developments of stronger upgraded houses, and fire prevention measures that make neighborhoods less disaster prone are being put in place. Overall, household sizes and occupancy densities are also gradually falling, making it less likely that large numbers of people will be affected by the collapse of these traditional homes.

However, there is also a trend toward higher occupancy buildings–larger developments of multi-story apartment blocks and office buildings that house many people at a time. The number of buildings containing more than 1,000 occupants has increased rapidly throughout Japan. Although they are carefully designed to resist earthquake forces, the large number of these buildings means that even small failure rates or defects in construction could lead to substantial casualties when high-intensity earthquakes hit.

Two scenarios in this report contrast these risks. The first scenario is an earthquake at night that causes extensive building collapse in old neighborhoods in Osaka, resulting in 10,000 deaths and 96,000 injuries. The second scenario is a daytime high-intensity earthquake hitting the center of a large city, in this example Tokyo, causing a small number of high-occupancy buildings to collapse and a major fire to spread through one of the older neighborhoods. This scenario results in 17,000 deaths from the shaking and another 8,000 killed from the fire. Hospitals performing emergency treatments for the 170,300 injured are running at full capacity.

Managing earthquake risk entails having a good understanding of the geographical distribution of policyholders relative to the seismic regions of Japan, and if possible, understanding the type and quality of the building stock where they live and work.

High occupancy buildings containing thousands of people can create the potential for higher fatalities if they were to fail

1.7 Tsunami Risk

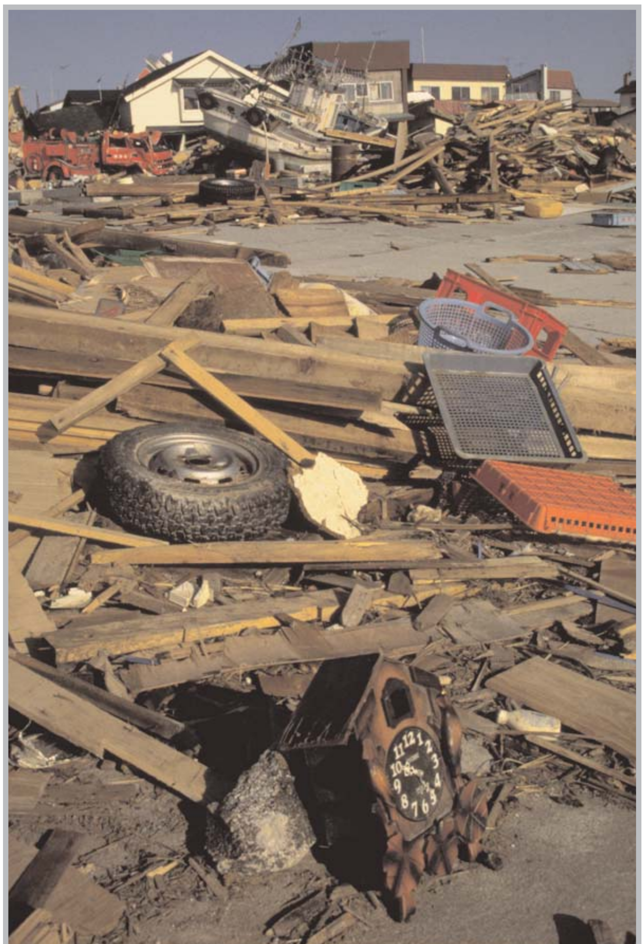
A tsunami hitting Japan can be particularly deadly, especially with coastal populations growing markedly during the last 50 years. Japan is prone to violent sea waves that have claimed at least 66,000 lives over the past 300 years. With 77% of the population of Japan living in coastal areas today, the risk is even greater. Over 9.6 million people live within 2 km (1.2 mi) of the main coastline. To protect itself against tsunami risk, Japan has invested in substantial coastal defenses that mainly provide protection against moderate tsunami run-up of 3 to 4 m (10 to 13 ft) and warning systems that are most effective against events originating a long way out at sea. Large tsunami waves generated by major magnitude earthquakes close to the shore, which by virtue of their proximity provide short warning times, still pose a significant threat.

The chosen scenario is a tsunami generated by a large magnitude earthquake on the Nankai Trough that produces 10 to 20 m (33 to 66 ft) wave run-up along parts of the coastlines of Shikoku and Kyushu, and 5 m (16 ft) wave run-up along the coastline of southern Honshu. In this event 37,000 people die (many bodies are never recovered), and 60,000 are injured.

Tsunami risk can be managed by ensuring a good geographical distribution within an insured portfolio that does not have excessive concentrations of insureds living and working very close to the shore.

1.8 Infectious Disease Risk

In Japan, infectious disease ranks third after cancer and heart disease as the primary cause of mortality. Epidemics of new strains of virulent diseases can cause significant sudden increases in mortality. Usually modern medicine finds a cure for a new disease, but developing a drug takes time during which the initial infection can take a heavy toll. At least 30 new disease agents, for which no cures are currently available, have been identified in human populations in the last few decades, including



Moderate catastrophes, like the tsunami that hit Okushiri Island only minutes after the 1993 M7.8 earthquake off the coast of Hokkaido, may not prepare Japan for the larger events that can kill many thousands (Source: NOAA)

human immunodeficiency virus (HIV), severe acute respiratory syndrome (SARS), Ebola, and hepatitis C and E. Unfortunately, as soon as medicine comes up with defenses against a disease, new versions evolve. Viruses have a natural process of genetic mutation to beat immune systems, and new versions of viruses pose significant threats to modern populations.

With today's heavy travel volumes and open borders between countries, a new disease originating almost anywhere in the world can spread quickly into susceptible populations in many countries–far faster than in previous generations. Modern cities, with their dense, interconnected social activities, school networks, and public transport systems enable infectious diseases to spread rapidly through the population.

A new mutation of the influenza virus is feared: the H5N1 virus that has caused avian flu in countries like Thailand and Vietnam is rapidly evolving and showing a propensity to be particularly deadly in humans. If it were to mix with the type of influenza virus that is easily transmitted between humans, the result could be a pandemic with particularly virulent characteristics.

RMS chose a scenario of an avian flu mutation that takes characteristics from both the highly pathogenic H5N1 virus and the highly transmissible H1N1 virus to illustrate the effects of the spread of infectious disease. The virus is introduced into Japan by travelers from Southeast Asia. Emergency measures taken by the Japanese government include distribution of large stocks of Tamiflu® and introduction of quarantine and travel restrictions. Even with these measures in place, the disease spreads rapidly: 35% of the population becomes infected with the virus within 100 days, 24 million people require medical treatment, and half a million people (0.4% of the population) die from the disease. This is similar to the higher ends of the projections of the Japan Health Ministry for the effects of a pandemic flu, but by no means the worst case scenario. If the virus had more aggressive characteristics, or if the efforts to contain it failed, the death toll could be far higher.

The risk of extreme losses from flu and other infectious diseases are more difficult to manage at a portfolio level, but knowing the demographic makeup of the policy holders and ensuring age and geographic distribution will minimize the potential for concentrations of loss.

1.9 Terrorism Risk

The new era of global terrorism, heralded by the terrorist attacks on September 11, 2001 that killed over 3,000 people in the U.S., is characterized by an increasing ambition in the scale of terrorist attacks and a ruthlessness to inflict maximum casualties and economic disruption on the G8 countries.[1] These trends pose a particular challenge for the insurance industry in target countries: mass casualties in commercial business centers mean that potential losses could be very significant.

Japan is an important member in the campaign against terrorism, but that also means that it has become a target for jihadist groups, with Japanese nationals suffering at the hands of terrorists. A jihadist attack on populations within Japan, possibly orchestrated by Jemaah Islamiya– the main jihadist threat group in the region– remains a small but significant threat. In addition, there are other potential sources of extreme terrorism also posing a risk to Japan. Historically, terrorism in Japan has been characterized by political extremists and religious cults carrying out violence against national targets. An attack by one of these groups– possibly inspired by the growing scale of attacks being attempted elsewhere– remains a threat to Japan.

1 *The G8 is a group comprised of eight industrialized countries, consisting of the U.S., U.K., Germany, France, Italy, Canada, Japan, and Russia*

Terrorist attacks can be very ambitious and destructive as seen in the use of a large truck bomb against the Khobar Towers in 1996 causing the collapse of apartment buildings containing more than 3,000 occupants at a U.S. Air Base in Saudi Arabia (Source: U.S. Department of Defense)

Japan has made major improvements in its counter-terrorism operations and is fairly effective in interdicting potential terrorist plots. However, with sufficient support, time, and careful planning, a determined group would be able to mount an attack. Likely terrorist attacks can range from minor attacks using small-yield explosive devices to major attacks using conventional weapons like car bombs or hazardous materials. The death tolls from the former are likely to run into the hundreds and low thousands. However, there is a real potential for a terrorist attack using a weapon of mass destruction, such as a chemical, biological, radiological or nuclear (CBRN) weapon. Terrorist groups, particularly the jihadist groups, are known to have explored the potential of obtaining and using these weapons.

To demonstrate terrorism risk in Japan, the chosen scenario depicts a terrorist group obtaining, refurbishing, and detonating a small-yield nuclear bomb in the center of Tokyo. Japan has, in its history, already experienced the effects of a nuclear detonation. The scenario envisions a nuclear bomb in Tokyo smaller in scale than those detonated in Hiroshima and Nagasaki during World War II. However, when detonated in the center of a modern metropolis, the blast kills many more people: a quarter of a million people are killed in the blast, and 50,000 die from the effects of radiation over the coming years. Extensive medical treatment is required for 60,000 people to combat radiation sickness and to reduce post-event mortality.

The nuclear detonation scenario is extreme, and the likelihood of it occurring is remote. However the use of CBRN weapons by terrorists is a significant and growing threat. Terrorists may be able to obtain and use biological weapons, like anthrax, that could be almost as deadly as a nuclear detonation.

Managing terrorism risk requires balancing the concentrations of policy holders likely to be working in the city centers of major cities of political and economic importance.

1.10 Probabilistic Assessments of Losses

As shown in these analyses, the more extreme the event, the less likely it is to occur. The probabilities of losses of different sizes can be estimated using a modeling framework, where a wide variety of scenarios are considered together with an assessment of their likelihood of occurrence. RMS has developed probabilistic models for earthquake, terrorism, and infectious diseases that can help insurance companies manage the risk to portfolios of life and personal accident policy holders.

The probability of a level of loss can be used to make decisions about capital requirements, desirability, and cost of risk transfer. It can also be used to analyze how different characteristics and geographical distributions of the portfolio affect the overall risk.

1.11 Managing the Risk

For an insurance company, managing its catastrophe risk means optimizing risk transfer mechanisms and maximizing the financial stability of cash reserves and future flows. The optimal outcome for insurers is for events to conform within the expected mortality and morbidity used to establish insurance rates and to avoid incurring a disproportionate share of loss compared to their market share. Risk management tries to balance demographic concentrations and avoid overexposure to locations and sectors with the potential of high losses.

Risk management depends heavily on having accurate data about the exposures held by the insurance company and analyzing this using the best knowledge of the perils to which they are exposed. For multi-line businesses, it is important to consider how catastrophes might affect more than one line of business simultaneously.

1. The first step is to have good exposure data. Reliable data is needed on how much is insured (either number of people or limits, including coverages, limits and deductibles), characteristics of the insured (including the age, demographics, and location), and information about the types of structures and resilience of the buildings for both home and work locations.

2. Once this data has been collected, the second important step is to identify and quantify accumulations that might lead to unacceptably large losses. This can be done by establishing a target maximum loss threshold and identifying all locations where this threshold is exceeded.

3. The third step is to look at what losses would be experienced under one or more scenarios, such as those presented here. Selecting loss limits by a scenario event is current practice for most insurers.

4. The fourth and final step of this process uses probabilistic risk analysis. Usually, this involves modeling a spectrum of potential events against a company's portfolio, and looking at the loss and associated probability of each event occurring to define a loss distribution or aggregate exceedance probability (AEP). The AEP can be used to assess the drivers of portfolio risk and to make risk transfer decisions.

Despite advances in modern healthcare, new infectious diseases still pose a risk of excess mortality

Catastrophe risk management is not an exact science, and prudent risk managers use multi-tiered approaches to triangulate risk and evaluate alternatives to manage or transfer risk. It requires knowledge of the risks faced by a company, a good understanding of the portfolio being analyzed, and the discipline to define and control the acceptable loss thresholds. By having this management structure in place, an insurance company can face the uncertainties and large potential losses of a catastrophe with confidence. Catastrophes may be unpreventable, but managing losses is a business imperative for a modern insurance company. ■

2 BACKGROUND

This report explores the potential impact of catastrophes on morbidity and mortality rates and their effect on life and personal accident insurance in Japan. It serves as a companion to the RMS report *Catastrophe, Injury, and Insurance: The Impact of Catastrophes on Workers Compensation, Life, and Health Insurance* published in April 2004, which looks at the impact of catastrophes on human exposures in the United States. This report discusses a range of causes and trends of mass casualty events in Japan, but the main focus is on modeling the severity of different scenarios of losses resulting from earthquake, tsunamis, infectious disease, and terrorism.

2.1 Routine Payouts in Life and Personal Accident

The insurance industry in Japan routinely pays out large sums for death and injury each year. Most of the approximately 1 million annual deaths in Japan result in insurance company payouts under life and personal accident policies. Tragic though it may be in human terms, the impact of a catastrophe that kills hundreds or even thousands of people at one time may be only a marginal event in terms of the additional financial costs for the insurance industry.

However, large scale events in which tens of thousands and even hundreds of thousands of people can die are possible and can lead to sudden excess payouts well above the average. These losses often can be concentrated in a single city or locality, and insurers with concentrations of policy-holders in the affected locality can find themselves with extremely large losses from a single event. 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; these events are considered later in this report.

2.2 The Risk Landscape

Over the last few years, the world has witnessed a great number of very large-scale catastrophes. Mass casualties resulted from events such as the Indian Ocean Tsunami in December 2004, severe floods across Europe in summer 2002, the May 2003 earthquake in Algeria, the Bam earthquake in Iran in December 2003, and Hurricane Katrina in the U.S. and the Pakistani earthquake of 2005.

Man-made catastrophes have also added to the death toll: the terrorist attack on United States on September 11, 2001 killed 3,000. Worldwide, terrorism has claimed the lives of over 10,000 people in the past three years.

The frequency of both man-made and natural catastrophes has been increasing since the 1980s, and there is evidence that this trend may continue. The number of people affected from a specific event has been increasing as well. The number of natural disasters that cause at least 10 fatalities has been steadily increasing each year, from 78 in 1970 to 348 in 2004. Approximately five large magnitude (M>6.0) earthquakes occur on the earth's surface each day, and one volcano erupts every week. In an average year, 40 hurricanes, typhoons, and cyclones batter the tropics, while landslides and floods occur in numbers too large to count. Although many of these events do not cause any damage or loss of life, the life loss can be extensive when they directly impact cities or human settlements.

2.2.1 Increasing Worldwide Terrorism Risk

The number of terrorist attacks across the world has increased dramatically over the past few years. In the year following the 9/11 attack there were approximately 100 major terrorist attacks (such as a car bomb or worse) worldwide. This has increased each year, and in the year prior to September 2005 there were over 200 attacks of this scale worldwide (excluding Iraq, which saw an additional 300). The increase has predominantly come from attacks perpetrated by militant Islamic terrorist groups. Inspired by the attacks and rhetoric of Al Qaeda, these groups have proliferated around the globe, carrying out attacks in over 30 countries since 9/11. Iraq continues to have the greatest terrorist activity in the world, and analysts warn that foreign insurgents operating there could unleash attacks on the U.S. and its allies in the future, in the way that the mujahideen resistance against Soviet forces in Afghanistan in the 1980s gave rise to an earlier generation of Islamic terrorism.

Attacks around the world have also become more deadly as terrorists target concentrations of people to maximize casualties. Car bombs in 2001-2002 averaged around 16 casualties per attack, but by 2004 there were approximately 45 casualties per car bomb.

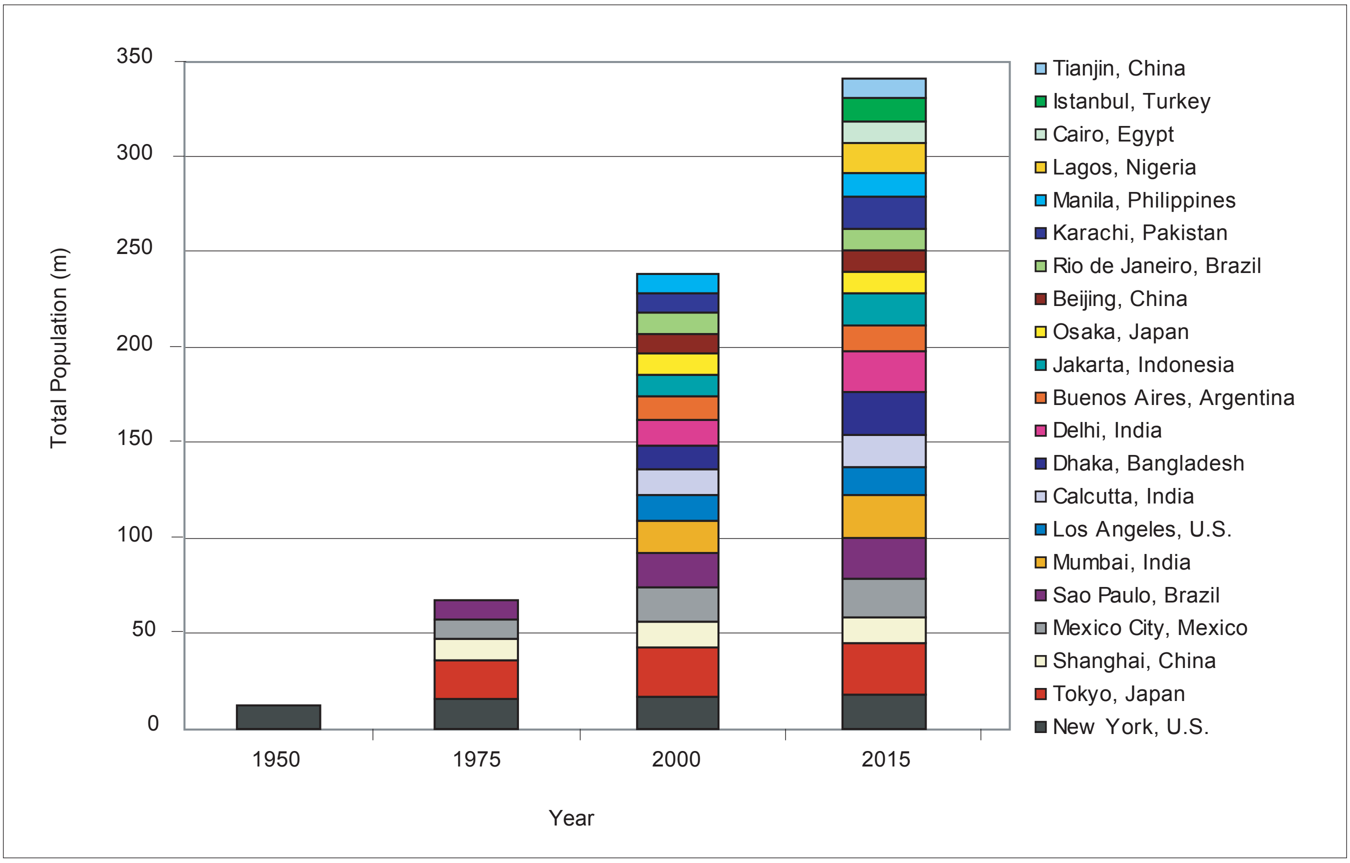


Figure 2.1 The growth of big cities has increased the potential for large concentrations of population to be affected by a catastrophe (Source: UN)

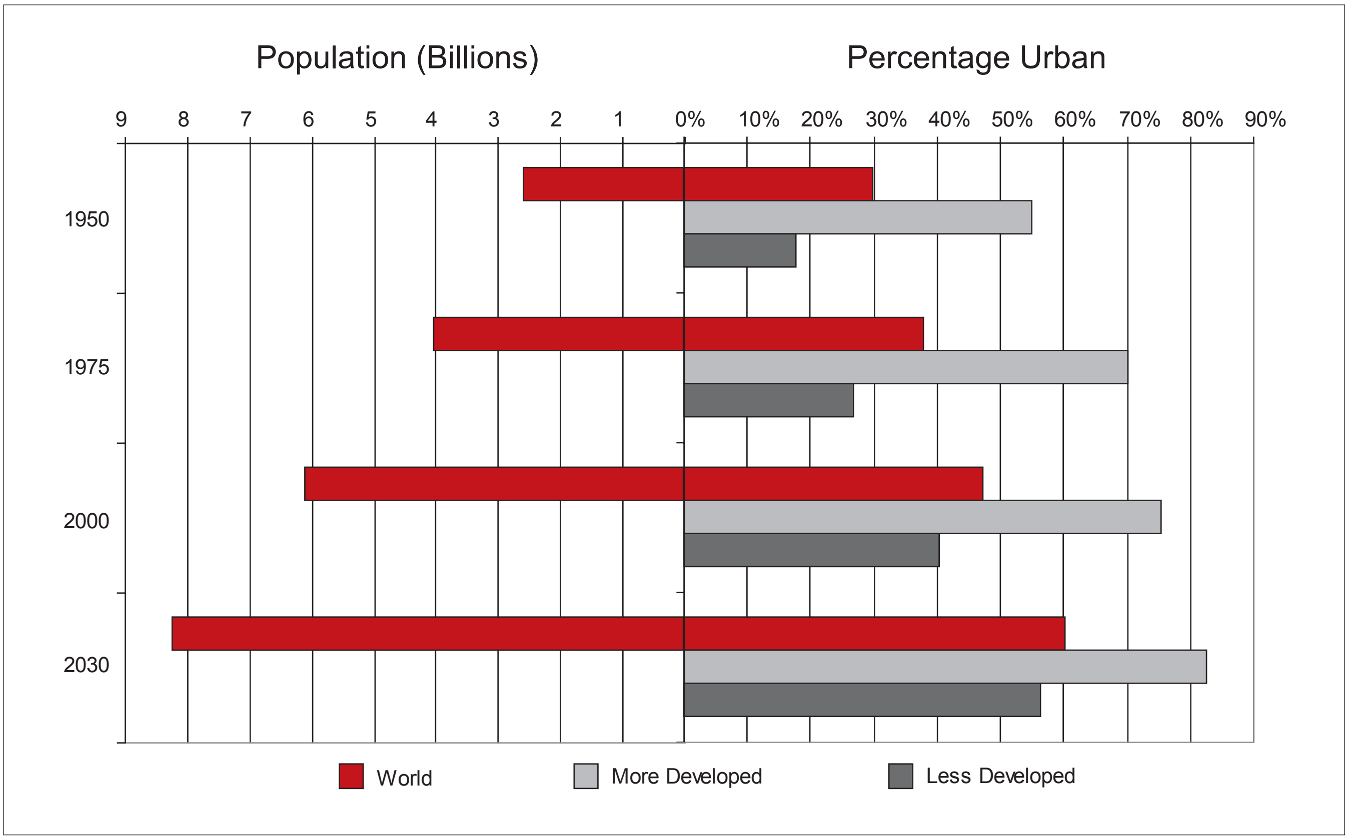


Figure 2.2 The world is becoming increasingly urban (Source: U.S. Census Bureau, UN)

2.2.2 Worldwide Urbanization

In the last 150 years, human populations have changed from predominantly agricultural and rural to industrial and urban.[1] In 1800, only 4% of the world's population lived in urban areas, but by 1900, almost 14% were city-dwellers. Now almost half of the world's population lives in cities.

Established metropolitan areas have grown rapidly and many new cities have been created. In 1950, New York City was the only city in the world to have a population of 10 million or more. In 2000, there were 411 cities with over 1 million people, and approximately 4% of the world population lived in what can be considered 'mega cities,' or urban areas with populations of 10 million or more. Today, Tokyo is the world's largest metropolitan area with a population of 35 million people,[2] and it is expected to remain the world's largest urban area until at least 2015.

Concentrations of population in cities means that any localized catastrophe has the potential to cause large numbers of casualties. As more cities are established, the chances of a natural hazard hitting an urban center increase. Part of the observed increase in frequency of natural disasters is due to there being more urban areas for hazards to affect. Urbanization can also increase the vulnerability of some of the population: urban growth creates pressure to develop land on flood plains or unstable slopes that would have otherwise been deemed marginal or unsafe. Construction booms in periods of rapid city expansion are often associated with poorer quality and more vulnerable buildings. Increasing urbanization also means that infectious diseases can spread more rapidly. Overall, urbanization is one of the main drivers of the increasing risk of human casualties in catastrophes.

2.3 Mass-casualty Catastrophes in Japan

The data in table 2.1, which shows fatalities from various events over the past 100 years, provides examples and indications of the types of events that could cause mass-casualty scenarios for insurers of the Japanese population. They do not, of 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 that influence the severity of the impact have changed during the century.

Concentrations of population in cities means that any localized catastrophe has the potential to cause large numbers of human casualties (Source: NISEE)

1 Countries differ in the way they classify population as "urban" or "rural." Typically, a community or settlement with a population of 2,000 or more is considered urban
2 In this report Tokyo is defined as the Tokyo urban agglomeration

Date	Event	Location	Fatalities
1923	Earthquake	Kanto Plain (Yokohama, Tokyo)	143,000
1948	Earthquake	Fukui	5,400
1995	Earthquake	Kobe, Osaka, and Kyoto regions	5,502
1945	Typhoon	Kyushu, Kanto	3,746
1933	Tsunami	Sanriku	3,000
1927	Earthquake	Tango, Honshu	2,925
1953	Flood	Most of the nation	2,566
1923	Tsunami	Atami, Ito, Simoda, Tokaido	2,144
1947	Flood	Honshu Island	2,000
1945	Earthquake	Mikawa (near Nagoya, Honshu Isl.)	1,961
1947	Typhoon	Honshu Island	1,930
1954	Typhoon	North Japan	1,761
1934	Fire	Hakodate	1,500
1946	Earthquake	Nankai	1,300
1958	Typhoon	Central Honshu	1,175
1954	Ferry Accident ('Toya Maru')	Tsugaru Strait	1,172
1927	Tsunami	South-West Kyoto	1,100
1943	Earthquake	Tottori (Honshu Isl.)	1,083
1912	Typhoon	Nagoya, Osaka	1,000
1982	Flood	Nagasaki	345
1985	Airplane Crash	Near Fujioka (between Tokyo and Osaka)	520
1964	Mine Explosion	Omuta	447
1950	Methyl Mercury Poisoning	Minamata Bay	439
1902	Volcano	Torishima	125
1972	Landslide	Oimawashi	80
1995	Terrorism	Tokyo	12

Table 2.1 Examples of historical death tolls in different types of catastrophes in Japan

To measure the risk of mass casualty events in Japan, 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 modeled in this way, and the process of prioritizing the hazards is discussed below.

2.4 Potential Mass-casualty Events in Japan

This study considers events with potential significance to the life and personal accident insurance industries. We have taken events killing more than 10,000 people as the threshold for this study. This number is approximately 1% of the average deaths each year, so the threshold of the event represents 1% excess mortality. Many moderate and accidental causes of death, including most transportation accidents, large scale fires to an individual building, or the majority of typhoon events are excluded since mortality levels in these types of events would not reach the threshold of loss of interest to this study. Our selection of events are not necessarily worst case scenarios– there are events that could potentially cause more losses than these–but they are plausible and for that peril have an annual likelihood of occurrence commensurate with return periods of several hundreds of years.

2.5 Perils of Greatest Concern

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

1. Earthquake
2. Tsunami
3. Infectious Diseases
4. Terrorism

RMS presents a general context for each of these perils as well as the effects of one or more scenarios. Where possible, the probabilities of different levels of loss are discussed. An outline of the methodology for modeling is described in the following chapter. ■

3 STUDY METHODOLOGY

3.1 Scenario Studies

3.1.1 Human Exposure Database for Insurance

To study the impact of catastrophes on Japan's life and personal accident insurance industry, RMS has created a high resolution, dynamic human exposure database. This database provides information on the geographic distribution of the population for both day and night, the demographics, and most importantly, the life and personal accident insurance coverages. For earthquake and infectious diseases analyses, the database covers the entire country of Japan at ward level. For the analysis of terrorism and tsunami risk, higher resolution exposure data is required and thus a more detailed database has been developed for Tokyo as a sample study area.

