CHAPTER

RISK AND VULNERABILITY

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CHAPTER SUMMARIES

Citizens collectively face risks from a range of large-scale hazards. Risk is the interaction of hazard consequences and likelihood. Using this formula, hazards are compared and ranked, allowing disaster managers to determine the most effective and appropriate treatment options. The goal of risk analysis is a standard measurement of likelihood and consequence, whether quantitative or qualitative. Consequence describes hazard effects on humans, built structures, and the environment. Losses may be direct or indirect, and tangible or intangible. Hazard likelihood and consequences can change considerably over time. These trends can be incremental or extreme, and can occur suddenly or over centuries. Risk evaluation is conducted to determine the relative seriousness of risks, and to compare and prioritize them. Disaster managers must decide what risks to treat, what risks to prevent at all costs, and what risks to disregard. These decisions are based on risk acceptability. The personal factors that dictate risk acceptability are guided by risk perception. Vulnerability is a measure of the propensity of an object, area, individual, group, community, country, or other entity to incur the consequences of a hazard, and is the result of physical, social, economic, and environmental factors.

Key Terms: consequence; direct and indirect losses; likelihood; qualitative risk analysis; quantitative risk analysis; risk; risk evaluation; risk matrix; risk perception; tangible and intangible losses; vulnerability.

INTRODUCTION

Risk is an unavoidable part of life, affecting all people without exception, irrespective of geographic or socioeconomic limits. Each choice we make as individuals and as a society involves specific, often unknown, factors of risk, and full risk avoidance is generally impossible.

On the individual level, each person is primarily responsible for managing the risks he or she faces as he or she sees fit. For some risks, management may be obligatory, as with automobile speed limits and seatbelt usage. For other personal risks, such as those associated with many recreational sports, individuals are free to decide the degree to which they will reduce their risk exposure, such as by wearing a helmet or other protective clothing. Similarly, the risk of disease affects humans as individuals, and as such is generally managed by individuals. By employing risk reduction techniques for each life hazard, individuals effectively reduce their vulnerability to those hazard risks.

As a society or a nation, citizens collectively face risks from a range of large-scale hazards. Although these hazards usually result in fewer total injuries and fatalities over the course of each year than individually faced hazards, they are considered much more significant because they have the potential to result in many deaths, injuries, or damages in a single event or series of events. In fact, some of these hazards are so great that, if they occurred, they would result in such devastation that the capacity of local response mechanisms would be overwhelmed. This, by definition, is a disaster. For these

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large-scale hazards, many of which are identified in chapter 2, vulnerability is most effectively reduced by disaster risk management efforts collectively, as a society. For most of these hazards, it is the government's responsibility to manage, or at least guide the management of, disaster risk reduction measures. And when these hazards do result in disaster, it is likewise the responsibility of governments to respond to them and aid in the recovery that follows.

TWO COMPONENTS OF RISK

Chapter 1 defines risk as the interaction of a hazard's consequences with its probability or likelihood. This definition and similar derivatives are used in virtually all technical documents associated with risk management. Clearly defining the meaning of "risk" is important, because the term often carries markedly different meanings for different people (Jardine and Hrudey 1997). One of the simplest and most common definitions of risk, preferred by many risk managers, is displayed by the equation stating that risk is the likelihood of an event occurring multiplied by the consequence of that event, were it to occur:

Risk = Likelihood × Consequence (Ansell and Wharton 1992).

LIKELIHOOD

"Likelihood" can be given as a probability or a frequency, whichever is appropriate for the analysis under consideration. There are multiple variants to how probability and frequency are displayed, but these all typically refer to the same absolute value. "Frequency" communicates the number of times an event will or is expected to occur within an established sample size over a specific period of time. Quite literally, it tells how *frequently* an event occurs. For instance, the frequency of auto accident deaths in the United States equates to approximately one death per 81 million miles driven (Dubner and Levitt 2006).

In contrast to frequency, "probability" refers to single-event scenarios. Its value is expressed as a number between zero and one, with zero signifying a zero chance of occurrence and one signifying certain occurrence. Using the auto accident example, in which the frequency of death is one per 81 million miles driven, we can say that the probability of a random person in the United States dying in a car accident equals 0.000001 if he or she was to drive 81 miles.

When disaster risk managers use a standardized method of calculating risk utilizing this formula across all identified hazards, comparison and ranking by severity is possible. If hazard risks are instead analyzed and described using different methods and/or terms of reference for each hazard, or even for groups of hazards, comparison and ranking becomes very difficult when prioritizing how limited resources will be dedicated to risk reduction efforts.

This ranking of risks, or "risk evaluation," is what allows disaster risk managers to determine which treatment options, whether mitigation or preparedness, or both, are the most effective, most appropriate, and will provide the most benefit per unit of cost. Not all hazard risks are equally serious, and risk analysis is what enables an informed decision-making process.

Without exception, governments have limited funds available to manage the hazard risks they face. While reducing the risk of one hazard may be less expensive or more easily implemented than reducing the risk of another, cost and ease alone may not be valid reasons to choose a treatment option. Hazards that have the potential to inflict great consequences (in terms of lives lost or injured, or property damaged or destroyed) and/or occur with great frequency pose the greatest overall threat. Considering budgetary limits, disaster risk managers should generally treat those hazard risks that pose the greatest threat first. Fiscal realities often drive this analytic approach, resulting in situations in which certain hazard risks in the community's overall risk profile are mitigated, while others are not addressed to any degree at all.

The goal of risk analysis is therefore to establish a standard, comparable measurement of the likelihood and consequence factors for each hazard identified. The different mechanisms through which values are derived for a hazard's likelihood and consequences fall into two general categories of analysis: quantitative analysis and qualitative analysis. Quantitative analysis draws upon mathematical and/or statistical data to achieve numerical descriptions of risk. Qualitative analysis also relies upon mathematical and/or statistical data, but instead uses defined terms (words) to describe and categorize the hazard risk likelihood and consequence value outcomes. And while quantitative analyses provide specific data points (e.g., dollars, probability, frequency, or number of injuries/fatalities), qualitative analyses consider ranges of possible values for which each qualifier is assigned. It is often cost- and time-prohibitive, and often not necessary, to determine the exact quantitative measures for the likelihood and consequence factors of a hazard's risk. Qualitative measures are much easier to determine and typically require less time, money, and, most important, expertise, to conduct. For this reason, it is the most commonly encountered method of assessment in practice. The following section provides a general explanation of how these two types of measurements apply to the likelihood and consequence components of risk.

Quantitative Representation of Likelihood

As previously stated, likelihood can be derived as either a frequency or a probability. A quantitative system of measurement exists for each. For frequency, this number indicates the number of times a hazard is expected to result in an actual event over a chosen time frame. For example, a particular area might experience flooding four times per year, one time per decade, ten times each month, and so on as calculated. Probability considers the same base data, but expresses the outcome as a measure that lies between 0 and 1 or as a percentage value that falls between 0 percent and 100 percent. In both cases, this represents the chance of occurrence. For example, if an area has experienced four flood events in the past 200 years where floodwaters reached 20 feet above the base flood elevation, then this severity of flooding has a one-in-fifty chance of occurring in any given year, or a probability of 2 percent, or 0.02, each year. This is also considered to be a 50-year flood. An event that is expected to occur two times in the next three years has a 0.66 probability each year, or a 66 percent chance of occurrence, and is much more probable than the 50-year event.

Qualitative Representation of Likelihood

Likelihood can also be expressed using qualitative measurement, applying words to describe the chance of occurrence. Each word or phrase represents a pre-established range of possibilities. For instance, the likelihood of a particular hazard resulting in an emergency or disaster event might be described as follows using a qualitative system of likelihood:

- *Certain*: >99 percent chance of occurring in a given year (one or more occurrences per year)
- *Likely*: 50–99 percent chance of occurring in a given year (one occurrence every one to two years)

- *Possible*: 5–49 percent chance of occurring in a given year (one occurrence every two to twenty years)
- *Unlikely*: 2–5 percent chance of occurring in a given year (one occurrence every twenty to fifty years)
- *Rare*: 1–2 percent chance of occurring in a given year (one occurrence every fifty to one hundred years)
- *Extremely rare*: <1 percent chance of occurring in a given year (one occurrence every one hundred or more years)

Note that this is just one of a limitless range of qualitative terms and values that can be used to describe the likelihood component of risk. As long as all hazards are compared using the same range of qualitative values, the actual determination of likelihood ranges attached to each term does not necessarily matter. (See exhibit 3.1.)

EXHIBIT 3.1 QUALITATIVE MEASUREMENTS: THE CONSIDERATION OF RISK PERCEPTION AND STANDARDIZATION

In brief, different people fear different hazards for many different reasons. These differences in perception can be based on experience with previous instances of disasters, specific characteristics of the hazard, or many other combinations of reasons. Even the word *risk* has different meanings to different people, ranging from “danger” to “adventure.”

Planners, or members of disaster risk management teams, are likely to draw from diverse backgrounds and may even be from different parts of the country or the world. Each will have a unique perception of risk (regardless of whether they are able to recognize these differences). Such differences can be subtle, but they make a major difference in the risk analysis process.

Quantitative methods of assessing risk use exact measurements and are therefore not very susceptible to the effects of risk perception. A 50 percent likelihood of occurrence is the same to everyone, regardless of their convictions. Unfortunately, there rarely exists sufficient information to make definitive calculations of a hazard’s likelihood and consequence.

The exact numeric form of measurement achieved through quantitative measurements is incomparable. The value of qualitative assessments, however, lies in their ability to accommodate for an absence of exact figures and their ease of use.

Unfortunately, risk perception causes different people to view the terms used in qualitative systems of measurement differently. For this reason, qualitative assessments of risk must be based on quantitative ranges of possibilities or clear definitions. For example, imagine a qualitative system for measuring the consequences of earthquakes in a particular city in terms of lives lost and people injured. Now imagine that the disaster management team’s options are “None,” “Minor,” “Moderate,” “Major,” or “Catastrophic.” One person on the team could consider 10 lives lost as minor. However, another team member considers the same number of fatalities to be catastrophic. It depends on the perception of risk that each has developed over time.

This confusion is significantly alleviated when detailed definitions are used to determine the assignation of consequence measurements for each hazard. Imagine the same scenario, using the following qualitative system of measurement):

1. *None.* No injuries or fatalities.
2. *Minor.* Small number of injuries but no fatalities. First aid treatment required.
3. *Moderate.* Medical treatment needed but no fatalities. Some hospitalisation.
4. *Major.* Extensive injuries, significant hospitalisation. . . . Fatalities.
5. *Catastrophic.* Large number of severe injuries. Extended and large numbers requiring hospitalisation. . . . Significant fatalities. (EMA 2000)

This system of qualitative measurement, with defined terms, makes it more likely that people of different backgrounds or beliefs would choose the same characterization for the same magnitude of event. Were this system to include ranges of values, such as “1–20 fatalities” for “Major,” and “more than 20 fatalities” for “Catastrophic,” the confusion could be alleviated even more.

CONSEQUENCE

The consequence component of risk describes the effects of the risk on humans, built structures, and the environment. There are generally three factors examined when determining the consequences of a disaster:

1. Deaths/fatalities (human)
2. Injuries (human)
3. Damages (cost, reported in currency, generally US dollars for international comparison)

Further distinctions have been made to distinguish between damages and *losses*, as is the case with the World Bank's Damage and Loss Assessment (DALA) methodology (see chapter 6). In this case, damages are defined as the destruction of physical assets, while losses are defined as foregone production or income. And while damages occur immediately and can be rebuilt, losses occur over a longer period of time and may not be recoverable.

Although attempts have been made to convert all three of these consequence factors into monetary amounts to derive a single number to quantify the consequences of a disaster, doing so has proved controversial (how can one place a value on life?) and complex (is a young life worth more than an old life? by how much?). As such, it is often most appropriate and convenient to maintain a distinction between these three factors when detailing an event's impact.

Categories of consequence can be further divided, and often are, to better understand their influence within social and economic contexts. Two of the most common distinctions are *direct and indirect effects (damages/losses)*, and *tangible and intangible effects (damages/losses)*.

Direct effects, as described by Keith Smith in his book *Environmental Hazards*, are "the first order consequences that occur immediately after an event, such as the deaths and economic loss caused by the throwing down of buildings in an earthquake" (Smith 1992). Examples of direct effects are

- Fatalities
- Injuries ("The prediction of injuries is often more valuable than the prediction of fatalities, because the injured will require a commitment of medical and other resources for treatment." [UNDP 1994])
- Cost of repair or replacement of damaged or destroyed public and private structures (buildings, schools, bridges, roads, etc.)
- Loss of possessions
- Relocation costs/temporary housing
- Loss of agriculture and livestock
- Loss of business inventory/facilities/equipment/information
- Loss of usable land
- Community response and cleanup costs incurred
- Loss of historical documents or records

Indirect effects, according to Smith (1992), "emerge later and may be more difficult to attribute to the event." Examples of indirect losses include:

- Loss of livelihoods/income potential
- Input/output losses of businesses

- Loss of community population
- Loss of community character
- Loss of critical services due to organization or business losses
- Reductions in business/personal spending ("ripple effects")
- Loss of institutional/tacit knowledge
- Mental illness/psychosocial impacts
- Bereavement/emotional loss

Tangible effects "are those for which it is possible to assign monetary values" (Smith 1992). Generally, only tangible effects are included in the estimation of future events and the reporting of past events. Examples of tangible effects include:

- Cost of building repair/replacement
- Response costs
- Loss of inventory or possessions
- Loss of wages
- Loss of tax revenue
- Loss of trained or technical staff

Intangible effects are those that "cannot be properly assessed in monetary terms" (Smith 1992). This is the primary reason that human fatalities and human injuries are assessed as a separate category from the cost measurement of consequence in disaster management. These effects are almost never included in damage assessments or predictions. Examples of intangible effects include:

- Cultural impacts
- Stress
- Mental illness
- Loss of community character
- Poor morale
- Consequences of a damaged environment
- Increased health risks
- Sentimental value
- Environmental losses (aesthetic value)

Although it is extremely rare for *benefits* or *positive effects* to be included in the assessment of past disasters or the prediction of future ones, they do arise in the aftermath of many disasters. Like losses, gains can be categorized as direct or indirect, tangible or intangible. Examples of tangible, intangible, direct, and indirect gains include:

- Decreases in future hazard risk by preventing rebuilding in hazard-prone areas
- New technologies used in reconstruction that result in an increase in quality of services
- Removal of old/unused/hazardous buildings
- Jobs created in reconstruction
- Greater public recognition of hazard risk
- Otherwise-unobtainable funds available for development or disaster risk reduction
- Environmental benefits (e.g., fertile soil from a volcano)
- Community cohesion

As with the likelihood component of risk, the consequences of risk can be described according to quantitative or qualitative reporting methods. Quantitative representations of consequence vary according to deaths/fatalities, injuries, and damages:

- *Deaths/fatalities.* The specific number of people who perished in a past event or who would be expected to perish in a future event; for example, *55 people killed.*
- *Injuries.* The specific number of people who were injured in a past event or who would be expected to become injured in a future event. Can be expressed just as injuries, or divided into mild and serious; for example, *530 people injured, 56 seriously.*
- *Damages.* The assessed monetary amount of actual damages and/or losses incurred in a past event or the amount of damages expected to occur in a future event. Occasionally, this number includes insured losses as well; for example, *$2 billion in damages, $980 million in insured losses.* For past disasters, damages may also be adjusted for inflation to enable a more meaningful comparison of events that occurred many years apart.

Qualitative Representation of Consequence

As with the qualitative representation of likelihood, words or phrases can be used to describe the effects of a past disaster or the anticipated effects of a future one. These measurements can be assigned to deaths, injuries, or costs (the qualitative measurements of fatalities and injuries are often combined). The list of qualitative terms included in Exhibit 3.1 is one example.

Additional measures of consequence are possible, depending on the depth of analysis. These additional measures tend to require a great amount of resources, and are often not reported or cannot be derived from historical information. Examples include:

- *Emergency operations.* Can be measured as a ratio of responders to victims, examining the number of people who will be able to participate in disaster response (both official and unofficial responders can be included) as a ratio of the number of people who will require assistance. This ratio will differ significantly depending on the hazard. For example, following a single tornado touchdown, there are usually many more responders than victims, but following a hurricane, there are almost always many more victims than responders. This measure could include the first responders from the community as well as the responders from the surrounding communities with which mutual aid agreements have been made. Emergency operations also can measure the mobilization costs and investment in preparedness capabilities. It can be difficult to measure the stress and overwork of the first responders and their inability to carry out regular operations (fire suppression, regular police work, regular medical work).
- *Social disruption* (people made homeless/displaced). This can be a difficult measure because, unlike injuries or fatalities, people do not always report their status to municipal authorities (injuries and deaths are reported by the hospitals), and baseline figures do not always exist. It is also difficult to measure how many of those who are injured or displaced have alternative options for shelter or care. Measuring damage to community morale, social contacts and cohesion, and psychological distress can be very difficult, if not impossible.
- *Disruption to economy.* This can be measured in terms of either the number of working days lost or the volume of production lost. The value of lost production is relatively easy to measure, while the lost opportunities, lost competitiveness, and damage to reputation can be much more

difficult. The loss of livelihoods can be extremely difficult to measure, especially in farming or fishing communities or communities centered around home-based production of crafts, for example.

- *Environmental impact.* This can be measured in terms of the clean-up costs and the costs to repair and rehabilitate damaged areas. It is harder to measure in terms of the loss of aesthetics and public enjoyment, the consequences of a poorer environment, newly introduced health risks, and the risk of future disasters.

It does not matter what system is used for qualitative analysis, but the same qualitative analysis system must be used for all hazards analyzed in order to compare risks. It may be necessary for disaster managers to create a qualitative system of measurement tailored to the country or community where they are working. Not all countries or communities are the same, and what amounts to a minor impact in one could represent a catastrophe in another. Qualitative measures of consequence should therefore accommodate these differences. For example, a town of 500 people would be severely affected by a disaster that caused 10 deaths, while a city of 5 million may experience that many, or even more, deaths just from car accidents in any given week.

Another benefit of creating an individualized system of qualitative analysis is the incorporation of the alternative measures of consequence (ratio of responders to victims, people made homeless/displaced). The more tailored a system of analysis is to the needs of the study area, the more meaningful its outcome will be to the disaster risk management process.

Intensive, Extensive, and Emerging Risk

Disaster risk managers are most often focused on addressing those hazards for which the likelihood of occurrence is highest and the consequences are greatest. The risk for such hazards is considered to be intensive. At the opposite end of the spectrum are those hazards for which frequency is high or very high, yet the consequences are generally much less severe—perhaps isolated to an individual or a neighborhood. Risk for hazards falling in this category are considered to be extensive. And while intensive risk is most often associated with events that impact a large area, this does not mean that extensive risk impacts only highly localized areas (though that is often the case.)

Events resulting from extensive risk are rarely if ever noteworthy or newsworthy, and often are not tracked by centralized disaster information systems. Likewise, the required response may be nothing beyond what is typical for the local emergency services to perform on any given day. It is the collective sum of extensive risk that is significant, in that it can—and often does—exceed that of the major disaster events incurred in any given year with regard to consequences. (See figure 3.1.) Extensive risk is thus important to the disaster risk manager not in terms of preparing for response, but rather because it is often true that the same mechanisms by which intensive risk is reduced hold true for extensive risk. (See chapter 4 for mitigation options.)

The United Nations Office for Disaster Reduction (UNISDR) reports that 97 percent of extensive risk is weather-related. It is interesting to note that extensive and intensive risks are relative terms, such that two events of equal consequence in two separate locations might be considered extensive—or routine—in a large city, yet intensive in a small village. And because of these distinctions between localities or countries, differences between extensive and intensive risk should be thought of as a matter of capacity.

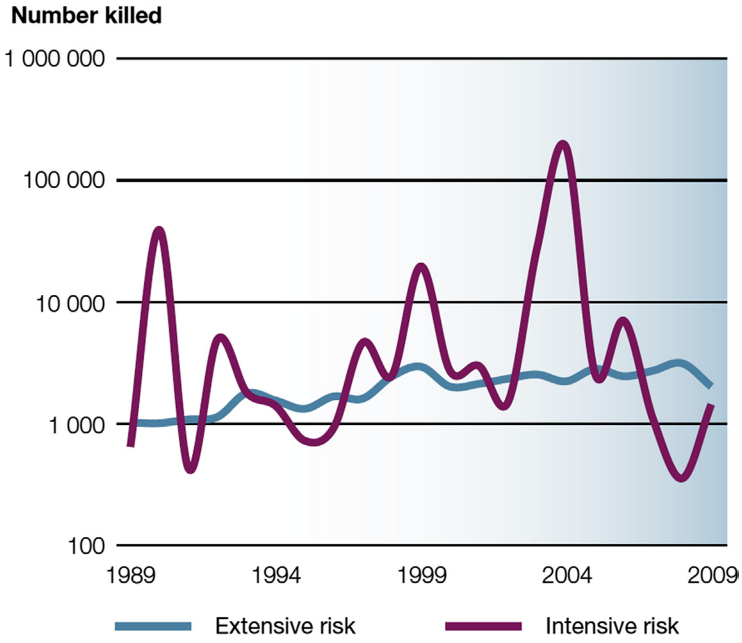


FIGURE 3.1

Mortality from extensive and intensive disasters between 1989 and 2009, in 21 countries in Africa, Asia, Latin America, and the middle East (including Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, India [Orissa and Tamil Nadu], Indonesia, Iran [Islamic Republic of], Jordan, Mexico, Mozambique, Nepal, Peru, Panama, Sri Lanka, Syrian Arab Republic, Venezuela, and Yemen)

Source: UNISDR, 2012.

The third special category, termed emerging risk, refers to hazards with traditionally low frequencies of occurrencebut which are nonetheless increasing due to new patterns of exposure, increasing frequencies, and changes in population vulnerability. Space weather is an example of an emerging risk. In this instance, there is not an increase in the incidence of solar flares, but the impact they have on modern technological systems, and the reverberations that has on contemporary social and economic systems, are significant. The expansion of tropical diseases into areas farther and farther from the equator are presenting another form of emerging risk. The chukungunya virus, which, like Dengue Fever in the 1980s, is moving quickly through the Caribbean, threatens many countries previously unaffected because of wetter and warmer conditions that enable breeding of the mosquitos that carry the disease.

TRENDS

Whether risks have existed for centuries or are just emerging, the likelihoods and consequences associated with them are rarely static. The number of events caused by a particular hazard might increase or decrease over time, whether due to changing global climate patterns, changes in human activities, or both. Likewise, the damaging consequences of existing hazards might increase or decrease, even if there are no changes observed in the total number of events that hazard causes. These trends can be incremental or extreme and can occur suddenly or over centuries. Several short-term trends may even be part of a larger long-term change.

CHANGES IN DISASTER FREQUENCY

A change in disaster frequency occurs when fewer or more disaster events of similar magnitude are noted in a particular area of study. Such changes can be the result of several things, including an increase in actual occurrences of a hazard, an increase in human activity in areas regularly exposed to the hazard, an increase in vulnerability to the hazard among the exposed population, or a decrease in disaster risk management capacity in the exposed area. It is important to remember that a disaster is not determined by the occurrence of a hazard, but rather the outcome of the hazard's consequences. A tornado hitting an open field, for example, is not considered a disaster.

Changes in climate patterns, plate tectonics, or other natural systems can cause changes in the frequency of particular natural hazards, regardless of whether the causes of the changes are natural (e.g., El Niño) or man-made (e.g., greenhouse gas emissions). Changes in frequency for technological or intentional hazards can be the result of many factors, such as increased or decreased regulation of industry and increases in international instability (terrorism).

Increases or decreases in human activity can also cause changes in disaster frequency. As populations move, they inevitably place themselves closer or farther from the range of effects from certain hazards. For instance, if a community begins to develop industrial facilities within a floodplain that was previously unoccupied, or in an upstream watershed where the resultant runoff increases flood hazards downstream, the risk to property from flooding increases.

CHANGES IN DISASTER CONSEQUENCES

A change in disaster consequences occurs when a hazard inflicts either more or less severe impacts to people, property, the environment, and the economy without any significant change in the number of events caused by the hazard. Similar to changes in disaster likelihoods, changes in consequences may be the result of one or more factors including changes in the attributes of the actual hazard (e.g., cyclones of greater intensity), changes in activity or development that influence the vulnerability of people or structures, or a decrease in the willingness or ability to take pre-disaster actions to reduce the impacts of hazard events (i.e., mitigation).

