3

Risk and 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 generally is impossible.

On the individual level, each person is primarily responsible for managing the risks he faces as he 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 wearing a ski 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 large-scale hazards, many of which were identified in Chapter 2, vulnerability is most effectively reduced by disaster 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, hazard 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 following recovery.

This text focuses on the management of international disasters, which are those events that overwhelm an individual nation or region's ability to respond, thereby requiring the assistance of the international body of response agencies. This chapter, therefore, focuses not upon individual, daily risks and vulnerabilities, but on the risks and vulnerabilities that apply to the large-scale hazards like those discussed in Chapter 2.

Two Components of Risk

Chapter 1 defined risk as the interaction of a hazard's consequences with its probability or likelihood. This is its definition in virtually all 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 & 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 & Wharton 1992).

Likelihood

"Likelihood" can be given as a probability or a frequency, whichever is appropriate for the analysis under consideration. Variants of this definition appear in virtually all risk management documents. "Frequency" refers to the number of times an event will 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* averages around 1 per 81 million miles driven (Dubner & Levitt, 2006).

In contrast to frequency, "probability" refers to single-event scenarios. Its value is expressed as a number between 0 and 1, with 0 signifying a zero chance of occurrence and 1 signifying certain occurrence. Using the auto accident example, in which the frequency of death is 1 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 was to drive 81 miles.

Disaster managers use this formula for risk to determine the likelihood and the consequences of each hazard according to a standardized method of measurement. The identified hazard risks thus can be compared to each other and ranked according to severity. (If risks were analyzed and described using different methods and/or terms of reference, it would be very difficult to accurately compare them later in the hazards risk management process.)

This ranking of risks, or "risk evaluation," allows disaster managers to determine which treatment (mitigation and preparedness) options are the most effective, most appropriate, and provide the most benefit per unit of cost. Not all risks are equally serious and risk analysis can provide a clearer idea of these levels of seriousness.

Without exception governments have a limited amount of funds available to manage the risks they face. While the treatment of one hazard may be less expensive or more easily implemented than the treatment of another, cost and ease alone may not be valid reasons to choose a treatment option. Hazards that have 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 the limited funds, disaster managers generally should recommend first treating those risks that pose the greatest threat. Fiscal realities often drive this analytic approach, resulting in situations in which certain hazards in the community's overall risk profile are mitigated, while others are not addressed at all.

The goal of risk analysis is to establish a standard and therefore comparable measurement of the likelihood and consequence of every identified hazard. The many ways by which likelihoods and consequences are determined are divided into two categories of analysis: quantitative and qualitative. Quantitative analysis uses mathematical and/or statistical data to derive numerical descriptions of risk. Qualitative analysis uses defined terms (words) to describe and categorize the likelihood and consequences of risk. Quantitative analysis gives a specific data point (e.g., dollars, probability, frequency, or number of injuries/fatalities), while qualitative analysis allows each qualifier to represent a range of possibilities. It is often cost and time prohibitive, and often not necessary, to find the exact quantitative measures for the likelihood and consequence factors of risk. Qualitative measures, however, are much easier to determine and require less time, money and, most important, expertise to conduct.

For this reason, it is often the preferred measure of choice. 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: 4 times per year, 1 time per decade, 10 times a month, and so on. Probability measures the same data, but the outcome is expressed as a measure between 0 and 1, or as a percentage between 0% and 100%, representing the chance of occurrence. For example, a 50-year flood has a 1/50 chance of occurring in any given year, or a probability of 2% or 0.02. An event that is expected to occur two times in the next 3 years has a 0.66 probability each year, or a 66% chance of occurrence.

Qualitative Representation of Likelihood

Likelihood can also be expressed using qualitative measurement, using words to describe the chance of occurrence. Each word or phrase has a designated range of possibilities attached to it. For instance, events could be described as follows:

- *Certain*: >99% chance of occurring in a given year (1 or more occurrences per year)
- *Likely*: 50–99% chance of occurring in a given year (1 occurrence every 1–2 years)
- *Possible*: 5–49% chance of occurring in a given year (1 occurrence every 2–20 years)
- *Unlikely*: 2–5% chance of occurring in a given year (1 occurrence every 20–50 years)
- *Rare*: 1–2% chance of occurring in a given year (1 occurrence every 50–100 years)
- *Extremely rare*: <1% chance of occurring in a given year (1 occurrence every 100 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).

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 U.S. dollars for international comparison)

Although attempts have been made to convert all three factors into monetary amounts to derive a single number to quantify the consequences of a disaster, doing so can be controversial (How can one place a value on life?) and complex (Is a young life worth more than an old life? By how much?).

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 upon 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."

Members of assembled disaster management teams are likely to be from different parts of the country or the world, and all have different perceptions 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% 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 in 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 upon 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 as 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 (adapted from EMA, 2000):

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 hospitalization
4. *Major.* Extensive injuries; significant hospitalization; fatalities
5. *Catastrophic.* Large number of severe injuries; extended and large numbers requiring hospitalization; significant fatalities

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 "over 20 fatalities" for "Catastrophic," the confusion could be alleviated even more.

Therefore, it is often most appropriate and convenient to maintain a distinction between these three factors.

Categories of consequence can be further divided, and often are to better understand the total sum of all disaster consequences. Two of the most common distinctions are direct and indirect losses, and tangible and intangible losses.