RMS has well-established catastrophe models for earthquake and terrorism risk that have been adapted for this study to examine the human casualties they cause. These models use a detailed understanding of the physical process of the events to construct the geographical extent and severity 'footprint' of destructive forces. By overlaying a 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 as well as other people in the streets, the consequences of building damage and other harmful effects of the event on the exposed population can be analyzed to estimate the numbers of people injured or killed.

3.1.2 Tokyo Study

While the Japan human exposure database covers the entire country, a case study area of the Tokyo prefecture was developed for the earthquake and terrorism scenarios to assess events in more geographical detail.

The national capital region is made up of Tokyo and the seven surrounding prefectures of Saitama, Kanagawa, Chiba, Gumma, Tochigi, Ibaraki, and Yamanashi. The greater Tokyo area, which is home to around 26% of Japan's total population, is made up of Tokyo and the three neighboring prefectures of Saitama, Kanagawa, and Chiba.

Tokyo is a metropolis made up of 23 wards, each of which is a self governing municipality with the status of a city. In addition to its famous neon jungle, skyscrapers, and

The human exposure database tracks workers inside city centers during the day as well as in residential buildings during the night

crowded subways, the Tokyo region also includes other features such as dams, lakes, farms, rivers, remote islands, and national parks.

Because of its location, population density, and status as the capital and the most important city in Japan, Tokyo is not only susceptible to great damage from natural catastrophes such as earthquakes, but also to terrorism. The Kanto region, which includes Tokyo, was the site of the 1923 Great Kanto Earthquake, and Tokyo was subject to numerous terrorist attacks in the last 10 years, both of which are discussed in later chapters. The fact that these scenarios are set in Tokyo is not indicative of actual risk to the city, but rather they are a means to illustrate the scale and types of losses that are possible in a city of that size and density.

3.2 Insurance Coverages

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

- Life insurance, both individual and group life
- Personal accident insurance

Other lines of insurance including health care and workers accident compensation are mostly covered by the government in Japan, so they are not covered in this report. Annuities are also not taken into account. Details of the ground up injury distribution are included for all perils and may be useful to insurers of lines not addressed in this study. 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 chapter.

3.3 Cost of Injuries

3.3.1 Insurance Cost Modeling

RMS has developed cost severities to estimate the insured loss for a person with a specific injury type. For purposes of this study, cost severities were determined for loss of life for individual life insurance, group life insurance, and personal accident insurance. These costs vary by prefecture and were created by using average policy amounts provided by client sponsors and developed through RMS research.

3.3.2 Multiple Coverages Per Person

One injury can cause several different payouts under multiple separate coverage types. For example, all of the following may be paid out in the case of a single death: a group life insurance policy, an individual life insurance policy, and a separate personal accident policy. An average person in Japan has more than one life insurance policy, so a single death can result in multiple payouts.

3.3.3 Industry Loss Curves

The scenarios set in the Tokyo area are illustrative of how events may affect other major cities in Japan. However, the probability that an earthquake might affect a city depends on the seismic sources around that city. Similarly, the chances of city experiencing a terrorist attack will depend on its political profile and the targeting priorities of the terrorist threat groups. The impact of a catastrophe on a city is likely to vary as construction types, density, and occupational patterns will affect the resulting casualties.

The probabilistic Japan casualty earthquake model created by RMS simulates 27,000 earthquakes of different magnitudes, locations, and probability of occurrence in a comprehensive representation of the seismicity of Japan. Each of these events has been modeled against the human insurance exposure to assess the casualties and insurance losses. This 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 exceedance probability (EP) curve, 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: this is a short-hand for probability rather than an estimate of the elapsed time interval between losses of that severity. Results are provided as an aggregate exceedance probability (AEP), which shows the probabilities that the aggregate losses in a year will exceed some loss threshold. There is a potential to have multiple events in a year, and the AEP measures probabilities that incorporate this.

The analysis of losses resulting from each of the 27,000 earthquakes can be used to identify where the largest losses with the highest probabilities might occur. It enables the probability of loss for each city and region to be identified and can be used to ascertain the probabilities of losses arising to each of the various insurance coverages and lines of business.

The RMS® Global Terrorism Risk Model is a probabilistic model representing possible terrorism loss in 228 territories worldwide. The targeting preferences and risk patterns of terrorist threat groups in each territory are reflected in the model. Probabilities can be assessed for different numbers of casualties and losses to different insurance lines. The results based on the Global Terrorism Model are presented in the terrorism chapter of this report.

3.3.4 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 companies in different regions. A company with a large market share in a particular city will likely take a big share of the loss from any catastrophe that occurs in that city. For each company, the most important losses will be from those events in the regions where they have heavy concentrations of exposure. The probabilistic industry losses described here are unlikely to scale exactly for an individual company as the loss probability for a company depends 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 loss probability.

Chapter 9 deals with data quality as well as the types and resolution of information that is needed to analyze risk using a catastrophe model.

3.4 Event Modeling

3.4.1 Earthquake Modeling

Earthquakes are modeled by considering the moment magnitude (M_W) of the seismic source and the severity of ground shaking at each distance and location from the fault rupture. The characteristics of each type of earthquake and the geological strata through which the energy disperses determine how strongly the earthquake is experienced at any location. The local surface geology also affects the severity of the ground shaking, with softer soils generally amplifying ground motion and harder ground damping it. The frequency content of the earthquake is also important–longer period vibrations affect taller buildings more while 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 the spectral acceleration depends on its type of construction, its height, and the resilience of the engineering design. Building stock across Japan has been analyzed to produce a database of the construction type and vulnerability of buildings in each ward.

RMS has converted earthquake ground motion 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 based on building damage or collapse. Six main classes of injury severity are derived: death, permanent total, permanent partial major, permanent partial minor, temporary total, and medical only. The human exposure database determines the insurance coverage for those affected by each degree of severity and the compensation levels incurred to each coverage from injuries are quantified.

Detailed documentation on the earthquake modeling methodology is available from RMS.

The collapse of multi-story buildings in the 1995 Kobe Earthquake would have killed more people had it occurred during the working hours

3.4.2 Tsunami Scenario

In chapter 6, RMS presents an analysis of a major tsunami affecting the costal areas of Japan. Each of the major coastlines at risk from potential tsunamis is studied and the population living within 0.5 km, 1 km, and 2 km (0.3,0 .6, and 132 mi, respectively) has been mapped. The impacts from historical tsunamis in Japan and from the 2004 Indian Ocean Tsunami are used to assess how a major tsunami in the future could affect Japan. Several scenarios of large scale tsunamis are considered, and one is chosen to illustrate the scale, type of injuries, and potential loss to life and personal accident insurers. The scenario shows the effects of a severe tsunami wave from a large magnitude offshore earthquake occurring in the Nankai Trough on Kyushu, Shikoku, and southern Honshu regions.

3.4.3 Influenza Scenario

To assess the impact of influenza, RMS created a model that divided the population of Japan into five sub-populations: susceptible, exposed, infected, treated, and recovered. The model assumes that a single strain of influenza affects the population and there is no cross-immunity against the strain. The baseline parameters for the model are based on estimates of the transmissibility of the 1918 flu but with a slightly lesser virulence. It is assumed that 50 people are initially infected before the strain is identified and preventative measures enacted. Other parameters include quarantine rate, quarantine effectiveness, length of infection, length of latency period, intervention

Forces of nature, such as the 1993 Hokkaido Nansei-Oki Tsunami and the ensuing fires, can destroy large areas and kill many people in the vicinity (Source: NOAA)

effectiveness, and percent of cases identified before the onset of clinical illness. Parameters were varied to demonstrate the effectiveness of different interventions in preventing a pandemic.

The output of the model is differentiated into the number of people infected, receiving medical treatment, and dead. Although infection rates would be regionally diverse and would almost certainly be higher in cities than in rural areas, the pandemic is assumed to be geographically uniform, affecting the entire population of Japan. 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.

3.4.4 Terrorism Modeling

The RMS® Global Terrorism Risk Model has been developed through the compilation and analysis of an extensive catalog of terrorism events worldwide. This historical catalog includes more than 18,000 events to date in 130 territories since the modern era of global terrorism began in 1998. In addition, the threats posed by more than 70 different terrorist organizations have been assessed in detail. The characteristics of terrorism in each country have been assessed in terms of the likelihood and severity of three classes of terrorism: micro-terrorism (small scale attacks), macro-terrorism (larger destructive and mass-casualty attacks such as vehicle bombs), and extreme loss events (spectacular attacks with multiple conventional weapons or chemical, biological, radiological, and nuclear agents).

Detailed documentation on the terrorism loss modeling methodology is available from RMS.

3.5 Report Conventions

- Time of Occurrence–earthquakes are shown for two times of the day: at 2:00 pm on a weekday, when occupancy is maximum in commercial buildings and the expected losses are the highest; at 2:00 am, when occupancy is maximum in residential buildings; and also a 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.
- Terrorism strikes are assumed at peak occupancy in commercial buildings, which is 2:00 pm on a weekday.
- All exceedance probability (EP) losses are aggregate exceedance probabilities (AEP).
- The AEP of a level of loss in a year is expressed as the annual probability and also as its reciprocal: a '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.
- All losses are presented in U.S. dollars. A conversion rate of 0.00849 Japanese yen to USD$ has been assumed.
- The scenarios illustrate potential ways that large numbers of fatalities can occur and are not intended to be predictive or to imply a knowledge of a safety defect in any particular facility. These examples are meant to show the type and scale of damage that could result from a possible event and its effect on life insurers.
- RMS defines six injury levels within our earthquake and terrorism casualty models:

1. *Medical*: minor injury that does not require a hospital stay
2. *Temporary Total*: injury which results in an individual being unable to work for some period of time, but from which a full recovery within a reasonably short period of time is expected (e.g., leg fracture)
3. *Permanent Partial– Minor*: a permanent injury, which results in only partial disability (i.e., a person can continue to work in some fashion) due to minor injuries such as loss of a finger or respiratory problems; typically, the disability is between 0% and 50%
4. *Permanent Partial*–Major: a permanent injury involving more serious levels of disability between 50% and 100% (e.g., loss of a leg, loss of an eye)
5. *Permanent Total*: severe disability, where the individual cannot work at all (e.g., loss of all limbs, paralysis)
6. *Fatal* ■

4 POPULATION AT RISK

4.1 Building the Human Exposure Data Model

To understand the risk of injuries and fatalities in catastrophic events it is important to first understand the exposed population. Life and personal accident insurers manage a portfolio consisting of hundreds of thousands or millions of people who hold their policies. The activity of these policy holders is dynamic: people move around, occupying different buildings hour by hour, traveling to and from work, visiting shops and cinemas, going on vacation, traveling on business trips, and sleeping at home. The risk of injury or loss of life depends on where they are, what the people are doing, and what kind of buildings they are occupying when the disaster strikes.

This mobility is captured in a dynamic human exposure database, which provides an estimate of the location of the population, their demographics, employment characteristics, and various insurance coverages for both daytime and nighttime activities.

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.

4.1.1 Demographic Segmentation

The population is segmented into the following primary demographic groups:

- *By gender*: male, female
- *By age*: working age (17 to 65), pre-working age (under 17), post working age (over 65)
- *By employment status*: employed, student, unemployed

4.1.2 Data Sources

The Japan human exposure database was built by compiling data from a number of primary sources including population data collected from the Japan Statistics Bureau and the Japan Statistical Research and Training Institute. Additional information was collected from providers of insurance market data and research. RMS is grateful for the information and inputs provided by its clients and sponsors of this study in the creation of the exposure database.

4.1.3 Data Resolution

The geographical basis of the mapping is ward level with data further segmented into 100-m (328-ft) grid cells to analyze highly localized impact perils such as terrorism and tsunami. The population in each ward is segmented into each of the key demographic groups.

4.1.4 Time Dimensions

The data is parceled separately for daytime and nighttime populations. It is further segmented into home and work distributions so that proper building inventory can be applied to the number of people at the respective locations.

The insurance lines modeled in this study, including personal accident policies, provide 24-hour coverage for insureds. Life insurance coverages apply to fatalities whenever they occur and are paid irrespective of other coverages. Therefore it is possible for multiple claims to be filed as the result of a single death.

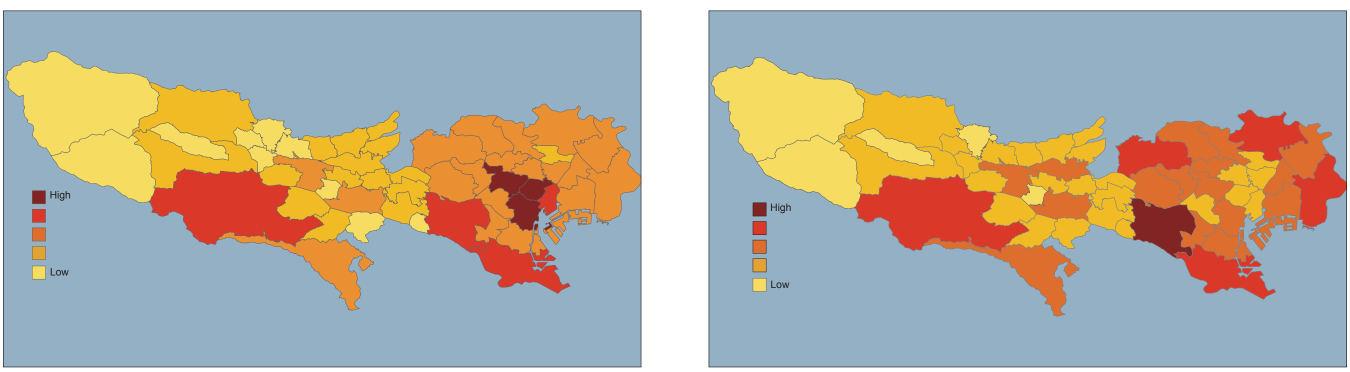


Figure 4.1 The population of Tokyo is concentrated in the central areas during the work day (left) but distributed over a wider geographical area at night (right)

4.2 Population Exposed to Catastrophes

The 128 million people of Japan are split between working adults, which comprise approximately half (63 million) of the population, and the rest of the country, which consists of non-working adults, children, and retirees. The demographic characteristics of the population vary geographically. There are higher proportions of older people in the more rural areas and a younger average age in the city of Tokyo. Certain neighborhoods around cities tend to have more families with children; other areas have higher proportions of young, single people.

The complex pattern of economic activity, migration, social trends, and other demographics become clearer when the population is mapped geographically. Key demographic factors for insured risk are employment type, earnings, and density of population. These relate to the insurance penetration (how many people are covered) and values at risk (values of the coverage) that determine insured exposure. In addition to the size and location of the event, the population density affects how many people can be impacted by an individual event.

Of the 63 million working adults, 60% are male. The primary industries of agriculture, forestry, and fishing employ 5% of the population; 30% are employed in the secondary industries of manufacturing and production.[1] The largest segment of the population is employed in the tertiary industries of wholesale and retail trade, service, and information industries (64%). Employment in these industries rose significantly in the 1980s due to advancements in new fields such as computer technology, biotechnology, and environment-related businesses and has continued to increase to the present day. Approximately 3.4 million people in Japan (5% of the labor force) are unemployed.

While the population of Japan has more than tripled since 1872, urbanization has also advanced rapidly, especially in already developed areas, leading to a dramatic increase in population density in the major cities. Currently there are an average of 327 people per km^2 (850 people per mi^2), making Japan three times more densely populated than Europe and 12 times more than the United States. This high population density has helped to create a legacy of high land and housing prices, making housing within the city centers expensive and creating extensive suburbs and hinterlands. This translates into lengthy commute times for many employees in Japan–two hours of traveling each way is not uncommon in the Tokyo area. The significance of this is that city centers become densely occupied during the day with workers, while at night they are dispersed over a very wide geographical area. There is a major disparity between potential casualties during day and night: a catastrophe striking a city center during the day can injure many people concentrated in a small area, whereas if it occurs at night, the same people will be spread over a wide area and fewer of them are likely to be affected.

The aging population of Japan is more vulnerable to catastrophes

The population of Japan is mainly concentrated around its major metropolitan centers. Approximately 44% of the population lives within 50 km (31 mi) of the three major cities of Japan (Tokyo, Osaka, and Nagoya), although this area comprises only 6% of the total land area of the country. The population density in Tokyo is approximately 4,000 people per km^2 (10,400 per mi^2) 2,200 (5,700) in Osaka , and 1,200 (2,100) in Nagoya.

4.3 The Aging Population of Japan

The population of Japan is gradually getting older. In the mid 1980s, less than 12% of the population of Japan was over 65 years old. A little more than a quarter century later, roughly 20% of the population is over 65, and it is projected that this demographic will comprise more than a quarter of the population by the year 2015. Japan has more aged people per capita than most other G8 countries. By comparison, the population over 65 averages 14% in European countries and 12% in the United States.

1 *According to Japan's Ministry of Internal Affairs and Communications, primary industries (agriculture, forestry, and fisheries), which once comprised a vast majority of all employment, have been declining in their importance to the Japanese economy; in 1960 this sector still employed over 30% of the workforce but that figure has declined to under 5% as the workforce has shifted to more advanced industries*

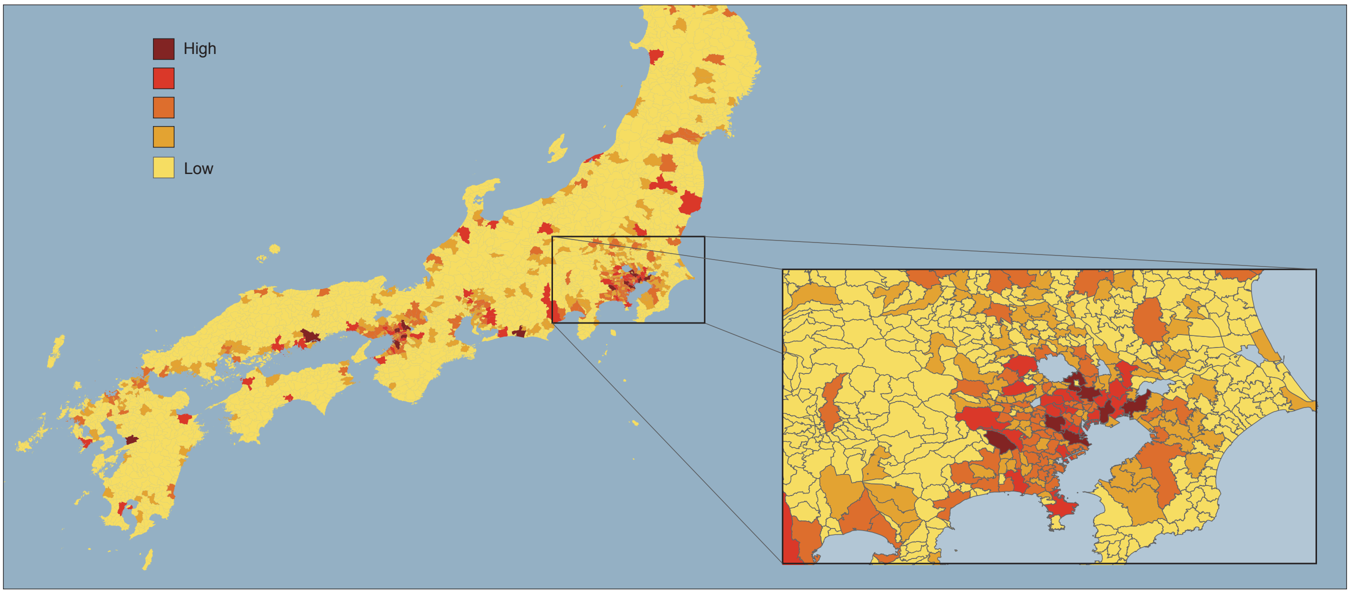


Figure 4.2 The distribution of working age population across Japan and in the Tokyo region

The rapid aging of the population of Japan can be attributed to the combination of longer life expectancies and decreasing fertility. In 1980, the birth rate per 1,000 people was 13.6 births, and today it is approximately 8.8. In 1980 the average life expectancy was 73 for men and 79 for women. Today, it is 79 for men and 86 for women.

The aging of the Japanese population has an important impact on catastrophe risk. Older people are more affected by catastrophes and more vulnerable to them. They are, for example, more likely to live in the older buildings that have a much higher chance of collapse in the case of a severe earthquake. In the 1995 Kobe Earthquake, more than half of the fatalities were people over 65 years old, even though this demographic comprised less than 20% of the population in the affected area.

The older the population is, the less likely it is able to escape or withstand injury in a catastrophic event. Access to medical attention in a catastrophe poses a challenge for the elderly: longer delays put people over 65 at greater risk of exacerbating existing conditions, worsening injuries, and death. Older people are also much more susceptible to disease outbreak. The natural aging process weakens the immune system making elderly people more susceptible to disease, and can trigger complications or worsen existing health conditions, such as asthma or congestive heart failure. Bacterial infections such as pneumonia, bronchitis, and sinus and ear infections can also develop more easily in older adults.

4.4 Building Types

For a hazard that affects a geographical area, such as an earthquake or a terrorist attack, the number of people injured or killed depends on the the location of the population and the type of building occupied (e.g., the construction material, age, height, form, and overall structural resilience).

4.4.1 RMS Building Stock Database

Building construction types and the quality of building stock are important components of the RMS exposure dataset. RMS has recently updated the building stock database for Japan, which provides information on the mixture of different building construction types and heights for each geographical region.

4.4.2 Human Vulnerability by Building Type

The human exposure database can be analyzed to ascertain the likely casualties from catastrophic events. These are derived in part from the damages sustained by occupied buildings. Because the differences in vulnerability between different construction types is reflected in injury estimates, expected building damage from the hazard severity of an event, such as an earthquake or a terrorist bomb blast, can provide an estimate of the injury rate. Not only can the vulnerability under specific hazard conditions affect the total number of people, but it may also influence the severity of the injuries sustained.

Individuals occupying highly engineered buildings during an event have different rates and types of injuries than those who are inside traditional family homes. Similarly, those who are inside pre-code reinforced concrete frame structures have different expected casualty rates than those working inside steel high-rises designed and built to code. Prevalent in all Japanese cities, traditional wooden homes become weaker as they get older. In general, older residential homes are also more likely to be adversely impacted in other catastrophes. In the event of a conventional terrorist attack or an attack that involved the release of a poisonous agent into the air, occupants of modern structures, which are most likely to include air treatment and filtering systems, would be less vulnerable than residents in older, naturally ventilated buildings.

4.5 Insurance Coverages

The Japanese insurance market is one of the most developed and complex markets in the world. It is the second largest insurance market worldwide in total insurance, exceeded only by the U.S., and the largest in terms of life insurance. The Japanese population dedicates almost 30% of their savings to life insurance. Annual life insurance premiums in Japan are approximately $400 billion, which accounts for over 30% of the world's total life insurance premiums.

4.5.1 Life Insurance

Approximately 90% of Japanese households have at least one life insurance policy; the average number of policies per family is 4.3. This level of coverage holds true for most prefectures, with Kinki having the highest at 93.5% and Tokyo the lowest at 84.8%.The average Japanese salary ranges between $30,000 and $40,000 per year.

Life insurance in Japan has traditionally been sold by Seiho ladies, an army of life insurance saleswomen who aggressively sell life insurance door to door, directly to the consumer. Today, 72% of life insurance is purchased this way, but as deregulation of the Japanese market continues and consumers are offered more choice, this percentage is decreasing year by year. The rest of the market is sold through insurance agents (approximately 7%), through work (approximately 6%), or through mail or Internet orders (6%), which has grown by eight times in the past 10 years. Only 2% of life insurance is sold through banks but is also expected to rise with deregulation.

The average individual life policy in Japan is worth approximately $82,000. This average varies geographically: an individual life insurance policy in Fukui is worth almost $99,000, while an individual life insurance policy in Hokkaido is worth about $66,000. Tokyo actually falls slightly below average for individual life policies with the average policy worth $80,000.

In contrast to the United States, where most life insurance policies are group life policies, Japan has far fewer group life than individual policies. The average group life policy in Japan is worth approximately one tenth of the average individual life policy.

The average amount of life insurance for an insured person in Japan is $313,000. This amount varies by person and depends on a person's specific cost of living, income, and the additional funds necessary to support their family. This amount also includes annuities and postal life insurance, but these lines are not modeled in this study.

4.5.2 Personal Accident

Personal accident policies in Japan cover bodily injury caused by any sudden and accidental event of external origin. This type of insurance provides indemnity benefits, which include loss of life within 180 days from the date of the accident, physical impediment, confinement daily indemnity, surgical operation indemnity, and non-confinement daily indemnity. Approximately 60% of personal accident policies are group policies and are purchased through work.

Around 53% of the Japanese population has personal accident policies, and most policy holders are employed. The average amount of coverage for a personal accident policy is $54,000.

Personal accident policies only cover earthquake-related risks when an endorsement (the Earthquake and Similar Disaster Coverage Endorsement) is attached to the policy. Approximately 25% of personal accident policies have this endorsement.

4.5.3 Other Lines

In Japan, both workers coverage and health care insurance are provided by the government. Although they can complement private policies, this study does not include these lines of business in the analysis.

4.6 Correlation with Perils

Catastrophe perils vary geographically. Natural catastrophes, such as earthquakes, typhoons, and tsunami, are highly dependent on geography, but their occurrence is largely independent of where the population is located. The coincidence of dense populations with seismic hazard for example greatly concerns insurers, but there is no systematic correlation between seismic hazard and population. Terrorism, however, is highly correlated to concentrations of population: terrorists target metropolitan areas, politically important targets, and economically significant facilities to achieve maximum impact and high death tolls, so major cities are more at risk from terrorism than rural areas. Spread of infectious diseases is also independent of geography but is subject to the demographic makeup and available treatment options. In the following chapters, the expected losses from different perils are explored. ■

5 EARTHQUAKE

Japan lies in one of the most seismically active areas of the world, at the junction of the Eurasian, Pacific, and Philippine Sea Plates. The historical record of damaging earthquakes in Japan extends over 1,300 years. In the past century alone, there have been at least 87 earthquakes that have caused loss of life.[1] Many of them caused relatively few casualties, but at least 9 events–an average of one earthquake a decade– have killed more than 1,000 people. The country's perilous tectonic setting is compounded by an extremely high concentration of exposure, yielding extensive damage to urban areas as experienced in the 1995 M7.2 Great Hanshin (Kobe) Earthquake. The earthquake threat in Japan has been met with an investment in more earthquake-related research than any other country in the world.

Earthquake is a major risk of loss for life and personal accident insurers. Insurance companies need to manage the potential concentrations of the people that they insure relative to the areas where large losses are likely. RMS has developed a model of earthquake risk in Japan that will enable insurers to estimate the probability of incurring losses to their insureds depending on their locations.

5.1 Seismicity of Japan

While constituting only 3% of the world's land area, Japan experiences approximately 10% of the world's earthquakes. The Japanese islands are located along the eastern edge of the Eurasian Plate, bounded to the east by the Pacific Plate and to the south by the Philippine Sea Plate. The subduction of the Pacific and Philippine Plates beneath the Eurasian Plate accounts for the majority of earthquakes in Japan as well as for the extensive volcanism that created the Japan islands. Three major subduction-related boundaries, marked by deep oceanic trenches or troughs, define the tectonics for the region. The Sagami Trough occurs along the interface of the Pacific and Philippine Plates; the Nankai Trough occurs as a result of the Philippine Plate subducting beneath the Eurasian Plate; and the Japan Trench is formed along the margin between the Eurasian and Pacific Plates. Each of these formations has high activity rates and has produced very large, damaging earthquakes.

On average, over 1,500 earthquakes are recorded in and around Japan each year, of which 68 are greater than M5.0, 12 are greater than M6.0, and 1.5 are above M7.0. Perceptible tremors, causing slight shaking of buildings, occur almost daily somewhere in the country.