Changes in the attributes of the hazard can occur as part of short- or long-term cycles, permanent changes in the natural processes if the hazard is natural, or changes in the nature of the technologies or tactics in the case of technological and intentional hazards. The consequences of natural hazards change only rarely independent of human activities. One example is El Niño events, with intense flooding increasing in some regions of the world and drought affecting others, possibly for years. Technological and intentional hazards, however, change in terms of the severity of their consequences all the time. The high numbers of deaths and the structural damage associated with the 1998 bombings of the US embassies in Kenya and Tanzania and the September 11, 2001, attacks on the World Trade Center and the Pentagon together display an increase in the consequences of international terrorism on Americans and American interests. A mutation of a certain viral or bacterial organism, resulting in a more deadly pathogen, can cause a drastic increase in consequences, as occurred with the West Nile virus, tuberculosis, mad cow disease, SARS, and MERS, to name a few.

Changes in human activities are probably the most significant cause of increases in the consequences of disasters. These trends, unfortunately, are predominantly increasing. While the effects of disasters worldwide are great, their consequences are the most devastating in developing countries. Smith (1992) lists six reasons for these changes:

1. *Population growth.* As populations rise, the number of people exposed to hazard risk likewise increases. Population growth can be regional or local if caused by movements of populations. As urban populations grow, population density increases, exposing more people to hazards than would have been affected previously.
2. *Land pressure.* Many industrial practices cause ecological degradation, which in turn can lead to an increase in the severity of hazards. Filling in wetlands can cause more severe floods. Lack of available land can lead people to develop areas that are susceptible to, for example, landslides, avalanches, floods, and erosion, or that are closer to industrial facilities.
3. *Economic growth.* As more buildings, technology, infrastructure components, and other structures are built, a community's vulnerability to hazards increases. More developed communities with valuable real estate have much more economic risk than communities in which little development has taken place.
4. *Technological innovation.* Societies are becoming more dependent on technology. These systems, however, are susceptible to the effects of natural, technological, and intentional hazards. Technology ranges from communications (the Internet, cell phones, cable lines, satellites) to transportation (larger planes, faster trains, larger ships, roads with greater capacity, raised highways) to utilities (nuclear power plants, large hydroelectric dams) to any number of other facilities and systems (high-rise buildings, life support systems).
5. *Social expectations.* With increases in technology and the advancement of science, people's expectations for public services, including availability of water, easy long-distance transportation, constant electrical energy, and so forth, also increase. When these systems do not function, the economic and social impacts can be immense.
6. *Growing interdependence.* The interdependence of individuals, communities, and even nations is increasing rapidly. Recent outbreaks of viruses, including SARS, avian influenza, swine flu, enterovirus 71 (EV71), and MERS highlight the ease with which pathogens can quickly impact dozens of countries in distant regions, thanks to international travel. The economic and social impacts of major disasters are global, as well. The September 11, 2001, terrorist attacks in the United States caused the global tourism market to slump, while the 2011 Thailand floods caused drastic cost increases to the global technology sector when production for more than one-third of the global supply of hard drives was halted.

The validity of identified trends must be verified. Some trends are simply the result of better reporting or detection. The technology used to detect many hazards has improved, allowing for recognition of factors where such recognition was formerly much more difficult or impossible. It is also common for a trend to exist simply because research or records are incomplete. And finally, standardizing the mechanisms for measurement across time is important. Costs of disasters, for instance, must be adjusted for inflation, or else increases in total disasters costs may be distorted. The same is true with injuries and deaths, which should be considered in light of total populations and population densities for specific hazard types such as epidemics.

COMPUTING LIKELIHOOD AND CONSEQUENCE VALUES

Because there is rarely sufficient information to determine the exact statistical likelihood that disaster will occur, or to determine the exact number of lives and property that would be lost, combining quantitative and qualitative measurements can provide highly useful yet obtainable risk measures. By combining these two methods, disaster risk management practitioners can achieve a standardized measurement of risk that accommodates less precise measurements of both risk components (likelihood and consequence) in determining the comparative risk between hazards.

The process of determining the likelihood and consequence of each hazard begins with both quantitative and qualitative data and converts it all into a qualitative system of measurement that accommodates all possibilities that hazards present (from the rarest to the most common and from the least damaging to the most destructive).

DEPTH OF ANALYSIS

The depth of analysis disaster risk managers take is determined by three primary factors: availability of financial and human resources, seriousness of the risk, and the complexity of the problem. Decisions regarding the level of effort and resources dedicated to the treatment of each individual hazard are informed by the hazard identification and assessment processes.

Each hazard may be analyzed in multiple ways as determined by the range of possible intensities that might be exhibited. The likelihood and consequences for each possible intensity will be different, which in turn results in different treatment (mitigation) options. (See exhibit 3.2.)

For instance, "earthquake" is a general term used to describe that hazard, though a magnitude 4.0 event is very different from a magnitude 9 event from the planning perspective. Generally, the lower a hazard event's intensity (and likewise the milder its consequences), the greater its likelihood of occurring will be. Several thousand earthquakes of very low intensity and magnitude occur daily with few or no consequences at all. Below a certain threshold, these low-impact events can be disregarded. However, lower-frequency strong earthquakes must be given greater consideration because of their potential to inflict massive casualties and damages.

EXHIBIT 3.2 F:N CURVES

Probability curves called *f:N curves*, which plot historical hazard intensities and likelihoods against the amount of damage inflicted, can provide an estimation of both the likelihood of events of specific magnitude and the consequences should those events occur. Examples of worldwide hazard f:N curves are shown in figure 3.2.

Individual communities would plot f:N curves for their locality using local historical data. This graphical representation illustrates the justification for dividing hazards according to possible intensities.

Source: *UNDP, 1994.*

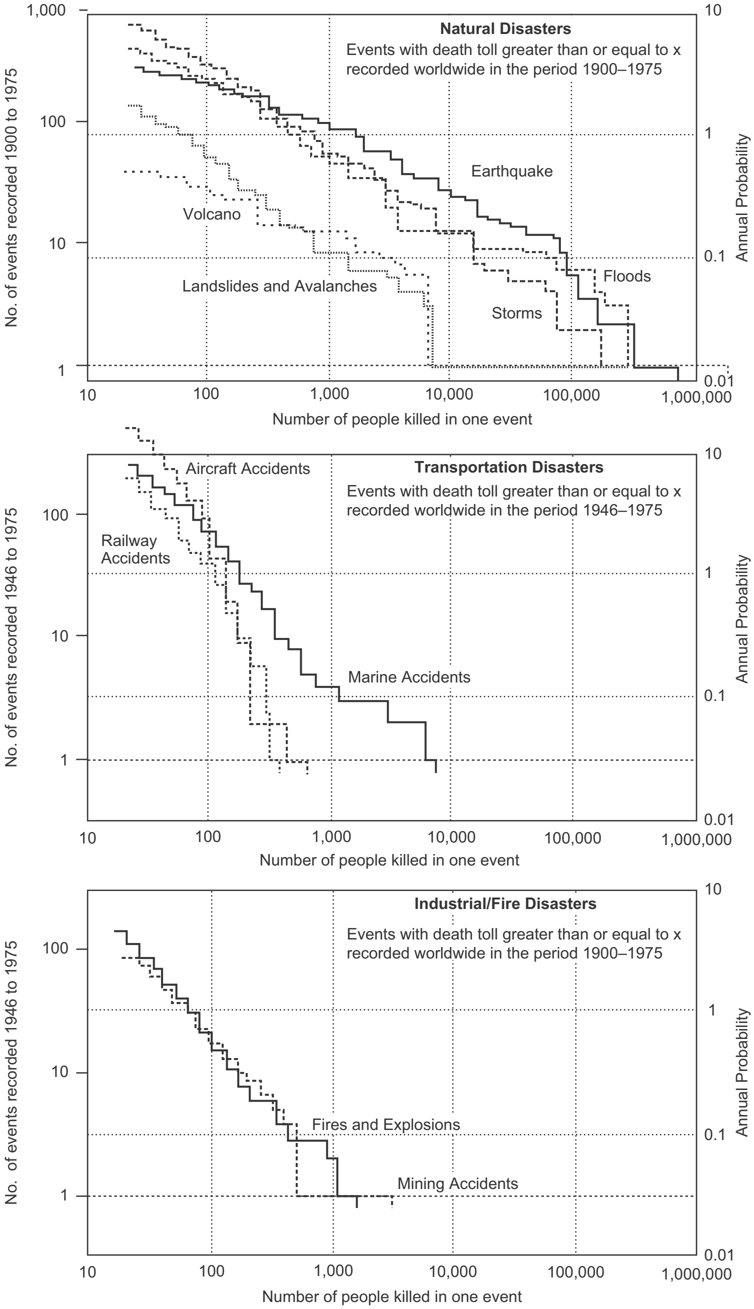


FIGURE 3.2

Examples of worldwide hazard f:N curves

Source: UNDP, 1946–1975.

The degree to which disaster risk managers subdivide hazards into specific intensities is driven by the time and resources available. While more divisions will presumably give a more comprehensive assessment, there exists a point at which the dedication of time and resources exhibits negative returns on investment.

In summary, effective qualitative risk analysis is performed using four steps:

1. Calculate the (quantitative) likelihood of each identified hazard (broken down by magnitude or intensity if appropriate).
2. Calculate the (quantitative) consequences that are expected to occur for each hazard (broken down by magnitude or intensity if appropriate), in terms of human impacts and economic/financial impacts.
3. Develop a locally tailored qualitative system for measuring the likelihood and consequence of each hazard identified as threatening the community.
4. Translate all quantitative data into qualitative measures for each hazard's likelihood and consequence.

Disaster risk managers begin their hazard analysis by calculating (to the best of their ability and resources) the quantitative likelihoods and consequences of each identified hazard risk. It does not matter whether the likelihood or the consequence is analyzed first, or if they are done concurrently, as neither depends upon the other for information. It is important, however, that the quantitative analyses are completed before the qualitative ones, as the qualitative rankings will be based on the findings of the quantitative analyses.

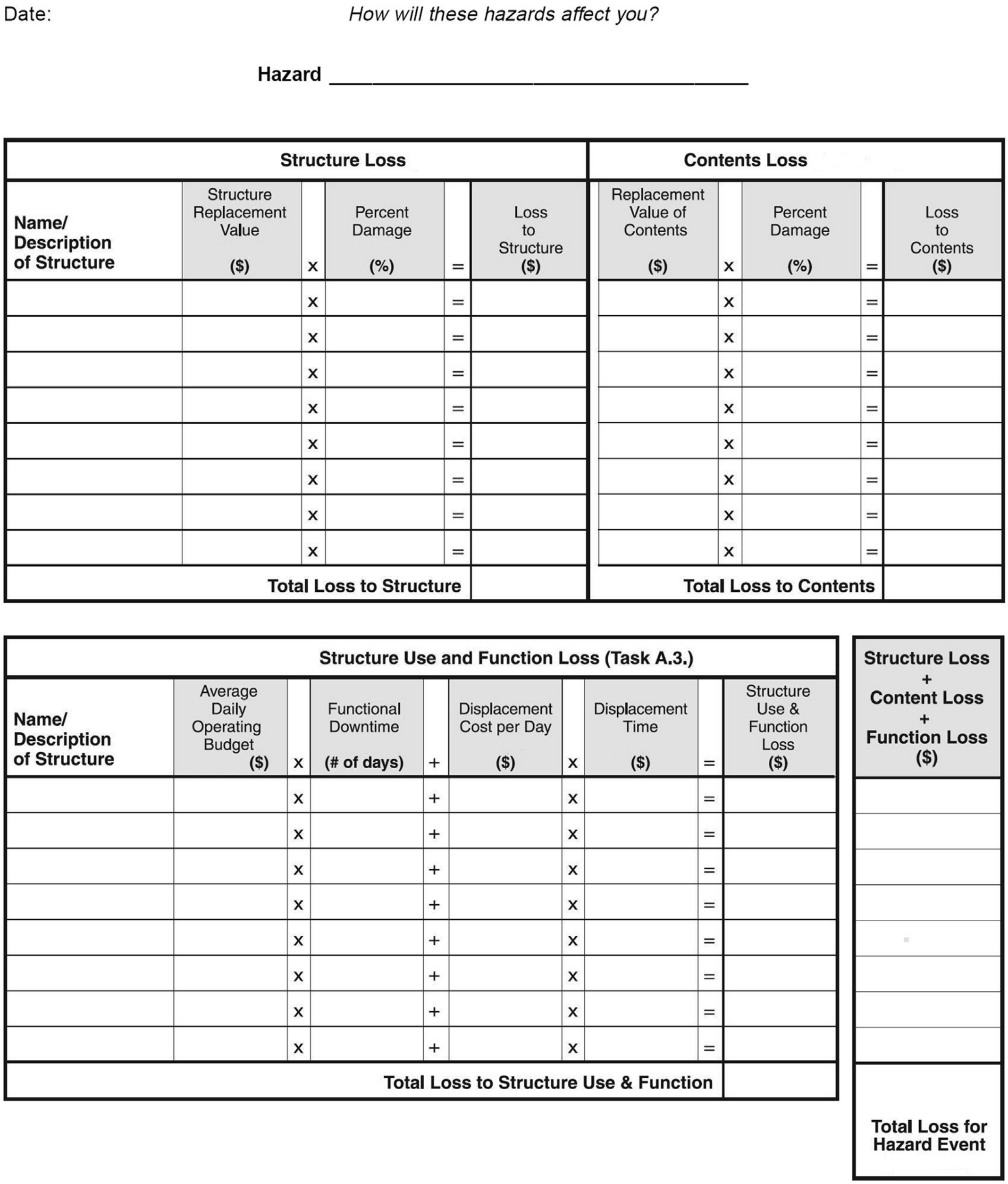
The following section describes the methods by which the hazards risk management team can perform the quantitative analyses of hazard risks.

QUANTITATIVE ANALYSIS OF DISASTER LIKELIHOOD

Quantitative analysis of the likelihood component of risk seeks to find the statistical probability of the occurrence of a hazard causing a disaster. These analyses tend to be based on historical data gathered in the process of describing identified hazard risks (often called a risk statement). The disaster managers performing a quantitative analysis of disaster likelihood must first establish a standard numerical measurement by which the results of all analyzed hazards will be reported.

One of the most common quantitative measures of likelihood, and the measure that will be used in this example, is the number of times a particular hazard causes a disaster per year. For example, "In country X, it is predicted that there will be three major snowstorms per year." (For major events that occur less frequently, like a major flood, this number may be less than one. A 20-year flood has a 5 percent chance of occurring in any given year, or would be expected to occur 0.05 times per year.) The hazard can now be analyzed according to the chosen standard. If the hazard is one that has been divided into individual intensities and magnitudes, a separate figure will be required for each magnitude or intensity.

If records have been maintained for disasters that occur regularly, such as flash floods or snowstorms, it will be fairly easy to calculate the number of occurrences that would be expected to happen in a coming year or years. More often than not, however, sufficient information does not exist to accurately quantify the likelihood of a disaster's future occurrence to a high degree of confidence. This is especially true for hazards that occur infrequently and/or with no apparent pattern of behavior, such as



Date: *How will these hazards affect you?*

Hazard ____________________________________

Structure Loss						Contents Loss				
Name/ Description of Structure	Structure Replacement Value ($)	x	Percent Damage (%)	=	Loss to Structure ($)	Replacement Value of Contents ($)	x	Percent Damage (%)	=	Loss to Contents ($)
		x		=			x		=	
		x		=			x		=	
		x		=			x		=	
		x		=			x		=	
		x		=			x		=	
		x		=			x		=	
		x		=			x		=	
		x		=			x		=	
Total Loss to Structure						**Total Loss to Contents**				

Structure Use and Function Loss (Task A.3.)										
Name/ Description of Structure	Average Daily Operating Budget ($)	x	Functional Downtime (# of days)	+	Displacement Cost per Day ($)	x	Displacement Time ($)	=	Structure Use & Function Loss ($)	**Structure Loss + Content Loss + Function Loss ($)**
		x		+		x		=		
		x		+		x		=		
		x		+		x		=		
		x		+		x		=		
		x		+		x		=		
		x		+		x		=		
		x		+		x		=		
		x		+		x		=		
Total Loss to Structure Use & Function										
										Total Loss for Hazard Event

FIGURE 3.3

FEMA standardized loss estimation worksheet

Source: FEMA, 2001.

earthquakes, pandemics, terrorist attacks, or nuclear accidents. This inability to achieve precision is a fundamental reason why qualitative measures are used in the final determination of a hazard's likelihood.

Rare and extremely rare hazards, such as terrorist attacks, nuclear accidents, and airplane crashes (outside of communities where airports exist) may have few if any data points on which to base an analysis. However, this does not mean that there is a 0 percent probability of the disaster occurring, even if there has been no previous occurrence. For these incidences, consulting with a subject matter expert (SME) is necessary to determine the likelihood of a disaster resulting from the hazard over the course of a given year and to gather any information on the existence of a rising or falling trend for that particular hazard. Organizations; professional associations; and other bodies, such as the United Nations (UN), national governments, and research facilities, maintain risk data on particular rare hazards. Modeling techniques also can be used to estimate the likelihood of infrequent events.

The more often a hazard has resulted in disaster, the more data points those performing the quantitative likelihood assessment have to work with, and the more accurate the historical analysis will be (given that the collected data is accurate). However, more than a simple investigation of the number of events per year must be performed.

The concept of increasing and decreasing trends in hazard likelihoods and consequences was previously introduced. Whether common or rare, events caused by a specific hazard type will likely change from year to year, decade to decade, or century to century. Few will have a steady rate of occurrence. These rising and falling trends must be accounted for if there is to be any accuracy attained in an analysis of likelihood.

For example, if a country has sustained an average of 35 wildfires per year for the past 40 years, it might easily be assumed that it is very likely there will be approximately 35 wildfires per year in the coming years. However, further inspection of historical records reveals that 40 years ago, there was one fire, and 39 years ago, there were three fires. The number of fires steadily increased until the historical record ended with 70 fires occurring in the past year. Over the 40-year period, the average number of wildfires is in fact 35 per year. However, the rate of wildfires has increased each year from one per year 40 years ago to seventy per year last year. Considering this trend, the expected number of wildfires next year cannot be expected to be 35, although the average per year is 35.

It must be assumed from these data that there is a rising trend in the occurrence of wildfires, and that there is likely to be 70 or more fires in the coming year. Why this rising trend is occurring and what can be done to counteract it will need to be examined in the process of determining vulnerability and generating mitigation and preparedness options.

QUANTITATIVE ANALYSIS OF DISASTER CONSEQUENCES

The quantitative analysis of disaster consequences seeks to determine the number of injuries, the number of deaths, the cost of direct damages to property and infrastructure, and the indirect costs associated with the disaster. (Depending on the scope of the analysis, other factors such as homelessness or displacement may be considered, as well.) A standard form of measurement must be established for deaths, injuries, and damages. It is most useful if the measurement is per occurrence, as opposed to per year or other time frame.

It will be necessary to analyze the expected consequences of each magnitude or intensity of a hazard if it has been broken down into subcategories.

Historical Data

As with the likelihood component of risk, the calculation of hazard consequences should begin by examining the historical data on injuries, fatalities, and property/infrastructure damage and destruction that was gathered during the identification of hazards. However, as previously described, human behavior and/or changes in hazard characteristics often result in either increasing or decreasing trends in disaster consequences over time. Changes in settlement or new development, for example, can significantly increase community vulnerability for two separate occurrences of a hazard.

Historical information does have its uses, however, especially with more common hazards for which data has been collected methodically and accurately for many years. Consequence data based upon historical information can act either as a benchmark to validate the findings of more in-depth analyses (described in the following section) or as the actual estimation of consequences, should disaster managers decide to perform a lower level of analysis.

The process of describing the community and the environment is explained in the section addressing vulnerability. In this process, information is gathered on the physical community, the built environment, and the social environment, as well as on the critical infrastructure and the interdependence of the community on surrounding and other external communities.

Using hazard maps created or obtained during the process of hazard identification, combined with the description of the community environment, disaster managers can develop numerical figures for the expected number of lives that will be lost, people who will be injured, and the dollar amount of the direct and indirect damages that may occur. (However, it is always important to keep in mind that even the most extensive analyses of consequences are imperfect, as they are heavily based on assumptions and historical data that may or may not indicate future behavior of hazards.)

Consequence analyses must look not only at the location of structures in relation to area exposed to the hazard, but also at the physical vulnerability of each structure. For instance, imagine that a school is located in a floodplain. Disaster risk managers have obtained information indicating that the school has been raised to an elevation where it will be affected by floods only of magnitude greater than the 50-year (2 percent chance per year) flood. Using this information, disaster risk managers can deduce that such a structure will likely sustain no damage during the course of a 20-year (5 percent chance per year) flood event.

While those tasked with disaster risk reduction will not likely possess complete information regarding the value of all structures within their study area, nor will they be able to determine exactly how much revenue and inventory will be lost, such data deficiencies are likely to be consistent across all hazard consequence analyses and thus cause minimal data reliability problems. More data generally result in more accurate assessments, but the amount of data that can be collected is always a factor of the time and resources available. Moreover, the process of translating the quantitative data resulting from these analyses into the qualitative determination of likelihood and consequence can be tailored to accommodate almost any lack of accuracy or depth of analysis.

Deaths/Fatalities and Injuries

The number of people who will be hurt or killed in a disaster event is typically estimated using one of two methods: estimation based upon historical data and changes in population, and modeling of disaster consequences.

To estimate the numbers of deaths and injuries using historical data, disaster risk managers first gather data on past disasters caused by the hazard in question. Then, using current community data, a conversion to current conditions can be made. For example, imagine that an EF 4 tornado struck a country in 1955, resulting in four deaths and 35 injuries. The population of the community at the time was approximately 10,000. Today, the population is estimated to be 15,000, increasing by a factor of 1.5. By multiplying the historical consequence data by this conversion factor, disaster managers could surmise that there would be approximately six deaths and 52 injuries if a Category IV hurricane struck today.

Bear in mind that these estimates do not account for mitigation measures taken or changes in development practices during the intervening years, which will influence both vulnerability and, likewise, outcomes. This is why the more recently a comparable disaster has occurred, the more accurate such conversions will be. The use of modern modeling techniques, such as HAZUS-MH (Hazards United States, Multi-Hazard), a nationally standardized, GIS-based risk assessment and loss estimation tool developed by the US Federal Emergency Management Agency (FEMA), can increase the accuracy of injury and death estimations.

Modeling Techniques

Modeling techniques that estimate disaster risk likelihood values and consequences are growing in their applicability and use. Map- and computer-based models can provide estimates of disaster consequences, including injuries and deaths, damages, and economic impacts, that vary widely in their accuracy. One of the most widely used computer models is HAZUS-MH, which was first developed by the US Federal Emergency Management Agency in 1997. This model calculates likely injuries and fatalities, shelter requirements, building structural and contents damages, and mass-care commodity needs (food and water), among other response requirements, that might arise in earthquakes, cyclonic storms, and floods. Users upload several layers of data, including population data, building stock, topography, and soil type, and then define a study area. Then a hazard of specific magnitude is selected, and the model uses pre-set algorithms to generate consequences. See exhibit 3.3 for more information on models.

Hundreds of different risk models have been developed. Examples include:

- CAMEO (Computer-Aided Management of Emergency Operations): Used to plan for and respond to chemical emergencies.
- CATS (Consequence Assessment Tool Set): A disaster analysis system for natural and technological hazards used before a disaster to create realistic scenarios for training and planning, during a disaster to estimate damages, and after a disaster to assess needs and locate resources for a sustained response. CATS is used for hurricanes, storm surges, and earthquakes.
- WaterRisk: A floodplain information management application that allows floodplain managers to manipulate and utilize the information currently generated by existing flood-modeling software.
- EM-Tools: A suite of modules developed by Canada’s Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP) to estimate earthquakes, floods, hazardous materials, and other hazards.
- TUFLOW: Simulates flooding in major rivers; complex overland and piped urban flows; estuarine and coastal tide hydraulics; and inundation from storm tides. It is currently the most widely-used flood modeling software in the UK and in Australia.
- KLAPS: The Korea Local Analysis and Prediction System investigates the relationship between existing weather conditions and past disasters to predict future events; this model only provides

EXHIBIT 3.3 HAZARD MODELS

There are several computer modeling techniques available, each offering a different product of analysis. Modeling techniques provide insight about the scope of expected disasters, the location and severity of damages, the risk to life and property, and the resources that are required to manage disasters, among other factors.