Direct losses, as described by Keith Smith in his book *Environmental Hazards*, are "those first order consequences which occur immediately after an event, such as the deaths and damage caused by the throwing down of buildings in an earthquake" (Smith, 1992). Examples of direct losses 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.)
- Relocation costs/temporary housing
- Loss of business inventory/agriculture
- Loss of income/rental costs
- Community response costs
- Cleanup costs

Indirect losses (also as described by Smith, 1992) may emerge much later and may be much less easy to attribute directly to the event. Examples of indirect losses include:

- Loss of income
- Input/output losses of businesses
- Reductions in business/personal spending ("ripple effects")
- Loss of institutional knowledge
- Mental illness
- Bereavement

Tangible losses are those for which a dollar value can be assigned. Generally, only tangible losses are included in the estimation of future events and the reporting of past events. Examples of tangible losses include:

- Cost of building repair/replacement
- Response costs
- Loss of inventory
- Loss of income

Intangible losses are those that cannot be expressed in universally accepted financial terms. 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 losses are almost never included in damage assessments or predictions. Examples of intangible losses include:

- Cultural losses
- Stress
- Mental illness
- Sentimental value
- Environmental losses (aesthetic value)

Although it is extremely rare for benefits to be included in the assessment of past disasters or the prediction of future ones, it is undeniable that they can exist in the aftermath of disaster events. 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
- Local/state/federal funds for reconstruction or mitigation
- Environmental benefits (e.g., fertile soil from a volcano)

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 incurred in a past event or the expected 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*.

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 often are combined). The following list is one example of a qualitative measurement system for injuries and deaths:

- *Insignificant*. No injuries or fatalities
- *Minor.* Small number of injuries but no fatalities; first aid treatment required

- *Moderate*. Medical treatment needed but no fatalities; some hospitalization
- *Major*. Extensive injuries; significant hospitalization; fatalities
- *Catastrophic*. Large number of fatalities and severe injuries requiring hospitalization

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 (can include both official and unofficial responders) 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 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.
- *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 a small impact in one could be catastrophic to another, so the measurement system should 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 number of deaths just from car accidents in a 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).

Trends

Both the likelihood and the consequences of certain hazard risks can change considerably over time. Some hazards occur more or less frequently because of worldwide changes in climate patterns, while others change in frequency because of measures taken to prevent them or human movements into their path. 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

Changes in disaster frequency can be the result of both an increase in actual occurrences of a hazard and an increase in human activity where the hazard already exists. It is important to remember that a disaster is not the occurrence of a hazard, but the consequences of a hazard occurring. 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 (El Niño) or man-made (global warming). 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 also can 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, it increases its risk to property from flooding.

Changes in Disaster Consequences

Similar to changes in disaster likelihoods, changes in consequences can be the result of changes in the attributes of the actual hazard or changes in human activity that place people and structures at either more or less risk.

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 bombings of the U.S. embassies in Kenya and Tanzania and the September 11 attacks on the World Trade Center and the Pentagon together display an increase in the consequences of terrorist attacks aimed at Americans. 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 HIV, the West Nile virus, mad cow disease, and SARS.

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 at risk 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.* Individuals, communities, and nations are increasing their interdependence on each other. The SARS epidemic showed how a pathogen could quickly impact dozens of countries on opposite sides of the world through international travel. In the late 1990s, the collapse of many Asian economies sent ripple effects throughout all the world's economies. The September 11 terrorist attacks in the United States caused the global tourism market to slump.

Disaster managers must investigate the validity of the trends they identify. It is common for a trend to exist that is based on incomplete records. The technology used to detect many hazards has improved, allowing for detection where it formerly was much more difficult or impossible. Therefore, the lack of recorded instances of certain disasters could possibly be based on a lack of detection methods.

Computing Likelihood and Consequence Values

Because there is rarely sufficient information to determine the exact statistical likelihood of a disaster occurring or to determine the exact number of lives and property that would be lost should a disaster occur, using a combination of quantitative and qualitative measurements can be useful. By combining these two methods, the hazards risk management team 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 undertaken by disaster managers depends on three factors: the amount of time and money available, the risk's seriousness, and the risk's complexity. According to the information they gather during the identification and characterization of the hazards, disaster managers must decide what level of effort and resources each individual hazard requires.

Each hazard analyzed can be considered according to the range of possible intensities it could exhibit. Depending on its characteristics, the hazard may be broken down according to intensity, with a separate analysis performed for each possible intensity. The likelihood and consequences for each category of intensity will be different, which in turn results in different treatment (mitigation) options (see Exhibit 3–2).

For instance, the general hazard of "earthquake" could be divided into events of magnitude 4, 5, 6, or 7, and so on. Generally, the lower the intensity of an event, the greater the likelihood of that event occurring, while its consequences tend to decrease. Several thousand earthquakes of very low intensity and magnitude occur daily with few or no consequences at all. However, the rarer large earthquakes must be treated differently because of their potential to inflict massive casualties and damages.

The degree of subdivision of hazards into specific intensities also depends upon the available time and resources. More divisions will give disaster managers a more comprehensive assessment, but a point will come when the added time and resources spent no longer provide enough added value.

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.

EXHIBIT 3–2: f:N CURVES

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 3–1.

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.

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 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 upon 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 upon 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 (see Figure 3–1).

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 1. A 20-year flood has a 5% 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 earthquakes, terrorism, or nuclear accidents. This inability to achieve precision is a fundamental reason that qualitative measures are used in the final determination of a hazard's likelihood.

Rare and extremely rare hazards, such as terrorist attacks, nuclear accidents, or airplane crashes (outside of communities where airports exist) may have few if any data points to base an analysis upon. However, this does not mean that there is a 0% 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.