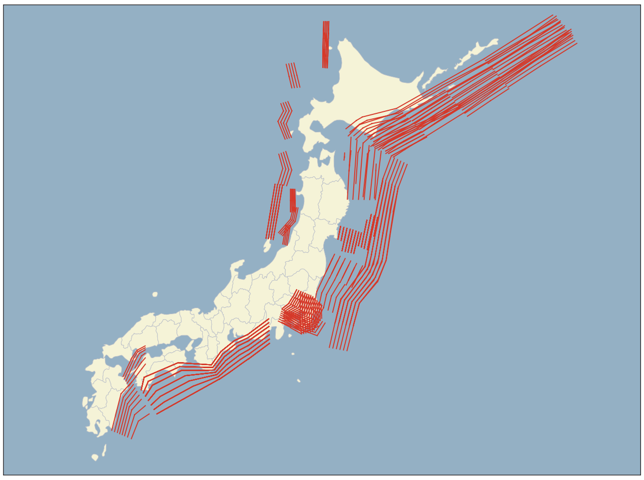


Figure 5.1 Japan has many seismic source zones capable of generating large magnitude earthquakes

In terms of earthquake risk, the most dangerous part of Japan is the Pacific coast region of the main island just south of Tokyo. This region is characterized by the underlying extensive subduction zone of Philippine Plate moving under the Eurasian Plate. The part of the subduction zone that lies southwest of Tokyo is called the Tokai Segment, which last ruptured in 1854 and before that in 1707. Prior to that, there were ruptures in 1605 and 1498, leading scientists to conclude that the rupture of this fault has a return period of approximately 100 to 150 years.[2] Since the last rupture was more than 150 years ago, it is therefore thought to be overdue.

Some of the historically important mass-casualty earthquakes in Japan include:

- *The 1923 Great Kanto Earthquake*: This was one of the most destructive earthquake in Japanese history, both in terms of damage and loss of life. An estimated 143,000 people were killed and another 100,000 were injured in this M7.9 earthquake centered on the Sagami Trough in Tokyo Bay. The cities of Tokyo and Yokohama were badly damaged and consumed by a major conflagration, which caused most of the damage and subsequent deaths.
- *The 1946 Nankai Earthquake*: A very large, M8.2 earthquake along a sizeable length of the Pacific Ocean, the Nankai Earthquake killed over 1,300 people and injured several thousand more across a very large area of central

1 RMS historical catalog of earthquakes causing fatalities

2 Rikitake, Tsuneji. "Probability of a Great Earthquake to Recur in the Tokai District, Japan: Reevaluation Based on Newly-Developed Paleoseismology, Plate Tectonics, Tsunami Study, Micro-seismicity and Geodetic Measurements." Earth Planets Space, 51, 147-157, 1999

Japan from Shizuoka prefecture in the north to Shikoku Island in the south. Casualties resulted from the collapse of over 12,000 houses, the fires that consumed 2,600 buildings, and the tsunami that washed away another 1,400.

- *The 1948 Fukui Earthquake*: The Fukui Earthquake killed 5,400 and injured more than 22,000 people, making it the most lethal earthquake since the Great Kanto event, a record it held until the Kobe Earthquake occurred almost 50 years later. A local earthquake of moderate magnitude (M7.1), it was similar in many ways to the Kobe event. The scale of fire damage was also similar; the proportion of burned buildings among the totally destroyed was 10% in Fukui and 6.5% in Kobe.
- *The 1995 Kobe Earthquake*: The Great Hanshin Earthquake, commonly referred to as the Kobe Earthquake, was the most devastating earthquake to hit Japan since 1948. The casualties were staggering: 5,500 people were killed, more than 26,000 injured, and 300,000 were left homeless.

Between the Fukui and Kobe earthquakes, there were many others– at least 37 destructive earthquakes were recorded– but their casualty totals were low. During this period of small losses, some analysts were suggesting that Japan had become earthquake resistant. The Kobe event demonstrated that earthquakes still pose a threat of mass casualties in Japan, and that the threat is evolving.

This severe intraplate earthquake (M6.9) struck the Kobe-Osaka metropolitan area on January 17, 1995. The rupture surface for the event actually extended beneath downtown Kobe. Numerous fires ignited, causing extensive damage to the older wooden houses that still made up a significant proportion of the Kobe building stock. It also caused unexpected levels of damage, including structural collapse of the modern engineered buildings that make up much of Japan's commercial stock. However, because it occurred at night casualties in these buildings were low.

One of the most destructive earthquakes in Japanese history, the 1923 Great Kanto Earthquake caused extensive casualties (Source: NISEE)

5.2 Casualties in Japanese Earthquakes

Building collapses are primary causes of casualties from earthquakes in Japan. The number of people killed rises with the total number of structures collapsed. In most of the earthquakes in Japan during the 20th century, there was an average of 1 person killed for every 10 buildings that collapsed or a 0.1 'lethality ratio.'[3] This average figure varies considerably: 1 in 10 earthquakes has a 0.25 lethality ratio (i.e., 1 person killed per 4 collapsed buildings).

In addition to these collapse-related deaths, fires have also been a major cause of deaths. Earthquakes with major fires have up to 10 times as many fatalities as earthquakes that cause only physical damage. The fires that followed the 1923 Great Kanto Earthquake were responsible for 85% of the earthquake-related deaths that occurred in Japan over the last century.

5.2.1 Occupancy Levels Affect Casualty Totals

Average residential occupancy level is a major factor affecting the numbers of people killed in an earthquake. In cities of high occupancy (e.g., Tokyo and other cities with tight space standards) the fatality levels can be generally higher, since not only does the earthquake affect more buildings, it also kills more people per collapse.

The lethality ratio of Japanese earthquakes has decreased noticeably during the past century, most significantly since the 1950s. The upgrading of the seismic design codes and a general improvement in the quality of building stock are partly responsible for the lower ratio. More critically, the decrease is due to significant reductions in occupant density in the post-WWII period, as the average number of people per dwelling fell from around 6 in 1920 to 3 by 1980. During periods of housing shortages immediately after WWII, when a large proportion of urban housing stock had been lost, average occupancies increased from 5 in 1940 to more than 7 in urban areas and 8 in Tokyo. Earthquakes affecting cities during this time of extreme crowding had some of the highest lethality ratios recorded: the 1952 Yoshino Earthquake had more than 0.4 fatalities per collapsed structure, the 1945 Mikawa Earthquake (affecting the heavily bombed Nagoya city) had around 0.3, and the 1948 Fukui Earthquake had more than 0.2, twice the country average.

3 Coburn, A.W. , H. Ohashi Murakami, Y. Ohta. "Macro Trends of Fatalities in Japanese Earthquakes." *Factors Affecting Fatalities and Injury in Earthquakes*, published by Chair for Engineering Seismology and Earthquake Disaster Prevention Planning, Hokkaido University, Japan, 1987

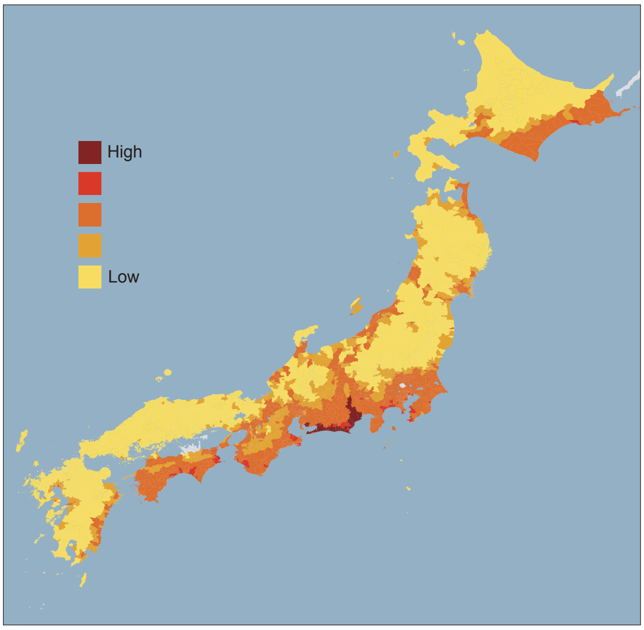


Figure 5.2 Casualty patterns expected from earthquakes are highly regional

5.2.2 Time of Day Affects Casualties

The time of day when an earthquake occurs can also affect the number of people killed and injured. Variations are based on the locations of the population at a particular time and the relative vulnerability of the residential and commercial building stock. Earthquakes between midnight and 6:00 a.m, when most people are at home, have lethality ratios of more than twice the average. Commercial buildings (e.g., offices, shops, factories, and warehouses) are generally stronger and built to stringent earthquake resistant design codes, so they are less likely to collapse. As a result, losses from an earthquake that occurs during work hours primarily depend on the performance of the commercial building stock and have lower overall casualty levels. Although, as experienced in the 1995 Kobe Earthquake, casualties not related to building collapse still can be considerable because of the collapse of elevated highways and railways or subways. Patterns of building occupation are factored into the overall estimation of risk.

5.2.3 High Occupancy Buildings

Increasingly, buildings in Japan accommodate large numbers of occupants– office buildings and major apartment complexes can contain thousands of people at a time. These tend to be built to more stringent design codes, and are less likely to collapse. However, if any of these highly populated structures do fail, the loss of life could be considerable.

Structural failures are rare, but a severe earthquake can reveal construction faults or design errors that would otherwise remain hidden. One of the major surprises in the Kobe Earthquake was the failure of modern buildings that had been designed to an earthquake code. Five percent of the engineered reinforced concrete and steel framed buildings in the city of Kobe (mainly those built before 1981) suffered collapse.[4] These were buildings of up to 14 stories high, many commercial and government office buildings that had been designed to withstand even the strong intensities experienced in Kobe without collapse. The average reduction of internal volume for the buildings that collapsed, a critical parameter for injury estimation, was 20%. Fortunately, the earthquake occurred at night when few of the collapsed buildings were occupied. Otherwise, casualties would have been much higher.

Following the privatization of regulation compliance in 1998, scandals charging builders of flouting earthquake code requirements have also raised doubts about the numbers of modern buildings that can withstand a strong earthquake in major cities.[5] Measures addressing deficiencies in the pre-1981 design code have been incorporated in the revisions of the Japanese building codes to reduce the chance of collapse. The lesson, however, is that design codes can be flawed, and construction quality may not always achieve required standards. This is unfortunately only revealed in a major earthquake.

Earthquakes in other parts of the world have illustrated how the collapse of high-occupancy buildings can cause mass casualties. In the 1999 earthquake that hit the Istanbul region in Turkey, the collapse of many of the new multi-story reinforced concrete frame buildings was responsible for the death toll exceeding 20,000. In the 1985 Mexico City Earthquake, the collapse of 500 high-rise buildings killed more than 6,000 people, including 600 people in the collapse of a single apartment building. In the 1986 San Salvador Earthquake, approximately 30% of fatalities were attributed to the collapse of several engineered commercial or industrial buildings.[6] These countries may have poorer construction standards than Japan and higher fatality and injury rates, but these examples illustrate the deadly potential of the collapse of high-occupancy buildings.

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4 *Pomonis, A."Damage Surveys, Human Casualties, and Socio-Economic Implications of the January 17, 1995 Earthquake in Kobe, Japan." Earthquake Engineering Field Investigation Team, 1995*

5 *Takayoshi Igarashi, Professor of Urban Planning at Hosei University in Tokyo, estimates that up to 180,000 structures could be sub-standard as a result of the scandal in which property developers like Huser are accused of falsifying earthquake-code structural assessments; The Times, December 8, 2005*

6 *Durkin, ME. "The San Salvador Earthquake of October 10, 1986–Casualties, Search and Rescue, and Response of the Health Care System." Earthquake Spectra: 3(3): 621-634, 1987*

5.2.4 Fire-related Deaths

In Japan, one of the most common causes of death in earthquakes has been fires triggered by ruptured gas pipes, falling heating appliances, and spilled flame sources. Building construction materials enable these fires to spread rapidly. In extreme cases, the high density of urban timber buildings has enabled multiple fires to cause a conflagration (uncontrolled burning over multiple urban blocks) of a region from which residents cannot escape, resulting in high death tolls. Large numbers of almost simultaneous ignitions and the urgent need for rescue resources often stretch firefighters to their limit, resulting in unchecked fires spreading over large areas.

Fire-spread conditions were considerably worse in historical times when timber buildings constituted the majority of housing. The earthquakes of Sonai (1894), Kita-tanba (1925), Kita-tango (1927), and Nankai (1946) all caused major conflagrations in Japanese cities and accounted for large proportions of the lives lost in these events.

Fire played a large role in the 1923 Great Kanto Earthquake. The ground shook while families were cooking their midday meals over open fires, which caused many simultaneous small fires. The dense, timber houses provided fuel for the fires, and winds spread the flames rapidly, while earthquake damage to the water mains hampered suppression. A large proportion of the city of Tokyo was lost to the flames, 316,000 houses in all. People could not escape because so much of the city was in flames. Around 80% of the 143,000 fatalities were caused by the fire, including 30,000 people who died while trapped in Rikugun Honjo Hifukusho city park.

Fire following earthquake can significantly increase damage and casualties, as seen in this neighborhood ravaged by fire by the 1995 Kobe Earthquake

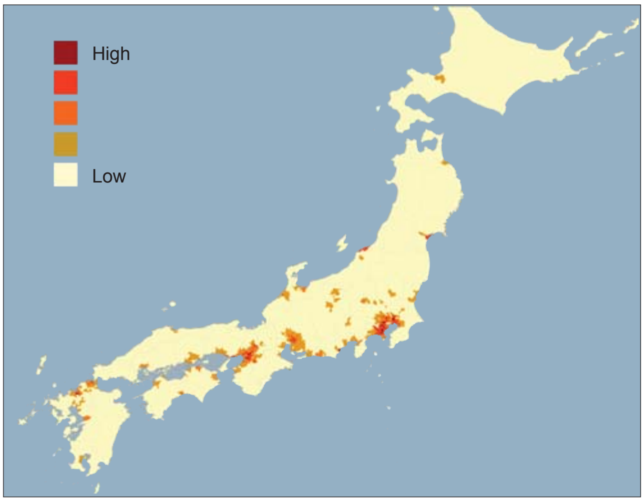


Figure 5.3 Casualty patterns expected from fires following earthquakes are centered on cities with high concentrations of flammable buildings

In the years since these fires, there have been major improvements in the fire resistance of cities. Buildings and contents are built of more fire resistant materials, many dense old neighborhoods have been cleared, urban fire breaks have been created and roads widened, stoves and lighting have become safer, and many gas supplies are now fitted with automatic shut-off valves. The city fire departments are also well prepared and equipped, and large underground water cisterns with capacity exceeding 40 tons are numerous in many of Japan's cities.

However, fire remains a major risk. In the Kobe Earthquake, around 300 fires erupted after the trembling ceased. Conflagration was avoided, but many deaths were nevertheless attributed to the fires that engulfed damaged and collapsed buildings still full of people.

Preparedness plans for earthquakes in other Japanese cities anticipate multiple fire outbreaks in future events. The Tokyo Fire Department expects to handle at least 580 fire outbreaks if an event similar to the Great Kanto Earthquake were to occur, and the Tokyo Metropolitan Government has zoned the city to identify neighborhoods with conflagration potential. Currently at least 228 km^2 (188 mi^2) in Tokyo prefecture are classified as high fire risk.

5.2.5 Earthquake-related Injuries

Insurers responsible for medical claims resulting from earthquakes are likely to see a wide range of types and costs of injuries. The majority of injuries are minor and require limited medical attention, such as strains, sprains, lacerations, and contusions. Fractures and serious lacerations require more significant medical attention. In mass casualty events, injuries that are not life threatening may be dealt with simply during triage, but are likely to require more costly follow-up treatments as a result.

Some injuries can be severe and lead to the loss of limbs and/or some degree of permanent disability, the most costly form of medical claim. Burns can be extensive and require intensive medical treatment. Severe injuries most commonly include crush injuries and trauma to the head, neck, or torso. In some cases these can result in permanent total disability, requiring that victims receive medical attention and insurance compensation for the rest of their lives.

Structural collapse is responsible for the large majority of earthquake fatalities. In an earthquake that does not result in a conflagration, it can be expected that 75% of the fatalities will be a result of structural collapse.[7] Survivors of structural collapses are likely to experience severe injuries, including multiple trauma, crush injuries, injuries to the head, spine, burns, and cardiovascular problems.

Between 1964 and 2005 in Japan, there were 17 earthquakes that resulted in deaths from a variety of causes: 84% of the 6,100 earthquake fatalities were due to building collapse; 5% due to tsunami; 5% due to fire following earthquake; 3% due to landslides; and the remaining 3% is attributed to other causes such as heart attacks, shock, and falling objects. Had the Kobe Earthquake occurred during the day, the loss of life would have been greater due to the collapse of highways, railways, and subways, which would have changed the above distribution. In the same time period, nearly 54,600 people were injured during these 17 fatal earthquakes (many more were injured during the non-lethal earthquakes), a ratio of around nine people injured for one every person killed. The ratio of serious injuries during the same time period was 14 to 1 (roughly 3,900 serious injuries).

Improvements in building codes failed to prevent the collapse of modern reinforced concrete buildings in the 1995 Kobe Earthquake

Lung damage and breathing difficulties are common among collapse survivors as a result of compression injuries to the chest or airway and the inhalation of dust, soil, or bodily fluids. Potentially, these injuries may be long-lasting and require prolonged care.

A delay in medical attention can exacerbate injuries. Dehydration and pain stress also weaken a trapped victim. Crush injuries are particularly dangerous for trapped victims: when released into the rest of the body, toxins built up in the trapped limb can cause renal failure. The likelihood of a recovery from a serious earthquake-related injury decreases rapidly as entrapment time is prolonged.

5.3 Improving Construction Standards

Japan has increasingly improved the design and construction quality of its building stock to make it more earthquake resistant and safer for occupants. Japan has the longest history of seismic design codes of any country in the world. Following the 1891 Nobi Earthquake, the Seismic Disaster Prevention Committee was established to lead seismic design in Japan. The first building code, the Urban Building Law Enforcement of 1919, introduced 'allowable stress design,' an important engineering concept that was copied by other countries. The 1923 Great Kanto Earthquake led to a more substantial seismic code that was mandatory in several major Japanese cities.

In 1950, Japan extended mandatory design standards to the whole country in a new code that specified earthquake design forces 40% greater than those required in California at the time. Japan has revised and updated seismic codes every few years and after important earthquakes. After the 1968 Tokachi-Oki Earthquake, further revisions introduced improvements to the ductility capacity of steel and concrete construction. Issued in 1981, the landmark code that required designers to examine collapse mechanisms in buildings– the first in the world–was acknowledged internationally.

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

After the 1995 Kobe Earthquake illustrated several shortcomings of the building code, several new laws and key code amendments were quickly introduced, including design requirements to prevent 'soft story' failures that cause collapse. In 1998, a privatization program passed on the time-consuming task of checking that regulations have been met from local government officials to private companies. Some of the companies that won these contracts were also property developers, and scandals related to the falsifications of code certification to build sub-standard buildings have cast doubt on the effectiveness of compliance procedures. The extent of the problem is unknown, although it is expected that it is confined to small numbers of buildings.

In recent years, Japan's engineering community has moved away from safety-based design guidelines in favor of performance-based designs (i.e., those reflecting performance in past quakes), which was introduced in a 2000 code revision. Overall, international engineers estimate that design code requirements make modern buildings in Japan some of the world's most earthquake resistant, even exceeding requirements for California.

5.3.1 Residential Buildings in Japan

High casualty levels in Japanese earthquakes have usually occurred in residential buildings, particularly the traditional post-and-beam timber frame structures with heavy tiled roofs. These older, more vulnerable and fire-prone buildings are being replaced in many cities, as authorities encourage their owners to rebuild and upgrade wherever possible. Grants are available to fire-proof and improve high-risk buildings in several metropolitan areas. However, this is a long-term goal, and most of the largest cities in Japan retain a significant population of these old buildings, often in a particular area of the city where street plans, land ownership, and building plot sizes restrict the opportunities for redevelopment.

Recently constructed houses with lightweight timber panel construction and shingle roofs are more earthquake resistant, and more of the population are choosing to live in these. People living in modern apartment buildings are becoming safer since these buildings are subject to rigorous engineering design codes.

Most fatalities in Japanese earthquakes are caused by the collapse of traditional post-and-beam wooden houses with heavy tiled roods, as was seen in the 1995 Kobe Earthquake

5.3.2 An Evolving Threat

Generally speaking, the Japanese population is becoming safer as older timber buildings are being replaced by multi-story, high-occupancy engineered structures. However, as a result, the source of mass-casualties in an earthquake is also evolving: there is now the threat of massive casualties from collapses of these extremely densely populated buildings. Experience from earthquakes in other parts of the world has shown that when multi-story reinforced concrete buildings collapse, they can kill 10% to 50% of their occupants depending on the typology of the collapse. Saving people from under the rubble of such collapsed buildings is extremely difficult, and it is expected that most of the trapped people will lose their life within the first 24 hours.

5.4 The RMS® Earthquake Model

RMS first developed a catastrophe model for earthquake loss for California in 1988. The first RMS earthquake model for Japan was released in 1995 and subsequently updated and improved to higher resolution in 1999. In light of the changes to the Japanese catastrophe insurance market and a growing understanding about seismic hazard in the region, RMS released a major revision of the Japan earthquake model in 2005.

Other earthquake-related catastrophes such as a collapsed highway, as was seen in the 1995 Kobe Earthquake, can cause additional injuries and deaths

The new version simulates 27,300 earthquakes that represent the frequency and severity likely to cause significant loss in Japan. The base seismic source model is derived from the Earthquake Research Committee[8] 2005 National Seismic Hazard Maps for Japan, which are a culmination of 10 years of research on seismic sources in Japan developed for disaster planning and mitigation.

The model has been used to assess the probability of loss from injury to different lines of insurance. 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 the seismic sources throughout Japan, and modeling how each could impact various cities, populations, and building stock in their vicinity.

This model shows that with current population and building stock, there is an annual probability of 3.7% (i.e., a return period of 27 years) that an earthquake could cause 1,000 fatalities or more in Japan and a probability of .42% (i.e., a return period of 240 years) that an earthquake could cause more than 10,000 deaths.

5.5 Earthquake Scenarios

To explore the impact of earthquake casualties on various insurance coverages, two scenarios were selected from the thousands available in the model. The first event with 10,000 casualties was chosen to illustrate losses for different insurance coverages in large earthquake events, within the probability range of concern to insurers. Another event with 17,000 fatalities from shake with an additional 8,000 fatalities from fire was chosen to illustrate the potential for catastrophic levels of human casualties from a very large magnitude earthquake directly impacting a major city.

The fatality totals represented by these scenarios could occur in a number of ways: from a moderate magnitude earthquake causing a direct hit close to a big city to a larger magnitude event affecting a large area of population. The time of day is also an important variable in the number of casualties. Many different combinations of earthquake magnitude, location of strongest impact, and time of occurrence could interact to cause these levels of loss.

5.5.1 Scenario 1: M7.3 Kinki Region Earthquake, 10,000 Fatalities

Located in the central area of Japan, and containing both the Osaka and Nagoya metropolitan areas, the Kinki Region is formed by multiple earthquake faults. it is delineated by Tsuruga Bay (in the Japan sea coast), the Naruto Strait (in the northeastern tip of Shikoku Island), and Ise Bay and Nagoya (in the east) with Lake Biwa in its center.

Japan lies in one of the world's most seismically active and complex zones. The constant west-northwestwards movement of the Pacific Plate and the north movement of the Philippine Sea Plate occurs against the east-southeast movement of the denser continental Eurasian Plate. As a result of the converging movement of these tectonic plates, the lighter oceanic plates sink underneath the

8 *The Earthquake Research Committee is overseen by the Headquarters for Earthquake Research Promotion, which is directed by the Ministry of Education, Culture, Sports, Science and Technology within the Japanese government*

Eurasian Plate forming two subduction zones east of Japan's Pacific coast. These are known as the Japan Trench and the Nankai Trough respectively. Due to these great tectonic movements, the main Japanese island of Honshu is undergoing severe deformations such as bending and the creation of an area of dense and complex surface faulting in its center. In recent years, extensive studies have culminated in mapping the inland active faults. Special attention has been paid to the study of the Kinki Region Seismic Zone because the area has potential for large magnitude earthquakes with immense destructive power. Seven seismic gaps have been identified in various sections of the numerous active faults of this area.[9] Temporal relationship with the occurrence of great earthquakes on the Nankai Trough has also been investigated. A theory has been proposed in which the occurrence of great subduction earthquakes in the Nankai Trough is preceded by large earthquakes in the Kinki Region and its immediate vicinity. It is believed that this process started with the 1995 Kobe Earthquake, which occurred within the Kinki Region.[10] This triangular region is characterized by reverse faults with a north-south strike.

For this report, we chose the scenario of a M7.3 rupture of the shallow background of the Kinki Region. This earthquake has been modeled at 2:00 am on a weekday when most of the population is assumed to be at home. This scenario results in an estimated 10,000 deaths and over 96,000 injuries. However, if this earthquake had been modeled during work hours, it would have caused approximately 9,000 fatalities.

5.5.2 Scenario 2: M8.0 Kanto Earthquake, 25,000 Fatalities

For this report, we have recreated the Great Kanto Earthquake. This event is assumed to occur at 5:00 pm on a weekday, at the time that many people are still at work, but many others are either at home or enjoying after-work activities. While the scale of loss is nowhere near the losses from the actual event, which hit at about 12:00 pm, killing 143,000 and injuring 100,000, the loss is still quite large. 17,000 people are killed from the earthquake itself, with an additional 8,000 fatalities from the fire that follows. If this earthquake had been modeled at 2:00 am, when most of the population is assumed to be at home, it would have caused approximately 30,000 fatalities.

9 *Kanaori, Y., Kawakami, S. and Yairi, K. "Space-time Distribution Patterns of Destructive Earthquakes in the Inner Belt of Central Japan: Activity Intervals and Locations of Earthquakes." Engineering Geology, Vol. 31, p 209-230, 1991*

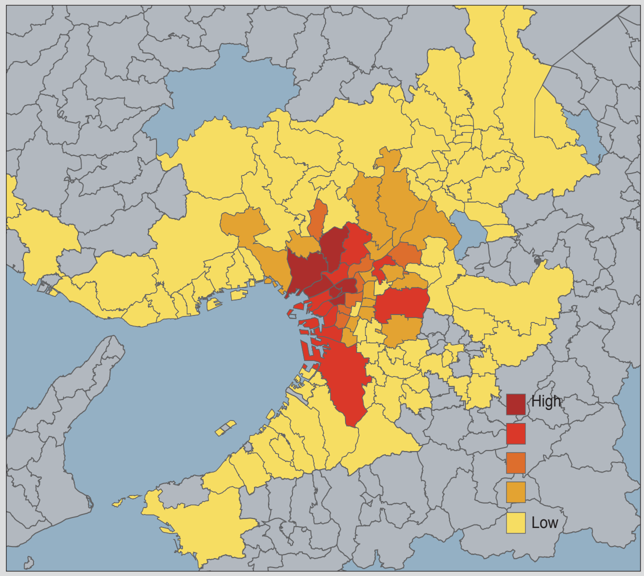
10 *Kawata, Y. (2001). "Disaster Mitigation Due to the Nankai Earthquake Tsunamis Occurring around 2035." International Tsunami Society, 2001 Proceedings, Session 1, Number 1-8, p 315-329*

HYPOTHETICAL SCENARIO 1: M7.3 KINKI REGION EARTHQUAKE

Osaka Metropolitan Area Immobilized by Strong Quake

Casualties are high as rescue teams struggle to find and treat victims

Residents of destroyed neighborhoods survey the damage



Distribution of fatalities by ward from the hypothetical Kinki Region earthquake

In the early hours of a cold spring night, more than nine million people across the metropolitan area of Osaka are shaken awake by a violent earthquake, which pounds and twists the ground for nearly a minute.

In their wooden house in Osaka, a couple is woken by a violent jolt and a deafening thunderclap. The shaking continues, and the building around them bends and groans noisily in the dark. They leap to their feet, hardly able to stand, and fumble out of their house into the narrow street outside. Further down the street, a cascade of heavy roof tiles crashes down, and the old wooden buildings are twisting and shaking around them. Overhead, the tangle of power lines and phone wires spark and fall, and the street lights are suddenly extinguished. A house at the end of the street twists and collapses in a huge cloud of dust. Several other houses, sagging under the heavy weight of their roof tiles, implode, filling the air with thick dust. People are running out of their houses, many shouting and calling to others. Eventually, the shaking dies down. There are calls from people trapped in one of the collapsed houses, and a group forms to lift timbers away to pull the trapped out from the wreckage.