While models can be used to measure both likelihood and consequence, the most common product of these models is an estimation or prediction of the consequences of a user-defined disaster. This type of modeling is called *loss modeling* or *consequence modeling*. Models have been developed to predict the consequences of virtually every hazard, natural or technological. Their accuracy of output, however, can vary widely.

Consequence and loss models are primarily Geographic Information System (GIS) based products, and their outputs are displayed in a map format. All models require the input of specific scenario parameters. Users must provide a range of data relevant to the disaster scenario and specific to the model or simulation in question, including (at minimum) the hazard and its associated magnitude/scope and the area that is impacted.

Some of the more widely applied modeling resources, including HAZUS-MH, contain pre-loaded baseline data layers such as building stock, populations and demographics, critical infrastructure, transportation infrastructure, pipelines, topography, and soil types, among others. Regardless of the model selected, the quality and accuracy of output data will increase as more relevant and timely data is entered into the system.

Like all analyses, consequence and loss modeling techniques are only as good as the data on which they are based. There is an adage in modeling that claims, “Garbage in, garbage out,” meaning that only timely, accurate, and complete data can provide accurate information. Most models are GIS-based and draw from a database of information that might include any range of inputs, including:

- Building stock (e.g., construction materials, value, use, construction standard)
- Transportation routes (e.g., roads and highways, bridges, railways, airports, maritime channels and routes)
- Land characteristics (e.g,. topography, soil type, features, use)
- Critical infrastructure components (utilities, dams, hospitals, police, fire departments, government)
- Population demographics (age, vulnerable populations, income)
- Components of disaster response (e.g., evacuation routes, shelters)

The following is a simplification of how consequence models often function:

1. A database of information defining the community is acquired or entered into the model by the user
2. The user defines the attributes of the hazard to be modeled; for instance, for an earthquake, this could include the magnitude, the location of the epicenter, the duration of the earthquake, the earthquake depth, the aftershock intensity, etc.
3. The model evaluates each data component individually to determine the predicted outcome of the interaction between that structure or feature and the disaster defined by the user
4. The model produces an output report detailing consequence data

Models use calculations and estimations that are based on scientific theory and historic data. They are not perfect, and do in fact have several disadvantages. For instance, they are heavily data dependent, and this data may not exist, may be inaccurate, or may be inconsistent across the study area. They are based on a set of assumptions that may not be true in the study area. When they underestimate consequences, they can give a false sense of security, and when they overestimate consequences, they needlessly cause fear and misdirect resources. And finally, they can be difficult to use, and their results may be hard to interpret by the untrained.However, the advantages of using models can easily outweigh the disadvantages. They typically give planners a higher level of analysis, and their output can provide a spatial, visual representation of hazard consequence and likelihood values. They can also be manipulated to incorporate environmental and social changes to a community in order to reevaluate levels of risk or consequence.

about 12 hours of advance warning, but enables more accurate pre-positioning of resources, warning, evacuation, and other pre-disaster activities.

There are many other models, computer-based or otherwise, that give estimates for other hazards such as tsunamis, storm surges, chemical releases, and explosions. The data collected on base maps and the hazard-specific maps created during the hazard identification and description process also can be used to estimate the population affected by the hazard.

Regardless of the method used, a high degree of accuracy is very difficult to attain when estimating the numbers of injuries and deaths that would occur in future disasters. Many confounding variables affect human behavior and the ability to react to hazard events, including warning times and warning accuracies; the nature of the hazard; and the numbers, resources, and abilities of the emergency responders. These estimations should always be taken as just that—estimations. The experience of the disaster management team and of other community experts such as first responders and the medical community can be just as valuable in making these estimates.

Abbreviated Damage Consequence Analysis

Disaster risk managers may elect to perform a lower level of analysis to determine a hazard's consequences. In such cases, two sets of data are required. The first is historical consequence data from all previous events caused by the hazard in question. The second data set details the population and structural changes that have occurred in the community in the years since past disasters occurred. With these two sets in hand, it is possible to extrapolate how similar disaster events might impact the community today, given alternations in the populations and structures that would be impacted. For instance, if hazards risk managers look at the spatial area of the community impacted in a major flood in 1955, and then inventory all of the structures and people that currently exist in that same area, a description of likely damages emerges. Note that this method can be highly inaccurate if it is performed without the consideration of hazard risk reduction efforts that occurred in the intervening years, such as elevating structures.

If a particular hazard has not affected the study area in an extended period of time, or if it has never struck the study area, alternative methods may be warranted. Planning workshops wherein a representative team of stakeholders is assembled to consider and postulate hazard outcomes can provide much more information than community planners might otherwise achieve. This team could include representatives from local and national government, NGO staff, private sector representatives, community members, and individuals with technical expertise (e.g., hydrologists, geologists.)

Full Damage Consequence Analysis

A full damage consequence analysis requires that disaster managers consider the current estimated cost of all physical assets within the country. These include:

- *Losses to structures.* Estimated as a percentage of the total replacement value. This figure is obtained by multiplying the replacement value of the structure by the expected percent damage to the structure.
- *Losses to contents.* Estimated as a percentage of the total replacement value. This figure is obtained by multiplying the replacement value of the contents by the expected percent damage.
- *Losses to structure use and function and cost of displacement.* The losses to structure use are a function of the number of days the structure is expected to be out of use multiplied by the average daily operating budget or sales (annual revenue or budget divided by 365 days). The cost of displacement is the product of the costs incurred as result of the business/service being displaced and the number of days that displacement is necessary. These calculations can apply to businesses, bridges, utilities, public services (libraries), and any other community asset.

A standardized loss estimation worksheet can be used to track calculated figures. An example of such a worksheet is shown in figure 3.3.

Each hazard will affect a structure and its contents differently. Many organizations and institutions have made tables available to determine this information for specific hazards. To perform a full damage consequence analysis, disaster risk managers require, at minimum, the following information (which is often gathered during the process of describing the community and environment and determining the vulnerability of the community):

- Replacement value of all community assets (homes, businesses, and infrastructure)
- Replacement value of property (business inventory, personal property in homes, contents of government offices and other buildings)
- Operating budgets/annual revenues of businesses and government assets
- Costs of relocation of operations/services

Once quantitative figures have been calculated for both the likelihood and consequence components of risk, the planners can begin the process of determining the qualitative values assigned to the likelihood and consequence for each hazard (and hazard intensity or magnitude, if the hazard is subdivided into such). They should begin by selecting a system of qualitative measurement or by designing one that suits the needs of both the format of results in the quantitative analysis and the characteristics of the particular country or community.

A disaster, as defined in chapter 1, is “a serious disruption of the functioning of a community or society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources” (UNISDR 2009). Therefore, a specific set of hazard consequences may constitute a disaster in one community but not in another. For instance, 10 injuries may exceed the capacity of the local clinic in a community of 500, but in a large city, 10 injuries could be easily managed.

Whether designing a new system of measurement or using an existing one, it is necessary for the disaster management team to be aware of the local capacity to know how many deaths and injuries and how much damage can be sustained before the local capacity is either stressed or exceeded. They will have the data collected in the hazard identification process and in the description of the community and the environment on which to base their new or acquired system of measurement.

Creating two measures of consequence can be beneficial: one measuring physical/material losses associated with buildings and property, and another measuring the human impacts, namely deaths/fatalities and injuries. Each qualitative term can have two associated value ranges that correspond to deaths/injuries and costs. This may result in instances where a hazard receives two separate rankings, with the more severe of the two the one that is used. For instance, in a release of a toxic gas, there may be no physical damages to structures, but many people may be injured or die. Other events may cause no immediate deaths or injuries, but cause a great amount of physical loss, such as a large-scale power outage. In either case, the factor that achieves the qualitative measure of greater (higher) consequence is used to determine the consequence of the hazard. Tables 3.1 and 3.2 are examples of qualitative measures of likelihood and consequence.

Once a measurement system has been chosen, each hazard may be assessed according to its qualitative likelihood and consequences using the quantitative data obtained in the previous steps of the hazard analysis process. These qualitative rankings are then recorded and assessed according to a risk assessment matrix (described next).

Table 3.1 An Example of a Qualitative Likelihood Measurement System

Descriptor	Description
Almost certain	Is expected to occur in most circumstances; and/or high level of recorded incidents and/or strong anecdotal evidence; and/or a strong likelihood the event will recur; and/or great opportunity, reason, or means to occur; may occur once every year or more
Likely	Will probably occur in most circumstances; and/or regular recorded incidents and strong anecdotal evidence; and/or considerable opportunity, reason or means to occur; may occur once every five years
Possible	Might occur at some time; and/or few, infrequent, random recorded incidents or little anecdotal evidence; and/or very few incidents in associated or comparable organizations, facilities or communities; and/or some opportunity, reason or means to occur; may occur once every twenty years
Unlikely	Is not expected to occur; and/or no recorded incidents or anecdotal evidence; and/or no recent incidents in associated organisations, facilities or communities; and/or little opportunity, reason or means to occur; may occur once every one hundred years
Rare	May occur only in exceptional circumstances; may occur once every five hundred or more years

Source: EMA, 2000.

Table 3.2 An Example of a Qualitative Consequence Measurement System

Descriptor	Human Life and Health	Property, Financial, Environmental
Insignificant	No injuries or fatalities. No displacement of people or displacement of only a small number of people for short duration. Little or no personal support required (support not monetary or material).	Inconsequential or no damage. Little or no disruption to community. No measurable impact on environment. Little or no financial loss.
Minor	Small number of injuries but no fatalities. First aid treatment required. Some displacement of people (less than 24 hours). Some personal support required. Some disruption (less than 24 hours).	Some damage. Small impact on environment with no last effects. Some financial loss.
Moderate	Medical treatment required but no fatalities. Some hospitalisation. Personal support satisfied through local arrangements.	Localised damage that is rectified by routine arrangements. Normal community functioning with some inconvenience. Some impact on environment with no long-term effect or small impact on environment with long-term effect. Significant financial loss.
Major	Extensive injuries, significant hospitalisation, large number displaced (more than 24 hours' duration). Fatalities. External resources required for personal support.	Significant damage that requires external resources. Community only partially functioning, some services unavailable. Some impact on environment with long-term effects. Significant financial loss—some financial assistance required.
Catastrophic	Large number of severe injuries. Extended and large numbers requiring hospitalisation. General and widespread displacement for extended duration. Significant fatalities.	Extensive personal support. Extensive damage. Community unable to function without significant support. Significant impact on environment and/or permanent damage.

Source: EMA, 2000.

When assessing the qualitative ranking for a hazard consequence, two different types of consequences are usually examined: human impacts (injuries and deaths/fatalities) and material/physical losses. In determining the qualitative consequence ranking, the more severe or greater of the two factors is applied. Differences between the severity of human and material losses does often exist. A poisonous gas leak is a good example of a hazard where few material or physical damages are likely, but many deaths and injuries could occur. In that case, the planning team would likely base their assessment on the human consequences of the hazard rather than the material/physical consequences.

RISK EVALUATION

Risk evaluation is conducted to determine the relative seriousness of hazard risks, whether for a country, community, or other focal area (e.g., a business). Using the processes listed earlier in this chapter and in chapter 2 to identify hazards, characterize them, and determine their likelihoods and consequences, the information necessary to carry out risk evaluation will have been gathered.

By the time the risk evaluation process begins, each hazard must be identified, described, mapped, and analyzed according to its likelihood of occurrence and its consequences should a disaster occur. Each natural, technological, and intentional hazard faced by the country or community requires a unique mix of mitigation and preparedness treatment options. Unfortunately, there rarely exist sufficient resources to reduce risk from this mix of hazards such that all disaster risk reduction goals have been met. Thus difficult choices must be made, and the best decisions are those that are best informed.

As is shown in chapters 4 and 5, there are hazards for which mitigation technology exists but is cost prohibitive. An example of an excessively expensive risk mitigation measure is the burying of power transmission lines, which can cost as much as 10 times that of above-ground options. On the other hand, the cost of converting (retrofitting) wastewater treatment plants utilizing dangerous chlorine gas to enable them to use less dangerous options (such as liquid chlorine bleach) is relatively inexpensive in terms of the risk reduction attained. Exhibit 3.4 illustrates the danger posed by chlorine gas, which is still widely used despite its known dangers.

Hazards will vary in terms of the risk reduction options that are available to treat them. Some may have many associated options, each with associated costs and benefits. And some will exhibit a direct correlation between the amount of risk reduction and the incremental increase in cost. A classic example is an increase in the number of firefighters or police officers hired in a community which, until reaching a threshold, results in decreased fire hazard or crime risk, respectively.

Fortunately, however, not all hazard risks require immediate action, and some require no action at all. Hazards that fit this description would include those for which both the likelihood and the consequences of the hazard's risk are extremely low, such as the threat of an avalanche in a community with few inhabited hills. Other hazards that also fit this category are those that do have significant associated risk likelihood or consequences, but for which the cost of even the slightest reduction in risk would be excessive (measured in terms of financial costs, human resources, service or resource losses, or others). An example of a hazard that fits this category would be a meteor strike. Disaster risk managers must be able to weigh such limiting factors in light of the full range of hazards and associated disaster risk reduction options if that information is to make any sense.

There are several additional factors that weigh heavily on the perceived seriousness of a hazard risk that extend beyond the straightforward calculation of simple hazard likelihood and consequences

EXHIBIT 3.4 DESCRIPTION OF THE DANGERS OF USING CHLORINE GAS TO PURIFY WATER

Chlorine is often used as a disinfectant in most of the world's water systems because of its cost-effectiveness. The chemical is usually stored in a pressurized, liquid state. When released, chlorine vaporizes into a highly toxic, invisible gas that concentrates at ground levels. Germany used chlorine gas during World War I for this reason, because it would settle into the trenches where British troops were hiding.

It has been estimated that anyone located within two or three miles from a ruptured 90-ton chlorine railcar would be killed if directly exposed to the ensuing cloud. Injuries, including fluid in the lungs and a permanently reduced breathing capacity, could result at distances as great as 10 miles.

Because of the increasing risk of terrorism and other criminal attacks on storage facilities, the US Environmental Protection Agency has distributed guidelines that encourage US chemical industry businesses to employ safer technologies. One such facility, the Washington, D.C.-based Blue Plains wastewater treatment plant, heeded this advice and fully converted from the use of chlorine-gas disinfectant to the safer liquid chlorine bleach. The plant's close proximity to the nation's capital placed it at high perceived risk of terrorist attack, but only as long as the highly volatile chlorine gas was stored on the site. In switching to liquid chlorine bleach, the threat has essentially been eliminated.

Many other drinking and wastewater treatment plants have also switched to safer technologies. In addition to liquid chlorine bleach, ultraviolet light and ozone may be used to purify the water.

Based on: *Davis, 2002*.

reduction. These can have as much, if not more, influence on disaster risk reduction priorities. For instance, anthropogenic (man-made) hazards are typically perceived as being less acceptable than those that are natural in origin. The relative degree to which man-made risks are perceived as being unacceptable also has an influence on the ability of disaster risk managers to secure the public or other funding and political will to support hazard mitigation. People are also concerned with whether their exposure to a particular risk is voluntary (they have a choice) or involuntary (they have no choice). Smith (1992) found that this distinction is actually of monumental significance, stating that, "there were major differences between voluntary and involuntary risks, with people being willing to accept voluntary risks . . . approximately 1000 times greater than that of involuntary risks."

Risk perception issues weigh heavily upon disaster risk reduction decisions. For instance, consider a rural community in which one person dies per year as result of cave-ins of abandoned mine shafts and approximately four people per year are drowned in a river that regularly experiences swift currents following storms. There is likely to be considerable public outcry over the yearly incidence of fatal accidents from the abandoned mines, while the river drowning is viewed as a controllable, easily reduced, voluntary, preventable, observable hazard whose effects are known to those exposed (risk perception concepts are described in greater detail in the section entitled "Vulnerability").

There are a number of hazards that societies are able to eliminate altogether but choose not to because the benefits that result from the condition or factor that creates the hazard would also disappear. (See exhibit 3.5.) This essentially implies that, when evaluating hazard risk, disaster risk managers must also consider the negative consequences of risk reduction or elimination. By eliminating a certain hazard's sources, the benefits to the community, country, or society would be lost, perhaps creating an even riskier situation—or at least, one that people are not willing to accept. Examples of situations where benefits of a hazard-causing condition are believed to outweigh the associated risks include the aesthetic value (for homeowners) and collected property taxes (for the community) associated with beachfront property construction. Other examples include the collection of taxes and creation of jobs in communities where

EXHIBIT 3.5 ACCEPTABILITY OF RISK

Almost everything that provides a benefit also creates some level of risk for either the benefactor(s) or others who do not necessarily enjoy those benefits. This risk ranges from barely measurable to severe. The side effects of certain prescription drugs, negative health effects from fast food, or skin cancer from the sun are a few examples at the personal level. On a larger scale, more specifically related to disaster management, is the inundation danger associated with the construction of a power-generating dam. As a society, citizens have come to accept most of these risks without question, although many present much greater risks than some people are willing to accept.

For instance, tens of thousands of people are killed and more than tens of millions suffer disabling injuries each year from falls while using stairs in their homes and elsewhere (Roderick 1998). It is unlikely that stairways will be eliminated, despite the fact that they injure and kill many more people than hazards like saccharin, fluoroscopes (shoe-fitting X-ray machines), and extra-long tandem trailer trucks, for instance. Why are people willing to accept one risk and not another? The answer can be found in the perceived benefits of each risk. People perceive that the benefit of having multiple stories in a house or other building is worth the risk of injury or death from using stairways. Society does not perceive the risk of injury, illness, or death resulting from saccharin, fluoroscopes, or tandem trucks to be worth the benefits gained from each (low-calorie sweetener, an X-ray look at your foot inside a shoe, and the truck's greater carrying capacity), even though each of these three examples poses less of an absolute population risk than stairways.

factories that produce, store, or emit hazardous materials are located, or the reduced reliance on fossil fuels and inexpensive costs of power generation associated with nuclear power plants.

A principal disaster risk management goal is the formulation of a prioritized list of hazard risks to be mitigated. This list should be based on a combination of factors that includes hazard likelihood and consequence values, the priorities and mitigation criteria (regarding their views on the acceptability of different risks) of the affected population, the benefit-to-cost ratios of different risk mitigation options, and any political and social impacts likely to arise.

Each hazard was examined individually in the previous steps in the hazards risk management process. As the process shifted to risk evaluation, cross-comparison of hazards began and priorities begin to emerge. There are a number of proven methods through which prioritization of risk treatment can occur, including:

- Creating a risk matrix
- Comparing hazard risks against levels of risk estimated during the analysis process with previously established risk evaluation criteria
- Evaluating risks according to the SMAUG methodology (seriousness, manageability, acceptability, urgency, growth)

The final product of the risk evaluation process is a prioritized list of risks, which is used to determine treatment (mitigation) options.

Hazard analysis determines qualitative values describing the likelihood and consequence of each hazard. For those hazards known to exhibit a range of magnitudes or intensities, the likelihood and consequence values were determined for several magnitudes or intensities across the range of possibilities.

Assigning these qualitative values is the first step in a process that allows for a direct comparison of the risks faced by a community. Armed with both the likelihood and consequence values, disaster risk managers can now begin comparing and ranking the identified risks.

To compare hazards according to their likelihood and consequences, a risk matrix must be selected or created to match the needs of the study area. A risk matrix plots relative risk values by comparing the two components of each hazard's risk, with likelihood and consequence values projected onto the chart's x and y axes.

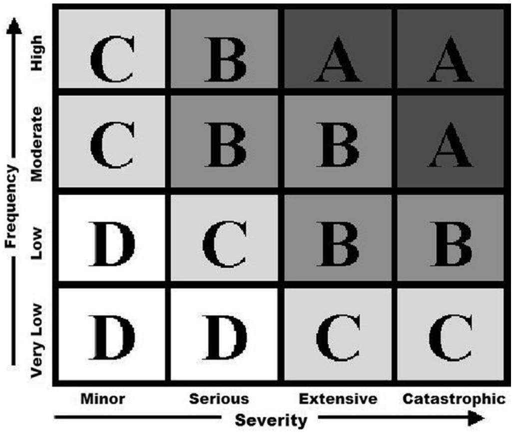


FIGURE 3.4

FEMA "Multi-Hazard Identification and Risk Assessment" risk matrix

While it does not matter which of these two risk components goes on which axis, the values that are used to annotate them must be exactly the same as the values used in the risk analysis qualitative assessments. This is because the terminology must be consistent throughout the process of "calculating" risk from likelihood and consequence, just as if quantitative (numerical) values were being used. For instance, if the possible range of values for the likelihood of a risk included the values "Certain," "Likely," "Possible," "Unlikely," "Rare," and "Extremely Rare," then the risk matrix must include all of those values (on the appropriate axis) in logical consecutive order.

Plotting these values on the matrix results in individual boxes that represent unique combinations of likelihood and consequence. The likelihood and consequence values on which each box is based can be determined by tracing from that box back to the values indicated on each axis. The number of possible combinations is the product of the number of likelihood values times the number of consequence values (i.e., if there are five values for likelihood and six for consequence, the matrix will have 30 possible combinations, according to which risk is evaluated).

Disaster risk managers either select a preexisting risk matrix or design a custom risk matrix that suits their specific needs. If they had previously chosen to create their own qualitative measurement systems during the risk analysis process, they must also create their own risk matrix. However, even if they used an existing set of qualitative measurements in the risk analysis process, a risk matrix to evaluate each risk may not exist, in which case they would need to make one.

To create a risk matrix, levels, or "classes," of risk representing increasing severity are established. These levels typically range from those that are so low that mitigation is not practical or necessary to risks that are so great that efforts to mitigate them are critically important.

One example of such a system is described in the FEMA's "Multi-Hazard Identification and Risk Assessment" publication (1997). The values in this risk matrix include (see figure 3.4):

- *Class A.* High-risk condition with highest priority for mitigation and contingency planning (immediate action)

- *Class B.* Moderate to high-risk condition with risk addressed by mitigation and contingency planning (prompt action)
- *Class C.* Risk condition sufficiently high to give consideration for further mitigation and planning (planned action)
- *Class D.* Low-risk condition with additional mitigation contingency planning (advisory in nature)

Emergency Management Australia (EMA 2000) annotated risk values use the following breakdown:

1. Extreme risk
2. High risk
3. Moderate risk
4. Low risk

Other systems include "Intolerable, Undesirable, Tolerable, Negligible," or "Severe, High, Major, Significant, Moderate, Low," and "Trivial."

Once determinant values are established and defined as they apply to the community or country's risk management priorities, they are plotted into the various points contained in the matrix (each representing a specific combination of likelihood and consequence). Their assignment is based on a mix of personal judgment, expert knowledge, and previously established risk management criteria.

With matrix values assigned, each hazard is evaluated accordingly and the derived values recorded. As it is possible (and likely) that each of the various risk classes (or levels) will correspond to more than one of the hazard risks analyzed because many hazards will elicit the same combination of likelihood and risk in a qualitative system, the outcome of this process is not a linear, "ordered" list of risk priorities. Rather, it results in hazard groupings. In other words, planners will end up with several classes of risks, each containing several hazards for which no intra-class priorities have been determined. For instance, if a 50-year flood was determined to be a Class C risk, and an accident involving a truck carrying hazardous materials was determined to be a Class C risk, they are given equal designation according to the risk matrix. (See exhibit 3.6). The results of the risk matrix do, however, simplify the subsequent process of definitive ranking by giving disaster risk managers an understanding of which hazards deserve their attention. The process of evaluation to achieve linear ranking follows.

It is helpful to record risk evaluation results using a standard form. The quantity of data and information gathered up to this point will be excessive, and such forms enable fast and easy reference to risk evaluation output data as is required to accurately compare and prioritize hazards. Risk registers, as these forms are called, often include the following information:

- Name of the hazard (including specific magnitude and/or intensity if it has been broken down into subcategories)
- Qualitative likelihood value
- Qualitative consequences value
- Class or level of risk as determined by evaluation on the risk matrix
- Priority rating
- Additional information, including any of the following:
  - Description of possible consequences

- Adequacy of existing mitigation measures or controls
- Known mitigation options and alternatives
- Acceptability of risk

Because people's risk perceptions differ, and because there may exist more risks than there are resources to mitigate them, disaster risk managers must develop overarching risk treatment criteria. Risk treatment criteria help disaster managers and citizens make judgments about what they consider to be the most serious hazards and set forth performance measures to judge progress in reducing the community's risks.