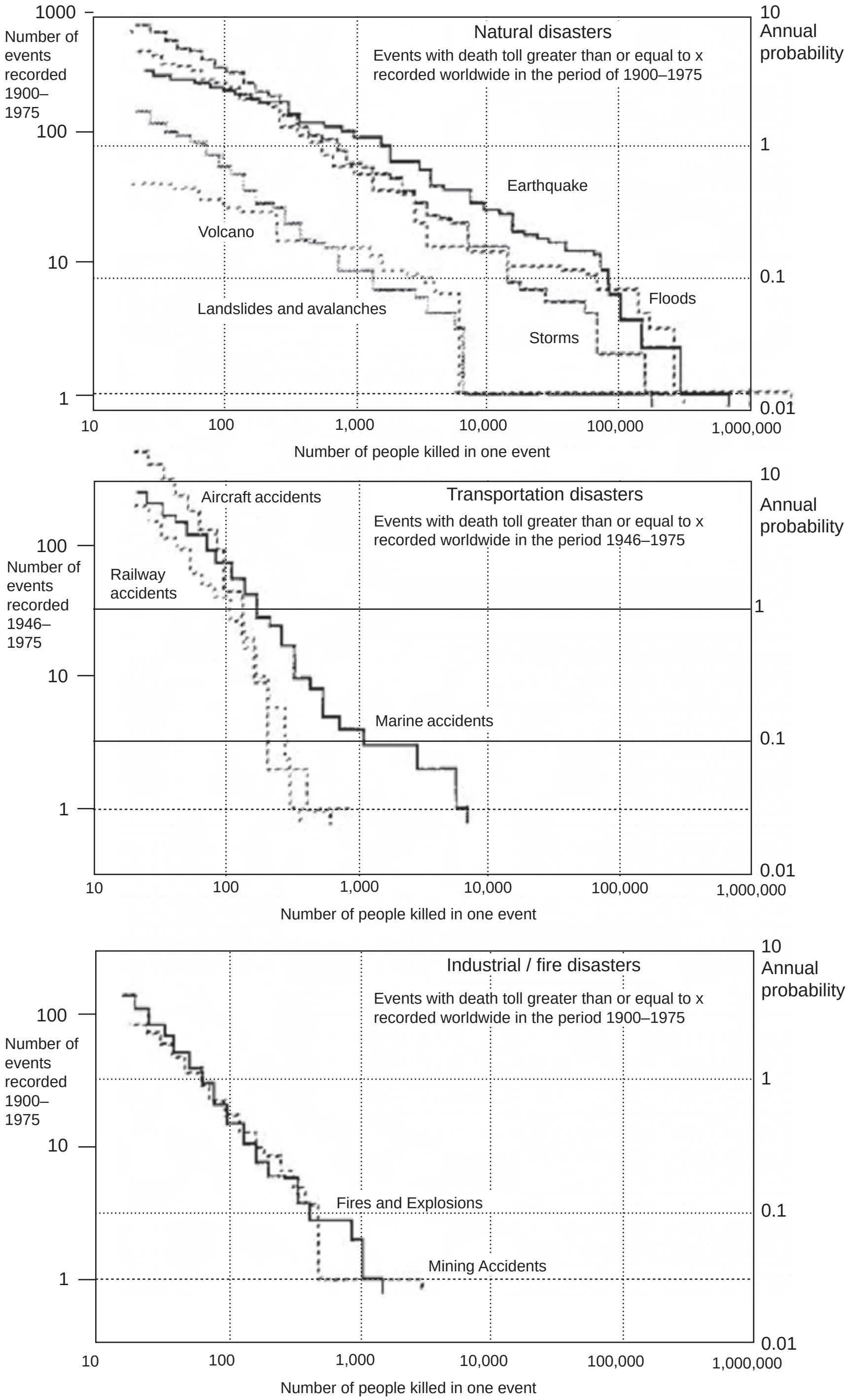

FIGURE 3–1 Examples of worldwide hazard f:N curves. (From UNDP, 1994)

The more often that a disaster occurs, the more data points those performing the quantitative likelihood assessment will have, and the more accurate the historical analysis will be (given that the collected data is accurate). However, more information must be examined than simply the number of events per year.

The concept of increasing and decreasing trends in hazard likelihoods and consequences was previously introduced. Both infrequently and frequently occurring disasters tend to exhibit either falling or rising trends over time, rather than having 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 community has sustained approximately 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 discovers 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 1 per year 40 years ago to 70 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 different 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.

In the section addressing vulnerability, we will explain the process of describing the community and the environment. 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 upon 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 the hazard but also at the vulnerability of each structure. For instance, imagine that a school is located in a floodplain. Disaster managers have obtained information indicating that the school has been raised to an elevation where it will only be affected by floods of magnitude greater than the 50-year (2% chance/year) flood. Using this information, disaster managers can deduce that such a structure will likely sustain no damage during the course of a 20-year (5% chance/year) flood event.

While disaster managers will likely not have the value of all structures within the community or be able to determine complete data pertaining to lost revenue and inventory, such data deficiencies probably will be consistent across all hazard consequence analyses and will probably not cause unreliable results; more data generally result in more accurate assessments. However, the amount of data that can be collected will always be a factor of available time and resources. 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 for almost any lack of accuracy.

Deaths/Fatalities and Injuries

Disaster managers can estimate the number of people who will be hurt or killed by using two methods: estimation based upon historical data and changes in population or modeling techniques.

To estimate the numbers of deaths and injuries using historical data, disaster managers must first assemble the data on historical incidences of disasters caused by the particular hazard. Then, using current data on the community, a conversion to current conditions can be made. For example, imagine that a Category IV hurricane struck a community in 1955, causing 4 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 6 deaths and 52 injuries if a Category IV hurricane struck today.

It must be kept in mind that these estimates do not account for mitigation measures taken or new development in the period between disasters. The more recently a comparable disaster has occurred, the more accurate the conversion 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 Federal Emergency Management Agency (FEMA), can increase the accuracy of injury and death estimations.