Across the city, hundreds of thousands of people are dealing with similar incidents. Houses have collapsed, and many people are trapped under the heavy old timbers and ceramic tiles. Power is out almost everywhere. Telephone lines are down, and the cell phone network has died. The fire brigades form into search and rescue teams– a well-practiced drill– and make their way through the streets with powerful flashlights, using their radios to call in incidents of building collapse into the central disaster preparedness control room. Some streets are impassible with debris and obstructions. At major collapse sites, where there are suspected trapped victims, a cordon is set up, floodlights are brought in, and a systematic search and rescue operation formed to get victims out. In some parts of the old neighborhoods, many houses have collapsed into a single mass of wreckage; the rescue operations in the area proceed in a race against time to beat the potential risk of fire.

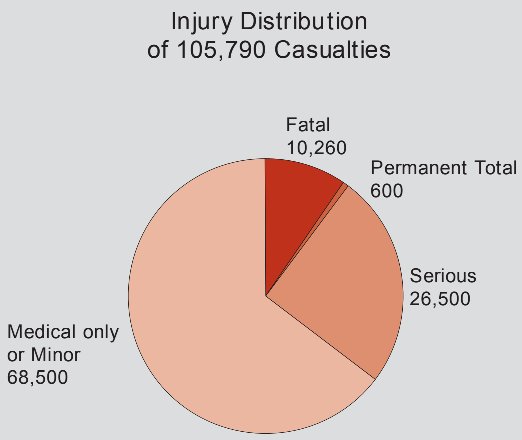
Gas pipes in most of the houses have shut off automatically. But in a few, electrical sparks or overturned kerosene heaters start fires. Most of the occupants are outdoors. Some manage to return and extinguish the fires; others cannot be contained. Individual houses are soon ablaze. Fire crews and volunteers try to contain each one from spreading to neighboring buildings. The water supply has lost a lot of pressure, but recent upgrading of some of the main underground pipes has ensured that many of the affected areas have at least some water. Additional local water storage tanks and portable tankers help augment the emergency supply. Although there are many fires, and the fire crews are spread very thin, there are only a few incidents where the fire spreads to whole urban blocks. Fire erupts inside some of the collapsed buildings where the search and rescue crews are working: they are beaten back from rescuing anyone inside the burning wreckage.

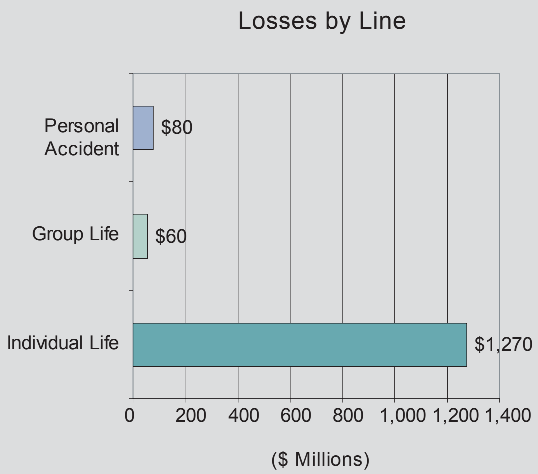
Thousands of people are emerging from the streets with injuries: head wounds, broken limbs, severe cuts, and some burns. Cars with injured passengers are clogging streets around the main hospitals. Many people walk or are helped by friends to get to medical treatment points.

Some of the main hospitals have suffered severe damage. At a major hospital in the Osaka center, the chief administrator has no option but to order the emergency evacuation plan into effect. Nurses and orderlies carry bedridden patients out into the courtyard and establish a temporary ward out in the open. Others establish a triage center at the hospital entrance to treat the incoming patients. An emergency room physician quickly classifies each victim as either in danger of dying without treatment, likely to recover without treatment, or likely to die even with treatment. Resources are concentrated on the first category.

A small emergency operating center enables surgeons to perform essential surgery on the neediest cases, but there are only a few surgeons, medical supplies are limited, and blood is in short supply. Patients are transferred to hospitals in cities less severely affected by the earthquake. For two days, helicopters shuttle critical patients between cities; many are sent by ambulance. Hospitals all over southern Japan take patients; for some specialist treatments like burns and spinal injuries, hospitals are at full capacity across the whole country.

Teams of paramedics treat tens of thousands of people. The large majority require only minor attention to cuts, bruises, and treatment for shock. Many need to have wounds dressed and fractures set. The huge demand means that time-consuming conventional procedures, such as x-rays and casts for fractures, cannot be performed; instead, these are dealt with using simpler procedures such as binding in a splint. After the initial emergency has passed, these patients are sent back to the hospitals for re-treatment and follow-up procedures, a practice that adds to the total treatment costs. Increased staffing is needed for most of the hospitals across the region for many weeks. Hospitals run at full capacity for nearly two months as treatment of victims continues.



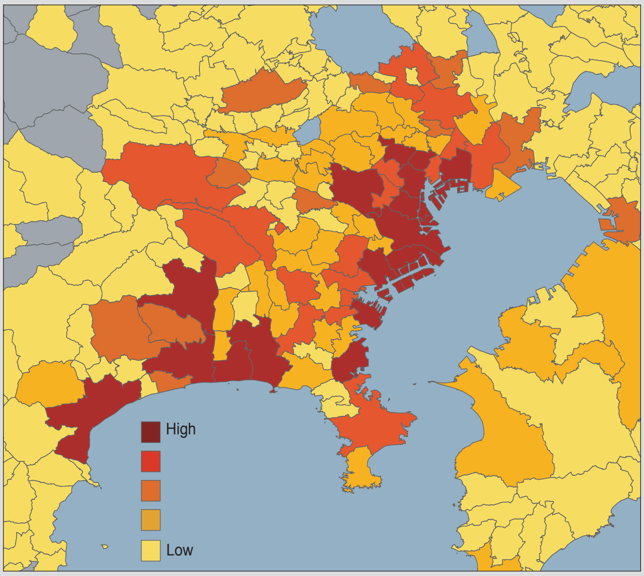


HYPOTHETICAL SCENARIO 2: M8.0 KANTO EARTHQUAKE

Rush Hour Earthquake Hits Japanese Capital

Hospitals are overwhelmed as thousands are treated for collapse and burn injuries

Fires in dense, older neighborhoods can cause many casualties, as seen in the 1995 Kobe Earthquake



Modeled casualties from the hypothetical earthquake scenario are experienced across a wide area of Tokyo and Yokohama

It is nearly 5:00 pm on a weekday, and offices are full of staff getting ready for the commute home. A lawyer working on the 12th floor of a building in central Tokyo looks up as the room sways slightly. He glances at his colleagues, and they recognize it immediately–an earthquake. The building starts to sway, and as flat screens bounce off desks and shatter onto the floor, everyone braces themselves. Cupboards open and shower out their contents. Part of the suspended ceiling gives way and falls into the room. Lights flicker and glass shatters.

Another office worker looks out the window and sees nearby buildings swaying strongly. One of the middle floors of a 20-story building collapses, and then one by one the top floors descend onto the ones below in a cloud of dust.

All across the city, citizens brace themselves inside doorways, and schoolchildren duck under desks. Drivers on the roads struggle to control their swerving cars, but most pull over safely. The shinkansen (the local bullet train) has already been brought to a halt, but other trains are thrown off their tracks. One commuter train, making an early trip home with only half of its normal passenger load, is thrown sideways and rolls down an embankment. Elsewhere, a section of elevated subway track collapses and a four-carriage train vanishes with it.

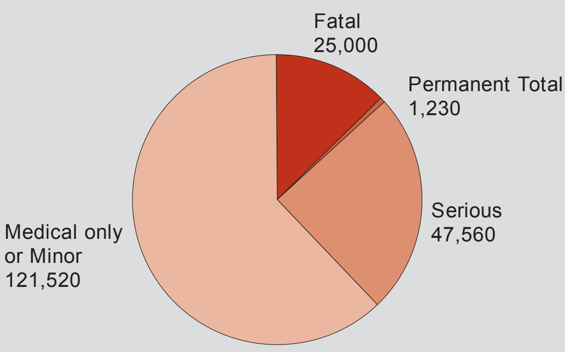
The shaking subsides, and there is a short period of silence. In the office building the lights flicker and die. People head for the stairs and join an exodus of others emerging from all the buildings of the downtown area. They walk across streets littered with broken glass to their pre-assigned refuge areas in the car parks and open spaces around the buildings. In the distance, the wail of sirens indicates the emergency services are already on the move. Helicopters are circling overhead as police reconnaissance and news teams appraise the damage. Initially, it appears that the city is shaken but apparently only superficially damaged. Then the helicopter crews spot crowds of people milling around a dusty vacant lot in one of the downtown blocks, eventually realizing that it is a building collapse. Reports come in of other buildings that have collapsed–only one or two in every few thousand, but these add up to several hundred in all. Many of them are large, multi-story offices and commercial engineered structures, each containing hundreds of occupants. One building, a recently-opened prestigious multi-story shopping mall, has collapsed on several thousand shoppers. The investigation after the event will lead to the indictment of the developers, architect, and code compliance officials on charges of non-compliance with earthquake codes.

Police set up barriers around the site of the building collapse. There are people trapped under the twisted concrete and steel, many killed instantly but a significant proportion still alive. Some are able to free themselves, and teams of volunteers directed by fire officers work to pull people out from the rubble. The rescue teams bring in power saws, crowbars, and expander jacks but make slow progress cutting through the reinforced concrete slabs. Mechanical diggers are brought in but are held back from being used because they may kill the remaining survivors in the rubble.

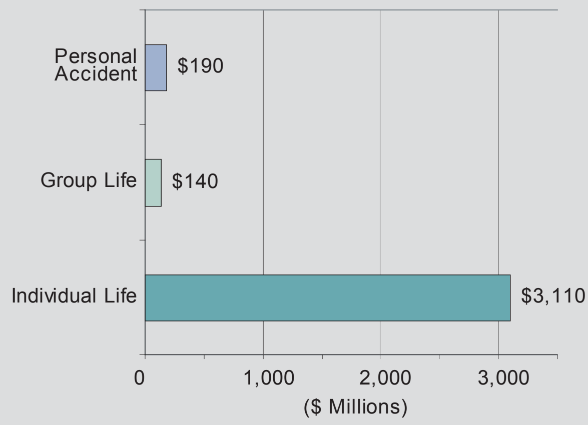
In the older dense neighborhoods of the center of Tokyo, several of the old wooden buildings have collapsed, and many have suffered severe damage. Narrow streets are blocked by wreckage and debris, and people are climbing over collapsed buildings to get out. The damage to these neighborhoods, particularly to the electrical systems, triggers fires, which rapidly take hold and fill the air with smoke. Flames can be seen in several parts of the wreckage. Fire brigades have difficulty getting into the area because of the debris, and the hydrants are dry. Dry winds are whipping the flames up and scattering burning embers through the streets. In minutes, the fires are burning in a continuous area across several blocks. A large group of survivors making its way out of the neighborhood sees the wall of flame and turns back to find another way out. To one side of the burning neighborhood is a large concrete apartment building 15 stories high. Several groups of survivors head for the apartment building, but the flames and scorching heat prevent them from getting closer. The heat from the flames is causing strong updrafts of hot air, searing hair and making it difficult to breathe. Firemen in the tall building call out to them, and several people try to run through the curtain of flame. Firemen finally connect hoses to a functioning high pressure water source and send a spray of cool water to form an avenue through which the survivors can run to safety. Thousands of others are not lucky as the flames consume the rest of the neighborhood.

By nightfall hundreds of individuals have been pulled out from 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 tunnel into the rubble with specialized equipment and look for routes through to find survivors. Each survivor is given emergency treatment inside the rubble by a rescue physician and secured to a body harness to protect any 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–their survival is heralded as miraculous by the world's media–but all are injured, weak, and dehydrated; several die later in hospital. The last survivor is found on the 10th day in a surprise discovery: an elderly woman trapped in an air pocket in a basement room. The victims of the earthquake are treated in over 1,000 hospitals across southern Japan.

Injury Distribution
of 195,310 Casualties



Losses by Line



5.6 Variations in Outcomes

These descriptions illustrate two potential earthquake scenarios that could cause several thousands of casualties. But as explained above, these are not the only locations where or ways in which large numbers of casualties can arise in major earthquakes. Different locations, time of day, and surrounding circumstances can all affect the losses.

More casualties will occur if there are 'follow-on' catastrophes. In scenario 2 we described a conflagration consuming a neighborhood–a 'fire following earthquake' phenomenon. Other catastrophes caused by the earthquake, such as the collapse of elevated highways and the derailment of trains, the collapse of subway stations, or the rupturing and spilling of hazardous material, can cause large numbers of additional casualties. The possibility of an earthquake damaging a major nuclear power plant is also a threat to life and health, as discussed below.

5.6.1 Time of Day

The exposure database captures the location of each segment of the population by daytime and nighttime locations. Analysis of the impact of the earthquake on the population in particular locations at different times of the day shows how casualty patterns change by time. In Japan, where the chance of high-intensity earthquake is great, the difference between seismic performance of residential and commercial buildings is very marked.

5.6.2 Nuclear Plants Affected

There are 52 nuclear reactors in Japan, almost all built along the coast where seawater is available for cooling. Their coastal location, however, makes them vulnerable to the activity of the underlying active faults, specifically along the Tokai Subduction Zone. Nuclear power stations are designed to very high standards of earthquake resistance, and the chances of one failing in an earthquake are extremely remote. However, if the containment was compromised and a significant radioactive release were to occur, a large population could be exposed to radiation that would cause health problems and major costs for health insurance portfolios.

The Hamaoka power station in particular is located right above the Tokai Fault Plane. If an earthquake were to occur, there is potential for damage to this power station. Any leakage of radioactive material could make rescue from the earthquake damaged area difficult. The nuclear accident at its maximum could possibly affect the inhabitants of Tokyo, which is approximately 200 km (124 mi) away from Hamaoka.

5.7 Probabilistic Assessment of Earthquake Loss

The chances of each of these individual catastrophic earthquake events occurring 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, we can obtain a complete assessment of the likelihood of different levels of loss.

The RMS® Japan Earthquake Model consists of a catalog of 27,000 potential earthquake events, comprising a complete representation of the seismicity in Japan. Using the best assessments of the Earthquake Research Committee and independent research, the model provides 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. The probability of each event occurring,

Annual Probability	Return Period (years)	Number of Fatalities Daytime	Number of Fatalities Nighttime
Average Annual		200	200
2.00%	50	1,800	1,900
1.00%	100	4,000	4,200
0.50%	200	8,400	9,100
0.40%	250	10,400	11,300
0.20%	500	18,900	20,800
0.10%	1,000	30,900	34,900
0.05%	2,000	47,400	54,500
0.02%	5,000	78,600	92,000
0.01%	10,000	112,000	132,000

Table 5.2 Exceedance probability of the number of fatalities resulting from earthquakes if they only affected daytime or nighttime populations

Annual Probability	Return Period (years)	Number of Fatalities	Number of All Other Injuries
Average Annual		200	8,900
2.00%	50	1,900	95,400
1.00%	100	4,200	107,800
0.50%	200	8,800	123,100
0.40%	250	11,000	128,800
0.20%	500	20,100	148,700
0.10%	1,000	33,400	169,100
0.05%	2,000	51,900	186,300
0.02%	5,000	87,100	197,900
0.01%	10,000	124,700	194,800

Table 5.3 Exceedance probability of the number of fatalities resulting from earthquakes occurring at random times during the day

Annual Probability	Return Period (years)	Individual Life ($ million)	Group Life ($ million)	Personal Accident ($ million)
Average Annual		25	1	1
2.00%	50	230	10	10
1.00%	100	520	20	30
0.50%	200	1,110	50	60
0.40%	250	1,380	60	80
0.20%	500	2,520	110	140
0.10%	1,000	4,170	170	240
0.05%	2,000	6,450	270	370
0.02%	5,000	10,810	460	620
0.01%	10,000	15,460	650	890

Table 5.4 Exceedance probability of the insured losses resulting from earthquakes occurring at random times during the day

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 of insured risk 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, and personal accident.

The exceedance probability (EP) of a level of loss in a year is expressed as an annual probability and also as its reciprocal: a return period (aggregate exceedance probability or AEP).

The average annual loss (AAL) is the integral of all EP levels, representing the burning rate of all losses if averaged over a long enough period of time.

5.7.1 Working Versus Home Hours

The analysis is carried out assuming a particular exposure at a particular time. To incorporate the time of occurrence differences into analysis, the earthquake exposure is divided into two categories: 'working hours' (2:00 pm) and 'home hours' (2:00 am). The exposure is assumed to be at its maximum occupancy for that mode, and a set of probabilistic analyses is derived for both of these occupancies. Since earthquakes occur randomly, the probability of experiencing a loss is a mix of these two loss probability results. Working hours represent about a quarter of the time, and home hours represent the remaining three quarters.

5.7.2 Casualty Return Periods

Loss return periods for death and injury in earthquakes are given in table 5.2 and 5.3. The EP curves for different times of the day show large variation in casualties. Although an earthquake can occur at any time, looking at the 2:00 am and 2:00 pm casualties can provide a range of possible outcomes because these times represent maximum occupancies at each location, home and work, respectively. ■

6 TSUNAMI

Japan's geographical position on the rim of the Pacific Ocean makes it susceptible to tsunamis–sea waves caused by offshore earthquakes, volcanic eruptions, and sea-bed landslides. It is no coincidence that Japan gave the world the word for the phenomenon: the island country has experienced frequent, deadly tsunamis. In addition to local seismic activity, earthquakes as far away as North and South America can cause devastating tsunamis affecting the coast of Japan.

6.1 The Phenomenon of Tsunami

The phenomenon of tsunami occurs most commonly due to an earthquake or landslide on the ocean floor that sends a pulse of energy into the sea water above it. It creates a low amplitude but powerful ripple that travels extremely rapidly across the ocean surface. When it reaches a coastline, it suddenly slows and builds into a wave of water that breaks violently onto the shore. Extensive stretches of coastline can experience waves of more than 10 m (30 ft) high. In exceptional circumstances, waves as high as 38 m (125 ft) have been recorded. A tsunami may go unnoticed by a boat out at sea; however, at the shoreline, the high waves are deadly, crushing buildings and sweeping people back out to sea. Tsunamis can occur as a sequence of waves, with the worst sometimes being the second or third inundation. Minor waves may continue for several hours. The height of a tsunami wave is known as its 'run-up': the elevation of water above the normal sea level at the time.

Japan has a long history of deadly tsunamis, as illustrated in this 1896 Shoukoku Yamamoto painting depicting the effects of the Sanriku tsunami

The height of the wave varies considerably with local features and the 'bathymetry' of the sea floor affecting how the wave hits the coast. For example, underwater ridges can intensify the wave, islands and reefs can shelter shorelines and refract the waves elsewhere, and wave heights can be amplified within bays that narrow from the entrance to the head but decreased in bays with narrow mouth.

6.2 The 2004 Indian Ocean Tsunami

One of the most deadly natural catastrophes of modern times was the tsunami in the Indian Ocean on December 26, 2004 that killed more than 270,000 people. A massive earthquake in the ocean off the island of Sumatra, Indonesia triggered tsunami waves of over 10 m (30 ft), killing 168,000 people. Run-up heights of 6 m (20 ft) were recorded along the coastlines of Sri Lanka, Thailand, and Malaysia, and run-ups of 3 m (10 ft) occurred in several other countries across Asia and Africa. The farthest recorded death due to the tsunami was at Port Elizabeth in South Africa 8,000 km (5,000 mi) away from the earthquake epicenter. The severity of the event combined with the sheer geographical scale made this the world's deadliest tsunami on record and demonstrated the destructive power of this form of natural catastrophe.

6.3 History of Tsunamis in Japan

Prior to December 2004, Japan had historically suffered the highest number of tsunami-related fatalities of any country. According to the historical catalog,[1] more than 62 destructive tsunamis are known to have struck Japan in the last millennium. Over the past 300 years, tsunamis have claimed at least 66,000 lives. The following are examples of significant historical tsunamis:

- *The 1896 Sanriku, Honshu Tsunami:* The largest recorded death toll of 27,000 people for a tsunami in Japan occurred in 1896. When the tsunami struck the coastline of Sanriku district in Honshu, most of the coastal residents were in the streets celebrating a national holiday. Almost everyone within 500 m (0.3 mi) of the coast died in the ensuing wave. Fishermen who had been out to sea when the wave struck returned home to find the sea strewn with bodies and wreckage and bare expanses and ruins where cities and villages once stood.

1 *Lockridge, P.A., R.H. Smith. "Tsunamis in the Pacific Basin: 1900-1983." National Geophysical Data Center, National Oceanographic and Atmospheric Administration, Boulder, Colorado, 1984*

Tsunami waves surge powerfully back and forth several times, sweeping shoreline property and anyone caught by the wave back out to sea, as seen in this sequence of the 1983 Japan Sea tsunami impacting the Akita coastline (Source: NOAA)

- *The 1933 Sanriku, Honshu Tsunami:* In 1933, a tsunami again impacted the Sanriku coast as it had done in 1896. It was caused by a M8.4 earthquake centered in the Japan Trench subduction zone in the Pacific Ocean about 350 km (215 mi) to the east of the city of Sendai. The earthquake created a tsunami that peaked at nearly 30 m (98 ft) high at one location along the eastern Honshu coastline. The town of Ofunato experienced run-up of more than a 3.6 m (12 ft). In the Sanriku district of Honshu, 9,000 houses and 8,000 ships were destroyed. More than 3,000 people were killed or lost in the wave.
- *The 1993 Okushiri Island Tsunami*: An earthquake in the Japan Sea in 1993 caused a localized tsunami on Okushiri Island that badly damaged the town of Aonae. Located on a cliff, the town was protected by a 4.5 m (15 ft) high sea wall that failed in one section and a 10 m (33 ft) high sand dune. Two tsunami waves hit the town 5 minutes and 8 minutes after the earthquake. The second wave had a run-up of 10 to 15 m (33 to 49 ft) and left the densely built town flooded with 3 to 7 m (10 to 23 ft) of sea water. Given the sudden onset of the tsunami and its high energy, it is amazing that more people were not killed: 231 people on the island lost their lives, including 7% of the town's 1,600 residents.
- *The Tsunami from the 1960 Chilean Earthquake*: The 1960 Great Chilean Earthquake off the coast of Chile–at M9.5 the strongest earthquake ever recorded–generated one of the most destructive tsunamis of the 20th century. It spread across the entire Pacific Ocean, with waves measuring up to 25 m (82 ft) high. The first tsunami arrived at Hilo Bay, Hawaii almost 15 hours after it originated, and the highest wave was measured at approximately 10.7 m (35 ft). More than 60 lives were lost, allegedly due to people's failure to heed warning sirens. When the tsunami hit Onagawa, Japan almost 22 hours after the quake, the run-up height was 3 m (10 ft) above high tide. The number of people killed by the earthquake and subsequent tsunami is estimated to be between 490 and 2,290.

6.4 Population at Risk from Tsunami

The death tolls of past tsunamis are not useful guides for estimating the levels of loss that could be experienced in extreme events today. The number of people living close to the coast has grown significantly, making many more people vulnerable to large run-ups. However, as discussed below, the Japanese government has invested in protective measures to offset this increased risk.

6.4.1 Growing Coastal Populations

Several of the historically large tsunamis affected long stretches of coastline that had sparse populations compared to the densely populated coastal cities of today. The population of Japan is now three times what it was a century ago and is overwhelmingly coastal. Although Japan has a long history of maritime activity, the urbanization of the coast is a phenomenon of the last 50 years. Japan transformed itself from a largely rural and non-coastal nation into an overwhelmingly urban and coastal country within two decades, from 1950 to 1970.[2] Today 77% of all Japanese live in urban areas along or near the coast.

2 Hinrichsen, D. "The Coastal Population Explosion." The Next 25 Years: Trends and Future Challenges for U.S. National Ocean and Coastal Policy, United Nations, 2000

6.4.2 Proximity to the Sea

Although casualties from a tsunami can be incurred up to 2 km (1 mi) inland, the large majority of people killed and injured are within 500 m (1600 ft) of the coast. The population living within this danger zone has increased substantially and is a key measure of the exposure to tsunami risk. The distribution of the population currently living within different distances of the coastline is shown in table 6.1.

Much of the Japanese coastline is mountainous. Populations living further inland tend to be at higher elevations and so are less likely to be affected by tsunami. However, most of Japan's major cities are on the flatter land of the coastal plains, where the elevation rise is less severe. As a result, populations living even at some distance from the coast still may be at risk.

Some tsunamis originate from earthquakes in the Sea of Japan and affect the western side of the country.

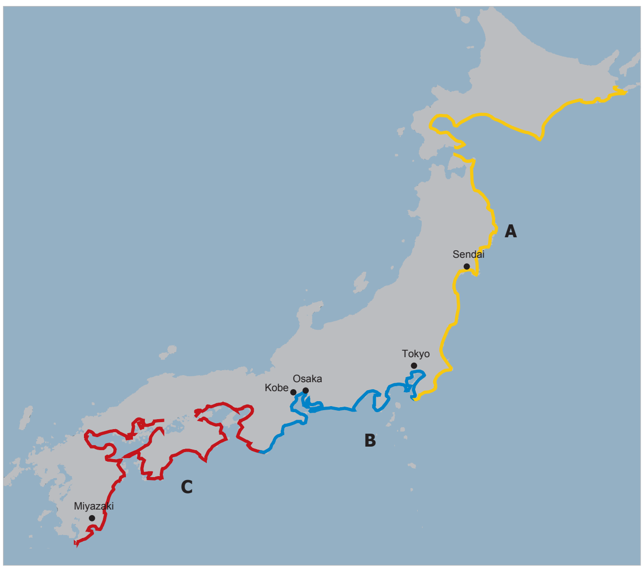


Figure 6.1 Coastlines most at risk to tsunami, with populations summarized in table below

However, the main tsunami threat is to the heavily populated coastlines on the east and south regions of Japan, which are affected by major earthquakes in the deep oceanic subduction zones, distant earthquakes, or other oceanic activity from the other side of the Pacific Ocean.

The most densely populated section of shoreline lies along southeast Honshu, and includes the Yokohama and Tokyo coastal suburbs, as well as the shoreline of the Nagoya metropolitan region. The second most populous coastal area is southwest Honshu, including the coastal areas of the cities of Osaka and Kobe and the southern coastlines of Shikoku and southeastern Kyushu.

Studies of tsunami risk have identified 402 municipalities threatened by tsunami along Japan's Pacific Ocean coasts. A survey of preparedness in 2004 established that only 15% of these municipalities have published their tsunami hazard maps, although more than 80% conduct tsunami response drills.[3]

6.5 Tsunami Protection in Japan

Japan has implemented extensive measures to reduce the likelihood of large death tolls from future tsunamis. Measures include building flood barriers, controlling land use and implementing stringent design codes along coastlines, as well as an early warning system combined with efficient disaster response.

6.5.1 Flood Barriers

The Japanese government has invested billions of dollars into building coastal defenses against tsunamis, such as breakwaters and concrete sea walls to blunt the impact of incoming waves. Other measures include extended beach areas and artificial offshore land-spits. Many harbors and river channels into urban areas are defended by

	Coastline A 1,600 km (1,000 mi)	Coastline B 500 km (310 mi)	Coastline C 1,200 km (750 mi)	Total
Distance from coast	Eastern Honshu & SE Hokkaido	SE Honshu	South Shikoku, SE Kyushu, SW Honshu	A, B and C
500m (1,600 ft)	382,687	861,726	1,102,843	2,347,256
1km (0.6 mi)	749,451	1,737,550	2,189,265	4,676,266
2km (1.2 mi)	1,376,551	3,694,195	4,579,080	9,649,826

Table 6.1 The distribution of the population currently living within different distances of the coastline

3 *Recommendations of the Japan Tsunami Protection Committee in the Wake of the 2004 Indian Ocean Tsunami, March 2005*

The tsunami warning system, which includes warning signs like pictured here, advises people close to the coast to get to high ground and to designated safe refuge places

sea gates that can be closed to mitigate the reach of a moderate tsunami wave if sufficient warning is given.

These defenses are designed to provide good protection against the more common occurrence of tsunami waves with a run-up of 3 to 4 m (10 to 13 ft) as well as the sea surges that accompany strong typhoons. The coastal defenses are not expected to withhold larger tsunamis.