EXHIBIT 3.6 RISK SCORING SYSTEMS

Risk scoring systems are, to a growing extent, replacing the use of risk matrices as the preferred method of analysis. The movement toward risk scoring is driven by the limitation of the outcome of the risk matrix. As an *x/y* graph, the risk matrix considers only two dimensions of risk in its calculation, namely likelihood and consequence. This necessitates considerable follow-on considerations in order to establish a linear prioritization of hazards rather than the grouping of hazards that risk matrices establish.

Like risk matrices, risk scoring systems are standardized. However, they investigate each hazard according to a list of factors to generate a total weighted score that can allow otherwise very different types of hazards to be compared equally. This total score is established by adding the individual scores obtained in each of the risk factors. Scores can range from zero at the low end up to any number at the high end, as determined by the design of the scoring system.

Like risk qualitative systems of analysis, including the risk matrix, risk ranking systems may be tailored to meet specific needs without considerable trouble. Disaster risk managers consider each of the factors that will weigh on the decision of whether or not to treat a hazard's risk, and then establish a range of values from low to high into which each hazard will fall. Note that the range of values for each factor can differ, as long as all hazards are assessed using the same range. For instance, human impacts might have a range from 0 (nobody affected) to 10 (all people affected) while another factor, such as impact on electrical power, might range from 0 (no loss of electricity) to 5 (more than one month disruption). Typically, the more influential a factor is on risk in the area of study, the higher the upper limit value for that factor will be.

The planning team typically decides which factors they wish to consider in their own analysis, but several of the factors more commonly seen in scored assessment systems are:

- Likelihood of the hazard event
- Consequences of the hazard event
- Vulnerability of the community
- The historical, or past occurrences of the hazard
- Spatial extent of the hazard
- Community exposure to the hazard, which can be further broken up into the following:
  - Critical facilities exposure
  - Environmental exposure
  - Transportation interruption
  - Structural exposure
  - Economic activity
  - Population exposure
- The possible magnitudes or intensities of the hazard event
- The destructive potential of the hazard event
- The population density in the areas likely to be impacted
- Annualized crop damage from the hazard event

In establishing these contextual criteria, disaster managers also define the political, social, economic, legal, and physical environment within which all of the hazards exist, specifically as they relate to disaster impacts. Some of the more common criteria include:

- Population issues
    - Death and injuries
    - Displacement
    - Loss of homes and property
    - Loss of jobs and income
    - Loss of sense of security
    - Loss of sense of community
- Business sector issues
    - Damage to facilities
    - Loss of income
    - Business disruption costs
    - Insurance losses
    - Loss of market share
    - Loss of trained employees
    - Bankruptcy
- Community issues
    - Damage or destruction of community infrastructure (i.e., roads, bridges, hospitals, jails, city halls, community service centers, etc.)
    - Loss of tax revenues
    - Disaster response and recovery costs
    - Reduced funding for other community priorities (i.e., education, social services, etc.)
    - Loss of population base
    - Increased community debt and borrowing
    - Economic repercussions
    - Environmental harm
    - Loss of culture/heritage

Disaster risk managers can also frame their analysis according to how disaster risk reduction efforts might be impacted by each or all of the following:

- Legal requirements
- Political will
- Cost and equity
- Social acceptability of risk
- Sustainability

Some hazards that have been evaluated according to the risk matrix might need to be recategorized to better reflect reality. It is possible that hazards have landed in a category that, upon consideration by planners or other subject matter experts, defines their corresponding risk as being either too great or not great enough. It is for this reason that both periodic review and the human component of the process are vital.

THE PURPOSE OF EVALUATING RISK

Gaye Cameron of the University of New South Wales (2002) wrote, “The purpose of evaluating risks is to determine that risk levels resulting from the risk analysis step [including the results of the risk matrix] reflect the relative seriousness of each risk.” She mentions three tasks that are important to perform at this point in the hazards risk management process:

1. Identify which risks require referral to other agencies (i.e., is the risk one that is better mitigated by another local, regional, or national agency rather than one that needs to be considered for mitigation options by the agency tasked with disaster risk management?).
2. Identify which risks require treatment by the disaster risk management agency or office.
3. Further evaluate risks using judgment based upon available data and anecdotal evidence to determine the accuracy of the final risk value assigned.

An example of a hazard risk that might be better mitigated by an entity other than the local, regional, or national agency tasked with disaster risk management is hazardous material exposure and other accidents that might occur at a facility or utility (like a nuclear power plant) that exists outside of the principal jurisdiction. Hazards created in one jurisdiction but whose consequences affect others have spurred significant debates over disaster risk reduction responsibility throughout history, and continue to do so today. These types of cross-jurisdictional problems are common in communities that share rivers and streams. Pollution content, increased flooding potential, and even decreased quantities of water can all occur in one jurisdiction but be caused by the actions of another. An illustrative example is changes in a river’s hydrology brought about by the construction of man-made levees (water-retention walls built along the banks of rivers that allow for higher water levels before flooding occurs). Dams and levees are river structures that often cause these problems. They can cause flooding both upstream, from rising water levels in reservoirs behind the dam, and downstream, from forced release or failure of the dam. (See exhibit 3.7.) Cameron (2002) wrote that there are two overarching issues that need to be addressed in the risk evaluation process. First, risk levels must be confirmed. Through a process of stakeholder consultation, these levels are reviewed to ensure (1) they reflect the relative seriousness of each risk, (2) the likelihood and consequence descriptions utilized for risk analysis are appropriate, and (3) local issues have been considered.

Cameron adds, “If, following stakeholder consultation, the risk level is considered inappropriate the risk should be subjected to further analysis using new information or data” (2002).

EXHIBIT 3.7 CLIMATE REPARATIONS

Cross-jurisdictional impacts of hazards, and debates about the responsibility for dealing with them, have reached global levels on account of the wide-reaching impacts of climate change. Several of the Pacific Island Countries and Territories (PICTs) appealed to action from the global community at the 2013 Warsaw Climate Change Conference. These countries, joined by many other developing countries, argued that they were feeling the greatest impacts of climate change, and that the increased costs of mitigation hazards and responding to disasters should be borne by the wealthy countries. The PICTs, and other Small Island Developing States (SIDS), are in fact at greatest risk from rising sea levels, given that even small increases threaten to render much of their land uninhabitable. Many of the wealthy countries in attendance rejected any assignation of blame that would result in a transfer of wealth to pay for the expenses of disaster risk reduction and disaster response and recovery costs in these low-lying islands. This concept is termed “Climate Reparations.”

Based on: *Burkett, 2009*.

Second, risk acceptability must be addressed:

> In almost all circumstances risk acceptability and treatment will be determined and/or carried out by the agency or agencies responsible for managing the treatment of risks. For those risks where no agency is responsible, the [disaster managers] will prepare treatment options for the management of the identified risks. (Cameron 2002)

One such method for the evaluation of risk is the SMAUG approach, designed by Benjamin Tregoe and Charles Kepner. This approach is widely used in Australia and New Zealand and is gaining traction elsewhere.

According to the SMAUG methodology, five individual factors are considered when determining how a list of risks can be generated that reflects the established priorities of the community. This list includes (each factor is accompanied by the upper and lower extremes by which each risk could be evaluated): This list includes:

1. Seriousness
    - **a.** The risk will affect many people and/or will cost a lot of money. (See exhibit 3.8.)
    - **b.** The risk will affect few or no people or will cost little or nothing.
2. Manageability
    - **a.** The risk could be affected by intervention.
    - **b.** The risk cannot be affected by intervention.
3. Acceptability
    - **a.** The risk is not acceptable in terms of political, social, or economic impact.
    - **b.** The risk will have little political, social, or economic impact.
4. Urgency
    - **a.** The risk urgently needs to be fixed.
    - **b.** The risk could be fixed at a later time with little or no repercussions.
5. Growth
    - **a.** The risk will increase quickly.
    - **b.** The risk will remain static (Lunn 2003). In recent years, SMAUG has been expanded to include two new factors:
        - Frequency, which is typically addressed through the risk assessment process; and
        - Awareness, which refers to the level to which different community stakeholders are informed about the hazard, and how closely their knowledge of about the hazard reflects its true risk.

The "Acceptability" factor from the original SMAUG acronym has been renamed Outrage, but still refers to the political and social acceptance of the hazard risk. The new acronym for this method is FSMAUGO.

Using the FSMAUGO criteria for evaluation, disaster risk managers can more precisely determine priorities for mitigating individual risks, beyond the characterizations that resulted from the risk matrix. After the risk matrix evaluation, risks were grouped into categories of seriousness. Now they can be assigned a numerical order defining specific priorities.

It is important to note that the list of priorities will likely change as the risk mitigation options are considered. Risk evaluation has given the hazards risk management team a better idea of those risks for which mitigation must be conducted at all costs because of their absolute unacceptability. However, for

EXHIBIT 3.8 CONSIDERING EXTREME EVENTS

Rae Zimmerman and Vicki Bier, in their chapter “Risk Assessment of Extreme Events,” shed some light on the extra considerations that must be made when prioritizing hazard lists that include man-made and intentional extreme event hazards such as terrorism. They write,

> *Predicting human behavior in emergency situations is already difficult. However, in attempting to estimate and manage the risks of intentional attacks, further difficulties become apparent. First, as pointed out by Woo (1992), “some idea of event likelihood is needed for intelligent benefit-cost analysis.” However, estimating the likelihood and nature of intentional attacks is an area with which most risk assessors are not yet familiar, although there has been some related work on this problem in other fields. For example, Dickey (1980) interviewed bank robbers to understand the criteria that they used in choosing banks to rob; he found that robbers preferred banks located near major highways, and banks with a single point in the lobby from which the robber could see all of the employees at once. Similarly, Crowe [2000] and de Becker (1997) report that criminals choose targets based not only on the attractiveness of the target, but also on the likelihood that they would be discovered and apprehended. Interviews with incarcerated terrorists could presumably be used to explore the criteria they use in selecting targets, to factor into quantitative risk assessments.*
>
> *More significantly, protection from a knowledgeable and adaptable adversary is a fundamentally different challenge than protection against accidents or acts of nature. For example, earthquakes do not get stronger or smarter just because we have defended our buildings against them. However, if one’s adversaries know or can easily learn about one’s defensive measures, then they can actively choose to either bypass or circumvent those defenses. Progress in and increased reliance upon detection technologies has made this a more important possibility to take into account. For example, metal-screening devices had prior to September 11th increased the security and safety of air travel. A network news report early in 2002 suggested that the box cutters used by the terrorists on September 11th to gain control of the hijacked airplanes are said to have fallen just below the detection settings of such screening devices.*
>
> *As noted by Dresher (1961), optimal allocation of defensive resources requires that “each of the defended targets yield the same payoff to the attacker.” Thus, even if some components can be hardened quite inexpensively, focusing protective investments only on those can lead to wasted resources, if adversaries instead choose to attack targets that cannot be hardened as cost-effectively. In other words, critical assets must be defended against all possible attacks, which is much more difficult than just shoring up a few “weak links.” As a result, Ravid (2001) has concluded that security improvements are generally more costly than safety improvements: “investment in defensive measures, unlike investment in safety measures, saves a lower number of lives (or other sort of damages) than the apparent direct contribution to those measures.”*

Source: *Zimmerman and Bier, 2002.*

risks with similar mitigation priority rankings, the factors of cost-effectiveness of mitigation, technological availability of mitigation options, and other risk treatment factors will require revisiting this priority list and re-ranking risks using additional information.

RISK ACCEPTABILITY

In performing hazard risk assessments and analyses of risk, disaster managers must make decisions about what risks to treat, what risks to prevent at all costs, and what risks can be disregarded because of low consequence, low frequency, or both. These decisions are based on the acceptability of risk.

Unfortunately, it is not ever possible to have complete information about all hazard risks faced by the country or community in terms of the number of people and the area affected, the actual frequency of the hazard in the future, and the actual benefit to be attained through mitigation, among many other factors. If disaster risk managers did have all of this information, determining risk acceptability and making mitigation decisions would be simple. However, in the absence of perfect information, judgments must be made about the severity of risk for each hazard, and whether the community is willing to accept that risk in light of known information.

Because disaster risk management is not conducted in a vacuum, many factors—political, social, and economic—influence the collective determination of what risks are acceptable and what risks are not. The mechanisms by which they can begin to determine such categorization are explained next.

Thus far, hazard risks have been identified, analyzed individually, and evaluated collectively. An ordered list of hazard risk has been produced, and treatment considerations must be made. Ideally, all risks would be treated such that nobody need worry about any of them ever again, but the risk-free-world scenario is inconceivable despite our best technology and engineering. Most risks can be reduced by some amount, but few can be completely eliminated. and rarely if ever do the funds exist to reduce all risks by an amount acceptable to everyone in the community. There will never be complete satisfaction with the decisions made by disaster risk managers, and this is mostly the result of differences in perception.

Two factors confounding the acceptability of risks are the benefits associated with certain risks and the creation of new risks by eliminating existing ones. For instance, to completely eliminate the risk from nuclear power generation plants, they would need to be dismantled and taken out of service. The resulting shortage of power would require that fossil-fuel-burning plants increase their production, which in turn would create increased carbon-based pollution, which would likewise create increased health and environmental risks.

ALTERNATIVES

The existence of alternatives weighs heavily on whether or not hazard risks are considered acceptable. Derby and Keeney (1981), two risk management experts, describe the importance of alternatives in establishing risk acceptability as follows:

> The key aspect of acceptable risk problems is that the solution is found by a decision among alternatives. The generic problem involves choosing the best combination of advantages and disadvantages from among several alternatives. . . . The risk associated with the best alternative is safe enough.

This is an important distinction—that risks deemed “acceptable” are not necessarily those with risk levels for which we are “happy.” They continue:

> We all would prefer less risk to more risk if all other consequences were held fixed. However, this is never the case. In a situation with no alternatives, then the level of safety associated with the only course of action is by definition acceptable, no matter how disagreeable the situation. Said another way, acceptable risk is the risk associated with the best of available alternatives, not with the best of the alternatives which we would hope to have available.

There are several factors that together influence the determination of risk acceptability. They include personal, political/social, and economic reasons. Although the three are interrelated, different processes drive them. These processes are described next.

PERSONAL

The personal factors that dictate whether a risk would be considered “acceptable” mirror the risk perception characteristics described in the following section. For example, a risk whose consequences are dreaded, such as the radiation sickness that could result from a meltdown at a nuclear power plant, is likely to be found less acceptable to individual members of the public than the long-term effects of increased solar radiation (such as skin cancer), which may be caused by a decrease in the ozone layer from increased automobile emissions.

Differences in individual acceptance between risks that are voluntary and involuntary are described in the United Nations Development Programme (UNDP) training program on Vulnerability and Risk Assessment as follows:

> Some risks are entered into voluntarily and a distinction is sometimes made between voluntary and involuntary risks. Many recreational activities and sports involve considerable levels of personal risk entered into voluntarily. Indeed the thrill of the risk is part of the enjoyment of the recreation. The benefits of the risk outweigh the costs and so the perception of the risk is reduced; i.e. the [threat] level that is deemed acceptable is much higher than a risk that is imposed from outside or involuntary. (UNDP 1994)

Other factors that have been shown to affect public acceptance of risk include personal values, gender, ethnicity, education level, and the treatment of the risk by the media.

POLITICAL/SOCIAL

The political/social acceptability of risk is the product of either democratic processes or other collective mechanisms of determination. In other words, political and social influences are representations of many personal determinations of acceptability. While it is almost certain that not every individual citizen will be happy with the final decisions made concerning a risk’s acceptability and treatment, the choice made will reflect the feelings of the majority if those choices are influenced by political and social acceptability.

Because of the differences in the makeup of different communities and populations, risk acceptance will not be universal. It is likely to change from place to place, from time to time, and from hazard to hazard (Alesch 2001). Acceptability is likely to change even within individual communities over time as the makeup of that community changes. It is these differences that make public participation in the disaster risk management process important.

ECONOMIC

Because countries or communities can rarely support the level of funding required to mitigate all risks, the risk acceptability decision must be influenced by how much each risk reduction alternative would cost and what alternative risk reduction options might be offset by dedicating funds to that particular option.

In general, disaster risk managers will have to address the costs of reducing a risk in terms of the actual risk reduction benefits that would result. Some countries or communities have chosen to simply live with a risk because the costs of reducing its consequences are prohibitive—and eliminating the risk altogether is unthinkable. For a simplified example, consider the use of the automobile, which highlights the cost-benefit scenario. At present, over a million road traffic fatalities occur throughout the world each year. This obviously presents an incredibly great risk, albeit extensive in nature. With increased cost, car manufacturers could easily make their cars much safer, and these fatality rates could be reduced significantly. However, such a cost would make automobiles too expensive for the average consumer. Thus, we accept the loss of over a million lives per year in exchange for the benefit of automobile affordability. Even if manufacturers did take the measures necessary to render cars completely "safe" for occupants, there would still exist an inherent risk as indicated by the great number of fatalities caused when pedestrians are struck by cars. (See figure 3.5.) The cost of totally eliminating this particular risk associated with automobiles is inconceivable.

W. Kip Viscusi, in the article "Economic Foundations of the Current Regulatory Reform Efforts" (1996), describes how the economics of an acceptability decision can be influenced by the political and social aspects of that decision. To illustrate his point, he produces a list of risk-reducing regulations that fail a cost–benefit "test" (cost is greater than the benefit), and a list of risk-reducing regulations that pass a cost–benefit test (benefit is greater than the cost). His results are shown in Tables 3.3 and 3.4.

Risk management decision making processes are not perfect, and in fact biases and "injustices" are commonly encountered in the establishment of what is acceptable and determination of what treatment options are best (MPPP 1999). The following are three areas where such problems have been identified:

1. *Those with money and vested interests can influence the process of determining the acceptability of risk.* Because the process of determining risk acceptability (including mitigation spending and

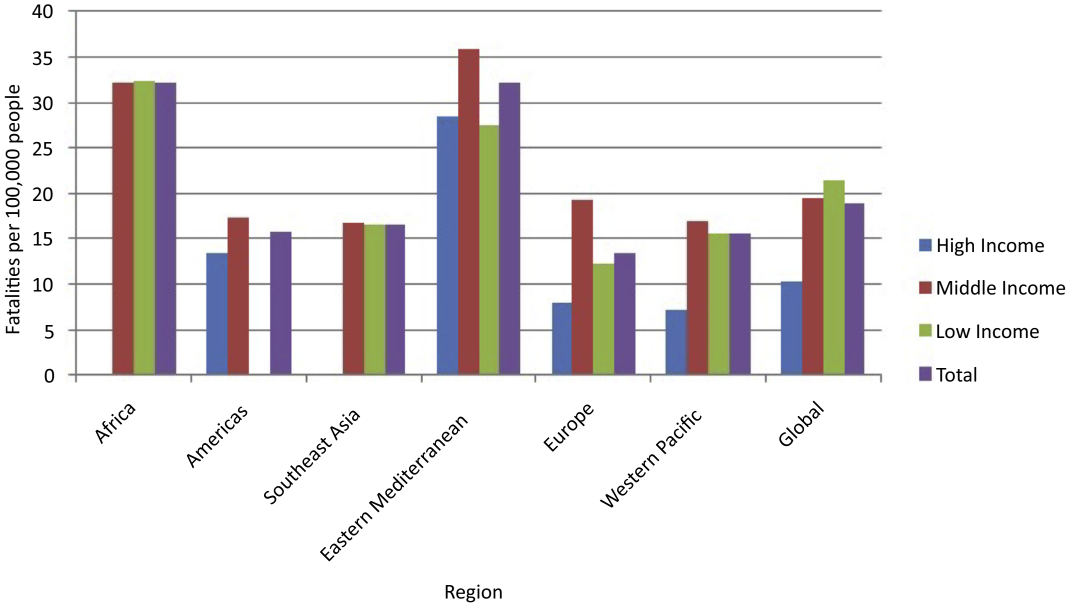


FIGURE 3.5

Worldwide road traffic fatalities

Source: *WHO, 2009*.

regulatory practices) is influenced by politics and may be shaped by political ideology, it is possible for corporate or interest groups to lobby and influence those decisions. This can be seen with hazards such as handguns and assault rifles, environmental degradation, soil and water pollution, and construction in hazardous areas. Increased citizen participation in the process can decrease this type of injustice. By increasing the decision-making power of the general public, a more democratic outcome is possible (although not guaranteed).

2. *Setting a dollar figure (in cost–benefit analyses) on a human life is unethical and unconscionable.* This is primarily a factor related to involuntary risks. To the individuals whose lives are being placed at risk, any dollar figure will seem low or inappropriate as a trade-off for the acceptance of the risk. Many people would (understandably) feel that their life is too great a price to pay for the existence of any involuntary risk. The cognitive processes that dictate these "price of a human life" determinations are often different for voluntary risks. As the automobile safety example illustrates, people are willing to accept a certain increase in risk to their own lives for the benefit of more affordable products. How much more affordable differs by person. But, as shown by

Table 3.3 The Cost of Risk-Reducing Regulations that Fail a Benefit-Cost Test per Life Saved

Regulation	Initial Annual Risk	Annual Lives Saved	Cost per Life Saved (Millions of $)
Grain dust	2.1 in 10,000	4	5.3
Radionuclides/uranium mines	1.4 in 10,000	1.1	6.9
Benzene	8.8 in 10,000	3.8	17.10
Arsenic/glass plant	8.0 in 10,000	0.110	19.20
Ethylene oxide	4.4 in 100,000	2.8	25.60
Arsenic/copper smelter	9.0 in 10,000	0.060	26.50
Uranium mill tailings (inactive)	4.3 in 10,000	2.1	27.60
Uranium mill tailings (active)	4.3 in 10,000	2.1	53.00
Asbestos	6.7 in 100,000	74.7	89.30
Asbestos	2.9 in 100,000	10	104.20
Arsenic/glass manufacturing	3.8 in 100,000	0.25	142.00
Benzene/storage	6.0 in 10,000,000	0.043	202.00
Radionuclides/DOE facilities	4.3 in 1,000,000	0.001	210.00
Radionuclides/elemental phosphorous	1.4 in 100,000	0.046	270.00
Benzene/ethylbenzenol styrene	2.0 in 1,000,000	0.006	483.00
Arsenic/low-arsenic copper	2.6 in 10,000	0.09	764.00
Benzene/maleic anhydride	1.1 in 1,000,000	0.029	820.00
Land disposal	2.3 in 100,000,000	2.52	3,500.00
EDB	2.5 in 10,000	0.002	15,600.00
Formaldehyde	6.8 in 10,000,000	0.010	72,000.00

Note: Viscusi (1996) assumes that $2.8 million per life saved is an acceptable cost. Any cost greater than $2.8 million per life fails the cost/benefit test.
Source: Viscusi, 1996.

Table 3.4 The Cost of Risk-Reducing Regulations That Pass a Benefit–Cost Test per Life Saved

Regulation	Initial Annual Risk	Annual Lives Saved	Cost per Life Saved (Millions of $)
Unvented space heaters	2.7 in 100,000	63	.1
Oil and gas well service	1.1 in 1,000	50	.1
Cabin fire protection	6.5 in 100,000,000	15	.2
Passive restraints/belts	9.1 in 100,000	1,850	.3
Underground construction	1.6 in 1,000	8.1	.3
Alcohol and drug control	1.8 in 1,000,000	4.2	.2
Servicing wheel rims	1.4 in 100,000	2.3	.2
Seat cushion flammability	1.6 in 10,000,000	37	.6
Floor emergency lighting	2.2 in 100,000,000	5	.7
Crane-suspended personnel platform	1.8 in 1,000	5	1.2
Concrete and masonry construction	1.4 in 100,000	6.5	1.4
Hazard communication	4 in 100,000	200	1.8
Benzene/fugitive emissions	2.1 in 100,000	.310	2.8

Source: Viscusi, 1996.

relatively recent lawsuits against tobacco companies by smokers who became ill, people may be unwilling to accept some voluntary risks despite previous knowledge about those risks. Because of the controversial nature of placing a value on life, it is rare that a risk assessment study would actually quote a dollar figure for the amount of money that could be saved per human life loss accepted. Post-event studies have calculated the dollar figures spent per life during a crisis, but to speculate on how much a company or government is willing to spend to *save or risk a life* would be extremely unpalatable for most.

3. *Risk management is usually an undemocratic process, as those who may be harmed are not always identified or asked if the danger is acceptable to them.* It is not difficult to recall a case in which a vulnerable or disadvantaged group of people was exposed to a risk whose benefits were enjoyed by others. Many toxic waste dumps are located in impoverished parts of towns, cities, and states, although the people in those communities had little say in deciding the location of such materials. Related to this injustice is the reality that the impoverished are usually less able to avoid such risks, as the properties or jobs available to them are often associated with these very same risks. It is often the poor who must live in the highest risk areas of a floodplain, or under high-tension power lines, or along highways. These people bear a larger share of the population risk, while many others enjoy much lower risk levels from those particular hazards, even though they enjoy a disproportionate amount of the benefits. Thus, risk communication and public participation are important to counteract these injustices.