Modeling Techniques

Various computer-modeling techniques are available to assist disaster managers in estimating the injuries and deaths that would occur should a disaster strike. For instance, HAZUS-MH can be used to estimate the numbers of injuries and fatalities that would result from earthquakes of varying magnitudes, strong winds associated with cyclonic storms, and floods. There are many other models that give estimates for other hazards including 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 to be 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

If disaster managers choose to perform a lower level of analysis on the consequences of the community's hazards, two pieces of information are needed. The first is the historical incidence of hazard damage for each disaster. The second piece of information is data on the population/structural changes in the community since the date of each historical disaster in order to compare to present-day data. Once that data are assembled, the team can calculate damages as they would be expected to affect the community as a comparison between the dates. For instance, imagine that a flood (of a specific magnitude) in 1955 caused $1 million in damages in a community. The community is found to have grown approximately 50% *in the floodplain* in the intervening years. Using this information, the hazards risk management team can estimate the consequences of a future event of similar magnitude to be approximately $1.5 million in 1955 dollars, or $11,884,047 in 2009 dollars. Currency inflation converters are widely available on the Internet: see www.westegg.com/inflation/.

If a certain hazard has not affected the community over a significantly extended period of time, or if it has never affected the community, the team may want either to use data from an example of the hazard affecting a community of comparable structure and size or to avoid performing a quantitative analysis for the rare hazard.

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.

To track calculated figures, a standardized worksheet is often created. One example of a standardized worksheet provided by FEMA is shown in Figure 3–2.

Each hazard will affect structures and their contents differently. Many organizations and institutions have made available tables to determine this information for specific hazards. To perform a full damage consequence analysis, disaster managers will need to have 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 inventory (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 disaster managers 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 society, causing widespread human, material, or environmental losses which exceed the ability of the affected society to cope using only its own resources" (UNDP, 1994). 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 upon which to base their new or acquired system of measurement.

Creating two measures of consequence can be beneficial: one measuring the tangible physical/material losses associated with cost and another measuring the intangible losses of deaths/fatalities and injuries. Each qualitative term should have two measures associated with it, corresponding to deaths/injuries and costs. In many instances, the tangible and intangible rankings will not be the same. For instance, there may be no physical damages to structures in a chemical spill, 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

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										Structure Loss + Content Loss + Function Loss ($)
Name/ Description of Structure	Average Daily Operating Budget ($)	x	Functional Downtime **(# of days)**	+	Displacement Cost per Day ($)	x	Displacement Time ($)	=	Structure Use & 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 3–2 FEMA standardized loss estimation worksheet. (From FEMA, 2001)

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 5 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 20 years
Unlikely	Is not expected to occur; and/or no recorded incidents or anecdotal evidence; and/or no recent incidents in associated organizations, facilities, or communities; and/or little opportunity, reason, or means to occur; may occur once every 100 years
Rare	May occur only in exceptional circumstances; may occur once every 500 or more years

Source: EMA (2000).

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, the disaster managers can assess each hazard 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).

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 hazards risk management team will choose whichever ranking is greater. (Differences between the severity of human and material losses 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 hazards risk management team would probably 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 for the country or community being assessed by the disaster manager. Using the processes listed earlier and in Chapter 2 to identify hazards that threaten the community, characterize them, and determine their likelihoods and consequences, the disaster managers will have gathered the information necessary to carry out the risk evaluation.

By the time the risk evaluation process begins, each hazard will have been identified, described, mapped, and analyzed according to its likelihood of occurrence and its consequences should a disaster occur. All countries and communities undoubtedly face a range of natural, technological, and intentional hazards, each of which requires a different degree of mitigation and risk reduction.

Table 3–2 An Example of a Qualitative Consequence Measurement System

Descriptor	**Human Life and Health**	**Property, Financial, Environmental**
Insignificant	No injuries or fatalities Small number or no people are displaced and only for a short duration Little or no personal support required	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 (<24 hours) Some personal support required Some disruption (<24 hours)	Some damage Small impact on environment with no lasting effects Some financial loses
Moderate	Medical treatment required but no fatalities; some hospitalization Localized displacement of people who return within 24 hours	Localized damage that is rectified by routine arrangements; normal community functioning with some inconvenience Some impact on environment with long-term effect Significant financial loss
Major	Fatalities Extensive injuries, significant hospitalization Large number displaced (>24 hours' duration) 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	Significant fatalities Large number of severe injuries Extended duration and large numbers requiring hospitalization General and widespread displacement for extended duration	Extensive damage Extensive personal support Community unable to function without significant support Significant impact on environment and/or permanent damage

Source: Cameron (2002).

Unfortunately, communities are rarely able to dedicate sufficient resources to mitigation to lower all of the community's risks to the lowest possible levels.

As will be shown in Chapters 4 and 5, there are hazards for which the technology exists for mitigation but are cost prohibitive. An example of a risk mitigation measure that is very expensive is the conversion (retrofit) at wastewater treatment plants to less dangerous chemicals, such as using liquid chlorine bleach or other disinfection technologies instead of the more volatile chlorine gas. Exhibit 3–3 illustrates the danger posed by chlorine gas, which is still widely used despite its known dangers.

Other risks may have many options available, each with an associated cost and benefit. Some have direct risk reductions with each incremental increase in cost. A classic example is the practice of increasing the number of firefighters or police officers in a community, which, until reaching a threshold, results in decreased fire hazard risk and decreased crime risk.

Fortunately, however, not all risks require immediate action, and some no action at all. These include those risks for which both the likelihood and the consequences of the risk are extremely low, such as a small meteor strike. While some risks can be reduced easily, others may require

EXHIBIT 3–3: 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 2 or 3 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 [U.S.] Environmental Protection Agency has distributed guidelines that encourage U.S. 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.

Source: Davis (2002).

exorbitant cash resources, time, and a committed effort to achieve even slight reductions. These possibly limiting factors must also be considered by disaster managers.

In addition to actual reductions in risk related to the likelihood and consequences of a hazard, several risk factors must be considered that weigh heavily on the perceived "seriousness" of the risk and therefore affect mitigation priorities. For instance, a man-made risk is likely to be considered much less "acceptable" than one that is natural in origin. The degree to which these man-made risks are perceived to be unacceptable can be an important determining factor in assigning mitigation funding. Smith (1992) discusses voluntary and involuntary risks and states, "[T]here is a major difference between voluntary and involuntary risk perception with the public being willing to accept voluntary risks approximately 1000 times greater than involuntary risks."