6.5.2 Land Use and Design Codes

Land use planning and permits for new construction in metropolitan areas of Japan take into account several natural catastrophe perils, including tsunami. Zones of potential high-wave impact from tsunami have been mapped for most of the urban areas in Japan, and some high-risk areas are 'restricted' for new development. In practice, however, areas designated as restricted are limited, due to development demand and high land prices.

The Building Standard Law of Japan (the Japanese building code) does not currently include specific design requirements to resist the forces and damage mechanisms of tsunami waves. However, Japan has some of the highest standards of earthquake and typhoon resistant design codes in the world. These high standards are thought to provide some level of protection against fluid wave impact, but the engineering of structures to withstand the pressures imposed by major tsunamis would be prohibitively expensive. In 2004, the Building Center of Japan established a research project on potential code requirements to address tsunami risk, but it will be many years before any specific requirements for tsunami resistance are incorporated into the building codes.

6.5.3 Tsunami Early Warning System

Since 1952, the Japan Meteorological Agency (JMA) has been operating a tsunami warning service to provide early warning of approaching tsunamis. The service consists of six regional centers connected to 300 sensors located across Japan's islands, including around 80 water-borne sensors, which continuously monitor seismic activity. The service coordinates with international efforts across the Pacific Ocean, including Hawaii's Pacific Tsunami Warning Center, to detect events that could trigger dangerous tsunamis. When seismometers detect a large, shallow earthquake under the ocean, it takes about three minutes for the JMA to verify it and to issue an alert. Other sensors in the ocean detect the progress of the tsunami wave and help predict the height, speed, destination, and arrival time of any tsunami destined for the Japanese shores.

If a large earthquake occurred on the North American coast, the wave would take about eight hours to arrive in Japan; from South America, the time would range anywhere from 10 to 20 hours. The lead time that this provides is useful in enabling response plan action. Disaster preparedness is well organized in most Japanese cities, and includes drills, evacuation plans, and rescue practice for a range of life-threatening perils such as fire, earthquake, typhoon, storm surge, and tsunami. Tsunami plans call for rapid evacuation of the areas most prone to high waves, moving as much of the population as possible inland and to high ground.

Evacuation plans, however, are unlikely to prevent all casualties: the old and infirm may not be able to evacuate, warnings may not reach everyone, and some may not be willing to move. For example, with three days notice that Hurricane Katrina was about to strike the Gulf Coast of the U.S. in August 2005, only 80% of the population of New Orleans was successfully evacuated, leaving 100,000 people stranded in the flooded city. While preparedness measures in New Orleans appear to have been less organized than most Japanese disaster operations, the logistical and social difficulties of evacuation cannot be underestimated.

In addition to tsunamis originating across the Pacific, Japan is also vulnerable to tsunamis resulting from large magnitude earthquakes along the subduction zone of the Japan Trench and the Nankai Trough, just a few hundred kilometers from the Japanese coast. A tsunami wave triggered by a large magnitude earthquake in the subduction zone could hit Japan within 8 to 10 minutes. Clearly, an evacuation with 10 hours warning is more effective than one with only 10 minutes.

6.6 Scenarios for a Catastrophic Tsunami in Japan

A major tsunami capable of causing mass casualties in Japan could potentially result from local events close to the coast or by distant events across the Pacific. While distant events can cause a tsunami that might affect very long sections of the Japan coastline, the amplitude of the waves is likely to be diminished by its distance.

6.6.1 Distant Sources of a Catastrophic Tsunami in Japan

Earthquakes in North and South America have caused tsunamis in Japan with run-ups of 3 to 6 m (10 to 20 ft). Examples of potential large (M8.0-9.0) distant earthquakes capable of causing tsunamis in Japan might include:

- Major earthquakes in Alaska on the Cascadia fault along the U.S.-Canada border: some researchers estimate that a M9.0 earthquake from Cascadia in 1700 caused a tsunami cresting as much as 5 m (16 ft) in Japan and affected the entire eastern and southern coastline with run-ups of more than 2 m (6 ft).[4]
- Major earthquakes along the South American coastal subduction zone: Earthquakes like the 1960 Great Chilean Earthquake described earlier, are capable of causing large waves in Japan. This is a region where extremely large magnitude earthquakes are possible.
- Other large magnitude earthquakes, landslides, or volcanic eruptions occurring within the Pacific Ocean or around its perimeter; a sizeable meteorite falling into the Pacific could also cause a tsunami that would affect Japan, but such events are extremely rare.

A tsunami from a distant source could affect the whole Pacific coastline of Japan with a run-up of more than 3 m (10 ft), which could lead to localized waves of more than 6 m (20 ft) in some areas. Coastal defenses in most locations around the country would provide reasonable protection, but would be overtopped or destroyed by the high waves. The warning time allowed is significant: if given 10 hours or more notice, the evacuation should be fairly effective (e.g., 90% or more of the population evacuated from the 500 m (0.3 mi) closest to the coast). Modeling these types of events suggests that fatality levels in Japan would be unlikely to exceed 10,000.

More devastating outcomes are possible with very large magnitude earthquakes that occur when circumstances favor the energy dissemination of the wave in the direction of Japan, such as tidal forces or a typhoon storm surge in progress when the tsunami strikes. Higher casualties could also be caused by operational failures of the warning system or inefficient evacuation measures.

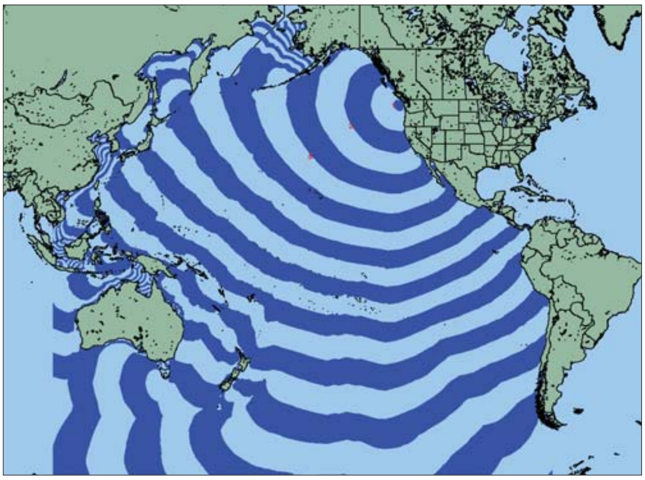


Figure 6.2 Produced by the West Coast/Alaska Tsunami Warning Center, this tsunami travel time map shows the expected tsunami travel time from a source in the Pacific Northwest; the contours are in 1 hour intervals (Source: NOAA)

4 Sakate, K., K.Wang, B. Atwater. "Fault Slip and Seismic Moment of the 1700 Cascadia Earthquake Inferred from Japanese Tsunami Descriptions." The Journal of Geophysical Research, November 2003

6.6.2 Large Magnitude Earthquakes in Japan Fault Zone

A large magnitude earthquake on one of the major subduction fault zones near Japan would cause a much more localized tsunami affecting a section of the Japan coastline, with the potential to cause higher run-ups and much shorter warning times. The Nankai Trough and the Japan Trench are both potential sources of large earthquakes exceeding M7.5.

A tsunami from an earthquake along the northern Japan Trench would primarily impact the slightly less populated coastline of eastern Honshu. The southern end of the Japan Trench passes some distance away from the highly populated coastline of southeastern Honshu, and it would take an unusually strong earthquake to focus a major tsunami on this densely inhabited coast.

A tsunami from an earthquake along the Nankai Trough would impact southwest Honshu, Shikoku and Kyushu regions. Running parallel to the major section of coastline that contains more than a million people living within 500 m (0.3 mi) of the coast, the Nankai Trough is capable of generating earthquakes of M8.0, which could cause very high tsunami waves that would swamp defenses and spread far inland over a major section of coastline.

This setting is the subject of our scenario: a M8.0 earthquake on the Nankai Trough generates a tsunami with a run-up of 20 m (66 ft) at localized points along the southern coast of Shikoku. A tsunami of 10 m (33 ft) high hits approximately 50 km (31 mi) of coastline, including parts of Kyushu and Honshu. Major sections of the coastline of southern Honshu, including parts of Osaka Bay, are hit by more than 5 m (16 ft) of water. Most of the remaining 800 km (500 mi) of the coastline of southern Honshu experience more than 2 m (7 ft) of tsunami run-up, but the coastal defenses are sufficient to blunt the impact of the water, and losses in these areas are light. The Tsunami Warning Service provides 14 minutes of warning, but this is sufficient time for only a fifth of the population along the affected coastline to scramble further inland. A total of 37,000 people die and 60,000 are injured in the event.

Tsunami walls can provide extra protection against moderate waves, weakening the impact on the urban areas, but are unlikely to withhold larger tsunamis (Source: USGS)

6.7 It Could Have Been Worse

This scenario is fictional but effectively illustrates the type of event that could cause tsunami fatalities of several tens of thousands in Japan. Although this is a severe scenario, there are other potential circumstances that could cause even greater losses. Larger earthquakes are possible in the Nankai Trough and elsewhere along the Japan coast, and these could cause larger tsunamis or impact longer lengths of coastline. It is also possible that earthquakes could produce larger tsunamis than expected– the science of estimating tsunami height from earthquake magnitude and fault rupture characteristics is still imprecise.

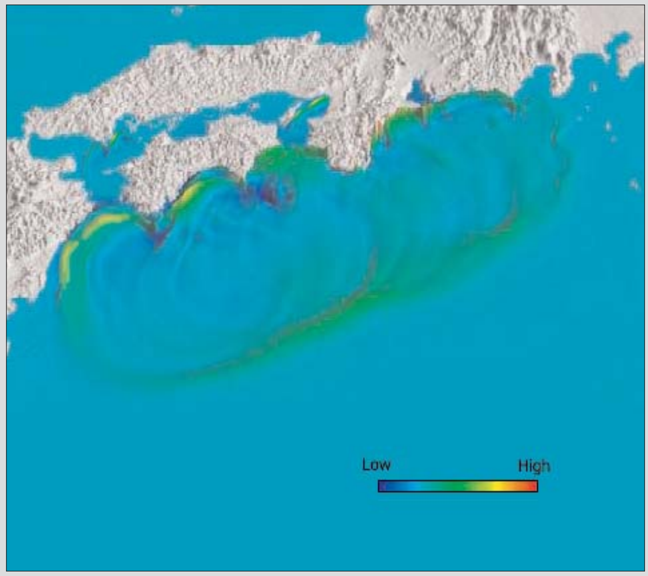
It is also possible that warnings are less effective than current expectations, which are largely based on the results of emergency practice drills. Many things can go wrong with evacuations, and it is not guaranteed that the performance levels achieved in practice will be realized in a real situation with more challenging obstacles, such as an event at night or in winter as described in the scenario. ■

HYPOTHETICAL SCENARIO 3: TSUNAMI OFF THE JAPANESE COAST

Powerful Waves Hit the Heavily Populated East Coast

Tens of thousands are missing after an early morning tsunami

Low-lying areas are heavily impacted by tsunami waves, but people who reach high ground are safe from its effects (Source: USGS)



The impact of tsunami waves on the Japanese coastline in the hypothetical scenario (based on simulations by the Disaster Prevention Research Institution, Kyoto University)

At 5:30 am in the twilight of a freezing February dawn, southern Japan is shaken by a strong earthquake. Many people are awoken, and authorities in 1,000 municipalities go through a well-practiced routine to check for damage. Within minutes, the Japan Meteorological Agency (JMA) has established that the earthquake was a large magnitude event at M8.0 and fairly shallow. Damage from the shaking appears relatively light because the source is at least 250 km (150 mi) out to sea, south of Shikoku, in the Nankai Trough seismic subduction zone.

The initial relief that damage appears to be light quickly turns to concern about warning signals triggered by JMA's Tsunami Warning Service. The earthquake rupture on the sea bed has sent shock waves through the water that are rippling out towards the mainland at the speed of a jet aircraft, about 900 km (560 mi) per hour. It has taken 3 minutes to make the diagnosis, and in another 14 minutes the wave will hit the mainland. A tsunami warning is flashed to the ward organizations on the coastline of southern Japan.

Households all along the coast hear the whining sirens of the tsunami warning. The more alert people are already up, awoken by the strong vibration from the earthquake, and understand what is going on. They grab clothes, calling to their children, relatives, and neighbors. Many others are less quick to grasp what is happening. Grabbing their valuables, they hurry out into the streets, which are already full of people shuffling slowly and laboriously through the snow. They look apprehensively towards the sea walls of the harbor, just a few blocks away. The sea appears calm and as though the tide has suddenly receded. Whistle-blowing wardens usher people towards refuges further inland.

However, many cannot evacuate. The neighborhood has many older people, and some family members stay with them. Hospitals are unable to move their patients. Some residents are too frightened to leave or sleep through the commotion. In just 14 minutes, an astonishing 20% of the population manages to evacuate 500 m (0.3 mi) away from the coast.

A wave of water 20 m (66 ft) high hits several locations along the coast of Kyushu, and it washes up to the slopes of the mountains. The resort cities of Myazaki and Nobeoka and several towns along the coast take the brunt of the peak wave. Reinforced concrete buildings are pounded apart and collapse. Dense neighborhoods of timber buildings are scoured and disappear, leaving an empty plain along the coast and a churning sea of debris in the water.

The wall of water surges up the Bungo Channel and into the coastal port of Uwajima on Shikoku: the 8 m (26 ft) wave breaks over the 3 m (10 ft) high harbor wall and sweeps away the docks, fishing factories, and many of the houses of its 70,000 population. Some 6,000 of its residents are never seen again.

At the other side of Shikoku, the wave is equally violent, surging into the Kii Channel and lashing its peninsula with 5 m (16 ft) waves. In Tanabe, Wakayama, residents have followed special signs that indicate the height of a given location above sea level and the direction of the ocean. Most of the 65,000 population are familiar with the tsunami procedures and have practiced avoiding narrow roads and vulnerable bridges to reach safe ground in 8 minutes. But the water rips onshore and up to the foothill slopes of Takaoyama Mountain, washing away everything in its path. Over 1,000 people are lost in Tanabe.

Waves of just over 4 m (13 ft) sweep along Awaji Island and wash into the Bay of Osaka. The bay conditions amplify the waves, which peak at 5 to 6 m (16 to 20 ft). There are more than 600 sea gates along the coast of Osaka prefecture, built mainly as a protection against storm surge. Since it takes 6 hours to shut all of the gates, only a few have been closed in time before the waves hit. The waves surge up the inlets and into the city streets beyond. Sea walls of 3 to 6 m (10 to 20 ft) protect the ports and harbors, but the 5 m (16 ft) tsunami pounds over the lower sea walls, and carries ships into the docks and refineries lining the sea front. It splits open oil tankers and uproots chemical storage tanks, polluting the waters. The water pours through the urban center of Osaka, filling the Osaka Municipal Subway, but casualties are light. The stations are empty of the tens of thousands of commuters expected just two hours later. Thousands of residents are caught in the waves, many of them still trying to reach the safety of the nearby refuges. Many are swept away by the water and their bodies are never recovered.

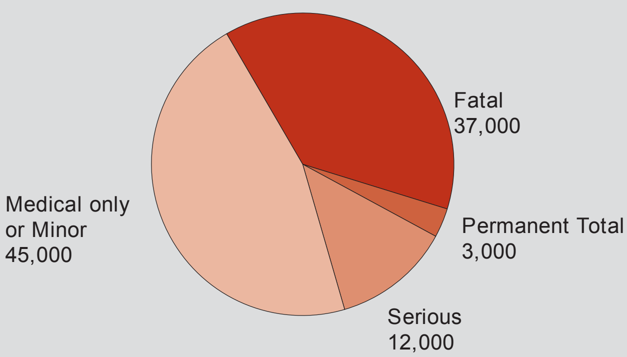
The residential areas of Kobe, on the opposite side of the bay, are similarly impacted by the destructive waves of water. Port facilities repaired after the 1995 Kobe Earthquake are torn apart by the violent waves. Tens of thousands of houses are destroyed or damaged.

In all, more than 240 km (149 mi) of coastline is impacted by the tsunami waves. Several major cities have suffered serious damage and lost many of their occupants. Hundreds of coastal towns and villages have suffered casualties. For another 800 km (500 mi) of coastline, as far as Yokohama and Chiba peninsula, tsunami waves of over 2 m (7 ft) have washed along the shore, but sea walls and gates have largely held, keeping damage light.

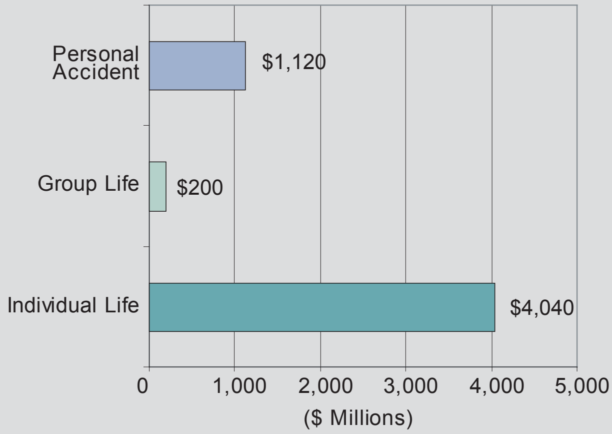
The sea around Kyushu, Shikoku, and Kii peninsula continues to churn for more than three hours, occasionally generating other small waves that wash inland. Wreckage and bodies fill the sea, and a massive emergency response and rescue operation is undertaken, led by the Japan Defense Agency. A major medical aid program is mounted to treat the injured, and resources are organized to transport the homeless to refugee centers in cities throughout Japan for the rest of the winter.

At the end of the emergency, 37,000 people are estimated to have been lost or drowned and 60,000 people have been injured and given medical treatment. The economic damage from a national disaster is unprecedented for Japan, considerably exceeding the 1995 Kobe Earthquake. A new national reconstruction program is instigated to rebuild the damaged communities.

Injury Distribution
of 97,000 Casualties



Losses by Line



7 INFECTIOUS DISEASES

Infectious diseases are the leading cause of death worldwide, accounting for a quarter to a third of all mortality. Peaks of infection, through epidemics or pandemics (an epidemic that occurs in more than one country), can be major causes of excess mortality. In Japan, infectious disease ranks third after cancer and heart disease as the primary cause of mortality. Despite developments in medical science, infectious disease rates continue to rise due to greater social interaction, increased travel, inappropriate use of antibiotic drugs, and the emersion of new and re-emerging pathogens.

Of more virulent and drug-resistant form, 20 known diseases have recently re-emerged or spread geographically. At least 30 unknown disease agents for which no cures are available have been identified in human populations in the last few decades, including the human immunodeficiency virus (HIV), Ebola, and hepatitis C and E. Infectious disease outbreaks pose a major threat both nationally and internationally as they easily cross borders and can threaten economic and regional stability as has been demonstrated historically by influenza and SARS epidemics.

7.1 Agent Characteristics

7.1.1 *Mutation*

Viruses are exceptionally adaptable organisms. They are constantly undergoing genetic change resulting in new strains of disease that are immune to standard treatments or that have more effective transmission. 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. The process of virus mutation may include jumping animal species or causing a greater threat to humans due to an increased degree of contagion and/or lethality. There are two primary mechanisms for viral mutation: 'antigenic drift' and 'antigenic shift.'

7.1.2 *Antigenic Drift*

Antigenic drift mutation involves natural selection, and over time the virus evolves into a new strain with novel characteristics, such as drug-resistance or increased transmissibility and/or severity. This process typically involves trade-offs between the contagiousness of a virus and its deadliness, and the characteristics of the resulting virus tend to be fairly similar to the prior strains. Rapid rates of evolutionary drift make it difficult to cure and are the reason why flu vaccines are only effective against a limited number of strains and for a short period of time.

7.1.3 *Antigenic Shift*

The less common but potentially more dangerous type of viral mutation is the antigenic shift. It occurs when a virus jumps directly between species, such as from bird to human by the use of an intermediate host such as a pig, or by reassortment. In reassortment, viruses bypass the natural selection process by combining the genetic material from two completely separate viruses. This instantaneous process can result in a new virus or a new strain with some characteristics from both of the parent viruses.

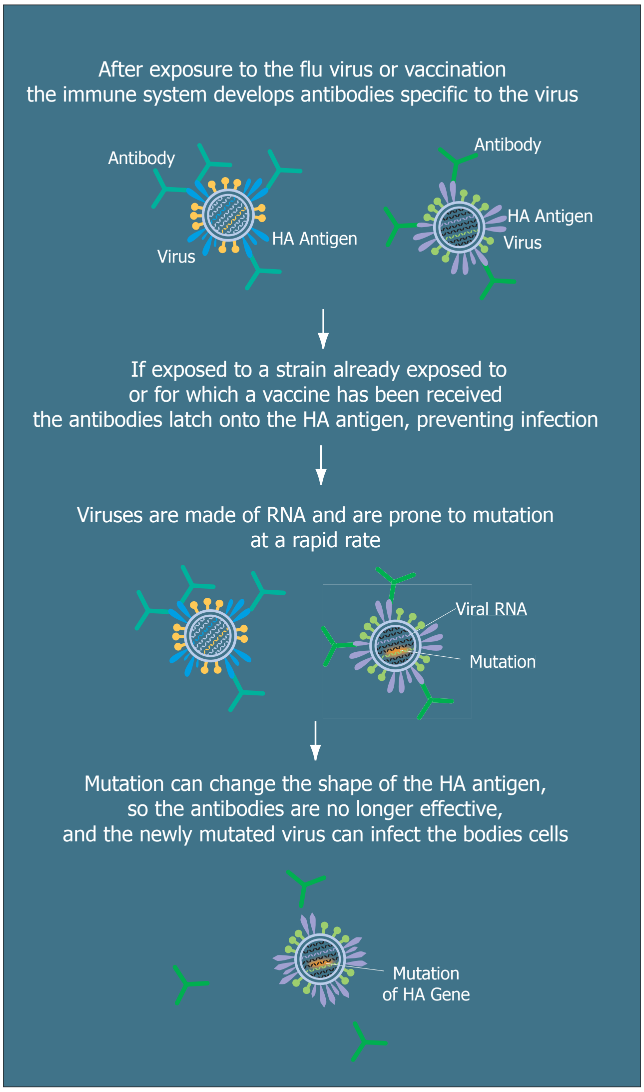


Figure 7.1 Antigenic drift is a gradual evolutionary change of a virus to evade human immune defenses

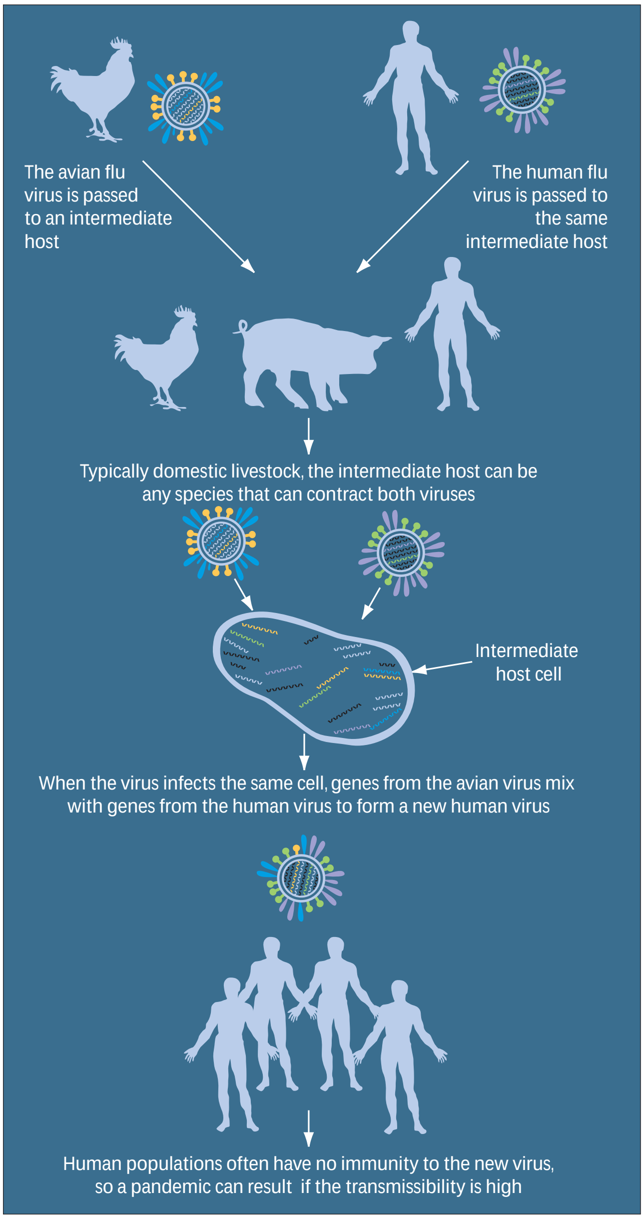


Figure 7.2 Antigenic shift is the process by which a virus makes a major genetic mutation, triggering a pandemic

7.2 Geography

Regional geography is important in determining the risk of suffering an infectious disease epidemic. According to the World Health Organization (WHO), 28% of the worldwide burden of infectious disease is in Southeast Asia. Proximity to Southeast Asian nations and travel traffic to and from these countries creates a significant amount of risk for Japan. Surveillance is paramount in preventing large disease outbreaks, since it is extremely difficult to stop a highly transmissible virus once established.

Asia has been the origin for all human influenza epidemics since 1930. The 1957 Asian Flu Pandemic was caused by a reassortment between three genes from Eurasian avian viruses and five gene segments from circulating human strains, which mixed together in swine to result in a human-to-human transmissible strain. In 1968, a similar mechanism resulted in the Hong Kong Flu, which was a combination of two genes from Eurasian avian viruses and six genes from circulating human strains. Close contact between poultry, swine, and humans is common in Asia, and it increases the risk of antigenic shift, the mechanism responsible for most pandemics. Infectious disease easily crosses geopolitical boundaries, and poor surveillance and public health response in a neighboring country could potentially result in a disastrous outbreak in Japan despite internal precautionary measures.

7.3 Recent Pandemics

The insurance industry is concerned about payouts arising from a major outbreak of a new disease or a resistant strain. The quantification of this risk is in its infancy, but studies are progressing to understand the scale of this threat. RMS has developed a model for influenza pandemic and for other infectious diseases, such as smallpox. Stochastic models of disease spread can assess the likelihood of outbreaks and model hypothetical future epidemics arising from viruses with different potential characteristics. Pathogens have continued to stay one step ahead of medical treatments, and although the diseases have changed, infectious diseases are as much a threat today as they were hundreds of years ago. Pandemics have been a constant threat throughout history, and it is only a matter of time before the next highly virulent and highly transmissible disease arises.

7.3.1 SARS

In 2003, severe acute respiratory syndrome (SARS) tested Asia's medical capabilities as cases were reported in over 30 countries. No confirmed cases occurred in Japan. SARS is a respiratory illness caused by a new type of coronavirus, for which a consistently effective medical treatment does not yet exist. 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. Healthcare workers became victims causing widespread panic in communities in Asia and worldwide. The ease of airborne transmission and the mobility of the carriers, especially international travelers, raised alarms about pandemic potential, but stringent quarantine measures and low transmissibility (relative to influenza) helped to contain the epidemic. However the speed at which the cases appeared across Asia and the world caused a global crisis. While there was a limited impact on life and health, the economic losses were estimated at $50 billion for Asia and $150 billion worldwide. Despite this significant economic impact on the worldwide economy, transmissibility is relatively low for SARS. Influenza strains likely to cause pandemics have three times the transmissibility of SARS and will undoubtedly have a much more significant caseload.

7.4 Influenza

Influenza is a notable source of morbidity in the Japanese population. There were approximately 16 million influenza infections during the 2004-2005 season, though mortality rates vary significantly by year. Historically, the Japanese government has taken drastic measures to reduce influenza-related mortality. Between 1962 and 1987, the majority of Japanese children were vaccinated, and during a period of 10 years, vaccinations were mandatory. This practice was discontinued, but it has since been estimated that these stringent controls prevented close to 50,000 excess deaths per year. In normal years, influenza mortality primarily affects the elderly and infirm, who die from complications such as secondary bacterial pneumonia. Occasionally, when genetic reassortment results in strains to which the general population has no immunity, such as H5N1 in 1918, populations of healthy adults can experience significant morbidity and mortality.