In determining the treatment of risks in a country or community, each hazard must be considered according to its current risk level, and it must be determined whether or not the risk is too great to be left as it is. If it is determined to be too great, an analysis of what else can be done to reduce the risk is warranted, and a new determination of acceptability in light of the reductions achieved must be made.

EXHIBIT 3.9 TOTAL RISK AVOIDANCE

The Great East Japan Earthquake and its associated tsunami caused one of the worst nuclear disasters in history. The Fukushima Daiichi nuclear power plant suffered meltdowns in three of its six reactors, which led to the release of a significant quantity of radioactive waste into the air and water surrounding the plant. The emergency situation and associated evacuation that resulted from this event persist to this day, with predictions claiming that many areas falling within the 20-kilometer danger zone surrounding the plant likely to never be resettled.

In the aftermath of the accident, thousands of Japanese citizens and many politicians called for a "nuclear-free Japan" in which all nuclear reactors were permanently shuttered. As a safety precaution, all reactors had already been idled, and alternative methods of power generation had been utilized to make up for lost production. This was primarily in the form of imported fossil fuels and natural gas, which resulted in an annual increase of $36 billion in production costs and was transferred directly to consumers. Thus far, residents have compensated for the reductions in available power and increases in costs, but the political and social will to solidify decisions to fully ban nuclear power has waned. With each year that has passed since the disaster, the number of people who state a preference for a "compromise option" wherein older, more vulnerable nuclear reactors are shuttered while newer, safer reactors are restarted, has grown. Concerns about the high costs of fossil fuel power and the impacts it has on the wider economy have shifted the perception of risk. An interesting side story in this saga is that the disaster did result in the banning of nuclear power in other countries that felt no direct impacts but wished to avoid the same fate. In 2011, just months after the Fukushima disaster, Germany vowed to complete the shuttering of its operational nuclear power plants by 2022. Soon after, Belgium vowed to close theirs by 2025.

Based on: *Fackler, 2014; Benson, 2011*.

Several methods for determining the acceptability of risks have been developed in the past and are used to varying degrees, depending on the needs of those performing the risk evaluation. They include:

The "no go" alternative. This alternative, which is not always available, is the complete elimination of the risk. Such action can be easier with technological hazards, especially those that are new. How easy depends on how dependent society has become on the technology in question. For example, when DDT was found to be bio-accumulating in birds and mammals, and it was feared this might eventually lead to a "silent spring," the chemical was banned from use. (A "silent spring," as described by Rachel Carson in her 1962 book of the same title, is what would result if DDT were used to the extent that all birds died as a result.) Alternatives to DDT existed, and while they may not have been as cost-efficient or effective, they were perceived as being much less detrimental.

For some countries, the more expensive alternatives were acceptable, while in others, DDT is still the preferred option on account of cost, effectiveness, or both. However, with hazards that have established a unique niche in society, such as the automobile, eliminating the risk is close to impossible. Hazard risk elimination is often only possible when viable alternatives exist. The possibility of eliminating the risk must always be considered in the assessment. (Because the option is to eliminate the *risk* and not the *hazard,* natural disasters can be considered for this option—if either the consequences or the frequency is lowered to zero, the risk becomes zero. However, this option is rarely possible, given economic and technological constraints.) The emergence of hybrid cars that rely on a combination of gasoline and electric power is a sign of movement toward a viable alternative in terms of fossil-fuel dependence. (See exhibit 3.9.)

Accept the risk. A second option is to simply accept the risk as it is, and do nothing to mitigate it. Certain hazards' risks may be so low that the resources spent to reduce them would be better dedicated to hazards of greater significance. In risk matrices, the hazards that fall within the lowest category of both consequence and likelihood are generally those that are considered acceptable. After all other hazards have been treated to acceptable levels, the low-risk hazards are revisited.

*Establish a "*de minimis *risk" level. De minimis* risk management methods operate by establishing a statistical level of risk for each hazard below which people need not concern themselves. This level is often set at either one in a hundred thousand or one in a million chance of occurrence over a selected period of time, usually a year (one year) or across a lifetime (70 years). The term *de minimis* is a shortened version of the Latin phrase *de minimis non curat lex*, which means "the law does not care about very small matters." This concept is widely used throughout Europe to set guidelines for acceptable levels of risk exposure to the general population. *De minimis* risk levels of one in a million over a 70-year life span have been set by the US Environmental Protection Agency (EPA) as a regulatory standard for pesticides (PMEP 1997). *De minimis* isn't used to eliminate hazards whose risks fall above the established level; rather, it states that risks falling below the level selected require no additional resources be spent on further reduction or prevention. If a product poses less risk than the *de minimis* level, for example, then it should be authorized for production and/or distribution. However, if the hazard's risk does not fall below the *de minimis* level, then consideration must be taken of what, if anything, can be done to reduce the associated risk, and whether the costs outweigh the benefits, among many other issues. Proponents for *de minimis* feel that governments can avoid wasting their time trying to increase the safety of risks already satisfying *de minimis* requirements, thus freeing them up to spend their resources on other risks of greater concern. Opponents are concerned that some risks exist for which even a one in a million risk would be too high (Mumpower 1986). One of their contentions is that risks that affect huge populations would result in a high number of deaths even though the risk is so "low." The smallpox vaccine, for example, has a one in a million risk of death. However, if the entire world population were to be vaccinated, approximately 6,000 fatalities would occur. Considering there are no deaths from smallpox in a given year and that the threat lies in the potential for a future release that may or may not happen, the risk from vaccination does not seem acceptable. Which brings us to the third group, which feels that the *de minimis* strategy is effective only if there are two *de minimis* levels working in conjunction—one that measures absolute risk (e.g., one in a million), and another that sets the maximum number of allowable expected fatalities (e.g., *x* number of fatalities for country *y*).

*Establish a "*de manifestis *risk" level.* Related to *de minimis* risk is the concept of *de manifestis* risk, or "obnoxious risk." With *de manifestis* risk, there is a risk level above which mitigation is mandatory. In practice, this level is generally set at one in ten thousand per vulnerable individuals. This practice is often cited regarding secondhand smoke exposure in the workplace (Ravid 2001).

Perform cost–benefit analyses of risks. Cost–benefit (or benefit–cost) analysis is probably the most widely utilized and accepted method by which hazard risks and risk treatment alternatives are evaluated for acceptability. Scientists participating in the Massachusetts Precautionary Principle Project (MPPP 1999) write:

> [Cost–benefit analyses are] where the risks reduced by taking a protective action (like imposing a stricter regulation on emissions) are equated to benefits (such as a life saved or reduced health costs). The "benefit" is then compared to the estimated "costs" of implementing the protective action (cost to the industry to install better pollution controls). Often a determination is made as to how much "cost" it is worth to save that life, usually 2 million dollars.

The inherent flaw of this approach is that regulatory actions may not be taken if the anticipated cost of controls greatly exceeds the perceived value of the life or lives saved. Among other flaws, cost–benefit analyses often fail to consider who reaps the benefits and who assumes the cost. They also perpetuate the myth that we must decide between economic or technological advancement and environmental or social protections. Cost–benefit analyses are heavily biased toward present-day regulation costs, thus discounting less quantifiable costs such as reductions in risk to health and life, among other benefits of prevention. They also commonly overestimate the costs of regulation and may underestimate the dollar value of unquantifiable factors such as pain and suffering, illness, disease, aesthetic losses, psychosocial impacts, and others. Many consider this unethical. Following the September 11 terrorist attacks in the United States, in which hijacked commercial airplanes were used as weapons, considerable effort went into (and continues to go into) securing airlines worldwide. As security measures increase, so does the associated cost, most of which is passed on to the consumer. How risk-tolerant or risk-averse a person is can often be determined by simply asking what financial sacrifices they are willing to make to ensure their own safety. Related to cost–benefit decisions are cost-effectiveness decisions. In the case of cost-effectiveness decisions, the minimum "unit cost" to reduce maximum risk is favored in considering the alternatives for risk mitigation within and between risks.

- *Acceptable risk as the best choice among alternatives.* Derby and Keeney (1981) write that "the answer to 'How safe is safe enough?' depends on . . . five steps. . . . Acceptable risk is determined by what alternatives are available, what objectives must be achieved, the possible consequences of the alternatives, and the values to be used." The five steps they refer to are:
    - Define the alternatives.
    - Specify the objectives and measures of effectiveness to indicate the degree to which they are achieved.
    - Identify the possible consequences of each alternative.
    - Quantify the values for the various consequences.
    - Analyze the alternatives to select the best choice. (Derby and Keeney 1981)
- Disaster managers will have already completed most of these steps by the time they are deciding which risks to treat. Derby and Keeney (1981) provide graphical illustrations of four factors that influence how risk alternatives are chosen and determined to be acceptable. These examples are shown in figures 3.6 through 3.9. In example A, it is assumed that the benefits of all the alternatives are equal. The differences are only in their financial cost and the level of risk (with 0 being the optimal level for both cost and risk). If only alternatives K and L are available, then the choice is between high cost with low risk and low cost with high risk. The acceptable risk would be the level of risk associated with the particular alternative chosen, either K or L.

If another alternative, M, were introduced into the problem, then M with lower cost and lower risk would be preferred to either K or L. Consequently, acceptable risk is now the safety level of alternative M. This risk is different from the level associated with the other alternatives. Clearly, the appropriate level of risk depends on the alternatives available.

Example B shows how acceptable risk changes with what objectives are achieved. In this example, only alternatives K and L are (known to be) available. If the sole objective is to minimize the risk, alternative K would be chosen. The acceptable risk would then be the risk level associated with K. However, if the sole objective is to minimize the cost, the alternative L would be chosen. Acceptable risk under this objective would be the risk level for L. Each objective leads to choosing different alternatives. In each case, the acceptable risk changes with the objective used to make the choice.

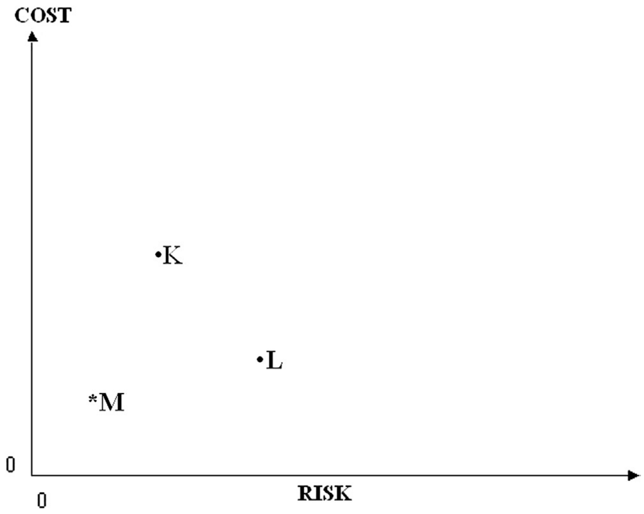


FIGURE 3.6

Risk acceptability example A

Source: Derby and Keeney, 1981.

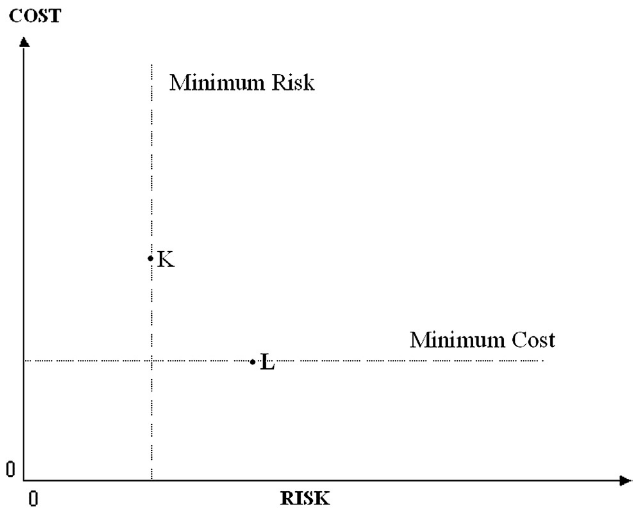


FIGURE 3.7

Risk acceptability example B

Source: Derby and Keeney, 1981.

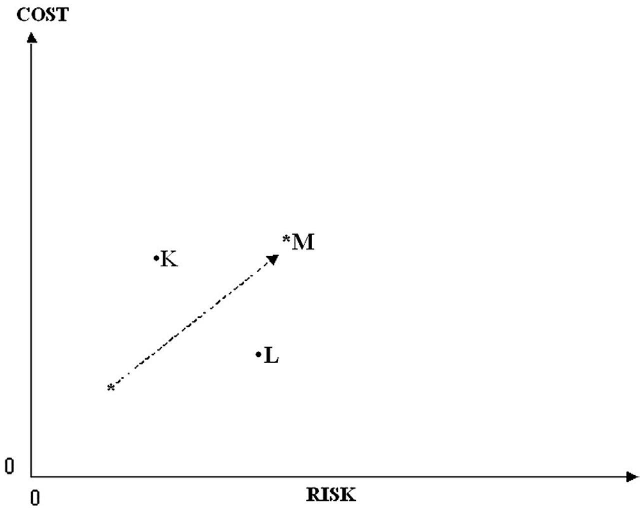


FIGURE 3.8

Risk acceptability example C

Source: *Derby and Keeney, 1981*.

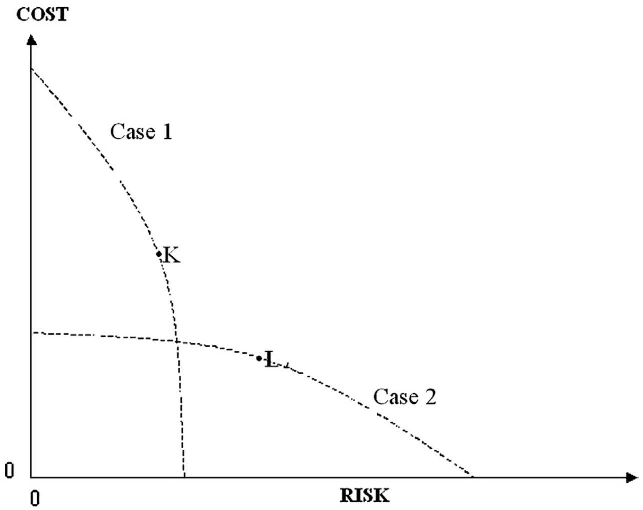


FIGURE 3.9

Risk acceptability example D

Source: *Derby and Keeney, 1981*.

Example C shows how new information can change the determination of what is considered acceptable risk. In this example, we assume that alternative M determines the acceptable risk, as in example A. However, additional information provided by experience, research, development, or analysis reveals that the initial assessment of alternative M must be revised. Instead of confirming that M has lower cost and lower risk than both alternatives K and L, the new information shows that M has both the high cost of K and the high risk of L. The acceptable risk is now determined by the choice between K and L.

Example D illustrates the effect of values and preferences on the choice between alternatives. In this example, different preferences for trading off increased cost for lower risk are represented by the two curves. In case 1, the trade-off curve reflects the willingness to incur large costs to reduce risk by small amounts. Alternative K is the most attractive choice with this preference. In case 2, the trade-off curve reflects less of a willingness to increase costs in exchange for specific reductions in risk. This preference selects alternative L as the best choice. Because acceptable risk is determined by the choice between the two alternatives, these different preferences change what is considered acceptable.

VULNERABILITY

The concept of vulnerability was defined in chapter 1 as being a measure of the propensity of an object, area, individual, group, community, country, or other entity to incur the consequences of a hazard. As this section illustrates, measurement of vulnerability requires examination of a combination of physical, social, economic, and environmental factors or processes. Each of these factors influences risk by causing an increase or decrease in likelihood and/or fewer or greater negative consequences.

It is important to first clarify the difference between the concepts of vulnerability and exposure, which are often confused. The two words are frequently used interchangeably to describe how a community, country, or region is likely to experience a certain hazard. However, this is factually incorrect and causes confusion. We can best understand the difference between vulnerability and exposure by considering the following statement, which appeared in the United Nations Office for Disaster Reduction document *Living with Risk*: “While most natural hazards may be inevitable, disasters are not” (ISDR 2004).

While vulnerability describes a propensity to incur consequences, exposure merely suggests that the individual, structure, community, nation, or other subject will be confronted by the forces associated with that particular hazard. For instance, imagine that someone says, on learning that Spain regularly experiences extended periods of lower-than-normal rainfall, “The Spanish are vulnerable to drought.” In the absence of additional information, this statement suggests more than the speaker intended. The use of the word “vulnerable” implies that the population is likely to incur negative consequences, whether because of poor coping capacity or other factors, rather than simply stating that droughts happen there. The reality, as figures 3.10 and 3.11 illustrate, is that while Spain is regularly exposed to drought, the nation is not vulnerable to its consequences.

Remember that risk is composed of two components: likelihood and consequence. Exposure, or the measure of whether a person, building, population, or nation is likely to experience a hazard, looks only at a hazard’s likelihood. Vulnerability, however, is a factor of how small or great the consequences will be *should the hazard manifest*. Figures 3.10 and 3.11 illustrate how the many different nations that are exposed to drought each exhibit differing levels of vulnerability to this hazard. In light of this, it would be more accurate to state that the Spanish face a drought risk because their exposure likelihood is

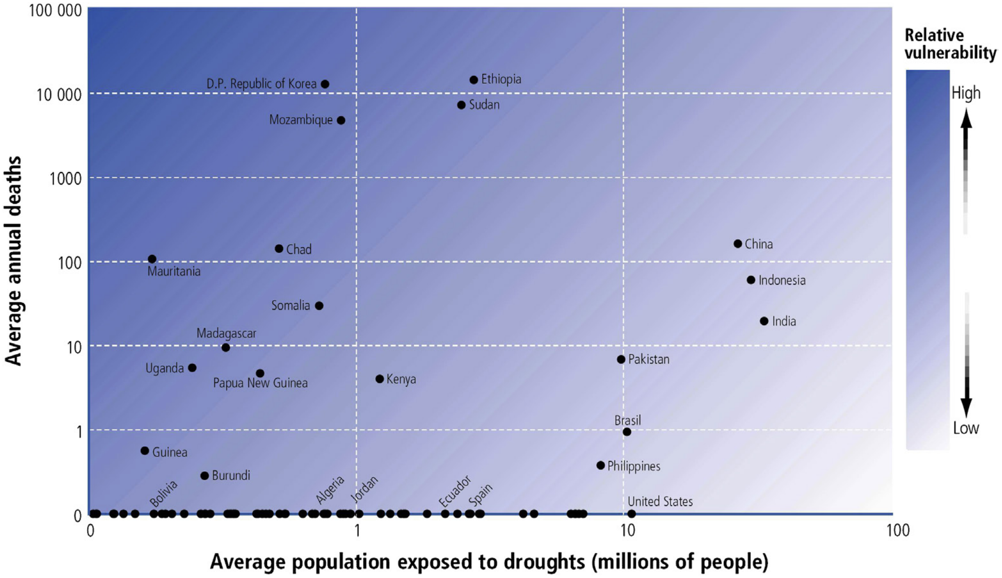


FIGURE 3.10

National vulnerabilities to drought risk as a factor of population exposure

Source: EM-DAT – International Disaster Database.

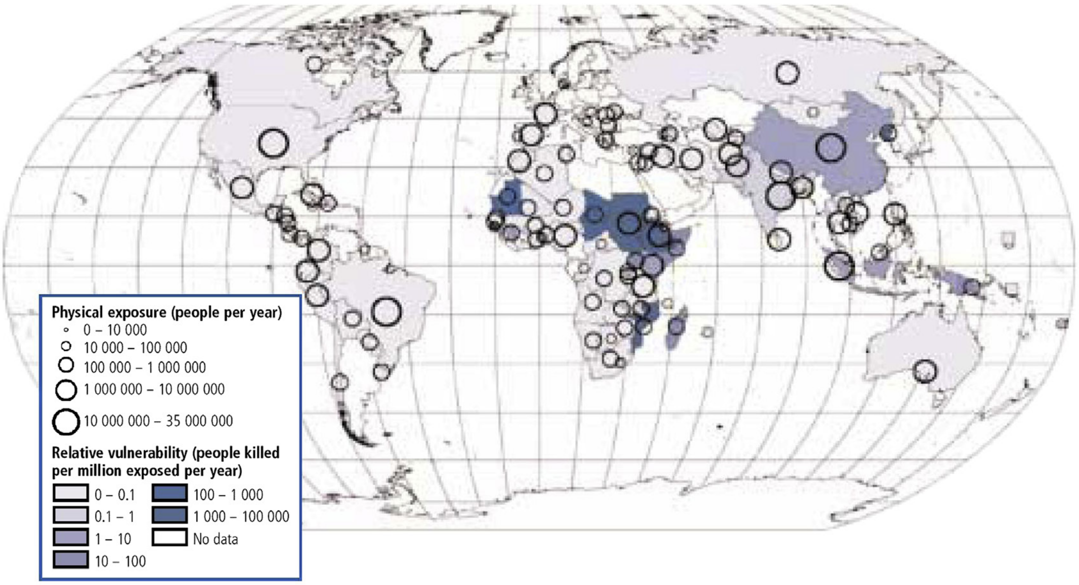


FIGURE 3.11

National vulnerabilities to drought risk as a factor of population exposure

Source: EM-DAT – International Disaster Database.

greater than zero, but because of the measures that nation has taken to minimize drought consequences, it is no longer *vulnerable* to the hazard.

Vulnerability, like likelihood and consequence, is something that can be studied and measured. Likewise, it can be decreased or increased depending on actions that are taken or events that transpire. By taking action to prepare for a hazard or mitigate that hazard's risk, the propensity to incur harm is thus reduced. (Mitigation and preparedness are detailed in chapters 4 and 7, respectively.) As vulnerability is decreased, resilience is increased. Resilience, which can be defined as the ability to prevent or avoid the negative consequences of hazards, is the opposite of vulnerability.

As the definition of vulnerability in chapter 1 explains, two identical manifestations of a hazard may result in a minor issue in one country and a major catastrophe in another. The impacted countries' vulnerabilities are what account for the difference in presentation. There are generally four different types of vulnerabilities: physical, social, economic, and environmental. Each is determined by a set profile of factors that are identifiable and measurable.

Physical vulnerability looks at the interaction between living things, structures, material objects, systems, and the physical forces of hazards. The choices societies make about placing structures, transportation routes, and populations either in or out of harm's way effectively determine physical vulnerability. Most of the risk reduction (mitigation) measures taken to reduce disaster risk seek to enable people, structures, objects, and systems to resist these physical forces, thus reducing societies' physical vulnerability to them. For instance, when a building constructed in a flood hazard zone is elevated above the limits of anticipated flood heights, its physical vulnerability is reduced. People are also physically vulnerable to hazards any time they have little protection from the physical forces of the hazards they encounter (or the forces of objects affected by the disaster and conditions created by the hazard). As populations move into areas of high risk of disaster, their exposure increases, and the knowledge they have and actions they take determine whether or not their vulnerability also increases.

Social vulnerability is a measure of the behavioral, social, political, and cultural factors that increase or decrease a population's propensity to incur harm or damage as a result of their exposure to a specific hazard. Certain collective and/or individual behaviors can contribute to or reduce each person's and each population's ability to protect themselves from harm. Within more general populations there are typically subgroups that exhibit different vulnerability factors than the population as a whole, as is often the case with the elderly, the poor, those with functional needs, and the very young, to name a few.

Economic vulnerability measures the financial means of individuals, towns, cities, communities, or whole countries to protect themselves from the effects of disasters. Within societies, there may be many economic delineations that further divide groups into economically vulnerable subgroups. As previously discussed, the poor are much more likely to suffer the consequences of disasters as they often do not have the financial means to avoid extreme hazards.

Environmental vulnerability refers to how health and welfare of the natural environment within the area of study factors into the propensity of the affected population to incur disaster consequences. Poor environmental practices, such as deforestation, a lack of land-use planning, and management of hazardous materials, can turn what would have been minor events into major disasters.

Each of these vulnerability elements is interconnected. Economic vulnerability in the form of poverty can lead to limited housing options (social vulnerability), which in turn causes populations to build on dangerous hillsides (physical vulnerability) thus reducing the ability of those slopes to remain intact during rainstorms (environmental vulnerability). This is but one of limitless examples of how each factor is equally important when considering impact of the vulnerability on risk.