Risk perception issues also weigh heavily upon such 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 later in the Section entitled "Vulnerability").

There are also risks that societies are able to eliminate altogether but choose not to because the benefits that result from such risks would also disappear (see Exhibit 3–4). This essentially implies

EXHIBIT 3–4: 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 over 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.

that, when evaluating risks, disaster managers must also consider the negative consequences of mitigation or elimination. Eliminating certain beneficial risks results in adverse effects on the community or society. Examples of situations where the benefits are believed to outweigh the risks include the aesthetic value to homeowners and collected property taxes for the community from beachfront property construction; collected taxes and created jobs for a community that result from the existence of a factory that produces, stores on-site, or emits hazardous materials; and the reduced reliance on fossil fuels and cheaper power generation costs that exists as result of a nuclear power plant.

One of the primary goals of disaster managers is to formulate a prioritized list of hazard risks to be mitigated. This list should be based upon a combination of factors that includes the hazard's likelihood and consequences, the county's or community's priorities and criteria (regarding their views on the acceptability of different risks), the benefit-to-cost ratios of mitigating different risks, and the political and social ramifications of certain mitigation decisions.

Hazards were examined individually in each previous step of this process. During the risk evaluation step of the process, risks are compared to each other and questions of priority begin to be answered. Prioritization can take place by many methods, and while there is no single correct method, there are many that have been used with success in the past.

The following may be used to determine the prioritization of risk treatment:

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

The final output of risk evaluation should be a prioritized list of risks, which will be used to decide 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 managers can now begin comparing and ranking the identified risks.

To compare hazards according to their likelihood and consequences, the team must select or create a risk matrix to suit the needs of the country or community. A risk matrix is a direct comparison of the two components of a hazard's risks. In other words, it plots the likelihood and consequence of hazards together in various combinations, with one risk component falling on the *x* axis and the other on the *y* axis.

While it does not matter which of these two risk components goes on which axis, the values used must exactly match the values used in the risk analysis qualitative assessments. Because the terminology must be consistent throughout the process of "calculating" risk from likelihood and consequence, much 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 representing unique combinations of likelihood and consequence. The likelihood and consequence values upon which the individual boxes are based can be determined by tracing from that box back to the values indicated on each axis. The number of possible combinations will be the product of the number of likelihood values times the number of consequence values (i.e., if there are 5 values for likelihood and 6 for consequence, the matrix will have 30 possible combinations required to evaluate risk).

Disaster managers must decide whether to use a preexisting risk matrix or to make a custom risk matrix that suits their specific needs. If they choose to create their own systems of qualitative measurement in the risk analysis process, they must make 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, disaster managers must first establish levels, or "classes," of risk representing increasing severity. The levels should range from those that are so low that mitigation is not necessarily needed to risks that are so high that efforts to mitigate them are of highest priority.

One example of such a system is described in the FEMA's "MultiHazard Identification and Risk Assessment" publication (1997). Their risk matrix values are:

1. *Class A*. High-risk condition with highest priority for mitigation and contingency planning (immediate action)
2. *Class B*. Moderate to high-risk condition with risk addressed by mitigation and contingency planning (prompt action)
3. *Class C*. Risk condition sufficiently high to give consideration for further mitigation and planning (planned action)
4. *Class D*. Low-risk condition with additional mitigation contingency planning (advisory in nature)

Emergency Management Australia (EMA, 2000) described risks according to the following breakdowns:

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

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

Once these values have been determined and defined as they apply to the disaster manager's priorities, they should be assigned to each combination of likelihood and consequence shown on the matrix. How they are assigned must be determined by personal judgment, expert knowledge, and previously established risk management criteria. An example of a risk matrix from FEMA is shown in Figure 3–3.

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)

Once the values have been assigned to each box on the matrix, each hazard can be evaluated accordingly and the derived values recorded. Because each "risk level" will likely be assigned to more than one matrix box, and because several risks could elicit the same combination of likelihood and risk, the hazards risk management team will not be creating an ordered list of risk priorities, but rather

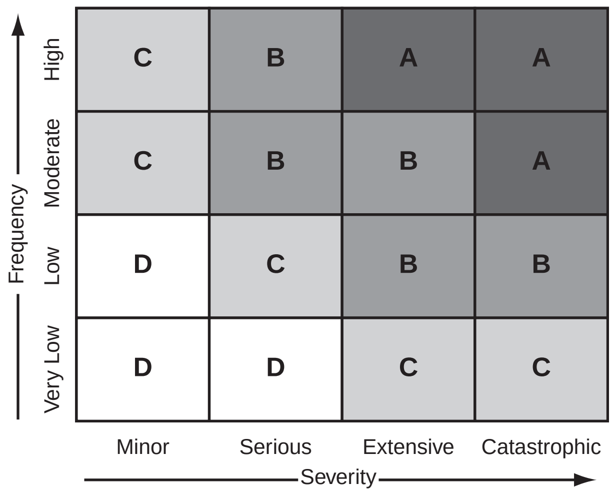

FIGURE 3–3 FEMA "MultiHazard Identification and Risk Assessment" risk matrix.

several categories of risk with several hazards falling within each category group. In other words, the disaster manager will have several "classes" of risks, each containing several risks 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 would be considered equal risks according to the risk matrix. The results of the risk matrix allow disaster managers to further classify the hazards threatening their country or community but do not provide a definitive list of priorities for mitigation. Such a list requires further evaluation, as will be described.

It is helpful for disaster managers to begin recording the results of their evaluations on a concise form that allows fast and easy reference to risk evaluation output data so these data can be more easily compared in the prioritization step. Risk registers, as they are called, provide a useful tool, and should include the following information:

- Name of the risk (including specific magnitude and/or intensity if the risk has been broken down into these categories)
- Qualitative likelihood value
- Qualitative consequences value
- 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 have different risk perceptions, and because there may be more risks than there are resources to mitigate them, disaster managers must develop risk evaluation criteria before any risk identification or analysis takes place. Risk evaluation criteria help disaster managers and citizens make judgments about what they consider to be the most serious risks and set forth performance measures to judge progress in mitigating the community's risks.