7.4.1 Antigenic Variation

Antigenic variation is the process by which an influenza virus mutates to evade the immune systems. Every few years antigenic drift results in a new virus that causes influenza epidemics. Every 30 years on average, a more serious antigenic shift occurs involving an exchange of gene segments between human and avian or swine influenza viruses. In these cases, a significant proportion of human protective antibody levels are absent, and a global pandemic results. Epidemiological models can replicate general patterns of sickness and mortality.

Actions to reduce the risk of an influenza pandemic arising from avian flu involve controlling the population of infected domestic birds (Source: AP)

Animals, such as swine or birds, serve as the main viral reservoirs. When animals carrying the virus come into close contact with human populations, the virus can adapt and infect human populations. In 1997 and again in 2001/2002, millions of 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 World Health Organization (WHO), which has developed an Internet application linking the global network of influenza centers (FluNet). A major objective of FluNet is to select strains to be included each year in influenza vaccines as well as to track new influenza strains before they become established in human populations.

7.5 Treatment and Prevention

Influenza causes the infected person to develop an immunity to that virus, so one person is rarely infected with the same virus twice. However, antigenic drift occurs extremely quickly. New strains arise all the time, and the population quickly becomes susceptible to a new strain of infection. Immunization is helpful in reducing the size and severity of epidemics. Vaccines incorporate inactivated virus particles or purified hemagglutinin, a surface protein on the influenza A virus. Each year a decision is made from surveillance data on which strains should be incorporated into the vaccine. Once a vaccine is administered, it takes time for protective level of antibodies to build up–and that means that once a virus is circulating in a population, a vaccine is not particularly helpful in controlling an epidemic.

7.5.1 Antibiotics

Antibiotics do not prevent transmission or control the flu virus, but they can limit mortality in flu epidemics. A common cause of flu-related death is secondary bacterial infections, such as pneumonia. Antibiotics were important in reducing the severity of secondary infections and are responsible for the reductions in mortality in the 1957 and 1968 pandemics.

7.5.2 Amantadine and Rimantadine

Antivirals that interfere with the production of the virus, these drugs inhibit one of the proteins needed for viral reproduction. They work against type A influenza strains but resistance to these drugs evolves quickly. Once resistance is acquired the drugs are useless, so it is unlikely that these will be helpful in combatting an emerging epidemic.

7.5.3 Zanamivir (Relenza®) and Oseltamivir (Tamiflu®)

Affecting an enzyme that inhibits the release and spread of virions, these drugs may reduce symptoms such as weakness, headache, fever, cough, and sore throat by up to three days. There is an ongoing debate on their effectiveness in preventing flu infection and concern over potential side effects. Many countries are relying on these drugs to reduce transmission and infection in the exposed. However, the efficacy of this approach remains unknown as does the ability of the influenza virus to develop resistance.

7.5.4 New Drugs?

Anti-viral drugs are significantly harder to produce than antibacterial drugs because the virus life cycle depends on the host. It is quite easy to kill most viruses; however, these methods will also kill the host cells as well. Research is currently being focused on developing drugs that target molecular machinery unique to the virus. The more knowledge gained about the molecular structure of viruses, the closer we come to developing a successful drug. The ever-changing characteristics of viruses make this a difficult task, and it is unlikely that a viral miracle drug will be developed in the near future.

7.6 Defining the Scenario

There have been three worldwide pandemics in the past century (1918, 1957, and 1968) where the number of flu fatalities was several multiples of the average number seen each year. These three pandemics caused mortality rates of 35 times, four times, and two times, respectively, the rate seen in normal years in developed countries. In individual countries, especially in Asia, local flu epidemics frequently occur in both human and animal populations.

The average time interval between human pandemics has historically been about 30 years, but the observed intervals range between 11 and 39 years, and the last influenza pandemic was in 1968. The chance of a pandemic in any given year is likely to be around 1 in 30, (i.e., about 1 in 3 for a decade), but it is likely that the risk increases with time since the previous event. A prime candidate for the next influenza pandemic is an antigenic shift related to the growing numbers of H5N1 avian influenza cases infecting birds and occasionally infecting humans in Southeast Asia. Avian influenza A (H5N1) is causing widespread outbreaks in poultry in Southeast Asia and sporadic transmission to humans. Untreated H5N1 is particularly deadly with a fatality rate of more than 30%. Cases of human-to-human transmission have occurred, but so far, the virus has been limited by low transmissibility. The main threat of H5N1 is reassortment with one of the three known subtypes of human flu viruses (H1N1, H1N2, or H3N2) or a genetic mutation allowing sustained human-to-human transmission.

Increased density and social interaction in public transit systems enable a flu strain to spread rapidly through the general population

The H5N1 virus is a concern because of its resemblance to the H1N1 virus responsible for the 1918 pandemic. In most places the 1918 H1N1 virus infected less than a third of the population and killed a fraction of those infected. However, there were a number of towns where mortality reached nearly 100%. The virus traveled globally, and no country was free of cases. Even where mortality was low, the illness incapacitated much of the population bringing much of everyday life to a halt. Communities closed, and in many places the majority of health care workers fell ill. The speed of the epidemic contributed to the disastrous consequences. For comparison, it took HIV/AIDS 25 years to kill 25 million people, while it is estimated that the 1918 flu killed that many within the first 25 weeks.

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

HYPOTHETICAL SCENARIO 4: INFLUENZA PANDEMIC

Flu Outbreak Impacts Millions Within Weeks

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

The 1918 influenza pandemic claimed a quarter of a million lives in Japan (Source: National Museum of Health and Medicine)

Vaccines for a new influenza strain may take many months to develop and may not be able to prevent the initial spread of the disease

A six-year old boy, the son of a farmer in the Ibaraki prefecture, is rushed to a Tokyo hospital with a high fever and acute respiratory distress. In the next three days, two members of the boy's family, three of his classmates, and a neighbor are all hospitalized with fever, cough, sore throat, and respiratory distress. Several members of the hospitalized staff also call in sick citing flu-like illness. The boy dies, and tests show he was infected with a common strain of influenza A (H1N1), the highly transmissible virus responsible for the 1918 Spanish Flu Pandemic and the avian flu strain (H5N1). Within a few days, virologists have determined that this new strain contains three chromosomes from the highly pathogenic H5N1 and five from the highly transmissible H1N1. However, by the time the virus has been characterized, cases are being reported around the country.

Vaccinations based on the traditional H1N1 virus are rapidly administered, but this does little to affect the transmissibility. Countries around the world scramble to begin producing virus-specific vaccine, but it is too late for Japan–in the months it takes to mass produce a vaccine the epidemic will have already run its course. Countries around the world restrict travel and close their borders.

With enough Tamiflu to treat only 25 million people, the Japanese government appeals to get more of the drug. However, the virus shows some resistance, and the drug does little to affect transmission rates. Fortunately, the drug does reduce mortality, and the regional mortality rates vary between 0.01% and 20% depending on the characteristics of the virus in the particular region, surveillance, and prophylaxis availability. The government is unable to implement effective quarantine measures, and the medical system is completely overwhelmed. The entire epidemic lasts less than 100 days, and in that time 35% of the population has become infected with the virus and 0.75% of the population has died. Cases begin to break out all over the world causing border closings, travel restrictions, and economic disaster. In the year it takes to develop and disseminate an effective vaccine worldwide, H5N1 has broken out in 30 countries with disastrous consequences.

The spread of H5N1 and the magnitude of the pandemic will be heavily influenced by the response of governments worldwide and the response of healthcare systems. The overall outcome of the pandemic will also heavily depend on the effectiveness of public health measures taken by the Japanese government. The following four outcomes show how the end results would differ with alternative strategies. The action plan published in November, 2005 by the Health, Labor and Welfare Ministry envisions a state of emergency being declared and treatment of high risk patients with Tamiflu (Outcome 2). If necessary, more extensive measures to prevent geographical spread will be taken (Outcome 3), and as a last resort, enforced restrictions (Outcome 4). Outcome 2 is the closest to the current plan and the losses are presented in more detail below. RMS modeled results are consistent with those of the Ministry's projections, which anticipate up to 640,000 deaths.

Outcome 1: No Measures Taken

Described above, government is overwhelmed and a flu response plan is not implemented.

Outcome 2: Treatment with Tamiflu

The Japanese government makes an effort to track close contacts of those infected and ensure they receive Tamiflu. Although it does not affect transmission, it significantly shortens the length of the illness and reduces the death rate for those treated. The stockpile of Tamiflu is not large enough to treat the whole country, but it is being increased (plans have been announced to increase the stockpile from 150 to 250 million doses). The medical costs for the epidemic are similar to Outcome 1, but mortality is cut by almost 50%, and the overall infection rate falls by nearly 10%.

Outcome 3: Geographic Containment

The Japanese government flu response plan is immediately enacted. Geographical containment measures similar to those that were implemented during the SARS epidemic are put into affect as soon as the virus is identified. The Japanese government limits travel into infected areas, and citizens are encouraged to wear masks and avoid close contact. By this time the virus has already spread to 50 people. An attempt is made to track close contacts of infected people and ensure they are quarantined and receive treatment. A vaccine is available five months after the outbreak, and a mandatory vaccination policy of all schoolchildren is immediately initiated. Despite best efforts, several infected people travel out of Japan. Limited epidemics break out in other countries causing worldwide panic and extensive travel restrictions, but the size of the epidemic is significantly reduced, and excess mortality is similar to that of a bad flu season.

Outcome 4: Strict Quarantine

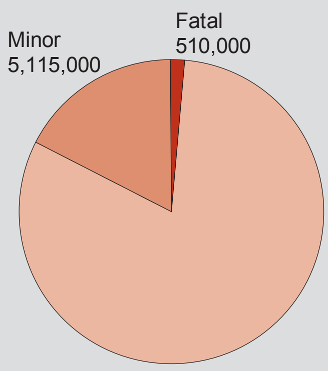
Extreme quarantine measures are put into effect by the government and military. Borders, schools, and workplaces are temporarily shut down. All identified cases are traced to the source, and all contacts are tracked down and quarantined. No travel is allowed in or out of infected areas. Mandatory treatment with Tamiflu is initiated in the infected regions, but several children suffer adverse reactions to the medicine. A pandemic is prevented but at an extremely high economic cost.

Potential Outcomes of Infected Population in the Influenza Pandemic

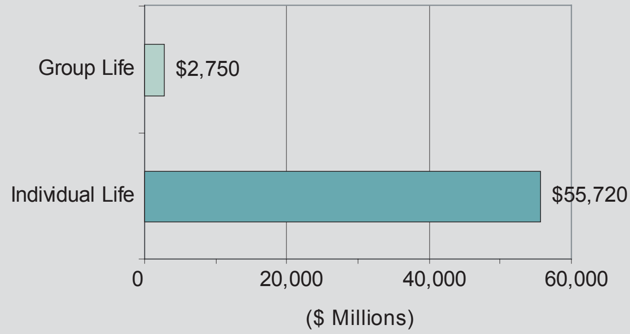
	Infected	Medical Treatment	Death
Outcome 1: No Measures Taken	45,000,000	34,375,000	975,000
Outcome 2: Treatment with Tamiflu	29,375,000	23,750,000	510,000
Outcome 3: Geographic Containment	1,125,000	1,000,000	55,000
Outcome 4: Strict Quarantine	6,250	5,625	1,250

Outcome 2: Treatment with Tamiflu

Injury Distribution
of 29,375,000 Casualties



Losses by Line
(Personal accident insurance does not cover fatalities from the flu and is omitted)



7.7 Discussion

This scenario illustrates the potential impact of H5N1. It appears likely that H5N1 will eventually go through an antigenic shift to become common in human populations. The main uncertainty is the characteristics of the virus when it does. This scenario demonstrated the impact of a highly transmissible virus with pathogenicity similar to that of the 1918 viral strain. The current H5N1 virus has mortality rates of more than 30%, which would result in far more devastating consequences. A nightmare scenario would be a mutation with transmissibility similar to the virus discussed above, but as lethal as the H5N1 avian flu strain. In all likelihood the virus will lose some of its virulence through genetic drift before becoming common in human populations; however, even a small change in excess influenza mortality can have significant economic impacts.

The outcome of an influenza pandemic across the world is a very real concern to health care professionals. This pandemic scenario would have considerable economic loss implications for the country as well as for insurers. Apart from the direct costs of health treatment and insurance payouts, there is indirect economic loss resulting from loss of productivity. In addition, efforts to curb transmission are likely to result in a significant slow down in international travel and business as well as decontamination and quarantine costs. The indirect costs resulting from economic disruption caused by a worldwide influenza pandemic will far exceed the direct medical costs and are likely to have catastrophic effects of the global economy.

Even if H5N1 does not cause a worldwide pandemic, it is only a matter of time before another virus has widespread consequences of human health. 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. The nature of these potential novel diseases, the chances of them occurring, and the likely impact on the population are the subject of continuing research and concern.

7.8 Insurance Costs

Insurance costs in an infectious disease outbreak can vary widely depending on the severity of the outbreak and the specific population affected. In this study it is assumed that life insurance for those who contract the flu is similar to the proportion of life insurance in the overall population. Therefore most fatalities from the outbreak will be covered under life insurance policies. For this study it is assumed that personal accident insurance is not covered for an outbreak.

7.9 Mitigation of the Risk

Vaccination before an outbreak occurs is the best mitigation measure for reducing the pandemic risk, but it is not always possible. The next best approach is vaccination after an outbreak, although this has limited effectiveness. The current practice of using tens of millions of hen eggs for vaccine production is too slow to respond to the emergence of an unfamiliar and unexpected virus. By the time a vaccine is produced the disease will have run its course in the country or region where the outbreak occurred. With clinical trials 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. However, even with rapid vaccine production, an outbreak in Southeast Asia could have serious consequences in Japan. Limiting the transmission in animal populations, vigilant surveillance, and international cooperation in quarantine and prevention measures are paramount in limiting potential pandemics. ■

8 TERRORISM

The Al Qaeda attacks against the United States on September 11, 2001 marked a new era of global terrorism. Over 3,000 people were killed in the U.S. in the aircraft-impacted buildings. Insurance losses were unprecedented, at over $30 billion, and almost a third of the loss resulted from injuries and deaths. Despite a major international campaign against terrorism, the removal of Al Qaeda camps in Afghanistan and the arrest of many terrorist suspects, jihadist organizations have continued to mount attacks in many countries around the globe. Jihadist groups target all of the G8 countries, including Japan: in their distorted rhetoric, the global economic powers stand in the way of the creation of a fundamentalist Islamic caliphate throughout the Middle East.

Japan is an important participant in the war on terrorism, contributing to anti-terrorist operations in Afghanistan and participating in the military action in Iraq. Jihadist terrorists see Japan as a global power acting against their interests and have kidnapped and killed Japanese nationals and mounted attacks on Japanese political and commercial interests in the Middle East and Southeast Asia. So far, however, no jihadist group has mounted an attack on the Japan homeland. Several members of the Iraq military alliance, including Spain and the U.K., have already suffered terrorist attacks in their homeland. The main jihadist threat group operating in Southeast Asia is Jemaah Islamiya, who although mainly focused on their home territories, have demonstrated an international reach. There is no evidence of a substantial jihadist presence in Japan at this time, but most terrorism experts consider this a significant threat.

Minor attacks against U.S. targets have been carried out within Japan in recent years. These attacks have not been attributed to a particular threat group. However, they indicate a general anti-American sentiment that could be harnessed by one or more threat groups in a more ambitious future attack.

The new era of global terrorism is characterized by an increasing ambition in the scale of terrorist attacks and a ruthlessness to inflict maximum casualties and economic disruption on the G8 countries. This poses a particular challenge for the insurance industry in target countries– the pursuit of mass casualties in commercial business centers means that potential losses can be very significant. Most terrorist attacks result in the deaths of fairly small numbers of people, but the growing capability of terrorists means that an attack that might kill tens of thousands of people is a remote but real possibility.

In addition to the risk from the jihadist organizations, there are other potential sources of extreme terrorism that threaten Japan. Terrorism in Japan has historically been characterized by violence used by political extremists and religious cults. Today there are an estimated 2,000 new-age esoteric movements within Japan, many with considerable followings and ambiguous attitudes towards using violence to attain political aims. An attack by one of these groups, possibly inspired by the growing scale of attacks being attempted elsewhere, remains a distinct additional threat to Japan.

The death of 3,000 people in the 9/11 terrorist attacks on New York heralded a new era of mass-casualty global terrorism (Source: AP)

State-sponsored terrorism also remains a possibility, although generally thought to be a declining threat. Under severe military stress, North Korea could potentially strike out against Japan using clandestine groups to carry out terrorist acts.

8.1 Modeling Global Terrorism Risk

Assessing the likelihood of a major terrorist attack is complex and requires an understanding of the motivation, psychology, and capabilities of highly secretive organizations. The chances of an attack are affected by the security levels in place, counter-terrorism actions taken by government agencies, and the quality of protection at potential targets. The RMS® Global Terrorism Risk Model[1] was developed by compiling and analyzing an extensive catalog of terrorism attacks worldwide, which includes more than 18,000 events in 130 territories to date. In addition, the threats posed by more than 70 different terrorist organizations have been assessed in detail. The characteristics of terrorism in each country have been assessed in terms of the likelihood and severity of three classes of terrorism: 'micro-terrorism' (small scale attacks), 'macro-terrorism' (larger destructive and mass-casualty attacks such as vehicle bombs), and 'extreme loss events' (spectacular attacks with multiple conventional weapons or chemical, biological, radiological, or nuclear agents).

RMS has drawn on its extensive and highly authoritative advisors network to develop and validate the worldwide terrorism risk model. These advisors are the leading authorities in their field from organizations such as the International Center for Political Violence and Terrorism Research at the Institute of Defense and Strategic Studies, Nanyang Technological University in Singapore. International advisors also include RAND, the Center for the Study of Terrorism and Political Violence (CSTPV) at the University of St. Andrews in Scotland, and Jane's Information Group.

The counter-terrorism environment in each country is graded according to expert assessments specifically carried out for RMS by Jane's Information Group Sentinel country monitoring team, incorporating aspects such as counter-terrorism intelligence capabilities, frontier security, legal environment, and international cooperation. This grading is used to assess the number of attempted attacks that are likely to succeed and cause loss.

8.2 Terrorist Incidents in Japan

During the past decade or so, actual terrorist attacks in Japan have been minor, and few have caused any substantial damage or large numbers of fatalities. However minor, they provide evidence of intent as well as information on targeting patterns. In all, they hint at larger scales of attacks that could occur in the future.

- *Rocket Attack on Japan Defense Ministry, Tokyo, February 17, 2004*: In an apparent protest against sending Japanese troops to Iraq, the grounds of Japan's Defense Ministry in Tokyo were rocked by two explosions caused by small projectiles assumed to be rocket propelled grenades (RPGs). Damage was negligible, and no one was injured.
- *Mortar Attack on U.S. Army at Camp Zama, November 19, 2002:* Two explosions rocked the U.S. Army Base Zama near Tokyo, Japan. A homemade mortar found near the base was similar to other attacks perpetrated by Japanese radical leftists, including an explosion near a U.S. Navy fuel terminal in February 2002.
- *Sarin Gas Attack on Tokyo and Yokohama Subway Station, March 20, 1995*: 12 people were killed and 5,700 were injured in a sarin nerve gas attack on a crowded subway station in the center of Tokyo, Japan. A similar attack occurred nearly simultaneously in the Yokohama subway system. The Aum Shinri-kyo cult was blamed for the attacks.
- *Bomb on Aircraft Headed for Tokyo, December 11, 1994*: A small incendiary device detonated aboard Philippine Airlines Flight 434, killing one Japanese passenger and wounding others. It blasted a hole in the cabin deck and severed the cables that controlled the plane's flaps. The pilot managed an emergency landing at nearby Naha airport. It was later determined that Ramzi Yousef, the principal suspect, boarded the plane at Manila, Philippines, assembled the bomb in the bathroom, and planted it in his seat. He left the plane during its layover at Cebu City, Philippines. The bomb exploded midway on the flight to Tokyo.
- *Bombing of UN Center in Osaka, July 7, 1993*: Terrorists exploded a homemade bomb at the United Nations (UN) Technology Center in Osaka, causing minor damage and no casualties. The Chukaku-Ha terrorist group claimed responsibility two days later.

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1 *More information about the RMS® Global Terrorism Risk Model is available from RMS at http://www.rms.com*

8.3 Threat Groups

8.3.1 Al Qaeda and Jemaah Islamiya

Al Qaeda and its associated groups are engaged in a global struggle to promote militant Islamic ideals through political violence. They carry out terrorist attacks in many countries throughout the Middle East in pursuit of extreme Islamic aims. Intended to change their foreign policy related to the Middle East, the groups have carried out major terrorist attacks in several Western countries, including against Western targets at military bases, embassies, hotels, tourist resorts, oil and gas installations, and other types of commercial interests.

Al Qaeda has several associated groups in Southeast Asia that could potentially pose a threat to Japan, most notably Jemaah Islamiya. Jemaah Islamiya is an Islamist group that aims to create an Islamic caliphate consisting of Indonesia, Malaysia, Singapore, Brunei, the southern Philippines, and southern Thailand. It has demonstrated international reach with unsuccessful plots in Singapore and Australia. The extent of its potential presence in Japan is unknown at this time. Japan maintains a proscription notice identifying Jemaah Islamiya as a major terrorist threat, and in 2002, it supported the UN resolution declaring Jemaah Islamiya a terrorist organization. It has also provided counter-terrorism training and resources to several countries in the region, including Indonesia and the Philippines.

8.3.2 Aleph and Aum Shinri-kyo

Aleph and Aum Shinri-kyo espoused utopia and embraced the apocalyptic struggle against its enemies, which included rival organizations, critics, government officials, U.S. military, and eventually, the general public and all non-believers.

The group was responsible for some of the worst terrorist attack attempts in Japan's history and has experimented with deploying weapons of mass destruction, such as sarin gas and anthrax. Most notoriously Aum Shinri-kyo carried out the sarin gas attack on March 20, 1995 on several Tokyo subway trains, killing 12 people and injuring around 6,000. The group was also responsible for other mysterious chemical accidents in Japan in the mid 1990s. While its efforts to conduct mass casualty attacks using biological agents were largely unsuccessful, the scale of the research and development efforts and the stockpile of conventional and chemical weapons they had amassed shocked many analysts when the organization was broken up by security forces in 1995. Japanese police arrested the cult leader, Asahara, in May 1995, and he and 11 other members were tried and sentenced to death in 2001.

Cult membership has declined significantly since 2001. At its height, Aum Shinri-kyo had as many as 9,000 members in Japan and up to 40,000 worldwide. By 2004, a raid on the group's offices indicated a following of 1,650 in Japan and 300 in Russia. The group had many of its recognition privileges revoked but escaped a complete ban. In 2000, longtime members Joyu and Muraoka took over the leadership, renamed it 'Aleph' and renounced many of its apocalyptic philosophies. It continues today as a religious organization, led by Fumihiro Joyu, who has made great efforts to change its image.

In July 2001, Russian authorities arrested a group of Russian Aum followers who had planned to set off bombs near the Imperial Palace in Tokyo as part of an operation to free Asahara from prison. In the early 2000s, reports also surfaced of a new interest in nuclear materials in the former Soviet republics by the Russian wing of Aleph.

8.3.3 Chukaku Ha

Chukaku Ha is the largest domestic militant group in Japan. Primarily active in mass demonstrations against Japan's imperial system and perceived Western imperialism, this group seeks to overthrow the constitutional system of Japan and its monarchy. The group should also be considered nominally anarchic, as it seeks to eliminate the current government but not to replace it with another.

Their attacks–mostly arson, rockets, and incendiary devices, some of which are quite sophisticated–typically do not cause significant damage or injuries. However, they have also been involved in assaults, beatings, sabotage, and murder. The group strongly opposed the expansion Tokyo's Narita International Airport, and it sabotaged parts of the Japanese railroad in the 1980s. They have targeted government offices, including the Liberal Democratic Party headquarters and the Imperial Palace grounds. The group is also anti-U.S. and has targeted U.S. military and diplomatic installations. They are suspected of launching a series of rocket attacks against the U.S. Army Base at Camp Zama in July 1993.

8.3.4 Sekigunha or Japanese Red Army Faction

The Japanese Red Army Faction (JRAF) is currently believed to be defunct, but is representative of how left-wing idealism and possibly state-sponsored terrorism could induce political violence. Known as "Sekigunha," it was formed in 1969 and advocated global revolution through armed struggle. Breaking away two years later and becoming a splinter group, the JRAF gained international notoriety in the 1970s through a series of terrorist acts abroad, supporting efforts by the Popular Front for the Liberation of Palestine.

The JRAF is most noted for the 1970 hijacking of a Japanese airliner to North Korea, where it received sanctuary. The group is believed to have had close links to, or been controlled by, North Korean intelligence.

8.3.5 Counter-terrorism Environment

The RMS assessment of terrorism risk in Japan incorporates an evaluation of the counter-terrorism environment and is based on a number of factors. This has been analyzed specifically for RMS by Jane's Information Group, using their Sentinel International Security Team, who compile information on the defense and security infrastructure in more than 200 countries. Their team has carried out a review and a rating of 10 major factors that relate to the Counter-terrorism Environment (CTE) in Japan.

The rating of the counter-terrorism environment in Japan is currently assessed as 'Restrictive.' Janes's assessment team comments: "Japan counter-terrorism intelligence forces have major resources, but their orientation is confused."

The quality of the counter-terrorism environment in a country is ultimately evidenced by the success of intelligence and security services to keep their country free of attacks. In the RMS model, the frequency of the macro-terrorism attacks is derived from an estimate of the number of macro attacks attempted in a particular country. The percentage that do not succeed and become a damaging attack is the 'failure rate.' Macro-terrorism attacks may fail because they are aborted by the terrorists, due to technical failure, or because they are interdicted and prevented by the security forces.

Countries like Japan with a CTE score of 'Restrictive' are estimated to have a failure rate of around 75% for macro-terrorism attacks.

8.4 Choosing the Terrorism Scenario

By looking at historical patters of attacks and recent intelligence, we can determine the mostly likely types of weapons and targets that would be chosen if a terrorist attack occurred today.

8.4.1 Most Terrorist Attacks Are Small Scale

The most likely type of terrorist attacks small scale, 'micro-terrorism' attacks, which make up more than 90% of all events in the historical catalog of terrorist events worldwide. Micro-terrorism attacks include small-yield explosive devices (e.g., pipe bombs, grenades, portable package bombs), small arson attacks, military-style guerrilla attacks, assassinations, killings, or hostage taking. They can be deadly and in a crowded restaurant or train could kill dozens of people.

8.4.2 Macro-terrorism Attacks: Vehicle Bombs

However, the rarer, large-scale attacks where terrorists coordinate teams and bring more resources into an operation designed to cause major destruction and force a political reaction–known as 'macro-terrorism' attacks–are of more concern. About 80% of all macro-terrorism attacks are vehicle bombs, typically with yields ranging from 300 lb (136 kg) to several thousand of TNT. Terrorists have used these types of bombs to deadly effect by blowing up whole buildings or devastating several blocks of a city center. These large bombs can kill hundreds of people and maim thousands. Jihadi terrorists have perfected the technique of exploding several vehicle bombs at different targets simultaneously to maximize their impact. In one unsuccessful attempted attack in Singapore in 2002, jihadists were discovered with 17 tons of explosives, destined for at least five vehicle bombs that would have caused massive destruction. For Japan, the most likely macro-terrorism attack is a coordinated multiple vehicle bomb attack using conventional explosives. This is likely to be carried out against government or commercial targets in Tokyo or another major city in Japan.

8.4.3 Other Types of Macro-terrorism Attacks

Other types of attacks also could be used to inflict major damage on cities in Japan. Conflagration attacks using tankers of gasoline set on fire have been used in several highly destructive attacks. Surface to air missiles (SAMs) are inexpensive, easily obtained, and an attack on an aircraft could cause massive economic damage to the airline industry. Even small firearms could be used to perpetrate a mass-casualty attack, particularly in a hijacking or sabotage attack.

The threat of another aircraft impact attack, such as perpetrated on 9/11, remains as examples of successful attacks like this are often imitated. They would be much harder to repeat on today's passenger airlines given new security measures and passenger awareness, but terrorists might use new variants of attack techniques to get around these improved security measures.

Just as the attacks of 9/11 used our own technology as a weapon–in this case fuel-laden aircraft–other attacks could potentially use our infrastructure and equipment against us. Attacks on industrial sites, particularly those storing flammable, explosive, or other hazardous materials could cause massive casualties and destruction in surrounding areas. Hazardous materials being transported through populated areas could be sabotaged to release their agents and cause harm. Attacks on nuclear power stations, although difficult to achieve with current defenses in place, could potentially cause widespread contamination through release of radiological materials.