Disaster risk managers can achieve a more comprehensive understanding of vulnerability by developing physical, social, economic, and environmental profiles for the area or population being studied. These four factors provide the context for a vulnerability assessment, which in turn better enables a planning team to estimate likely consequences and understand which mitigation and preparedness measures would be most appropriate to treat the causative hazards. Descriptions and samples of these profiles are provided in the following section.

THE PHYSICAL PROFILE

The physical profile of a country, which dictates its physical vulnerability, is generally a collective examination of three principal components: geography, infrastructure, and populations. The more that is known about each component, the better understood physical vulnerability will be. Each of these components contributes to the nature of risk, including how likely a risk is to occur and how its consequences will manifest themselves.

The geographic component of the physical profile focuses on the natural makeup of the area of study. For instance, it is estimated that almost three billion people, or about half of the world's population, currently reside in what is classified as coastal land. This includes all but two of the world's 15 largest cities (ISDR 2004). The economic and industrial benefits associated with a seaside location were the drivers behind the original siting of coastal settlements, but in moving there, the residents increased their exposure to many different hazards, including severe windstorms, flooding, and tsunamis. Whether or not this physical location represents vulnerability depends on the actions that individuals and communities take to reduce their risk.

The following list provides several examples of what geographic factors are important to consider in forming a geographic profile:

- Land cover (vegetation)
- Soil type
- Topography
- Slope
- Aspect (the direction something such as a mountain slope faces)
- Water resources (lakes, rivers, streams, reservoirs, etc.)
- Wetlands and watersheds
- Seismic faults
- Climate (wind, rainfall, temperature)

The infrastructure component of the physical profile focuses primarily on the interaction between people and the land. This profile is diverse, and may be generalized for regions or segments. (See exhibit 3.10.) Examples of infrastructure factors commonly studied when forming a physical profile include:

- Land use
- Location and construction material of homes
- Location and construction material of businesses
- Zoning and building code delineations
- Critical infrastructure components
- Hospitals and clinics

EXHIBIT 3.10 SECTORING

Sectoring helps to further understand the ways in which a disaster would affect segments of a country or community. Not all areas of a community will be affected by an unforeseen event. Sectoring divides an area into manageable segments or portions based on local geography in relation to a specific hazard. It allows disaster managers to categorize parts of their study area in terms of response and impacts. It is used to identify local service areas in relationship to a hazard and physical features, and allows for the identification of especially vulnerable areas, evaluation of how an area could be or has been affected, and what can be done to respond to specific events.

Knowing the hazard and the potential of its impact in each sector allows for a more accurate identification of appropriate mitigation actions as well as warning and emergency response needs. Sectoring can also be used to organize and conduct emergency response needs within a sector or across adjacent sectors.

Sectors should be defined by easily identifiable boundaries that can be seen on the ground, such as bluffs, rivers, and major highways. These features often dictate who responds and how a response is managed. Things to think about in identifying sectors include:

- People
  - How many people in each sector
- How many subdivisions in a sector
  - Where people work
  - Where people recreate
  - Where people live
  - Where people gather for civic events
  - Where the special needs populations are located
- Animals and livestock
  - Where animals are located
  - What types of animals are in a specific sector
- Housing and living quarters
  - How many housing units in the sector
  - What types of housing units are present
  - Whether all units are insured
- Critical facilities and response
  - Fire station locations
  - Ambulance locations
  - Hospital locations
  - Emergency first-response locations
  - Emergency coordination locations
  - What the responding zones are
- Special facilities and community resources
  - School locations
  - Nursing home locations
  - Health care service locations
  - Prison and jail locations
  - Important historical or cultural locations
- Infrastructure and lifelines
- Utilities, including pipelines and power lines
  - Roads and bridges
  - ailroads and yards
  - Airports
  - Navigable waterways
  - Dikes, dams, and flood protection
- HAZMAT facilities/public health concerns
  - Leaking underground storage tank (LUST) sites

EXHIBIT 3.10 SECTORING—cont'd

  - Municipal emergency services (MES) sites
  - Chemical storage sites
  - Hazardous materials locations
  - Funeral homes
  - Sites containing radioactive materials
- Commercial and industrial facilities
  - Commercial business areas defined
  - Industrial business areas defined
  - Agricultural business areas defined
  - Port facilities identified

- Schools
- Senior citizen centers
- Daycare/child care centers
- Government and other public facilities
- Prisons and jail facilities
- Power generation facilities and transmission
- Water purification facilities and pipes
- Wastewater treatment and sewer lines
- Gas lines
- Oil and gas transport pipelines
- Oil and gas storage facilities
- Transportation systems
- Roads and highways
- Railroads
- Airports
- Public transportation systems
- Waterways and port facilities
- Bridges
- Communication facilities
- Landfills
- Dikes and flood protection structures and facilities
- Nuclear power generation plants
- Dams
- Military installations
- Industrial sites that manufacture and/or store hazardous materials
- Emergency management systems
- Ambulance services
- Fire services
- Law enforcement services
- Emergency first response services
- Early warning systems

- Emergency operations centers
- Emergency equipment (fire trucks, ambulances, response vehicles, etc.)
- Hazardous materials (HAZMAT) equipment
- Weapons of mass destruction (WMD) detection teams
- Evacuation routes and shelters
- Historical and cultural buildings and areas

The population component of the physical profile is a study of where people are and how they move throughout the day and the year. Disasters that occur at different times of the day or the year can have different consequences, and knowing where people are likely to be at certain times helps to determine vulnerability. Some cities can double or triple in size during the day on weekdays, when workers arrive from outlying areas. New York City's Manhattan Island, for instance, grows from a population of 1.5 million at night to over 3 million during the day when commuters arrive. Time of day also factors into what types of structures people will be inhabiting, which can influence how they are impacted by a disaster. At night, most people are likely to be in their homes, while during the day on weekdays they will be at their jobs. The 2008 Sichuan Earthquake struck at 2:28 pm local time, which meant that children were in schools and workers were in factories. Because so many schools and factories had not been constructed to resist seismic forces, this timing of the event translated to thousands of children and workers being crushed. For this reason, physical vulnerabilities vary depending on the time as population movements occur. Examples of measures that help form the physical profile include:

- Population by jurisdiction (i.e., county, city)
- Population distribution within a county or city
- Population concentrations
- Animal populations
- Locations of schools, major employers, and financial centers
- Areas of high-density residential and commercial development
- Recreational areas and facilities

THE SOCIAL PROFILE

The social makeup of the population found within a planning area has a strong influence on disaster vulnerability. Aspects of the social profile are diverse and comprise education, culture, government, social interaction, values, laws, and beliefs, among others. Within most countries, and even within individual communities, the vulnerability of different groups varies because of a range of sociocultural peculiarities that help or prevent people from being able to protect themselves from disasters. The prevalence of epidemics, in particular, is heavily influenced by social norms and behaviors. (See figure 3.12.)

Certain religious, cultural, and traditional practices and beliefs can help or hinder disaster management practices. Although it may not be evident to the people practicing such behavior, their practices be a product of adjustment to a hazard. In India, for instance, there is a group of people called the *Banni* who adapted to the use of a traditional style of single-story, round houses called *bhungas* after a particularly devastating earthquake in 1819. In 2001, when an earthquake struck in Gujarat, India, killing more than 20,000 people (primarily as result of residential structure failure), not a single *bhunga* collapsed.

Disaster managers must be able to recognize when social interactions are either helping or hindering people in reducing their vulnerability to hazards, and must recognize what aspect of that social process is causing the alteration. People tend to be very attached to places and practices. For instance, despite an ongoing epidemic of the Middle East Respiratory System (MERS) virus in Saudi Arabia in 2014, two million pilgrims from around the world felt their religious duty to visit Mecca superseded the risk of infection and possible death (Batrawy 2014). An outsider recommending change without considering the original reasons for the social practices is unlikely to be taken seriously in that community. Additionally, changing certain social practices without regard for their historical bases can actually increase vulnerability because of the common but unintended consequences resulting from a social reaction in response to the change.

Culture can also influence the manner in which response and recovery are conducted, especially when external resources are involved. Responders need to understand and respect the culture—even if they don't understand its basis or it conflicts with their own—if they are to avoid compromising the aid operation. For instance, in the island country Tonga, maintaining the Sunday Sabbath is a constitutional requirement. The docking of ships and the landing of planes is prohibited. In past disasters, foreign responders have had to postpone deliveries of aid until Monday when the government of Tonga refused their entry on Sunday. To the outsider this may seem extreme, but many if not most of the victims impacted by the cyclone that caused the disaster agreed with the decision.

Examples of factors to consider in scoping a social profile include:

- Religions
- Age breakdown

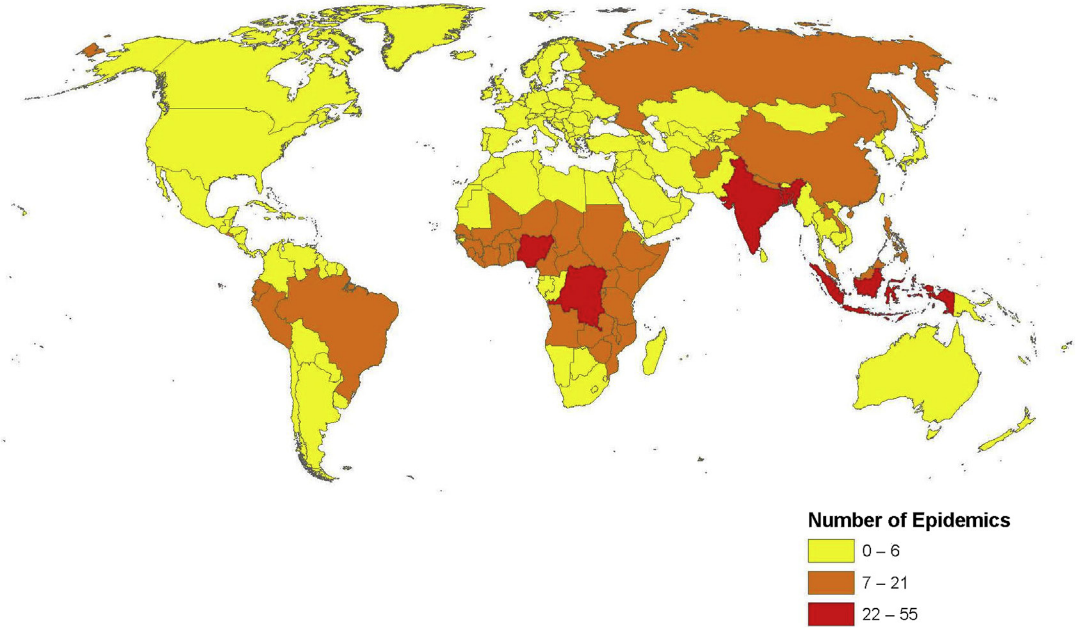


FIGURE 3.12

Number of epidemics by country from 1974 to 2003

Source: EM-DAT – International Disaster Database.

- Gender-related issues
- Literacy
- Language
- Health
- Politics
- Security
- Human rights
- Government and governance (including social services)
- Social equality and equity
- Traditional values
- Customs
- Culture

THE ENVIRONMENTAL (NATURAL) PROFILE

The natural environment of a country or community plays a critical role in defining its hazard vulnerability (see figure 3.13), and helps to define what risk reduction practices and actions are possible and most effective. For instance, a mountainous country whose government does not or is not able to restrict clear-cutting of timber on unstable slopes is likely to have an increased probability of mass-movement disasters, whereas a country that does not manage the draining or filling in of wetlands may

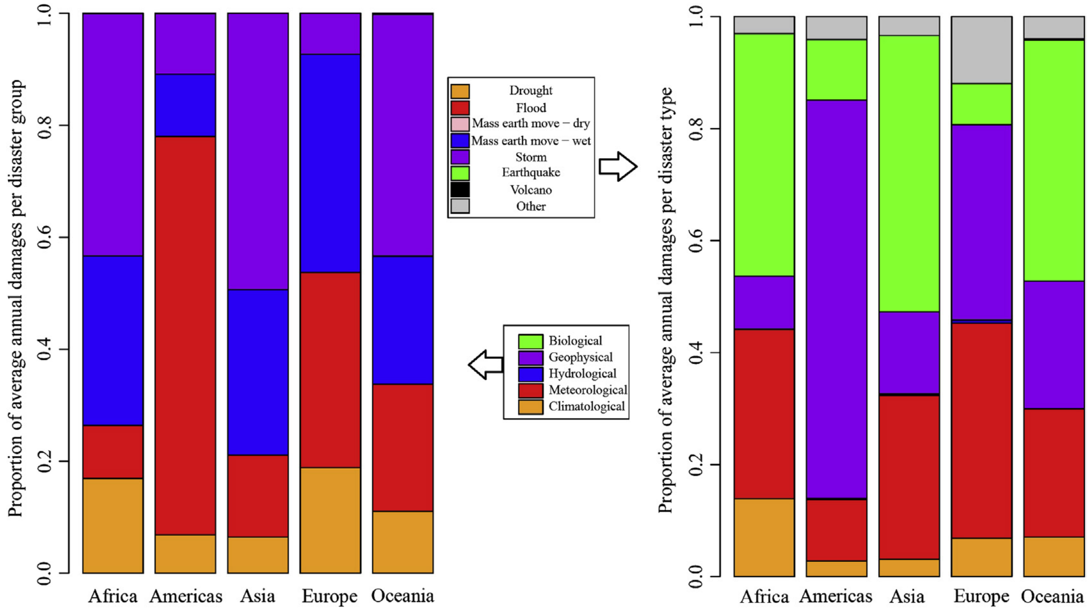


FIGURE 3.13

Regional differences in hazard portfolios from 1990 to 2011

Source: EM-DAT – International Disaster Database.

show an increase in flood propensity. And the natural environment itself can be impacted by a disaster, which has associated social and economic impacts and can further impact the likelihood that future hazards result in disasters.

The health and vitality of the natural environment are critical when measuring vulnerability to each identified hazard. A healthy and productive natural environment can provide excellent protection from a variety of hazards, while a damaged and unhealthy natural environment can reduce protection from specific hazards and, in some cases, increase a hazard's impact. Healthy and productive wetlands provide invaluable flood protection by soaking up excess rainwater. Healthy forests are less vulnerable to catastrophic wildfires and reduce landslide dangers on slopes. Dunes on coastlines provide buffers from storm surges caused by hurricanes and severe storms. Figure 3.14, developed by the UN as part of the International Strategy for Disaster Reduction (ISDR), illustrates this process of risk augmentation through environmental degradation.

Understanding the direct link between a healthy and productive natural environment and a country's vulnerability to specific hazards is critical to developing an effective risk management strategy. Conducting an inventory of the features of the country's natural environment is an important step.

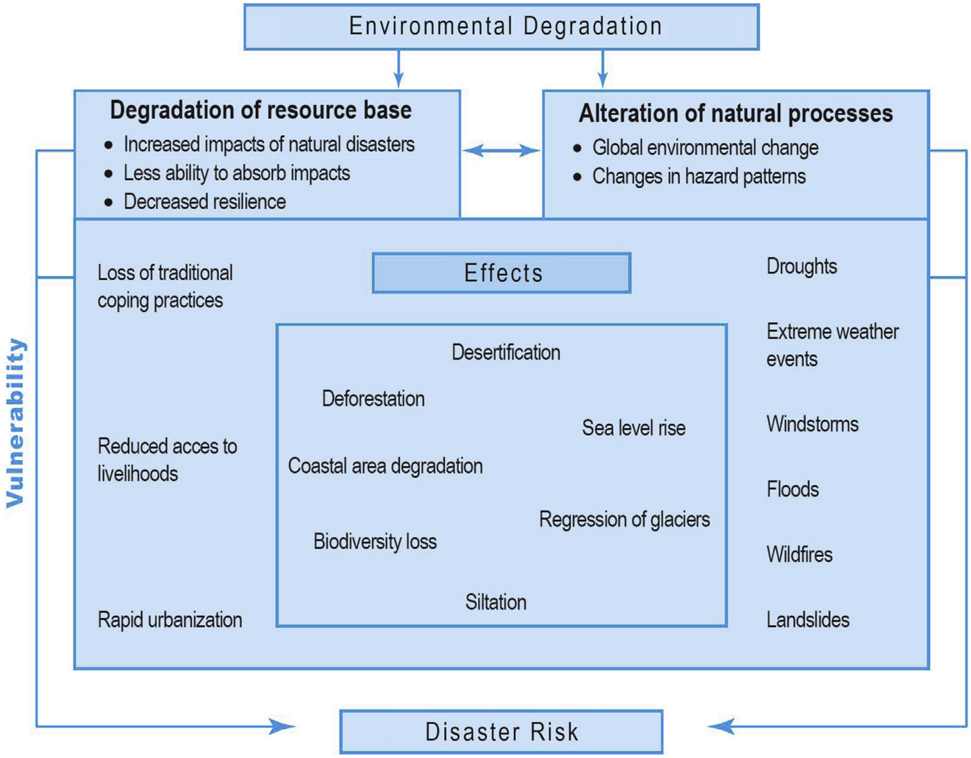


FIGURE 3.14

The link between environmental degradation, natural disasters, and vulnerability

Source: ISDR, 2004.

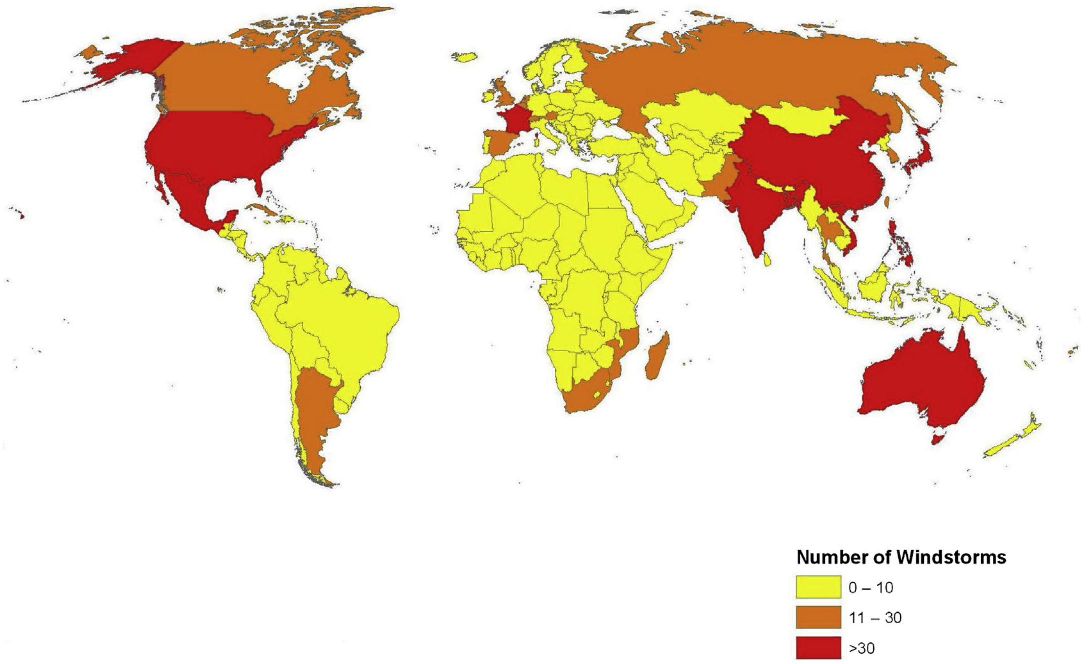


FIGURE 3.15

Number of severe windstorm events by country between 1974 and 2003

Source: EM-DAT – International Disaster Database.

Measuring the health of the country's natural environment is vital in understanding the role that it can play in protecting a community and reducing the impacts from hazard events. (See figure 3.15.) Features of a community's natural environment include, but are not limited to,

- Health of waterways (rivers, streams, creeks, etc.)
- Status of wetlands
- Management of lakes
- Management of forests
- Health of coastal dunes
- Health of coral reefs

Human practices that affect the environmental profile of a country (see exhibit 3.11) include:

- Diking or damming rivers and creeks
- Filling in wetlands for development
- Channeling coastal areas such that marsh and wetlands areas are destroyed
- Clear-cutting forests
- Mismanaging forests such that deadwood builds up (serving as fuel for a forest fire)
- Destroying coastal dunes

EXHIBIT 3.11 ILLEGAL DESTRUCTION OF CORAL REEFS WORSENED IMPACT OF TSUNAMI

The illegal mining of corals off the southwest coast of Sri Lanka permitted far more onshore destruction from the 26 December 2004 tsunami than occurred in nearby areas whose coral reefs were intact. This is the principal finding of a team of researchers from the United States and Sri Lanka who studied the area earlier this year. Their report is published in the August 16 issue of Eos, the newspaper of the American Geophysical Union.

Some of the differences were startling. Lead author Harindra Fernando of Arizona State University reports that in the town of Peraliya, a wave of 10-meter (30 foot) height swept 1.5 kilometers (one mile) inland, carrying a passenger train about 50 meters (200 feet) off its tracks, with a death toll of 1,700. Yet, a mere three kilometers (two miles) south, in Hikkaduwa, the tsunami measured just 2–3 meters (7–10 feet) in height, traveled only 50 meters (200 feet) inland, and caused no deaths.

The researchers found that this pattern of patchy inundation to be characteristic of the study area and was not related to such coastline features as headlands, bays, and river channels. Rather, the key factor was the presence or absence of coral and rock reefs offshore. At Hikkaduwa, the hotel strip is fronted by a rock reef and further protected by coral reefs that the local hoteliers protect and nurture, the researchers report. Relatively little damage and few deaths were recorded from there to Dodanduwa, around 6 kilometers to the south.

From Hikkaduwa north to Akuralla, however, damage and loss of life were extensive. Local residents, interviewed by the authors, say that illegal mining had decimated coral reefs in that area, especially by use of explosives that result in harvests of both coral and fish.

Some eyewitnesses to the tsunami described a visible reduction in the height of the water wall and its deflection parallel with the shore as it approached the coral reef. The researchers conclude that waves that had been blocked by the reef caused even more inundation and damage where they found low resistance gaps due to removal of coral by humans.

The scientists note that the brunt of the tsunami had hit Sri Lanka's eastern shore, but that the southwestern, or leeward, side had also been hit hard. Their analysis of the available data concludes that two or three waves hit the area within an hour, having been channeled and bent around the southern tip of the island, and that another wave struck around two hour later, having bounced back after hitting India or the Maldives. They say that existing computer models cannot adequately explain or predict the wave amplitudes in southwest Sri Lanka, likely due to small-scale ocean processes, including topographic variations due to coral removal, that are not yet well understood.

The authors note that the low-lying Maldives islands directly in the path of the tsunami escaped destruction. They suggest that this may have been due to the presence of healthy coral reefs surrounding the islands. Apparently, in Sri Lanka, very little healthy coral was damaged by the tsunami.

Source: *American Geophysical Union, 2005*.

Natural processes also affect the natural environment, such as:

- Rainfall averages
- Wind
- Snowfall and snowmelt averages
- Seasonal trends in severe storms and cyclonic storms
- Seasonal drought
- Lightning

THE ECONOMIC PROFILE

The financial status of a government, the nonprofit sector, businesses, and populations deeply affects how a country or community is able to protect itself from the consequences of disaster. Financial well-being, however, does not indicate that these entities and individuals *will* take protective action; rather, it is merely a measure of the capacity to do so. Other insight may be gained from the economic profile. Trends and tendencies associated with wealth, or the lack thereof, can be deduced. For instance, the poor are often marginalized and forced to live on more dangerous land. Their housing is more likely to be constructed of materials unable to withstand environmental pressures. They are more likely to have little to no tolerance for delays in basic commodities and services that often follow disasters.

Economic measures that inform vulnerability assessments include:

- Gross domestic product
- Debt
- Access to credit
- Insurance coverage
- Sources of national income
- Availability of disaster reserve funds
- Social distribution of wealth
- Prevalence of business continuity planning
- Economic diversity (the range of products and resources that drive the economy)
- Philanthropic giving

It is recognized that poor countries experience more disasters than wealthy ones, as figure 3.16 illustrates. This is not surprising, however, when considering the definition of a disaster and the concept of vulnerability. An event only becomes a disaster when the local capacity to respond to the event is exceeded, requiring external assistance to manage the consequences. The economic strength of wealthy nations better enables them to develop preparedness, mitigation, response, and recovery mechanisms before events occur, and thus these nations are better able to manage disasters effectively when they happen. Identical events that occur in a high-income country and a low-income country may manifest as a routine event in the high-income country but result in a full-scale disaster in the poor country. Income is not the only factor that would play into the variance in vulnerability between the two countries, but it is a dominant one.