In establishing these contextual criteria, disaster managers will also define the political, social, economic, legal, and physical environment within which all of the hazards can occur. Some of 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 managers would also define their analysis as it relates to mitigating the country's or community's hazards. This could include several or all of the following:

- Legal requirements
- Cost and equity
- Risks that are clearly unacceptable
- Risks that should be kept as low as reasonably practicable

Additionally, risks that have been evaluated according to the risk matrix will need to be verified for accuracy. It is possible that a risk may have been placed in a category that defines it as either too great or not great enough—only further analysis can correct such errors.

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 disaster managers?).
2. Identify which risks require treatment by the disaster managers.
3. Further evaluate risks using judgment based upon available data and anecdotal evidence to determine the accuracy of the final risk value recorded.

A risk that might be better mitigated by another local, regional, or national agency is hazardous material exposure and other accidents that might occur at or from an extrajurisdictional utility (like a nuclear power plant) adjacent to a second country or community. Hazards created in one jurisdiction but whose consequences affect another have caused many cantankerous debates throughout history. These types of cross-jurisdictional problems are most severe on 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.

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.
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."

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)*

For each risk, the levels of risk acceptability (by both the public and the disaster managers) must be determined for the level of mitigation effort required to be determined. Risk acceptability will be discussed in greater detail in the Section entitled "Risk Perception."

Once the risk levels of each hazard have been compared to the previously established risk evaluation criteria, the risks must be prioritized, or ranked in the order that the disaster managers feel they should be addressed.

This prioritization can be accomplished in many ways, most of which rely upon the information gathered in the previous steps of the process and build upon the results of the risk matrix. Risk prioritization takes the evaluation of a country or community's hazards beyond merely comparing risks as factors of likelihood and consequence, and uses the expert judgment of the hazards risk management team to add experience, knowledge, and contextual influence to the final determination of mitigation priority.

In risk prioritization disaster managers must consider the degree of control over each risk and the cost, benefits, and opportunities presented by each risk, and decide which risks are unacceptable at any cost.

One such method for the evaluation of risk, the so-called SMAUG approach, designed by Benjamin Tregoe and Charles Kepner, has gained wide acceptance by emergency managers in Australia and New Zealand.

According to this methodology, disaster managers consider five individual factors in 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):

1. **Seriousness**
   a. The risk will affect many people and/or will cost a lot of money (see Exhibit 3–5).
   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).

Using the SMAUG criteria for evaluation, disaster 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, due to their absolute unacceptability. However, for 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 upon the acceptability of risk.

Unfortunately, no disaster manager will ever have complete information about all risks faced by the country or community regarding 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 the disaster manager did have all of this information, determining risk acceptability and making mitigation decisions would be simple. However, in the absence of this 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 the known information.

EXHIBIT 3–5: 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 extreme event hazards that are man-made and intentional, 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 they preferred banks located near major highways and banks with a single point in the lobby from which they 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, which could be factored into quantitative risk assessments."

"More significantly, protection against 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 defend our buildings against them. However, if adversaries know or can easily learn about their target'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 more important to take into account. For example, metal-screening devices 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 fell 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 shored up quite inexpensively, focusing protective investments there can lead to wasted resources if adversaries choose to attack targets that cannot be shored up 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) concludes that security improvements are generally more costly than safety improvements: '[I]nvestment 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).

Because disaster managers do not work in a vacuum, many factors—political, social, or 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.

The disaster managers have thus far identified the risks affecting the country or community, analyzed them individually, and evaluated them collectively. They are now left with an ordered list of risks that they must consider for treatment. Ideally, they would treat all risks such that nobody would have to worry about them ever again, but that risk-free-world scenario is inconceivable despite modern technology and engineering. While most risks can be reduced by some amount, 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 ultimate decisions made by disaster managers, mostly because 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

Derby and Keeney (1981), two risk management experts, wrote:

> *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 continued:

> *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.

The United Nations Development Programme (UNDP) training program in Vulnerability and Risk Assessment (UNDP, 1994) described the differences in individual acceptance between risks that are voluntary and involuntary:

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.

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 choice 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 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 mitigation alternative would cost and what other possible risk mitigation measures would be offset through funding of a specific mitigation effort.

In general, disaster managers will have to address the costs of reducing a risk in terms of the benefits (actual risk reduction) that would result. Some communities have chosen to simply live with a risk because the costs of mitigating its consequences are prohibitive, and eliminating the risk 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 a great risk. 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 for the benefit of having affordable cars. Even if manufacturers spent the money to make cars completely "safe" for occupants, however, there would still be an inherent risk associated, as indicated by the great number of fatalities that are caused by pedestrians who are struck by cars (shown in Figure 3–4). The cost of totally eliminating this particular risk associated with automobiles is inconceivable.