8.4.4 Terrorist Attacks Using CBRN Weapons

Although less likely, a terrorist attack using chemical, biological, radiological, or nuclear (CBRN) weapons presents great concern. The potential destruction that could be achieved by these weapons makes them attractive for small groups engaged in 'asymmetrical warfare.' Many terrorist groups are known to have investigated the possibility of using CBRN weapons: the Central Intelligence Agency (CIA) has identified over 20 terrorist organizations worldwide that have expressed interest in using them.[2] In testimony to Congress, CIA Director Porter Goss concluded: "It may be only a matter of time before Al Qaeda or another group attempts to use chemical, biological, radiological or nuclear weapons."[3]

Preparedness for attacks using biological weapons includes bio-hazard containment systems, such as this bag issued to emergency response teams

Acquiring and deploying CBRN weapons, however, is very difficult. The technology is complex, and large resources and high skill levels are needed to develop and deploy them successfully. Aum Shinri-kyo had very significant financial and technical resources when in the 1990s it tried to develop chemical, biological and possibly even nuclear weapons, but had only limited success in achieving a mass-casualty event. The group was broken up after their sarin gas attack killed 12 people in the Tokyo subway,[4] but police found industrial scale chemical production facilities and hundreds of graduate researchers in their organization.

Counter-terrorism analysts fear the most a terrorist group acquiring a CBRN weapon on the black market from stockpiles of failed states or corrupt regimes. However, once the agent has been acquired, the logistics of transporting it internationally, smuggling into the country, and

2 *Porter Goss, Director of Central Intelligence, Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions, November 2004*

3 *Testimony by Porter Goss to the Senate Intelligence Committee, February 2005*

4 *In terms of the apocalyptic mass casualties that Aum Shinri-kyo were aiming for, the Tokyo subway attack was a failure: 'only' 12 people were killed, and 6,000 injured. The volatility and impurity of the sarin gas used saved many lives*

deploying a weapon successfully at a target in Japan without being detected are still formidable. The deployment of a chemical weapon, the effective dispersal of a biological agent, or the priming and detonation of a nuclear weapon are complex operations requiring very skilled people and a large logistical support team. Nevertheless, there is clear intent to carry out such an operation, and over time, a determined group may be able to overcome these difficulties and evade our detection.

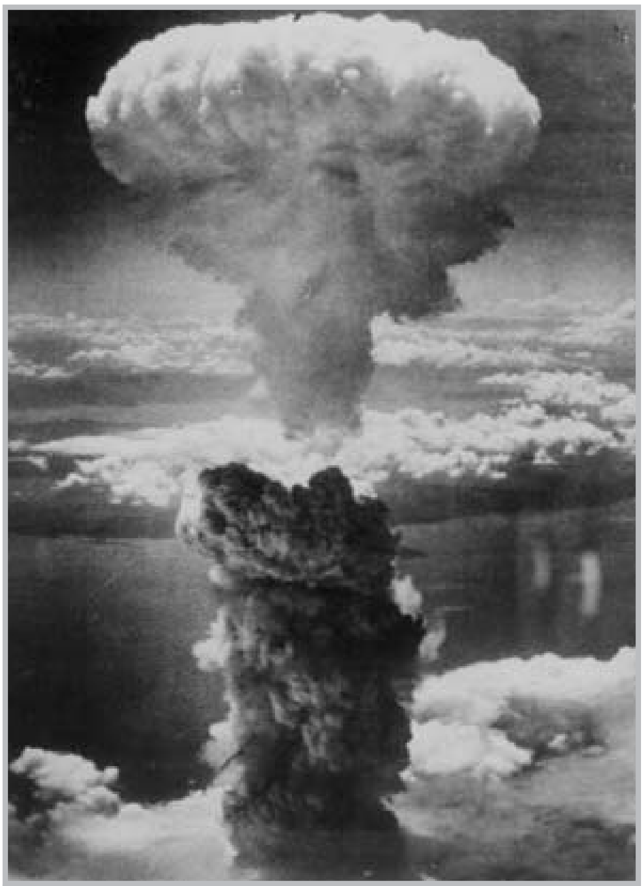
8.4.5 Chosen Scenario: Nuclear Bomb

The scenario chosen to illustrate the potential severity of loss from a terrorist attack is the detonation of a nuclear bomb in the center of a major city like Tokyo. This scenario is close to being a worst-case scenario for a terrorist attack, although there are scenarios where even greater losses could occur. The probability of such an occurrence is extremely low. As the scenario shows, the terrorist group needs a large team of very skilled and diverse specializations, an extremely large budget, and has to operate without detection by or betrayal to the counter-terrorism authorities. The more difficult a project is, the more likely it is to fail or for the terrorist group to choose to undertake a different, perhaps less ambitious and less destructive plan to make their political point. However, the scale of the destruction that could be achieved and the massive political impact that would result means that weapons of mass destruction remain highly attractive to terrorists.[5]

8.5 Nuclear Bomb

8.5.1 Nuclear Devices and Terrorism

There are no historical cases of a terrorist group obtaining or using a nuclear device. 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 nuclear and radiological weapons. Documents seized in Afghanistan training camps in 2002 indicated a rudimentary understanding of nuclear fission devices and led to an assessment that "Al Qaeda was intensifying its long term goal to acquire nuclear weapons and would likely have succeeded if it had remained powerful in Afghanistan for several more years."[6] 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."[7] Chechnyan leaders and Palestinian terrorists have in the past made statements claiming to have obtained nuclear weapons.



Terrorists obtaining and detonating a weapon of mass destruction remains one of the worst fears for security services

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5 *Graham, Allison. Nuclear Terrorism: The Ultimate Preventable Catastrophe. New York: Times Books, 2004*

6 *David Albright, former nuclear weapons inspector, 'Al Qaeda's Nuclear Program: Through the Window of Seized Documents', Nautilus Institute Policy Forum Online, 6 November 2002*

7 *Interview with Osama bin Laden, Time Magazine, December 22, 1998, also repeated on ABC News Transcript of Interview with Osama bin Laden, December 24, 1998*

Emergency responders are increasingly trained to deal with a potential radiological hazard as terrorist groups have shown interest in using these weapons to cause mass casualties

8.5.2 Size of a Nuclear Attack

Some analysts claim that a group of two or three people with appropriate skills could design and fabricate a crude nuclear explosive device using stolen nuclear waste material from reprocessing plants, capable of achieving yields of over 100 tons.[8] Others strongly disagree, suggesting that technical information in the public domain is insufficient, and that such high levels of experience and skills are needed that an amateur team would not be capable of building one from scratch. It is noted that "… even sovereign states with substantial resources at their disposal have failed to construct nuclear devices. After 20 years of trying and the outlay of more than a billion dollars, Iraq did not produce a single nuclear device."[9] Most commentators believe that the most likely way for a terrorist group to obtain a nuclear device is from a military source.

Small yield (1 - 10 kiloton) portable tactical nuclear devices, such as the U.S. Special Atomic Demolition Munition (Mk-54) and the 'suitcase nuclear bomb' developed by former Soviet Union, are rarer than larger yield nuclear bombs, but represent devices that may be easier for terrorists to obtain or even to develop. In testimony to a U.S. House of Representatives committee in 1997, Alexie Yablokov, former science advisor to Boris Yeltsin, stated that he believed that the whereabouts of "dozens" of these small-yield devices was unknown.

The chosen device for this scenario is a 5 kiloton tactical nuclear bomb. This represents the lower end of the scale of military nuclear weapons that could be obtained from a rogue state or stolen from the arsenal of a nuclear power. Military nuclear weapons range from tactical and battlefield devices of several kilotons to strategic thermo-nuclear devices with megaton yields. The device exploded over Hiroshima was around 13 kilotons. A modern nuclear cruise missile has a 200 kiloton yield. Losses that result from any nuclear detonation are so severe that a low-end yield was enough to demonstrate the severity of loss that could seriously impact an insurer. Thus, this scenario does not delineate the maximum loss that could be experienced from an event of this class.

8.5.3 Likelihood of a Nuclear Attack

It is generally believed that despite their interest, research, and development activities, 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. The U.S. and its allies have since invested considerable resources to delay and disrupt the ability of terrorists to obtain this capability. The invasion of Iraq was, controversially, justified on the basis of denying terrorists the opportunity to acquire weapons thought to be stockpiled in Iraq.

The possibility of a terrorist group obtaining a nuclear device from a military power, successfully smuggling it into a country, arming and detonating it remains. In March 2002, there was a security scare around this scenario, when a security information source codenamed "Dragonfire" warned, incorrectly, that a terrorist group had obtained a 10-kiloton nuclear weapon missing from the Russian arsenal and was planning to smuggle it into New York City to detonate.[10]

8 Barnaby, Frank. *How to Build a Nuclear Bomb and Other Weapons of Mass Destruction*. London: Granta Books, 2003, p. 36

9 Laqueur, W. *The New Terrorism*. New York: Oxford University Press, 1999, p 74

10 *Time*, March 11, 2002

8.5.4 Scale of Loss from a Nuclear Bomb

The scale of physical damage and loss of life from a nuclear bomb can be extensive, as Japan experienced after the bombings at Hiroshima and Nagasaki during World War II. Most of the population within 1 km (0.6 mi) of the bomb blast died from the blast and intense heat. Outside of this zone, intense heat caused both severe burns and loss of eyesight; these injuries were reported in areas as far as 3.5 km (2.2 mi) from the site of the bomb.[11]

The atomic blast itself caused an enormous shock wave and then a rapid expansion of air, creating enormous wind pressure, which reached up to 35 tons per m^2 (3.25 tons per ft^2). The blast also caused intense wind velocity reaching 440 m (0.3 mi) per second. Houses within 2 km (1.2 mi) collapsed from the sheer force of the blast. Concrete buildings that were near the blast site had their windows and doors blown off and their ceilings collapsed. Trapped under these structures, many people were either crushed or burned to death.

Exposure to the radiation from the blast was fatal for people within the immediate 0.5 km (0.3 mi) zone. The specific symptoms seen from the blasts included fatigue, headaches, loss of appetite, nausea, vomiting, diarrhea, fever, and an abnormally low white blood cell count. People at distances of up to 5 km (3 mi) away from the blast later showed symptoms of the after effects of radiation, including cancers, keloids (massive scar tissue on burned areas), and cataracts.

The effects of radiation can be separated into acute and long-term effects. Acute radiation syndrome includes symptoms observed with in a few months of exposure. Symptoms include vomiting, diarrhea, reduction in blood cells, bleeding, hair loss, and the clouding of lenses in the eyes. These effects are all due to damage caused by radiation to rapidly dividing cells. Cells that divide less frequently such as muscle and nerve cells are not as sensitive to the effects of radiation. Causes of death from acute radiation may include disorders of the bone marrow or damage to the intestinal cells. Long-term effects of radiation include an increase in cancer development especially leukemia, immunosuppression, digestive disease, liver disease, and respiratory disease.

The medical technology and treatments for radiation exposure today are far superior to the technologies in the World War II era. Animal studies show that by administering growth factors to stimulate stem cells growth in bone marrow can help to facilitate more rapid recovery from radiation injury.[12] This could significantly impact the number of people who die from acute radiation injury. If the immune system is bolstered and current cancer treatments are administered, the proportional number of fatalities from radiation is likely to be significantly less than what was observed in Hiroshima and Nagasaki.

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11 *Hiroshima Peace Memorial Museum*

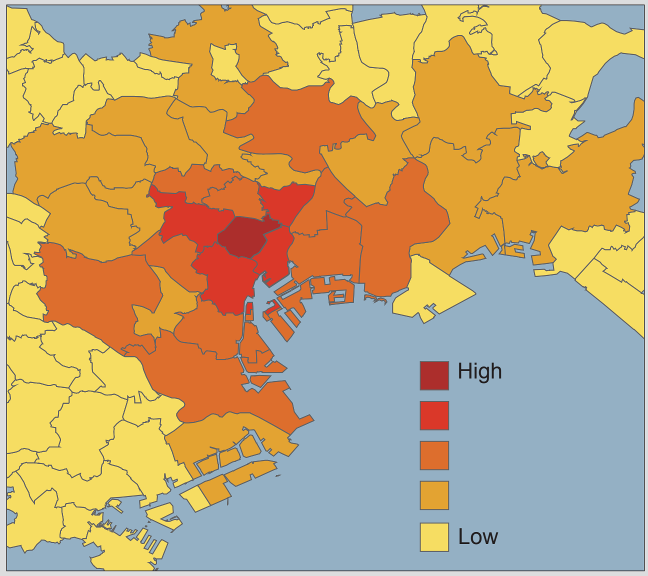
12 *International Atomic Energy Agency and World Health Organization. "Diagnosis and Treatment of Radiation Injuries." Vienna: IAEA, 1998: 49*

HYPOTHETICAL SCENARIO 5: 5KT TERRORIST NUCLEAR BOMB IN TOKYO

Smuggled Bomb Detonated in Downtown Tokyo

State of emergency declared as blast kills 300,000 and radioactive fallout affects thousands more

Security specialists fear that small-yield tactical nuclear weapons could some day fall into the hands of terrorists (Source: U.S. Department of Defense)



The death toll is severe at the center of the city, and casualties extend for some distance from ground zero

The Beth group, a secretive sect led by a charismatic leader, preaches the end of the world and its responsibility to purge the earth of "the corruption of modern society." Beth has a small number of followers, but it raises large sums of money to pursue its aims: several of its members are very wealthy and others obtain money through internet scams and cyber-crime. Through links to sister groups, like Aleph in Russia, the group negotiates with Chechen rebels to purchase a nuclear weapon. The weapon is an obsolete Soviet Atomic Demolition Munition ADM50 stolen from a military base in Kazakhstan during its de-nuclearization program in 1993. It is designed to produce a 5 kiloton yield–a tactical weapon that will obliterate a battlefield or enemy installation with about one third of the yield of the Hiroshima bomb. There are many larger nuclear weapons in the ex-Soviet arsenal, but these are all carefully inventoried and inspected. The tactical weapons however had fewer controls and several are known to be missing. The stolen weapon cannot be armed and is in poor condition, but still has its component parts. The bomb is trucked overland to a warehouse of a Beth-owned chemical import and export company in Vladivostok.

In the warehouse, a team of Beth specialists assess the weapon. It is a 4-m (13-ft) long cone, weighing about 300 kg (660 lb). The electronics are non-functional, and the device is fitted with permissive action link (PAL) controls, requiring sophisticated codes to arm it. A previous attempt to forcibly remove the electronic locks has caused the weapon to automatically switch into a 'non-use' mode in which the weapon cannot be detonated. In addition, the high-explosives used in the shaped charges around the core have deteriorated and are defunct. The small plutonium radioactive core of the weapon is still viable and strongly emitting gamma rays. The air-tight seal encasing it is still good, so the chances of operators inhaling deadly plutonium particles is minimized, though no technician can work too close to the weapon for more than a few hours without becoming sick from gamma ray exposure. Since gamma rays can be detected by hand-held gamma-ray or neutron spectrometers from a few meters away, the group needs to evade chance detection by law-enforcement agencies. They have built a lead-lined workshop to reduce the risk of detection, and they wear the heavy lead aprons used by x-ray technicians.

Over the next nine months, a team of 20 people–all committed Beth believers–work undetected on the restoration of the bomb. The team of highly skilled and experienced technicians, including scientists from nuclear research laboratories, explosives experts, and electronics engineers has been carefully chosen and in some cases individually recruited by the leader himself. They are some of the finest minds in Japan, convinced by the rhetoric and charisma of the Beth cause.

Replacing the high-explosive charges, which have to be precisely milled and exactly placed, is the most complex task. The electronics are completely rebuilt and the coding and detonation sequencing reconstructed. Each element is tested and re-tested separately before assembly. Finally, satisfied that the bomb will detonate successfully when triggered, the leader moves the operation to its final phase.

The bomb is encased in a lead casket and put inside a container with bulk chemicals; it is then loaded onto a ship bound for Nagoya. Members of the Beth team have already established that the inspection rate of industrial cargo at Nagoya, one of the largest ports in the world, is minimal. Unlike in U.S. ports, inspectors here are not equipped with radiation detectors, and terrorism screening is not a priority. With authentic paperwork, the container is off-loaded at the port, certified, and passed by customs. The container is one of several hundred loaded onto a cargo train for Yokohama. There, the lead casket is leaded onto the back of a large truck.

The team checks if the bomb is intact and still functioning. The leader gathers his followers and addresses them about the day of reckoning. They have a ceremonial farewell–they will shortly strike at the heart of authority and purge society of its government. The leader tells his followers to prepare for a new society.

The next day, the truck is driven into the center of Tokyo and parked in a service yard at midday. The leader goes through a final ceremony and detonates the nuclear bomb.

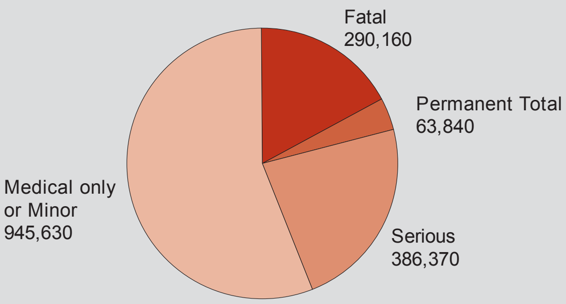
The blast incinerates everything within 2 km (1 mi). Buildings 4 km (2 mi) away are torn apart by the pressure wave; multi-story buildings collapse. The heat sets the ruins on fire and causes buildings even further away to burn. Most of the inhabitants of the center of the city are killed. The initial detonation kills a quarter of a million people.

The dense residential neighborhoods beyond the city center are in flames. The military set up an 8-km (5-mi) containment perimeter around the damaged zone, and redirect people to hospitals and decontamination centers. Hospitals in the vicinity are also damaged, and many of the doctors are also victims. A triage regime is quickly established, where treatment is prioritized for lifesaving– those who will recover anyway or who are likely to die are low priority. Those needing further treatment are sent to hospitals outside the affected areas, but the need to treat the injured overwhelms the medical capacity of the entire region. Medical supplies quickly run short and blood donation centers are established. Many victims have burns, but there are insufficient burn injury units in the country to deal with all the patients.

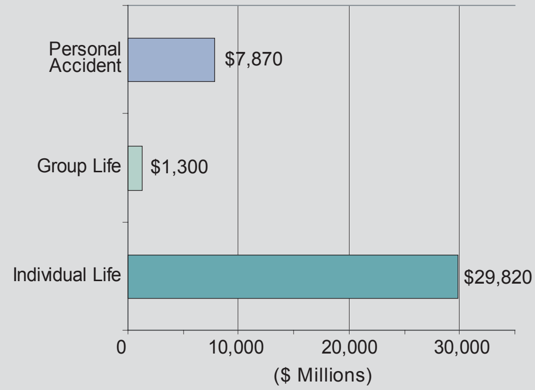
Many others have radiation injuries, which are challenging to treat. Several thousand people have been exposed to radiation doses of more than 4,000 rads that will rapidly damage their central nervous system and kill them within 36 hours. Those who experienced lower dosages, such as 500 rads, are likely to exhibit gastrointestinal radiation symptoms including nausea and vomiting, which will be fatal within two weeks. Low doses of radiation, below 100 rads, will also cause nausea and vomiting. These people will recover in a few days, but may will experience infection and internal bleeding for several weeks from damage to bone marrow. It is impossible initially for physicians to tell what dose of radiation a victim has received, so prioritizing treatment is difficult.

Prioritizing children, authorities issue potassium iodide tablets to the population of Tokyo to prevent thyroid cancers that result from radioactive iodines in the fallout. These tablets have been stockpiled in case of a radioactive release from a nuclear power station but are now used to combat the effects of the nuclear strike.

Injury Distribution
of 1,686,000 Casualties



Losses by Line
(50,000 Radiation fatalities assumed to be excluded from insurance coverages)



8.6 Losses from Terrorism

The death of more than half a million people in a single deliberate act by terrorists may seem impossible to contemplate, but such acts are feasible and indeed considered by our potential adversaries. In public statements, an Al Qaeda spokesman has threatened the death of up to four million Americans through the use of weapons of mass destruction.[13]

If such an attack were ever carried out, the consequences would be world-changing. There would be massive political reaction, changes in foreign policy, police powers, and civil liberties, affecting every avenue of our daily lives to try to prevent such an event ever occurring again.

The total loss to property, infrastructure, and people would be trillions of dollars. The impact on the economy would be substantial, and would require many years of decontamination and planning before the city could be reoccupied and rebuilt.

The impact on the insurance industry would also be severe. Not only would property insurers suffer major losses from the commercial property destroyed, many other lines of business, ranging from auto and fine art through to liability and life and health, would also suffer record-breaking losses. In addition, it is possible that stock markets would dip and insurers could face a situation of extreme loss combined with a sudden devaluation of their asset portfolio.

Life and health insurers can consider this type of scenario as a useful stress test for their risk management procedures, enabling them to develop plans in view of different levels of loss.

8.7 Other Types of Terrorism Scenarios

The detonation of a nuclear bomb in the center of a major city is one of the worst-case scenarios for a terrorist attack on a G8 country. Larger losses are possible–a larger yield nuclear bomb could be used, or several nuclear bombs could be detonated on multiple cities simultaneously, or terrorists could target unusual concentrations of population to increase the loss–but these scenarios are even less likely.

Terrorists might carry out different types of severe attacks that would result in lower numbers of fatalities but would require distinctly different types of treatment and associated costs for the injuries caused. Other weapons of mass destruction, such as biological weapons are also very difficult to develop but may be easier for terrorist groups to obtain than a nuclear weapon. The effects of a major attack using, for example, anthrax spores dispersed into the air in an urban center would likely be less severe than the nuclear bomb scenario described here, but the types of injury and the devastation it would cause would achieve many of the aims of terrorists. Analysis suggests that more than 100,000 people could be killed in such an event and over a million people affected.[14] Inhalational anthrax is the most common injury, and if not immediately treated with a strong antibiotic, can cause bronchial failure and require intensive medical treatment, including respirators and special medical facilities.

8.8 Probabilistic Modeling of Terrorism Losses

The 2006 RMS® Global Terrorism Risk Model indicates that there is low probability of mass-casualty attacks in Japan. The large majority (more than 80%) of terrorist incidents in Japan are likely to continue to be micro-terrorism events. A conservative estimate of the average annual fatalities resulting from micro-terrorism incidents is likely to be less than 10 people. There is a small but significant chance of a larger scale macro-terrorist attack such as those seen in other countries. On most estimates, the probability of a successful macro terrorist attack occurring in Japan in the next 12-month period is currently less than 4% (1 in 25).

There is also a very small chance of extreme terrorist attacks, such as those involving CBRN or massive destruction achieved through conventional weapons. However, given the history of attempts and the threat of extreme attacks by Islamist militants, this is not a threat that can be completely dismissed.

The RMS model estimates that only 1 in 10 macro-terrorist attacks carried out in Japan would be an extreme event of this type, so in a given year the chances are less than 0.4% (1 in 250). The chances of a severe attack causing many thousands of fatalities, as described in these extreme scenarios, is even lower. These are provided in the modeling of casualty exceedance probabilities.

13 The threat to kill four million Americans was made in an audiotape released to Al Jazeera TV network in June 2002, by Al Qaeda spokesman Sulemain Abu Gheith

14 In "Catastrophe, Injury, and Insurance: The Impact of Catastrophes on Workers Compensation, Life, and Health Insurance" (2004), RMS' analysis for the U.S. life and health insurance industry, the chosen terrorism scenarios included two different scales of anthrax attacks on Chicago; the larger attack caused 106,700 fatalities and 942,900 casualties

Annual Probability	Return Period (years)	Individual Life ($ million)	Group Life ($ million)	Personal Accident ($ million)
Average Annual		1.9	0.1	0.8
2.00%	50	12.5	0.9	5.4
1.00%	100	21.0	1.6	9.1
0.50%	200	30.7	2.3	13.3
0.40%	250	34.3	2.5	14.9
0.20%	500	48.3	3.6	21.0
0.10%	1,000	71.8	5.3	31.5
0.05%	2,000	111.1	8.2	48.8
0.02%	5,000	183.5	13.6	80.7
0.01%	10,000	254.3	18.9	111.8

Table 8.1 Exceedance probability for insured losses resulting from terrorist attacks in Japan, using the RMS® Global Terrorism Risk Model

Annual Probability	Return Period (years)	Number of Fatalities	Number of All Other Injuries
Average Annual		20	60
2.00%	50	110	560
1.00%	100	190	970
0.50%	200	280	1,450
0.40%	250	310	1,640
0.20%	500	440	2,420
0.10%	1,000	660	3,880
0.05%	2,000	1,020	6,170
0.02%	5,000	1,680	10,220
0.01%	10,000	2,330	14,180

Table 8.2 Probability of number of deaths and total casualties resulting from terrorist attacks in Japan using the RMS® Global Terrorism Risk Model

8.8.1 Casualty Exceedance Probabilities

Tables 8.1 and 8.2 show the probability of exceeding certain numbers of fatalities and casualties from terrorist events in Japan, as derived from the RMS model.

The RMS model estimates that the likelihood of a terrorist event killing more than 1,000 people in a 12-month period in Japan is approximately 0.05% (1 in 2,000), while the probability of an event causing 10,000 casualties (injuries plus fatalities) is 0.02% (1 in 5,000). The chances of an event causing the scale of death and injury described in our scenario are therefore very small.

These types of events are possible nevertheless, and if they occur, in addition to doing immense harm to our society and economy, they would have a severe impact on insurance companies. It is important for life and health insurance managers to include these remote but severe scenarios into their contingency planning and risk management activities, as described in the next chapter. ■

9 MANAGING THE RISK

This report explores a number of credible disaster scenarios and the estimated injuries and fatalities to people in Japan. The true scope of these and other catastrophes extends beyond the immediate physical harm and can cause indirect impacts such as homelessness, relocation, and job loss. Many of these events would be accompanied by large scale property damage and a significant impact on the national and local economies. The financial consequences, in particular, can be extremely severe, compounding the risk to the government, financial markets, private enterprise, and individuals.

Although many of the catastrophes likely to affect Japan are inevitable, such as earthquakes, the risk to insurers can be quantified and actively managed. Insurance is an effective form of risk transfer for those faced with the potential of a large loss. This chapter presents a number of challenges faced by the insurance industry and the practices that can help maximize risk management and minimize the potential for insolvency.

Proactive risk management strategy can now leverage better information and data, state-of-the-art technology, including catastrophe risk management software, and best practices that have been developed over the past two decades in response to the growing risk. Specific practices include:

- Improved data collection
- Monitoring of exposure accumulations
- Deterministic loss modeling
- Probabilistic loss modeling

A discussion of each of these practices and how insurance and reinsurance companies are using them to manage their risk is included in the following sections.

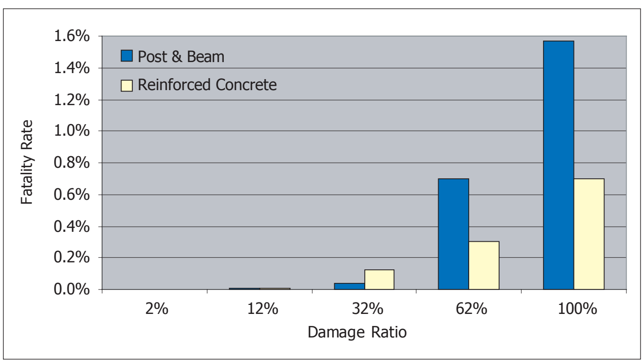


Figure 9.1 Building construction can have a significant impact on the fatality rate in perils like earthquake

Specific risk management processes vary from company to company and depend on the type of business written, the geographic location and spread of that business, and the perils to which that business is exposed.

9.1 Helping Insurers Understand the Risk in Japan

The Japanese population is exposed to a wide range of potential catastrophes. Natural disasters including earthquakes, volcanoes, typhoons, and tsunamis cannot be prevented and may affect large geographic areas. Man-made or man-enabled disasters such as terrorism, influenza, fire, and industrial accidents can also be very costly.