Another economic factor that influences how significantly an event affects a country is the gross domestic product (GDP). GDP is a measure of the value of all goods and services produced within a nation in a given year. When considered in the absence of a nation's GDP, the financial consequences of a disaster do not provide a relative sense of how badly the country was impacted. However, presenting damages and losses as a percentage of GDP provides a much better perspective of how deeply the nation's economy was impacted. For example, a disaster that causes $2 billion in damages may represent upward of 38 percent of total GDP for a country like Honduras, while it would be equal to less than one-tenth of a percent of Japan's GDP. Large-scale disasters that affect poor countries can literally wipe out all of their economic gains for a year or more. Wealthy nations with strong economies are better able to absorb the effects of disasters, and many even have reserve funds set aside for expected events, which would further lessen the impact. Poor countries, on the other hand, often must borrow significant amounts of financial capital while concurrently cutting vital social and economic programs in order to cover the expenses of disaster relief and recovery. Long-term development can stall in the face of such measures and may lag for many years after the disaster has struck—especially when debt responsibilities weigh heavily on future budgets. Figures 3.17 and 3.18 illustrate how differently disaster events affect economies of varying sizes.

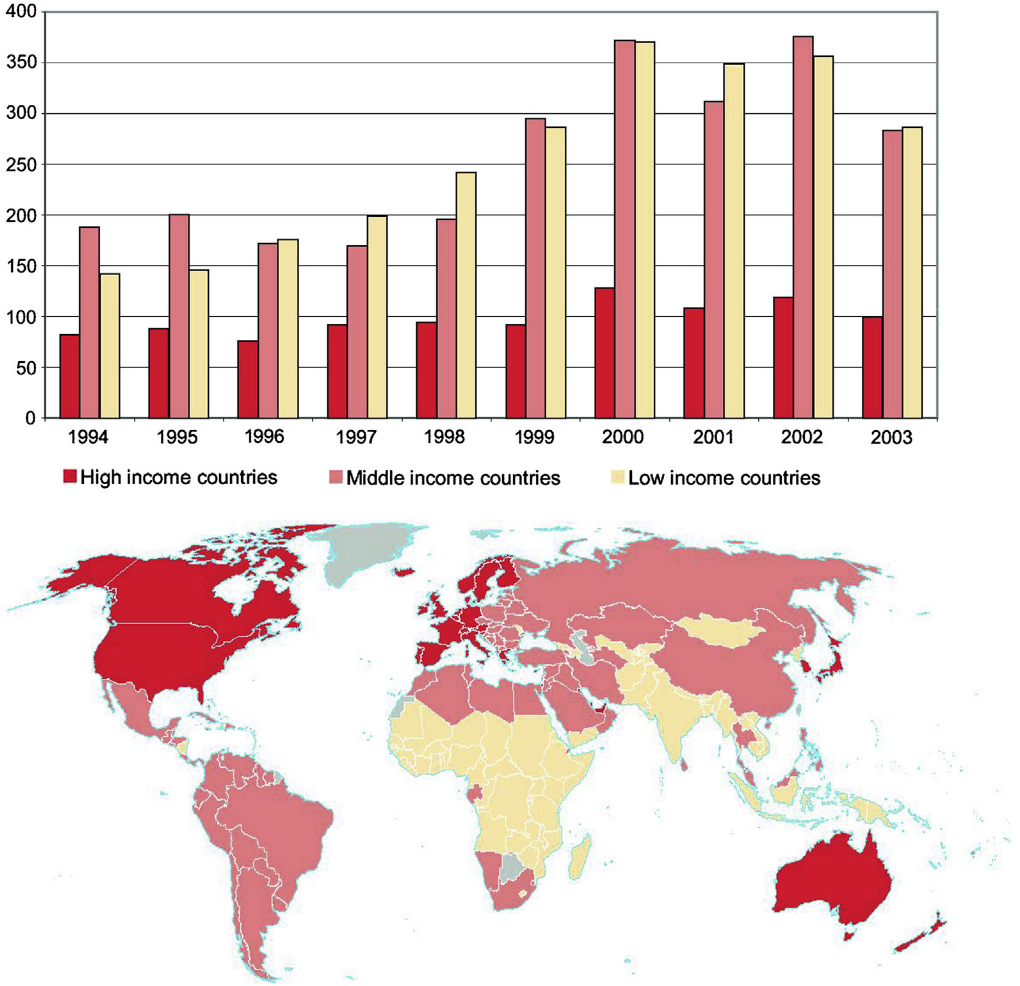


FIGURE 3.16

Total number of disasters by year from 1994 to 2003 (by income; reference map provided)

Source: EM-DAT – International Disaster Database.

RISK FACTORS THAT INFLUENCE VULNERABILITY

In the United Nations Development Programme report *Reducing Disaster Risk: A Challenge for Development*, two main factors influencing the risk levels of nations and their populations are identified: urbanization and rural livelihoods (UNDP 2004). Each of these factors influences and is influenced by the four main hazard vulnerability factors previously discussed.

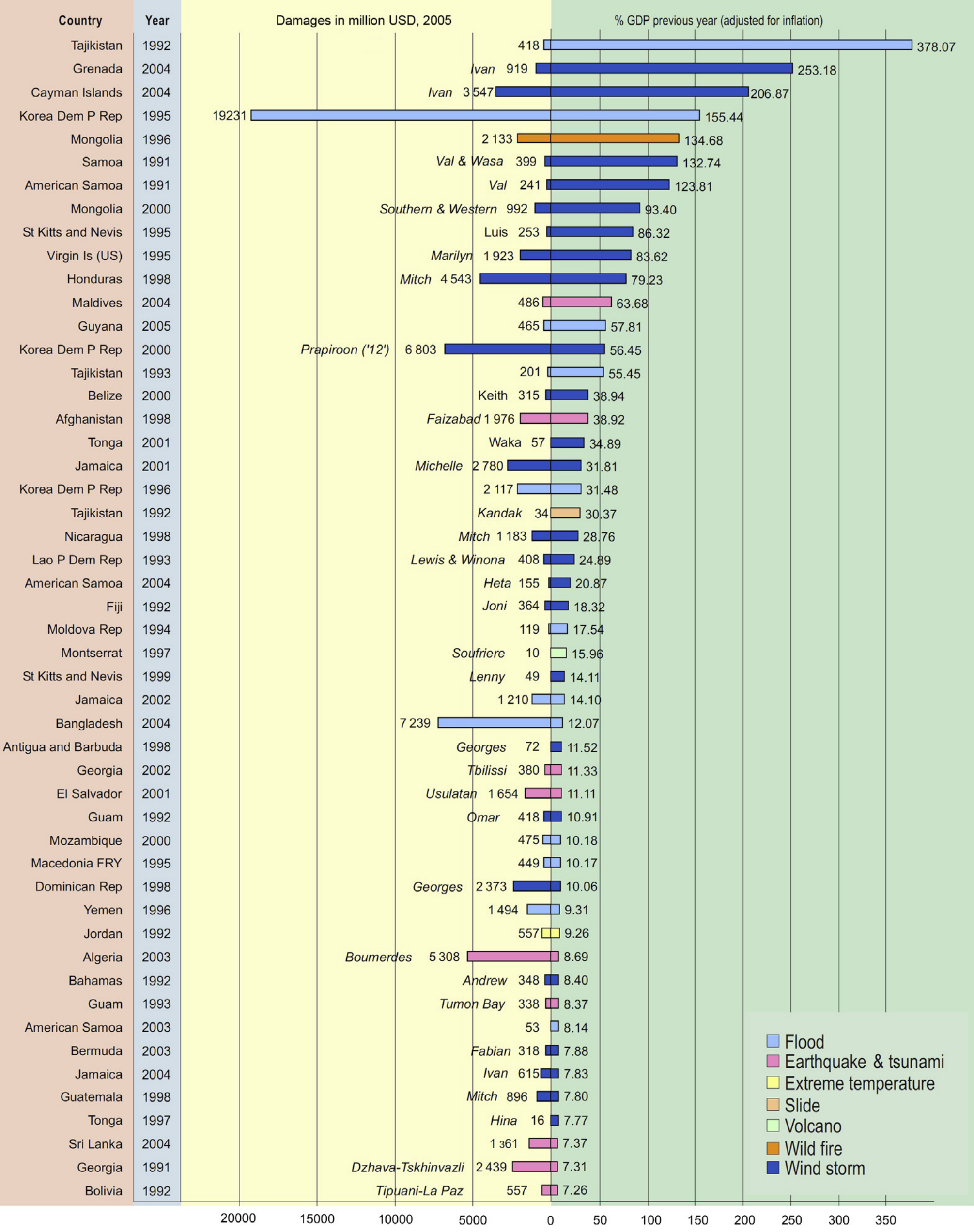


FIGURE 3.17

Disaster damages as a percent of GDP between 1991 and 2005

Source: EM-DAT – International Disaster Database.

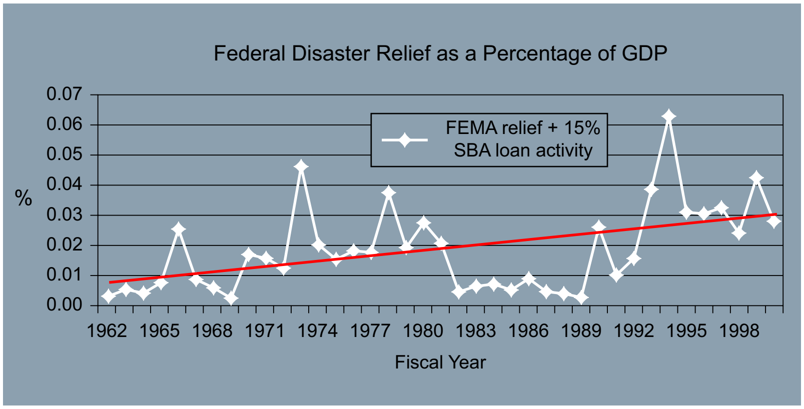


FIGURE 3.18

Disaster relief costs as a percentage of GDP in the United States

Source: *Congressional Natural Hazards Caucus and Princeton University, 2001.*

Urbanization

Populations are concentrating in urban centers throughout the world. Between 2008 and 2010, the world shifted from a majority rural to a majority urban population as urbanization rates topped 50 percent. This number will exceed 70 percent by 2050 if the current rates are maintained. This movement is fueling the development of large "megacities," defined as urban centers containing more than 10 million inhabitants. As of 2014, there are 30 megacities. An increase in the number of cities that exceeds one million people is also occurring. In 1950, there were 75 cities that met this threshold, while in 2014 that number has risen to more than 450, and it is expected to continue to rise to more than 545 by 2025. (Minto 2011). Of these, 69 cities currently have more than 5 million inhabitants (World Atlas 2014).

Urbanization, especially rapid urbanization, presents significant challenges for disaster risk managers and urban planners. In the most basic terms, the concentration of people concentrates risk. The absolute numbers of people who are exposed to individual hazards increases as those people settle in closer and closer proximity. As populations become denser, land pressures require the poor to settle in undesirable, often dangerous, parts of urban centers, such as unstable slopes, in floodplains, and on seismically unstable soil. Without current census data and risk assessment, governments may not be aware for months, or even years, that these groups are at such high risk.

In addition to concentrating populations, urbanization concentrates national wealth and resources into small, often vulnerable pockets. Exposure is likewise concentrated, and when disasters occur, there is a great increase in the likelihood that a significant portion of the nation's infrastructure, industrial output, and governance will be affected. As urbanization increases, housing, distribution of food, transportation, communications, public health, and many other resources and services are also impacted to a much greater degree.

The ability of government to ensure the safety of urban populations decreases significantly when surges in population occur in a haphazard, informal manner. It can be very difficult, if not impossible, for officials to prevent people emigrating from rural areas from building and operating in a way that increases their risk, most significantly in the short term. Disaster management and emergency services capacity must grow in line with population expansion to ensure adequate protection. Even wealthy countries often experience capacity gaps as recognition and funding catch up. In poor countries, these lags are compounded by political pressures and the competition of financial interests that rob disaster management programs of much-needed funding.

Several reasons why urbanization contributes to risk and vulnerability have been identified by the UNDP, including:

- *Risk by origin.* Some cities are inherently risky because of their location. Mexico City, for example, is located very near active seismic faults and was built upon soft soil that amplifies seismic waves to dangerous levels in certain parts of the city. In this case, the vulnerability of the population is increasing through urbanization because the urban center itself is inherently risky.
- *Increasing physical exposure.* As mentioned earlier, when rapid urbanization occurs, marginalized groups are very often pushed to the more dangerous, riskier parts of the city, even to places where construction may previously have been prohibited. In this case, overall population exposure increases because people are moving into higher risk pockets that exist within the overall boundaries of the urban environment.
- *Social exclusion.* Rural areas often have community-based coping and support systems that allow for decreased overall vulnerability to the consequences of hazards. However, these bonds are much less common in urban areas. Migrants often have trouble adjusting to the new demands of city life, requiring them to disregard many of the protection measures they may have otherwise taken. Their social safety nets are reduced or eliminated when they move away from families and friends, and it may be years before they are able to fill the resulting void. These groups tend to face the greatest risk from disaster consequences.
- *Modification and generation of hazard patterns.* Rapid urbanization not only changes the character and size of a city but also affects its natural and built environments, as well. Growing populations alter the way many services and resources, such as water, sewerage, garbage disposal, and hazardous materials generation, are managed. These increased pressures can easily create or modify existing hazards, or can result in completely new hazards. For instance, land pressure often results in the filling of wetlands to allow for new construction. The decreased hydrological holding capacity of the land may result in increased flooding where flooding was previously not a problem. This filled land may be less stable in the event of an earthquake because of the lack of bedrock below foundations.
- *Increasing physical vulnerability.* In addition to causing people to move into high-risk areas (increasing their physical exposure), urbanization tends to cause groups to live and function in a manner that increases the likelihood that they will become victim to a disaster. Moving into risky areas does not automatically imply that vulnerability has been increased. With the proper mitigation measures, the likelihood and consequence factors of risk can be reduced. However, because it is the poor who are most likely to move to these areas, expecting that the great (and expensive) measures required to compensate for the increased hazard risk in the area will be taken is unrealistic. As such, population vulnerability increases. It should be noted, however, that even in previously populated areas, increased density can result in conditions that increase vulnerability.
- *Urbanization of new regions.* It is not uncommon, in the modern age of transportation, commerce, and communications, for previously undeveloped areas to transform into large urban centers in a relatively short time. New markets, newly discovered resources, and increased population mobility

can result in rapid settlement of people in an area at particular risk for one or more hazards about which few or no people are aware. The UN points out that the disasters resulting from earthquakes in Peru in 1990 and 1991, in Costa Rica in 1991, and in Colombia in 1992 were consequences of new region urbanization.

- *Access to loss mitigation mechanisms.* Rapid urbanization places increased pressure on the government to provide mitigation and other disaster reduction and response services. However, even if these services are increased or developed, there is always a lag in time between recognition of the increased vulnerability and the development of services to reduce that vulnerability. Apart from major disasters, marginalized groups, especially those in informal squatter communities, face the risk of devastating consequences from minor storms, fires, landslides, and other hazards that normally would cause little or no damage.

Rural Livelihoods

More than half the world's population and, according to the World Bank (2014), more than 70 percent of the impoverished live in rural areas. Like their urban counterparts, rural populations experience vulnerability from disasters because of a unique set of factors resulting directly from the classification of their living conditions as rural. The following lists several of these factors.

- *Rural poverty.* In the absence of large, organized government entities, rural communities may be left to fend for themselves for disaster mitigation and response resources. This is pronounced in the developing world. With little or no money to spend on prevention, the rural poor have few options to mitigate for disaster risk. When what little they are able to do ultimately fails as result of a disaster, the catastrophic loss of crops, equipment, livestock, housing, and possessions is devastating, and relief resources may be nonexistent. Although they may have developed long-established social systems to counteract the effects of disasters, those systems may fail for many reasons, including changes in the demographic makeup of the community, climate change, changes in markets, and environmental degradation.
- *Environmental degradation.* Many of the world's rural poor engage in environmentally destructive practices. Most often, these practices are directly related to agricultural or other income-generating practices. Deforestation, overgrazing of land, poor farming practices, and alteration of waterways all can lead to an increase in the likelihood or consequence factors of risk. In these cases, it is typical for common events such as normal annual rains to begin resulting in disasters such as mudslides and flash floods, which had not previously affected the region.
- *Nondiversified economies.* Many rural areas rely on just a few sources or even a single source of income. This increases the possibility that a hazard could significantly impact or fully destroy the area's capacity for income generation. A plant epidemic is one example of a hazard capable of causing a disaster but which could have been easily mitigated with greater diversification. Shifts in global market prices for a specific commodity can also cause significant reductions in local income if there exists a high degree of dependence on that one resource. If market demands shift during the crisis as a result of customers looking elsewhere for the same product or moving to adapt an alternate product, the negative impacts on the nondiversified economy could become permanent.
- *Isolation and remoteness.* Rural populations that are far outside the reaches of national and regional government services often have little outside intervention to reduce their vulnerability

from disasters. Poor transportation and communications infrastructure severely hinders pre- and post-disaster assistance. When a disaster does occur, days or weeks may pass before news of it reaches the outside world and assistance is provided. War-torn areas are especially susceptible, as was evident after the 2004 tsunami events in Banda Aceh province in Indonesia.

RISK PERCEPTION

A key requirement of effective disaster risk management is recognition that a hazard exists. However, recognizing the hazard is only the beginning, as one must also be able to judge the relative seriousness of that hazard in comparison to other hazards. The process of risk analysis helps disaster managers to do just that. For lay people, however, and in the absence of such technical and involved analysis, the mechanisms by which they *perceive* the hazards that threaten them can be very different, and very complex.

The study of why people fear the things they do (and also why they do not fear other things) is called risk perception. Traditionally, people do not tend to fear the things that are statistically most likely to kill them, and an abundance of research has been dedicated specifically to finding out why. Understanding these trends in public risk perception can help disaster managers understand why people are disproportionately afraid of spectacular hazards they are statistically less vulnerable to than, for instance, automobile accidents, food poisoning, heart disease, or cancer.

In their article “Rating the Risks,” acclaimed risk perception experts Paul Slovic, Baruch Fischhoff, and Sarah Lichtenstein begin, “People respond to the hazards they perceive” (Slovic et al. 1979). This statement is important for two reasons. First, its opposite is true. People generally do not respond to the hazards they do not perceive. Second, it has been found that these stated perceptions are primarily based on inaccurate sources of information, such as mass media outlets, social networks, and other external sources, as opposed to personal experience and expert knowledge.

Slovic et al. (1979) identified four “risk perception fallibility” conclusions to explain the ways in which people tend to inaccurately view the hazards in their world. These conclusions, which help to explain how populations decide which disasters to prepare for and why, are:

1. *Cognitive limitations, coupled with the anxieties generated by facing life as a gamble, cause uncertainty to be denied, risks to be distorted, and statements of fact to be believed with unwarranted confidence* (Slovic et al. 1979). People tend to fear a specific risk less as they become better informed and have more details of the risk. However, what a person can discover about a risk will almost never be complete, as the actual likelihood or consequence most risks pose cannot be quantified in a way that addresses the specific threat faced by individuals, even well-known risks such as cancer or heart disease (Ropeik 2001).The more uncertainty a risk poses or, as Slovic et al. (1979) state, “the more of a gamble something is,” the more people fear it. In the face of uncertainty, people consciously or subconsciously make personal judgments based on very imperfect information to establish some individual concept of the risk they face. Judgments based on uncertainties and imperfect information often cause people to wrongly perceive their own risk in a way that overstates reality. In Mexico City, for instance, where a public insecurity crisis is a priority political topic and a constant subject in the press, but where no reliable crime statistics have been available for more than seven years, people have overestimated their personal risk from violent crime by up to 86 percent. According to a 2002 comprehensive countrywide poll

measuring the incidence of crime, approximately 14 of every 100 citizens of Mexico City would fall victim to some form of crime in the 12 months following the survey (ICESI 2002). However, when asked in a poll what they believed their chance was of falling victim to crime in that same time period, many people thought they had an 80 to 100 percent chance.

2. *Perceived risk is influenced (and sometimes biased) by the imaginability and memorability of the hazard. People, therefore, may not have valid perceptions about even familiar risks* (Slovic et al. 1979). People are more afraid of those things that they can imagine or remember. The likelihood of occurrence of these easily available risks, as they are called, tends to be overestimated. For instance, we rarely hear about a person dying from a "common" cause such as a heart attack, unless somebody close to us dies of that specific cause. However, the media will report heavily on a death that is the result of an "uncommon" cause, like the West Nile virus. The result tends to be that people underestimate common risks and overestimate rare risks. Social scientists Slovic, Fischhoff, and Lichtenstein performed a study to measure this phenomenon and found that people greatly overestimated their risk from rare events such as botulism, tornadoes, pregnancy complications, and floods while underestimating their risk of stroke, diabetes, cancer, and heart disease (Slovic et al. 1979). Generally, people tend to fear what they hear about repetitively or often. This phenomenon is referred to as the "availability heuristic," which states that people perceive an event to be likely or frequent if instances of the event are easy to imagine or recall. This perception bias can be correct when considering events that really are frequently observed, such as people who believe that automobile accidents are common because almost everyone they know has been involved in one. However, when a risk that is spectacular but not necessarily common receives constant media attention, people often wrongly assume that similar events are very likely to occur.
3. *[Disaster management experts'] risk perceptions correspond closely to statistical frequencies of death. Lay people's risk perceptions [are] based in part upon frequencies of death, but there were some striking discrepancies* (Slovic et al. 1979). It appears that the concept of risk for lay people includes qualitative aspects such as dread and the likelihood of a mishap being fatal. Their risk perceptions are also affected by catastrophic potential. It can be difficult for people to fully understand statistics they are given, and even more difficult to conceptualize how those statistics apply to them personally. Furthermore, statistics tend to do little to affect how people perceive the calculated risks. This is not to say that the average person lacks sufficient intelligence to process numbers; rather, the numbers are not the sole source of influence on public risk perception. Extensive research has discovered that people rank their risks by using other, more heavily weighted *qualitative* factors, as well as the quantitative likelihood of a hazard resulting in personal consequence (Slovic et al. 1979). People are generally more concerned with the consequence component of risk than they are about the likelihood component (recall that Risk = Likelihood × Consequence). It is important to examine the quality and usefulness of statistics provided to the public by the media regarding risks. Without complete information, media-provided statistics are meaningless and likely misleading. In the absence of complete information, people tend to overestimate rather than underestimate their vulnerability. Economists have classified this tendency to overestimate unknown or unclear risks as "risk-ambiguity aversion" (Economist 2002).However, even if statistics provided by the media or other sources are straightforward, people have difficulty understanding how those numbers affect them as individuals, even if they are risk "experts." Few people can conceptualize the difference between a "one-in-a-million" and a "one-in-one-hundred-thousand"

chance of occurrence (Jardine and Hrudey 1997). People tend to need other clues to help them put these numbers into perspective. Many tend to view their chances of being affected by rare but spectacular hazards in a comparable fashion to how people believe they can beat long odds to win a state lottery. James Walsh writes in his book *True Odds:*

> The odds are greater you'll be struck by lightning than win even the easiest lottery. They're better that you'll be dealt a royal flush on the opening hand of a poker game (1 in 649,739). They're better that you'll be killed by terrorists while traveling abroad (1 in 650,000). Bill Eadington, director of the Institute for the Study of Gambling and Commercial Gaming at the University of Nevada at Reno, looks at it this way: If you bought 100 tickets a week your entire adult life, from age 18 to 75, you'd have a 1 percent chance of winning a lottery. "[Lotteries] really play on the inability of the general public to appreciate how small long odds are." (Walsh 1996)

In Walsh's calculations, the odds of winning the lottery are 1 in 57 × 52 × 100 × 100 = 29,640,000. It is the qualitative factors that people consider most heavily when weighing their personal risk. Slovic, Fischhoff, and Lichtenstein (1980) propose that there are 17 risk characteristics that influence public risk perception. These characteristics fall under two subgroups called *factors*: Factor 1 is related to dread, and Factor 2 is related to how much is known about the risk. A third factor, encompassing a single, eighteenth characteristic that measures the number of people exposed to the hazard, is not covered in this section.