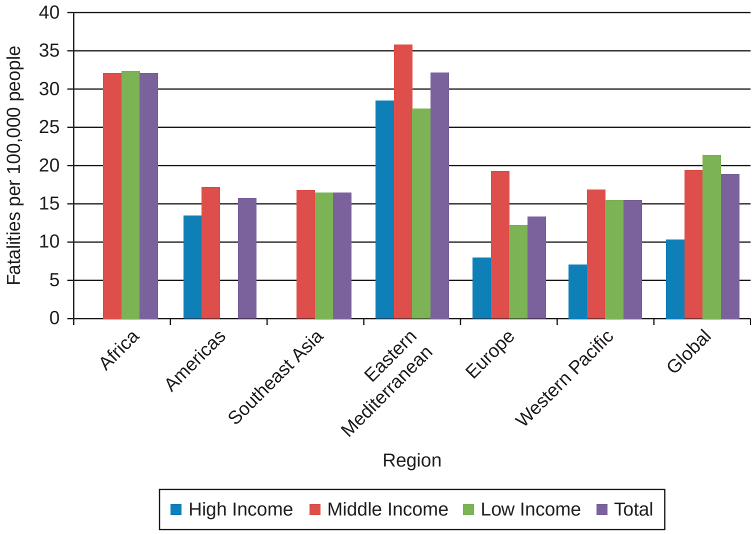

FIGURE 3–4 Worldwide road traffic fatalities. (From WHO, 2009)

W. Kip Viscusi, in the Chapter "Economic Foundations of the Current Regulatory Reform Efforts" (1996), described how the economics of an acceptability decision can be influenced by the political and social aspects of that decision. To illustrate his point, he produced 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.

"Injustices" are commonly seen in the disaster management decision-making process, especially concerning the treatment and acceptability of hazard risks (MPPP, 1999). Following are three criticisms of the processes by which risk acceptability is determined:

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 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, or 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

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	3500.00
EDB	2.5 in 10,000	0.002	15,600.00
Formaldehyde	6.8 in 10,000,000	0.010	72,000.00

Viscusi (1996) assumed that $2.8 million per life saved was an acceptable cost. Any cost greater than $2.8 million per life fails the cost–benefit test.
Source: Viscusi (1996).

shown by 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 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 property 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

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	0.1
Oil and gas well service	1.1 in 1,000	50	0.1
Cabin fire protection	6.5 in 100,000,000	15	0.2
Passive restraints/belts	9.1 in 100,000	1850	0.3
Underground construction	1.6 in 1,000	8.1	0.3
Alcohol and drug control	1.8 in 1,000,000	4.2	0.2
Servicing wheel rims	1.4 in 100,000	2.3	0.2
Seat cushion flammability	1.6 in 10,000,000	37	0.6
Floor emergency lighting	2.2 in 100,000,000	5	0.7
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	0.310	2.8

Source: Viscusi (1996).

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, disaster managers must consider each hazard according to its current risk level and determine if the risk is too great to be left as is. If it is determined to be too great, they must analyze what can be done to reduce the risk, and then make another determination as to the acceptability of the new risk level.

Several methods for determining the acceptability of risks have been developed in the past, and are used to varying degrees (dependent upon 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 bioaccumulating in birds and mammals and was feared to eventually lead to a "silent spring" (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), the chemical was banned from use. There were alternatives to DDT, and while they may not have been as cost-efficient or -effective, they were not perceived as being as harmful. For some countries, the more expensive alternatives were acceptable, while in others DDT is still the preferred, cheap option.

  However, with hazards that have established a unique niche in society, such as the automobile, eliminating the risk is close to impossible. Eliminating risks is often only possible with the existence of viable alternatives. 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.

- *Accept the risk.* A second option is to simply accept the risk as it is—to do nothing. Certain risks may be so low that the money spent to reduce them would be better spent to treat a more severe hazard. In risk matrices, the risks that fall within the lowest category of both consequence and likelihood are generally the risks that are considered acceptable. After all other risks have been treated to the satisfaction of the hazards risk management team, the low risks can be revisited.
- *Establish a* "de minimis *risk" level. De minimis* risk dictates that a level of statistical risk for hazards exists, below which people need not concern themselves. This level is often set at either 1 in 100,000 or 1 in 1,000,000, and is set either for a 1-year period or for 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. An example of its use in the United States includes a regulation *de minimis* risk set by the Environmental Protection Agency (EPA) for human lifetime risk from pesticides of 1 in 1,000,000 over a 70-year lifetime (PMEP, 1997).

  De minimis does not seek to prohibit any risk above the levels set. The theory only states that, if a risk falls below that level, no resources need to be spent on its 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 risk associated with a product does not fall below the *de minimis* level, then risk managers need to assess if anything can be done to reduce its risk and if 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 1 in 1,000,000 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 1 in 1,000,000 risk of death. However, if the entire world population were to be vaccinated, approximately 6000 fatalities would occur. A third group 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., 1 in 1,000,000), 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 1 in 10,000 per vulnerable individual. 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, analyses, are probably the most widely used and widely accepted method by which risks and alternatives are evaluated for acceptability. The Massachusetts Precautionary Principle Project (MPPP, 1999) wrote:

  [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.

  If the cost of controls greatly exceeds the cost of the life saved, regulatory actions may not be taken. Among other flaws, cost–benefit analysis fails to consider who reaps the benefits and who assumes the cost. It also perpetuates the myth that we must decide between economic growth and environmental protection. Cost–benefit analysis is also heavily biased toward costs of regulation today, discounting less quantifiable costs such as health damage and benefits of prevention. Cost–benefit analysis often overestimates the costs of regulation. It also tries to quantify the unquantifiable, or translate the noneconomic—pain and suffering, illness, and disease—into money. Many consider this unethical.

  Following the September 11 terrorist attacks, in which hijacked commercial airplanes were used as weapons, considerable effort went into (and continues to go into) securing airways around the world. As security measures increase, so does the cost of ensuring that security, and most of this cost is passed along to the consumer. Questions that require people to consider the financial cost of their own safety are often used to determine individual risk-seeking or risk-averse behavior.

  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) wrote that "The answer to 'How safe is safe enough?' depends upon [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 are referring to are:

  1. Define the alternatives.
  2. Specify the objectives and measures of effectiveness to indicate the degree to which they are achieved.
  3. Identify the possible consequences of each alternative.
  4. Quantify the values for the various consequences.
  5. Analyze the alternatives to select the best choice.
- Disaster managers will have already completed most of these steps by the time they are deciding which risks to treat. Derby and Keeney (1981) provided graphical illustrations of four factors that influence how risk alternatives are chosen and determined to be acceptable. These examples are shown in Figures 3–5 through 3–8.