For an insurance company, catastrophe risk depends on the total losses experienced, risk transfer mechanisms in place, and the financial stability of the insurer both in terms of cash reserves and future cash flows. Does the insurer incur a disproportionate share of loss compared to its market share? Do the loss of life and number of non-fatal injuries greatly exceed the expected mortality and morbidity rates used to establish insurance rates? Is there an extreme number of claims? Is there a demographic concentration, such as of wealthy business people, that is overly represented among the insurance claims? Answering these questions before a catastrophic event occurs is a key goal of risk management, and these answers depend heavily on accurate data and the right set of analytical tools.

9.1.1 Event Foresight, Not Event Prediction

Predicting when or where an event occurs would be extremely useful, but information which would allow forecasts is rarely available. Moreover, even if it were, it might be of limited value for insurers. A good risk manager needs to understand a wide range of possible scenarios in order to prepare for the potential outcomes and the type and scale of the events likely to be faced, even if the scenario events themselves will not occur exactly in the way they are anticipated.

The scientific community provides a wealth of information related to catastrophic risks and serves as a good starting point in the development of foresight that can be used to manage risk. In Japan, there is an extensive historical record dating back several hundred years that chronicles earthquakes, tsunamis, and other disasters.

The past provides insight into potential future events, but it may be insufficient alone. The historical record may fail to identify larger magnitude events, but scientists can draw out better data through their research.

Similarly, there are new types of risks that didn't exist before. Nuclear disaster, whether accidental or intentional, would not have been a concern more than 60 years ago. But the extensive use of nuclear power generation in Japan and elsewhere as well as the proliferation of nuclear weapons creates the potential for extreme mass casualty scenarios.

The manner in which communities develop and interact with the rest of world is yet another consideration. The extreme population density in Japan, particularly in Tokyo, increases the likelihood that even a small disaster will affect a large number of people. And the ease with which people can travel and interact face-to-face with others only increases the potential risk from influenza and other infectious diseases.

Now more than ever, people are exposed to a large number of perils. Simply understanding what these are and how they might impact the population places insurers in greater control of managing the risk they assume.

9.1.2 What is a Credible Event?

The fact that a catastrophic event could occur does not imply that it must be considered to effectively manage overall catastrophe risk. Some events are extremely unlikely–so much so that it does not make practical sense to manage the risk of them occurring. An example would be the effects of an asteroid 10 km in diameter (6 mi) that impacts the earth. Not only is this not a very likely scenario, but if it were to occur, it would likely wipe out the human race. This outcome is so extreme that an insurance company cannot manage it.

Thus, we are considering scenarios that are not only credible (i.e., they could conceivably occur) but are realistic for risk assessment in terms of likelihood, impact, and management. These issues will be addressed later in this section as part of the deterministic and probabilistic loss modeling practices.

9.1.3 Who is at Risk?

Understanding the nature and scope of a catastrophe is important, while more critically, insurers need to understand who is insured and where they are at the time disaster strikes. An earlier chapter of this report addressed the population at risk. An insurance company is not concerned so much with the total population but with the portion of the population it insures.

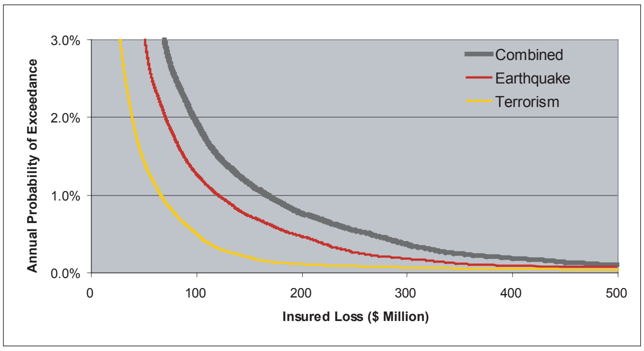


Figure 9.2 Sample exceedance probability (EP) curve that can be used for managing multi-peril risk

Demographic or statistical summaries of an insurance company's exposures are useful but insufficient for an accurate risk analysis. Specific data requirements needed for this level of risk management are addressed in detail later in this chapter.

9.2 Lessons Learned from the U.S. and Europe

Japan is the 60th largest country in the world by area and 10th largest in population. Most of the people reside on only 30% of the land, making it one of the most densely inhabited regions in the world. As we have highlighted, Japan is exposed to a wide range of perils. But it is not unique in this regard, and life insurance companies in Japan face many of the same challenges as those in other parts of the world. Therefore, lessons learned from the experiences of insurers in the U.S. and Europe are beneficial.

9.2.1 Catastrophes: an Impetus for Action

The occurrence of severe catastrophes has often resulted in major changes within the U.S. and European insurance markets. In some cases, major events have highlighted deficiencies in companies' insurance practices. Other events provide costly lessons for insurers who fail to manage against all perils to which they are exposed.

Life and health insurers in the U.S. and Europe, like their property insurer counterparts, have learned from their experiences and take a more proactive approach to managing catastrophe risk. Some of the lessons learned relate to the importance of data capture, understanding the correlation of losses between different lines of business, managing portfolio risk through intelligent underwriting, and adopting technology to assist them with risk management.

9.2.2 Improved Data Capture

Prior to 1990, most insurance and reinsurance companies captured only a minimal amount of data on their risks. What was captured was used mostly for billing, marketing, regulatory reporting, and pricing. Hurricane Andrew in 1992, followed by the Northridge earthquake just two years later, alerted property insurers to the risks of not aggressively managing risk geographically.

Life and health insurers learned a lesson on September 11, 2001 when terrorists attacked and destroyed the World Trade Center. The 3,000 fatalities resulted in close to $2.5 billion of life insurance claims, which sent the message to insurers that they were not immune to large and costly catastrophic events. The events of 9/11 further highlighted the issues of data resolution and how important it is to understand with great precision where exposures are located.

More recent events including the European floods in 2002 and Hurricane Katrina and the ensuing Great New Orleans Flood in 2005 only solidify the message that the ability to identify details, such as proximity to bodies of water and elevation, may not only be useful, but critical to their risk management practices.

9.2.3 Correlation of Loss Between Lines of Business

Companies that have multiple business units are wise to manage risk across all lines of business rather than managing them independently. The 9/11 terrorist attacks produced the largest ever single event loss for commercial property, life, and workers compensation insurance lines. Some companies ended up with large losses not from just one business unit, but several. Additionally, the event highlighted the fact that incidents that produce very large casualty losses in the form of fatalities and injuries are also likely to produce significant physical property damage.

9.2.4 Portfolio Impact

Historically, catastrophe risk management activities usually involved a periodic assessment of the company's overall portfolio. This subjected those companies to unforeseen losses if events occurred between cycles and the portfolio did not have sufficient geographic spread of risk, leaving them overexposed. Active hurricane and windstorm seasons in the U.S. and Northern Europe in recent years have led to more proactive portfolio management. Individual risks are increasingly being evaluated not only on their own merit, but on the impact they will have to the entire existing portfolio.

9.2.5 Adoption of Technology

Prior years of large losses combined with the more recent availability of data, improvements in computing speed and capabilities, and increased competition have resulted in widespread adoption and use of technology

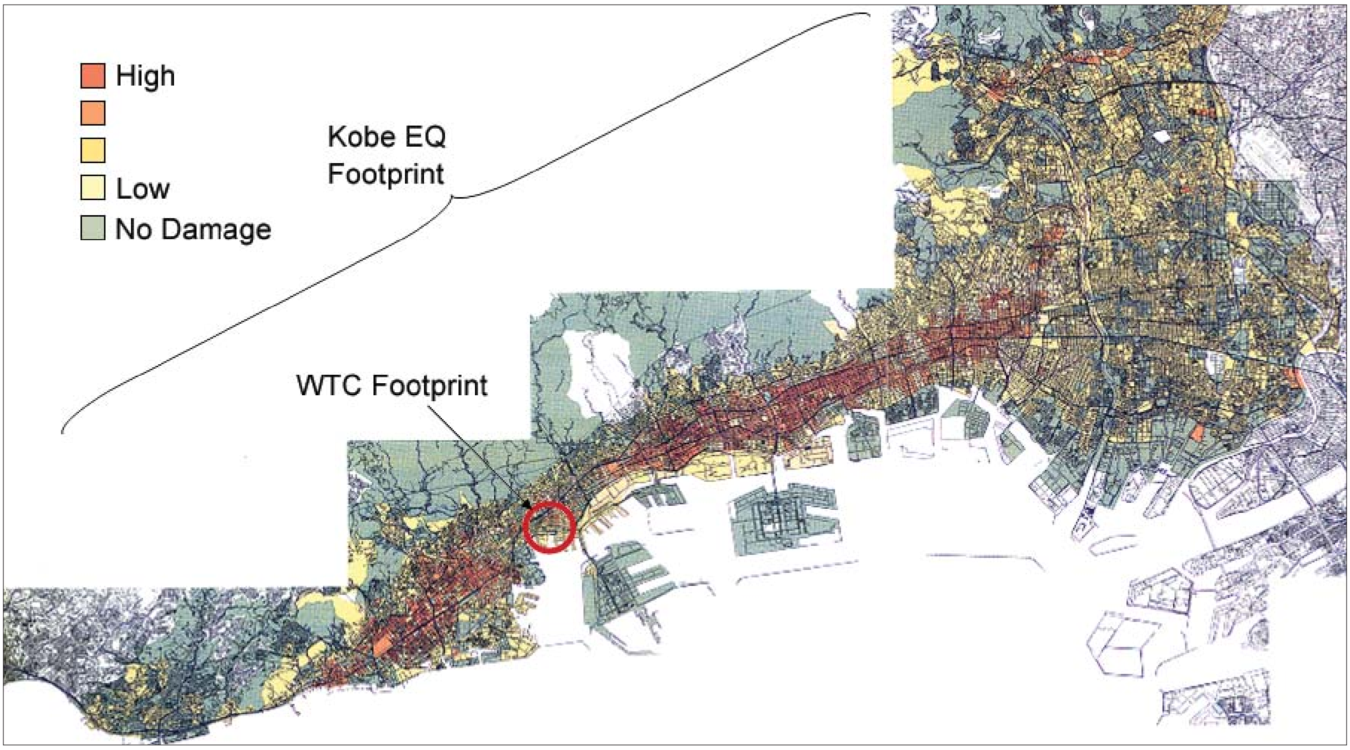


Figure 9.3 While their total insured losses were comparable, the 1995 Kobe Earthquake losses were spread over a much more extensive area than those of the 2001 terrorist attack on the World Trade Center, shown to the same scale for comparison

to manage risk. From Geographic Information Systems (GIS) software, to sophisticated underwriting workstations and catastrophe risk analysis models, integration of technology is now common practice. With property insurers leading this charge in the mid to late 90s, life and health writers are following suit.

9.3 Data Collection

The importance of data in managing risk has been emphasized, but new questions arise: what information is needed, and are the costs of collecting data warranted? The widespread practice of capturing total limits by prefecture in Japan today does not seem to satisfactorily address these questions, the answers to which are critical in the management of catastrophe risk.

If life 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 of three main areas:

1. *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).

2. *Where are the insured people located?* The magnitude of catastrophe risk varies dramatically with geographic location. For a peril capable of destroying a building and its occupants, knowing which buildings you have insured and the personnel inside is important. Capturing an accurate physical assessment 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 details for both a work and home location to better understand their exposure.

3. *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 affect 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, having the information listed above is imperative, and the potential impact of each is discussed in the following sections.

Japan has some of the world's best prepared emergency responders such as firemen seen here carrying out a drill to reduce the casualties in a future catastrophe (Source: U.S. Department of Defense)

9.3.1 Insured Limit

For most types of insurance, an insured limit defines the maximum amount for which the insurer is liable in the event of a claim. The limit for a life insurance policy may be expressed as specific limit or a multiple of an employee's salary. For modeling purposes, the limit should be expressed in the relevant currency and not as the multiple.

Group life insurance policies may cover many individuals. In such cases aggregate limits can be provided, although groups of individuals at different physical locations still should be reported separately.

9.3.2 Number of People

Risk analysis can include the total number of insured people per location. Even if the loss is determined by an insured limit, as in the case of life insurance, providing the number of people per location will allow not only for losses to be quantified, but also the number of fatalities and/or injuries expected. For some lines of business, such as health insurance, the number of people is required as the actual loss amount is determined by the number of people injured or killed and the costs associated with those injuries.

Additional details, such as the maximum number of people at a location at any time, can help to refine the answer by putting realistic bounds on the expected loss. If the insured workers are employed, then providing additional details such as their work shifts can be used to estimate exposure at a particular time of day or point in time.

9.3.3 Geographic Data

The ability to specify the geographic position of a location or group of people is critical for detailed risk analysis. In Japan, using high-resolution geographic information such as a sonpo or postal code or specific address is ideal. If possible, using precise coordinate data (e.g., latitude and longitude) can yield the most accurate results. Less accurate data such as city name or prefecture may still lend themselves to certain types of risk analysis but will fall short of delivering accuracy in many cases.

Some perils affect a relatively small area, but are still capable of producing large losses. When small event footprints are involved, only data at the best resolutions can be trusted to produce realistic loss results.

9.3.4 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 a 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.

9.3.5 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.

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.

9.3.6 Market Share Information

In the absence of detailed data, 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 by region or prefecture, and assuming the appropriate proportion of loss from each modeled event in the RMS industry loss event set, a rough indication of the aggregate exceedance probability (AEP) of various levels of losses for that company can be obtained.

However, a market share analysis may be misleading because losses for a specific company do not average out in the way a market share analysis assumes. When perils affect only a small geographic area, the market share approach becomes less useful to accurately assess risk.

9.3.7 Impact of Data Quality

Insurance executives use the output of catastrophe models to support decisions that can have major financial implications for their business. As with any model, the quality of the output is only as good as the quality of the input data. In the case of catastrophe risk modeling, the critical data relates to the exposure in a company'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. Models may be designed to make assumptions in the absence of factual user-supplied data. In terms of the quality of results, this is not an acceptable substitution, and decision-making will be more accurate when such assumptions are not needed.

Uncertainty in the quantity of exposure will have a unit-per-unit impact on the output. For example, if the number of people modeled is 80 but the actual number of people is 100, then this would suggest that exposure is understated by 20%. Uncertainty in the physical location of an exposure has a less certain outcome. While we know that low-level resolution exposure, for example one that geocodes to a prefecture level, is not reliable, we cannot say for sure whether correct data would produce a larger loss or a smaller loss.

9.3.8 How Models Treat Unknown Data

Even in the best circumstances, complete data may be nearly impossible to obtain. Fortunately, many catastrophe risk assessment models are prepared to deal with this situation. Using supplemental information to analyze the characteristics of a company's portfolio, it is possible to estimate the risk level. RMS builds 'intelligent' assumptions into the model that can be substituted for missing data. 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.

There are numerous examples of ways the model can be used to augment coarse resolution data. For example, when building construction type is not supplied, rather than assume any one construction type, the model would consider that a mix of different construction types are common in a particular geographic area and use this mix to create a composite damage curve using the relative weights of different classes.

Incomplete data can make a material difference in 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.

9.3.9 The Obstacles to Getting Accurate Data

It is not always practical to obtain most accurate or near-perfect data for it often comes at a cost–time, money, or both. For some companies, the process of improving data quality involves changing back-office systems and front-office data collection and may take 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. Cost constraints may warrant a disciplined approach that considers where data quality will have the most significant impact and take action only in those cases.

9.4 Monitoring Exposure Accumulations

A starting point for risk management, once the necessary data is available, is identifying accumulations of exposure. Between the high population density in Japan and the geographically focused nature of various mass casualty events, there is a clear need to identify and quantify accumulations that might lead to unacceptably large losses above a company's threshold.

Understanding the location and movement patterns of policy holders helps to manage risk

9.4.1 Identifying Concentrations

To identify exposure concentrations, three questions must be answered:

1. Where in the country do you look 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 may be possible to identify concentrations throughout the country, and a risk manager's knowledge of the perils and hazards that pose the largest threat can be very important. For example, concentrations on the coast at low elevations should raise concerns because those are these areas are at greatest risk to tsunamis and typhoons. Similarly, exposure concentrations in and around major skyscrapers elevate loss potential if a fire or terrorism attack were to occur there. Also, exposures in highly seismic areas may be worse off than those in areas of reduced seismicity.

Understanding the construction type of buildings where policy holders live and work is also important

Non-discriminate identification of exposure concentrations can be educational, but isn't always practical. Introducing one's knowledge of risk and catastrophes can help focus limited resources and prioritize those areas that require ongoing monitoring.

9.4.2 Specifying the Size of an Accumulation Area

What exactly constitutes an unacceptable concentration? We have already suggested the importance of defining a financial or numerical threshold, but the size of the area around this concentration also matters. The concentration of $500 million in life insurance limits in all of Japan probably would not create undue concern, but if this entire amount was concentrated within 1,600 m^2 (0.0006178 mi^2) in downtown Tokyo, this would be a clear risk that should be managed. So then, how large an area should be used to assess concentrations?

The answer to this question depends again on the likely risk factors. If terrorism is a peril of concern, then focusing on an area within 400 m (0.25 mi) of likely terrorist targets would be acceptable since most conventional attacks do not cause extensive damage further away than this. If there is concern about the stability of a nuclear reactor, then perhaps it is best to monitor accumulations within 16,000 m^2 (0.006178 mi^2) of the reactor. Still some risks, like an influenza pandemic, defy conventional definitions of area, since the entire population of Japan may be at risk.

Many companies define multiple thresholds or areas to address this issue. A company with accurate, high-resolution data is in a better position to define accumulation areas. Other companies may be forced to rely on geographic or political boundaries such as wards, prefectures, or in an extreme case, islands.

9.4.3 Managing Accumulation Limits

The level of exposure accumulation that raises concerns is specific to each company and should be addressed by senior management. A maximum threshold for multi-line exposures (recall that the correlation of loss between different lines of business warrants an enterprise-wide view) 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.

9.4.4 Monitoring Accumulations

One-time identification of accumulations is not an aggressive risk management approach, so the ongoing monitoring of exposure is needed to determine if risk is being managed effectively and whether new accumulations are being created unbeknownst to the portfolio manager.

9.5 Deterministic Loss Modeling

The third step of the risk management process is to look at modeled losses under one or more scenarios. The disaster scenarios provide a few examples, but they may not be the most appropriate for all companies. 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.

The selected event should be extreme, but still likely. Using a deterministic event that has a very low likelihood of occurrence may not be appropriate because it may be unduly conservative for senior management. For this reason, for example, many insurers in the U.S. choose to manage terrorism risk to conventional vehicular bomb attacks rather than the low-probability attacks involving chemical, biological, radiological, or nuclear (CBRN) weapons.

9.5.1 Loss Limits

Selection of a threshold for each company under the benchmark scenario (the level that modeled multi-line losses should never exceed) is a management decision that will depend on a variety of factors including surplus level, risk appetite, rating agency, and regulatory requirements. Deciding where the benchmark scenario should be modeled follows a similar process as selecting accumulation areas. Specific threats in high-risk areas would have greater priority, with secondary consideration given to all other possible locations. This is useful in identifying the maximum credible loss that may affect the portfolio.

If benchmark scenario losses exceed management set thresholds, analyses should be performed to identify the account(s) and line(s) of business that contribute to the losses. Appropriate remedies include risk transfer using facultative or treaty reinsurance, non-renewal, or modification of policy limits, or attachment points.

9.6 Probabilistic Loss Modeling

The fourth and final step of the risk management process uses probabilistic risk analysis. Usually, this involves modeling a spectrum of potential events against a company's portfolio, and looking at the loss and associated probability of each event occurring to define a loss distribution or aggregate exceedance probability (AEP). Available catastrophe risk models may already define these scenarios along with associated probabilities. By using the scenarios along with portfolio exposure data, a loss profile can be produced.

9.6.1 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 average annual loss (AAL) from a variety of perspectives, we can learn about portfolio risk. Examples include AAL by line of business to determine which line drives risk, by city to discover the region driving risk, and by source of event to determine if exposure should no longer be written nearby.
- *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 the reduction of risk to acceptable levels.
- *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.

9.7 Putting It All Together

Catastrophe risk modeling is not an exact science, and there is uncertainty in any type of loss model. Despite this uncertainty, models provide a useful and practical framework to assess risk potential. Prudent risk managers use multi-tiered approaches to triangulate risk and evaluate alternatives to manage that risk or transfer it away. Effective catastrophe risk management is an interactive process. As described in this chapter, it requires some knowledge of the risks faced by a company, a deep understanding of the portfolio being analyzed, and the discipline to define acceptable loss thresholds and stick to them.

Probabilistic modeling can be taken further by viewing catastrophe risk not only in silos for specific perils, but by broadening that perspective to evaluate multi-line, multi-peril risk. Creating an AEP from this set of variables will enable an overall corporate view of catastrophe risk. The cycle should begin with a regular review of management thresholds, portfolio risk analysis, and risk management decisions, then back to review. The frequency with which this process is repeated will ultimately depend on how aggressive a company wants to manage risk, the rate at which the risk environment, technology, and science change, and whether a portfolio's risk profile can change quickly with the addition or removal of individual risks. ■

10 CONCLUSION

This report illustrates potential scenarios in which catastrophes trigger more than 10,000 fatalities and many more injuries. The threshold of 10,000 is significant because it represents 1% excess mortality, or an increase of 1% on the average annual number of one million deaths in Japan if an event of this magnitude occurred. In these examples the Japan life and personal accident insurance industry faces payouts of $1.4 billion for the smallest earthquake scenario to $74 billion for the flu pandemic. Most insurance companies with policy holders across Japan would likely take a share of these losses, but some individual companies with higher numbers of policy holders in the locations and age groups most affected would face higher losses than their market share.

10.1 Comparison of Events

The scenarios presented in this report quantify a range of losses that could be incurred by the insurance industry given these different types of events. RMS picked these individual scenarios to illustrate the potential impact of four different perils: earthquake, tsunami, terrorism, and infectious diseases. Each peril is considerably different in the mechanisms by which it causes death and injury, and each has identifiably different characteristics in terms of the likely profile of the victims. For example, casualties in an earthquake are likely to be occupants of specific types of vulnerable buildings, yet in a tsunami, they are likely to be people living near the coast. The victims of a terrorist attack may be members of the general public in major cities, perhaps workers in commercial or government services, while those worst affected by a flu pandemic are likely to be of a particular age range.

10.2 Credibility of the Scenarios

Disasters on this scale are rare, but not unprecedented. There have been many natural catastrophes in the last century in Japan, the greatest of which–the 1923 Great Kanto Earthquake–killed 142,800 people. Circumstances have changed since then, so it is unlikely that an exact recurrence of this type of event would cause an equally large number of casualties. Most events and incidents in the past several decades have been limited to a few thousand casualties at worst, but analysis shows that larger magnitude losses are feasible and that insurance companies should expect and plan for them. This report suggests that a variety of circumstances and different perils can cause disasters on a very large scale.

Hazardous events that trigger high casualties occur very rarely, so the natural inclination is to assume they cannot happen. However, as shown in several of the perils the risk may actually be increasing as a result of growing populations, aging populations, and changes in the locations and type of buildings inhabited.

The analyses in this report are derived from and tested against known phenomena and observations. The occurrence of each peril is verifiable, and most events in these scenarios are replays of real events that have occurred somewhere at sometime. The potential for losses from earthquakes and tsunamis in Japan on the scale RMS has illustrated has been seen throughout history and in various locations around the world. Worldwide, there have been influenza pandemics that have caused as many fatalities as described. The potential for mass-casualty terrorism on this scale is a relatively recent phenomenon, and although there is no historical example, the world's security experts are convinced that this is a real danger. RMS believes that these scenarios represent credible catastrophic events.

10.3 Super Catastrophes

Catastrophes of the past have shown that events with high numbers of casualties tend to be those in which several things go wrong at once, compounding the losses. Examples include a large earthquake causing an industrial release of hazardous materials or a landslide triggering a dam burst. Follow-on catastrophes like these can increase the losses disproportionately by overwhelming emergency response resources, preventing containment plans from working effectively, or consuming medical capacity. These effects contribute to 'non-linearity' in catastrophes, and those events exhibiting this non-linearity have been termed 'Super Catastrophes.'[1] A history of moderate levels of loss in minor events does not prepare people for the massive escalation of loss that occurs in a Super Cat.

10.4 Other Sources of Mass Casualties

The four perils highlighted are primary potential causes of a mass casualty event of 10,000 deaths or more. Other types of events are also possible including:

- Industrial accidents involving explosions, mass fire, or the release of toxic chemicals in urban areas
- The secondary effects of a severe typhoon, with heavy rain and storm surges causing mass flooding, landslides, mud-flows, and other follow-on catastrophes

1 *RMS defines and explores the concept of Super Catastrophes in its October 2005 report "Hurricane Katrina: Profile of a Super Cat," available from www.rms.com*

Scenario	Fatalities	Casualties	Individual Life Losses ($ million)	Group Life Losses ($ million)	Personal Accident Losses ($ million)
Influenza Pandemic H5N1	510,000	29,375,000	55,720	2,750	N/A
Nuclear Bomb – Downtown Tokyo	290,160	1,686,000	29,820	1,300	7,870
Tsunami from Nankai Trench	37,000	97,000	4,040	200	1,120
Kanto Earthquake M8.0	25,000	195,310	3,110	140	190
Kinki Region Earthquake M 7.3	10,260	105,790	1,270	60	80

Table 10.1 Summary of the losses from the scenarios, ranked by total fatalities

- Accidents that could impact public gatherings or large crowds, such as in sports stadium, convention, or terminal
- Aircraft crash, fire, structural failure, or other sudden impact disaster affecting high-occupancy buildings

10.4.1 Volcanic Risk

Mass casualties arising from a volcanic eruption are possible, but remote. Japan has 86 active volcanoes, and a sudden, unforewarned explosive eruption that can send scalding gases and hot rocks into populated areas, potentially killing large numbers of people. However, major populations are generally located at some distance away, and most volcanic eruptions give enough advance warning to evacuate. Therefore, the probability of a mass casualty volcanic event in Japan is very low.

10.4.2 Slow Onset Perils Pose Less Risk

Hazards with a slow onset, like major floods and typhoon-related events that have caused high casualties in the past are mitigated today by sophisticated forecasting systems. These can predict likely rising water and incoming typhoons. Evacuation systems in place also are able to move large populations in advance, preventing mass casualties. 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. However, if prediction or evacuation procedures were to fail, then large casualties could still occur. It is possible for fires to catch large numbers of people unexpectedly or floods to overwhelm defenses, catching populations off guard. But the chances of these events are low, and thus they are not modeled in this study.

10.5 Likelihood of Mass-casualty Events

We have discussed the likelihood of different levels of casualties being triggered in Japan for each peril. The threshold of 10,000 fatalities is different for each of the perils: for earthquake the return period is several hundreds of years, for tsunami it is of a similar order but slightly shorter, for terrorism the return period is several thousands of years, while for pandemic flu the return period is measured in decades. Overall these events are broadly independent of one another (onshore earthquake risk is largely independent of tsunamis caused by distant offshore events) and their likelihoods are additive.

The combined likelihood of these four perils means that the probability of an event causing more than 10,000 fatalities in a given year in Japan is in the range of 5% to 2.5% (i.e., a return period of 20 to 40 years). With other uncommon causes also included, the probability is likely to be at the lower end of this range. Thus each year there is about a 5% chance of experiencing a mortality level in excess of 1% of the average annual fatalities.

10.6 Managing Loss

The scale of losses faced by the insurance industry from these events can be sizeable and significant. Larger losses are possible, and the potential for other events that could cause larger losses have been described in each chapter.

This study has not attempted to relate scale of loss to capital adequacy of the insurance industry or individual companies. However, while the more extreme scenarios are clearly of concern, some companies may be stressed by the losses they would experience in less severe scenarios. Losses are rarely distributed by market share, and individual companies with concentrations of exposure may find that they experience a large proportion of the loss.

Techniques for understanding the nature and exposure to loss of this type of loss are outlined in the previous chapter. The first step to managing portfolio risk is understanding the loss exposure by examining exposure data. The process of capturing information required to fully analyze the nature of the risk may be a lengthy one. However, having accurate data is highly valuable in checking loss potential and monitoring the chances of experiencing a large loss.

Ultimately a company will want to assess its own capital needs and requirements for risk transfer to make more informed decisions. This report is intended to highlight an approach to assessing risk so that companies can identify the scale of loss they may face and appropriately manage it.

Insurance losses from injuries in catastrophes are manageable risks. This report is a first step to quantifying risk and assisting in that management process. ■

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