Using these 17 characteristics, Slovic et al. (1980) examined public perceptions of 90 risks and plotted their findings on a two-dimensional graph depicting Factor 1 on the *x* axis and Factor 2 on the *y* axis. Characteristics of Factors 1 and 2 are described in the following lists:

Factor 1: Factors Related to Dread

a. *Dreaded versus not dreaded.* People fear risks that cause painful, violent deaths more than risks that do not. David Ropeik, director of risk communication at the Harvard Center for Risk Analysis, wrote, "What are you more afraid of: being eaten by a shark or dying of a heart attack in your sleep? Both leave you equally as dead, but one—being eaten alive—is a more dreadful way to go" (Ropeik 2001). Of course, millions of people around the world die from heart attacks while sleeping every year, but fewer than 15 fall victim to sharks in the same time period (Wiggins 2002).

b. *Uncontrollable versus controllable.* People tend to be less fearful of risks that they feel they can control. For instance, most people feel safer as a driver in a car than as a passenger because they are controlling the movement of the vehicle, and they know their own skills in accident avoidance. When people lack control of a situation, a risk seems more pronounced. Examples of uncontrollable risks are airplane travel, street crime, pesticides in food, and terrorism.

c. *Globally catastrophic versus not globally catastrophic.* Risks that have the potential to affect the entire world tend to be deemed greater than those that would only affect local or national populations. For instance, the effects of nuclear war, whose aftermath could include widespread nuclear fallout and long-term physiological effects beyond the borders of any one state, is far scarier than are the effects of a conventional war taking place in a country other than one's own.

d. *Fatal consequences versus not fatal consequences.* A risk that results in death is more feared than other, nonlethal risks. For example, even though auto accidents are much more likely than airplane accidents, the chance of fatality is much greater for airplane accidents, and airplane accidents are thus more feared.

e. *Not equitable versus equitable.* Risks that affect one group with a greater statistical likelihood and/or consequence than the general population tend to be considered greater risks than those that affect all people equally, especially to those within the groups more severely affected. This is especially true if the risk disproportionately affects children.

f. *Catastrophic versus individual.* Risks that affect a great number of people in one location or at one time are more feared than those that affect individuals one at a time over a wide location. Terrorism and earthquakes are examples of catastrophic hazards, while heart disease, auto accidents, and drowning are considered individual hazards.

g. *High risk to future generations versus low risk to future generations.* A risk that extends across generations, especially one that will affect future generations, is considered scarier than ones that will be mitigated or prevented in our own lifetimes. The most apparent example of this is nuclear radiation, which can remain dangerous for thousands of years. Because of this extended danger, there are still no agreements on where spent nuclear fuel will be stored in the United States after it is no longer useful for power generation.

h. *Not easily reduced versus easily reduced.* People are more afraid of risks that cannot be easily mitigated. The effort required to reduce crime or drug use is much greater than the effort required to prevent drowning or bicycle injuries. Simply wearing a helmet on a bike, or a life preserver on a pleasure boat, greatly reduces the likelihood of injury or death. However, it takes months or years to combat a crime wave or drug problem plaguing a town or city.

i. *Risk increasing versus risk decreasing.* A risk that appears to be growing in likelihood or consequence becomes more feared. However, if a risk appears to be more easily mitigated or is decreasing in likelihood or consequence, people begin to fear it less.

j. *Involuntary versus voluntary.* Why are people more afraid of drunk drivers than of eating high-cholesterol food that will raise their risk of heart disease? How can some people smoke cigarettes, wholly unconcerned about their cancer risk, while those around them complain incessantly? The most obvious answer for both questions is that people are more concerned with risks that are involuntary than with those they bring upon themselves. Keith Smith, in *Environmental Hazards: Assessing Risk and Reducing Disaster,* discusses voluntary and involuntary risk and states, “there is a major difference between voluntary and involuntary risk perception with the public being willing to accept voluntary risks approximately *1,000 times greater than involuntary risks*” (emphasis added; Smith 1992).

k. *Affects me versus does not affect me.* Terrorism has been reported almost daily in the media for years, but until September 11, 2001, Americans who did not travel abroad did not worry about it. After that date, preventing terrorism became a national concern and a government priority. The *statistical* risk to the average person in the United States was raised only a minuscule amount, but the mere fact that people suddenly knew *for certain* that foreign terrorism could occur at home made them much more afraid.

l. *Not preventable versus preventable.* A risk that cannot be mitigated or prepared for is more feared than one that can be. For instance, in the early 1980s HIV and AIDS were seen as always fatal and were terribly feared. With modern medicine, people who are HIV-positive can live for years without contracting AIDS. While the disease is still feared, it is not perceived to be as dangerous as it was 20 years ago.

Factor 2: Factors Related to How Much Is Known about the Risk

m. *Not observable versus observable.* Risks that can be seen are less feared than those that cannot be seen or visualized. The dangers associated with radon or genetic manipulation are considered not observable, while secondhand smoke is observable.

n. *Unknown to those exposed versus known to those exposed.* If people have no way of knowing whether they are exposed to a risk, they will fear that risk more. Food irradiation and biological terrorism are examples of risks where people may not be able to know if they have been exposed.

o. *Effect delayed versus effect immediate.* Risks that cause immediate harm or damage tend to be less feared than those that cause negative effects at some future time following exposure. This is the primary reason people tend to fear the effects of biological terrorism more than conventional or even chemical warfare.

p. *New risk versus old risk.* Risks we are facing for the first time are much scarier than risks we have had plenty of time to become "accustomed" to. Few people fear cars for their accident risk or fear the risk posed by vaccines, as we have lived with these technologies for decades. When anthrax was mailed to news agencies and politicians in New York, Washington, DC, and Florida, people became extremely frightened when opening their mail, while today it is highly unlikely that anyone continues to wear a mask and rubber gloves while opening letters.

q. *Risks unknown to science versus risks known to science.* When risks can be explained using scientific evidence, people fear them less because of increased understanding. Many diseases raise questions when they are first discovered, but once their methods of transmission, prevention, and cure are revealed, they become less of a concern.

4. *Disagreements about risk should not be expected to evaporate in the presence of "evidence."* Definitive evidence, particularly about rare hazards, is difficult to obtain. Weaker information is likely to be interpreted in a way that reinforces existing beliefs (Slovic et al. 1979). Slovic et al. (1979) discovered that "people's beliefs change slowly and are extraordinarily persistent in the face of contrary evidence. . . . New evidence appears reliable and informative if it is consistent with one's initial belief; contrary evidence is dismissed as unreliable, erroneous, or unrepresentative." They added, "Convincing people that the catastrophe they fear is extremely unlikely is difficult under the best conditions. Any mishap could be seen as proof of high risk, whereas demonstrating safety would require a massive amount of evidence" (Slovic et al. 1979), evidence that is sometimes impossible to obtain in an accurate or timely manner This stubbornness is compounded by the fact that once people make their initial judgments, they believe with overwhelming confidence that they are correct. This phenomenon, called the "overconfidence heuristic," states that people often are unaware of how little they know about a risk, and of how much more information they need to make an informed decision. More often than not, people believe that they know much more about risks than they actually do. Slovic and his colleagues (1979) conducted a study to determine whether people knew if homicides were more frequent than suicides. Of participants who answered incorrectly, 12.5 percent gave odds of 100 to1 that their answer was correct, and 30 percent gave odds of 50 to 1 that their answer was correct. In fact, suicides happen much more frequently than homicides, with an incidence of 1.7 suicides per homicide (CDC 2002).The overconfidence heuristic has been linked to media coverage of other spectacular events, specifically regarding how people's rating of risks is dependent on the amount of media coverage a risk receives. For example, one study showed that a greater percentage of crimes covered by the

media involve perpetrators and victims of different races than occurs in reality. In other words, a news story is more likely to describe a white victim of a black attacker than a black victim of a black attacker, even though the latter is more common. This inconsistency in coverage is seen as the main reason Caucasians overestimate their likelihood of being a victim of interracial crime by a factor of three (Twomey 2001). Paul Slovic writes that "strong beliefs are hard to modify" and "naïve views are easily manipulated by presentation format" (Slovic 1986). Often, only time will change people's opinions about the risks they personally face. One reason that people are more scared of a new risk than an old risk is that they have not been able to gather enough information to alter their initial fearful impression. After time has passed and they realize that their expectations for victimization have not been realized for themselves or anybody they know, they can begin to question the validity of their views.

Elspeth Young of the Australian National University describes social constructs of risk. These are human attributes that define how different people assess risk and determine personal vulnerability. Young (1998) writes:

1. *Socioeconomic characteristics (e.g., age, gender, ethnicity, income, education, employment, and health).* Older people and children may be much more vulnerable than active adults. Poorer people, with fewer capital resources, are likely to suffer far more from the effects of hazards such as flood invasion of their homes. Some specific ethnic groups . . . may be much less able to take advantage of the assistance offered because of communication problems and cultural differences.
2. *People's knowledge of the environment and the hazards that the environment poses to them* e.g., traditional ecological knowledge (TEK). TEK may be effectively used to cope with a situation that outsiders perceive to be threatening, and generally provides much more detailed understanding of local environments. It can be valuable in predicting the threats posed by hazards (e.g., when significant floods are actually likely).
3. *Their ignorance.* . . . For example, people who have newly moved into a vulnerable area often lack knowledge of the actual threats posed by hazards such as severe [wild]fires, and fail to take suggested precautions seriously.
4. *Their ability to cope with those hazards.* [People are able to cope] through technology, financial attributes, education, political power, and having a voice. Knowledge, high levels of education and high incomes generally give people more confidence in articulating their feelings and needs and hence they may be able to cope better with adversity.
5. *Their ability to access help from outside.* Having confidence . . . makes asking for assistance much easier.

The ways in which hazard risk is presented or reported greatly influence how people perceive the hazard. For instance, Slovic and Weber (2002) describe several ways that a risk manager could explain the risk from a nearby factory to an exposed population. All of the measurements will describe the same risk factor, but each one is likely to produce a different number. The ways in which people perceive that number will be different, as well. Such measurements include (Slovic and Weber 2002):

1. Deaths per million people in the population
2. Deaths per million people within **x** miles of the source of exposure
3. Deaths per unit of concentration
4. Deaths per facility

5. Deaths per ton of air toxin released
6. Deaths per ton of air toxin absorbed by people
7. Deaths per ton of chemical produced
8. Deaths per million dollars of product produced
9. Loss of life expectancy associated with exposure to the hazard

Richard Wilson (1979) describes ways in which risks can be compared by calculating risks that increase a person's chance of death by one in one million (0.000001). It must be noted that these risks are population risks as opposed to individual risks. See exhibit 3.12.

Risk comparisons can also cause incorrect perception of risk if they are not presented in an appropriate manner. Kenneth Warner (1989) describes how the media often use vivid comparisons to better explain risks to their audience. He gives the following three examples of comparisons provided by the media to describe the risks associated with cigarette smoking:

1. On average, cigarettes kill as many people as would die if three passenger-laden jumbo jets crashed every day, month after month, year after year.
2. In one year, cigarettes kill more Americans than died in World War I, the Korean War, and the Vietnam War combined.
3. The annual death toll associated with cigarette smoking is equal to that of a hydrogen bomb dropped in the heart of a city such as Miami, Kansas City, Cleveland, or wherever. (Warner 1989)

EXHIBIT 3.12 RISKS WHICH INCREASE CHANCE OF DEATH BY 0.000001 (1 IN 1 MILLION; FOLLOWED BY CAUSE OF DEATH)

- Smoking 1.4 cigarettes (cancer, heart disease)
- Drinking one-half liter of wine (cirrhosis of the liver)
- Spending 1 hour in a coal mine (black lung disease)
- Spending 3 hours in a coal mine (accident)
- Living 2 days in New York or Boston (air pollution)
- Traveling 6 minutes by canoe (accident)
- Traveling 10 miles by bicycle (accident)
- Traveling 300 miles by car (accident)
- Flying 1000 miles by jet (accident)
- Flying 6000 miles by jet (cancer caused by cosmic radiation)
- Living 2 months in Denver on vacation from N.Y.(cancer caused by cosmic radiation)
- Living 2 months in average brick or stone building (cancer caused by natural radioactivity)
- One chest X-ray taken in a good hospital (cancer caused by radiation)
- Living 2 months with a cigarette smoker (cancer, heart disease)
- Eating 40 tablespoons of peanut butter (liver cancer caused by aflatoxin B)
- Drinking Miami drinking water for 1 year (cancer caused by chloroform)
- Drinking 30 12 oz. cans of diet soda (cancer caused by saccharin)
- Living 5 years at site boundary of a typical nuclear power plant in the open (cancer caused by radiation)
- Living 20 years near PVC plant (cancer caused by vinyl chloride [1976 standard])
- Living 150 years within 20 miles of a nuclear power plant (cancer caused by radiation)
- Eating 100 charcoal-broiled steaks (cancer from benzopyrene)

Source: *Wilson, 1979.*

Warner describes how the conceptual differences between the slow death associated with smoking-induced cancer or emphysema and the immediate deaths associated with being shot in a war, incinerated in a hydrogen blast, or killed in a plane crash render such comparisons ineffective. These comparisons attempt to elicit the fear associated with the risk characteristics identified by Slovic et al. (1979). Studies have shown, however, that these types of comparisons lack the desired effect.

People's perceptions of risk can also be influenced by the emotions elicited by a particular report on a hazard. According to a report in the Washington Post, Jennifer Lerner of Carnegie Mellon University discovered that people who watched media reports framed in a way to cause fear, like one on bioterrorism, would likely overestimate their personal exposure to risk. However, people who watched reports that elicited anger, such as ones showing Palestinians and other people celebrating the 9/11 attacks, were likely to perceive their exposure to terrorism as relatively less than the fearful group's perception. Lerner attributes to the effects of these fear-inducing reports the fact that "in surveys conducted after 9/11, Americans felt they faced a 20 percent chance of being a direct victim of future attacks, and felt that the 'average American' faced a 48 percent chance" (Vedantam 2003) of being a victim.

Lerner found that women tended to respond more with fear to terrorism risk-related articles, while men tended to respond more with anger. She contends, "the government and the media can unwittingly alter risk perception by making people either fearful or angry," and further states, "Used responsibly, that connection could also be used to better communicate the real degree of risk" (Vedantam 2003).

Risk Perception Is Necessary for Disaster Management and Communications

Most people do not rely on statistical likelihoods to determine what risks they fear but consider other qualitative aspects, which can be due to attributes of the hazard itself or each individual's personal experience and information exposure. The outcome of these risk perception effects is that there is no single, universal, agreed-upon ranking of hazard risks.

Disaster managers need to consider risk when performing their assessments, but also are influenced by the effects of risk perception, regardless of their knowledge or expertise in risk management. C. J. Pitzer writes in the *Australian Journal of Emergency Management:*

> We make a fundamental mistake when we, as safety managers, deal with risk as a "fixed attribute," something physical that can be precisely measured and managed.
>
> The misconception of risk as a fixed attribute is ingrained into our industry and is a product of the so-called science of risk management. Risk management has created the illusion that risk can be quantified on the basis of probability, exposure to risk, and from the likely consequences of accidents occurring. Risk management science can even produce highly technical and mathematically advanced models of the probabilistic nature of a risk.
>
> The problem with this is that risk is not a physical quantum. It is, instead, a social construction. Everyone has a unique set of assumptions and experiences that shape their interpretations of objects or events. People tend to ignore, "misperceive" or deny events that do not fit their worldview. People find what they expect to find. (Pitzer 1999)

Elspeth Young (1998) writes:

> Risk should not be defined solely by pre-determined, supposedly objective criteria that enable its various levels to be gauged through quantification. It is also a social construct, interpreted differently

> by all of us. Some find certain events or situations unacceptably risky and will do their utmost to avoid being involved, while to others the same events may offer exhilaration and thrills that stimulate their whole purpose of living. There may even be others to whom the particular event is a non-issue, something to be totally ignored. These differences in perception and response, coupled with differences in people's socio-economic characteristics and circumstances, result in a wide range of vulnerability in any community. Social aspects of risk interpretation must be recognized if risk is to be effectively managed, and community participation in the practical management of the problem faced is a vital component of this approach.

When disaster risk managers perform the hazards risk management process, they take many steps during the process that require the use of both qualitative assessments and personal experience and opinions. Because of differences in risk perception, the hazards risk management process can be flawed if risk managers do not accommodate inconsistencies between their own and their constituents' perceptions and reality.

During hazard identification, a hazard first must be perceived as a risk before it is identified as one. Perception is not the same as awareness. An obvious example is a hazards risk management team that is *unaware* that chlorine is used to purify water in the community. Without this knowledge, they may not know that the hazardous chemical (capable of causing mass casualty disasters) is not only transported by truck through populated areas several times a year, but also stored in a location where a leak or explosion could result in many fatalities. This is *not* an issue of risk perception. Now, imagine that the same team is aware of the above information but they have never heard of a disaster actually happening, or the one accident they have heard of did not result in any deaths, and they decide that the chlorine is something they do not need to worry about in their assessment. This is a result of the effects of risk perception (the availability and overconfidence heuristics, in this case).

Risk perception may have the opposite, compounding effect for disaster managers. For instance, it is possible that a risk that is essentially harmless or has extremely low likelihood or consequence is perceived to be much greater than reality by a manager or by the public. Such faulty perceptions on the part of the disaster management team could result in time or funding wasted in mitigation and preparation for a risk that may never happen, at the expense of neglecting a more severe risk that threatens the population to a greater degree. However, if the disaster managers have an accurate impression of a risk and determine that it is low enough to not worry about, while the public perceives it to be significant, they run the risk of appearing negligent. Only effective public education and risk communication can counter the effects of public (mis)perception of risk.

Risk perception can also influence the way the mitigation of a hazard is considered by decision makers or by constituents within a community. If a hazard is not perceived to be a significant risk by those who decide to fund mitigation projects, funding is unlikely to be provided without significant efforts to correct those perceptions. Likewise, if the public does not perceive a hazard to affect them personally, they are unlikely to take any personal measures to prepare or mitigate for that hazard. Once again, the presence of differing risk perceptions highlights the need for effective risk communication as a component of mitigation and preparedness.

Risk perception can lead to difficulties in making important decisions on the management of hazard risks. Slovic and Weber (2002) write:

> Public perception of risk plays an important role in risk analysis, adding issues of values, process, power, and trust to the quantification issues typically considered by risk assessment professionals

> (Slovic 1999). Differences in risk perception lie at the heart of many disagreements about the best course of action. Such differences have been demonstrated between technical experts and members of the general public (Slovic, 1987), men vs. women (Finucane et al. 2000; Flynn et al. 1994; Weber et al. 2002), and people from different cultures (Weber and Hsee 1998, 1999). Both individual and group differences in preference for risky decision alternatives and situational differences in risk preference have been shown to be associated with differences in perceptions of the relative risk of choice options, rather than with differences in attitude towards (perceived) risk, i.e., a tendency to approach or to avoid options perceived as riskier (Weber and Milliman, 1997; Weber, 2001).

Managing risk perceptions is an important component of the hazards risk management process. With an understanding of the perceptions and misperceptions of risk made by their constituents, hazards risk managers can work to correct those misperceptions and address the public's fears and concerns. Failure to do so could easily lead to any of the mistakes discussed here.

Barry Glassner provides one example of the secondary effects of misperception of risk on a community. In the 1990s, the media widely reported on a "crime wave" against tourists in Florida that resulted in 10 murders. Glassner writes,

> [It was called] a crime wave because the media chose to label it as such. Objectively speaking, ten murders out of 41 million visitors did not even constitute a ripple, much less a wave, especially considering that at least 97 percent of all victims of crime in Florida are Floridians. Although the Miami area had the highest crime rate in the nation during this period, it was not tourists who had most cause for worry. One study showed that British, German, and Canadian tourists who flock to Florida each year to avoid winter weather were more than 70 times more likely to be victimized at home (Glassner 1999).

This widespread misperception of risk was not adequately managed and made many tourists think twice before traveling to Florida; the tourism industry suffered as a result.

It is important for risk managers to evaluate personal perceptions because they will undoubtedly influence the process of risk identification, subsequent analysis, and treatment. Because much of the risk identification and analysis processes are based on qualitative information, great discrepancies can exist, even between experts.

Risk managers must be as certain as possible that their assumptions and perceptions concerning risk mirror reality as closely as possible. Risk managers who incorrectly overstate a hazard will devote a disproportionate and inappropriate amount of available resources and time to that hazard.

For hazards risk management to be effective, an overall philosophy of cost-effectiveness must be employed, and without accurate information and risk perceptions, such cost-effectiveness is unlikely.

Disaster risk managers must not assume anything. They must utilize as many historical records and officially recognized hazard profiles as possible. Many public, private, and nonprofit agencies specialize in specific hazards and are likely to have the most accurate information concerning risk likelihood and consequence data.

The public is likely to overestimate some risks and underestimate others, depending on the general risk perception characteristics listed above. If the public collectively overestimates the likelihood or consequence of a particular hazard, such as the presence of a nearby nuclear power plant, then they may demand from public officials a significant effort to decrease what they see as a great risk. While initiating an increased level of preparedness and mitigation may not be a particularly effective and efficient use of resources, simply ignoring the public's concerns can have significant political implications.

With an understanding of the public's perceptions, disaster risk managers can initiate a program of risk communication and public education to increase understanding and steer public concern toward risks of greater consequence and likelihood, such as house fires and floods.

Conversely, disaster risk managers should be aware of a collective public risk perception that underestimates the incidence or consequences of a certain hazard, such as underground power lines. A significant number of people have been killed who made contact with underground power lines while performing construction or landscaping work. Public education campaigns have regularly stressed to citizens the significance of the hazard. Similar campaigns are employed for risks such as drug abuse, forest fires, smoking, poisons, and so on. These risks tend to be ones that kill many more people than all natural hazards combined, but are not considered appropriately "risky" by the public.

The Term Safe

Those involved in disaster risk management are often faced with defining what level of safety from hazard exposure is considered sufficient. There is not necessarily a correct answer to the question "How safe is safe enough?" (Derby and Keeney 1981). Most people assume that referring to something as "safe" implies that all risk has been eliminated. However, because such an absolute level of safety is virtually unattainable in the real world, risk managers must establish thresholds of risk that define a frequency of occurrence below which society need not worry about the hazard. Derby and Keeney (1981) contend that a risk becomes "safe" or "acceptable" if it is "associated with the best of the available alternatives, not with the best of the alternatives which we would *hope* to have available" (emphasis added).

This definition can cause great disagreement between the public and disaster risk management officials. The public may expect a level of safety determined to be zero risk for some hazards, such as terrorism in the United States. Officials may need to continually recalibrate the public's perception of these hazards to let the public know that, while the risks are in fact still possible, they have been mitigated to the best of the country's or community's social, economic (available resources), and technological abilities. While the chances of a terrorist attack will always exist, governments strive to attain levels of security dictating that the risks are so low that people need not worry.

To determine what level of safety is most acceptable, Derby and Keeney (1981) contend that "the best combination of advantages and disadvantages" must be chosen from among several alternatives. For instance, although the risk of car accidents is one of the greatest we face on a daily basis, eliminating the risk by prohibiting the use of cars is impractical. However, we can make cars more resistant to impact, add seat belts and air bags, and enact laws and regulations that limit the ways in which cars are operated. The result is a level of safety upon which society agrees is acceptable in relation to the benefits (mobility) retained.

Paul Barnes of the Australia Department of Primary Industries explains the importance of establishing an agreement on what constitutes safety in the community. He writes:

> Is our goal Community Safety or Safer Communities? As a societal outcome, Community Safety can be sought via efficient and effective regulation at an institutional level. Associated with this regulation must be similarly high standards of risk management applied at the community level. The establishment of safer communities, however, is a different matter. Before this can be sought as a goal, determinations must be made about what safety means to the communities themselves. To do this, institutional regulators must ensure that use of their expertise does not promote inflexibility in understanding the world-views of the public. (Barnes 2002)

CONCLUSION

Reduction of risk and vulnerability is paramount to reducing the injuries, deaths, and damages associated with disasters. All nations, regardless of their wealth or facilities, have the capacity to address the root causes of risk. Yet for most nations, the focus of disaster risk management is on the post-disaster—namely response and recovery. Global efforts, including the Hyogo Framework for Action and the Post-2015 Framework for Disaster Risk Reduction, have attempted to raise the bar and call nations to action. The roots of risk and vulnerability run deep, however, and simple structural answers to the problems that persist will not be enough. By looking at how disaster risk management, sustainable development, and, to a rapidly increasing degree, climate change adaptation, together serve to build resilience, rising trends in disaster risk may soon be stabilized and, with luck, reversed.

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