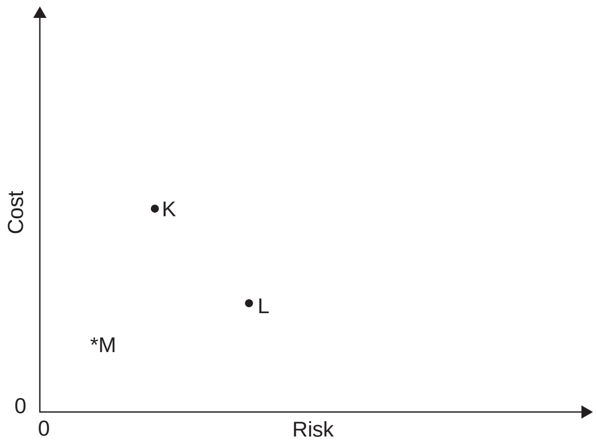

FIGURE 3–5 Risk acceptability Example A. (From Derby & Keeney, 1981)

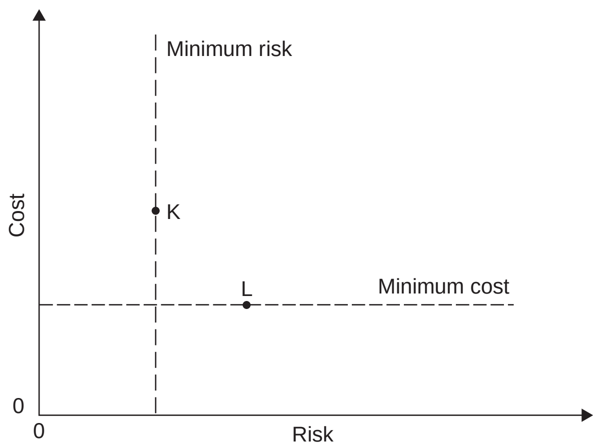

FIGURE 3–6 Risk acceptability Example B. (From Derby & Keeney, 1981)

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.

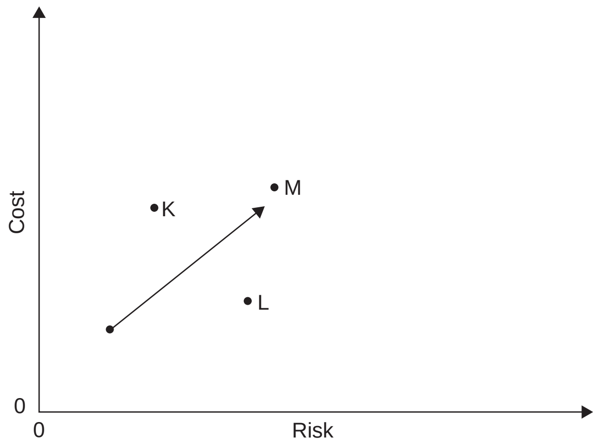

FIGURE 3–7 Risk acceptability Example C. (From Derby & Keeney, 1981)

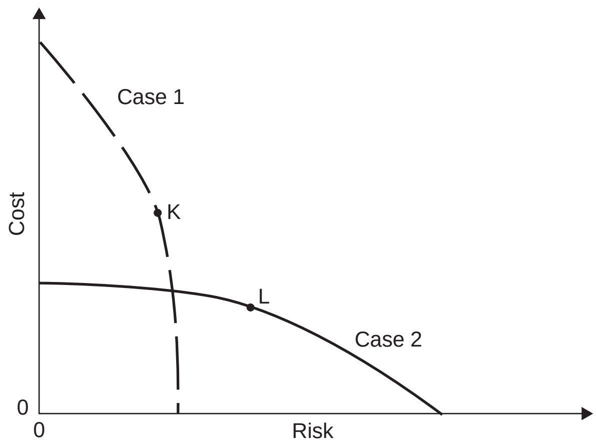

FIGURE 3–8 Risk acceptability Example D. (From Derby & Keeney, 1981)

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.

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 first presented in Chapter 1 and defined as 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 results from a combination of physical, social, economic, and environmental factors or processes. These factors are the primary determinant features that dictate how the likelihood and/or consequences components of risk are increased or decreased.

It is important to first clarify the difference between the concepts of vulnerability and exposure, which are often confused. The two words are used interchangeably to describe how a country, region, or community is likely to experience a certain hazard. However, this is incorrect, as the discussion on vulnerability factors shows. The United Nation's risk reduction document *Living with Risk* embodies this concept, saying, "While most natural hazards may be inevitable, disasters are not" (ISDR, 2004).

While vulnerability defines the propensity to incur consequences, exposure merely suggests that the individual, structure, community, nation, or other subject will be *exposed* to the hazard. For instance, one might say, "The Spanish are vulnerable to drought," meaning that Spain regularly experiences the drought hazard. But this statement implies more than the speaker intended. The use of the word "vulnerable" implies that the population is likely to incur negative consequences as a result of factors that make it less likely to protect its citizens and built and natural environments from harm, not simply that drought happens there. The reality, as Figures 3–9 and 3–10 illustrate, is that while Spain is regularly exposed to drought, the nation is not vulnerable to its consequences.

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 likelihood. Vulnerability, however, is a factor of how small or great the consequences will be *should the hazard manifest*. Figures 3–9 and 3–10 illustrate that, although many different nations are exposed to drought, each experiences differing vulnerabilities. In light of this, it may be more accurate to say that the Spanish face a drought risk, because their exposure likelihood is greater than zero, and that because of measures the nation has taken to reduce drought consequences, it is no longer *vulnerable* to the hazard.

Vulnerability can be studied and measured. Likewise, it can be decreased through actions that lower the propensity to incur harm or increased through actions that increase that propensity—mitigation and preparedness. How these processes are conducted will be detailed below and in Chapters 4 and 7. As the definition in Chapter 1 states, two identical events may be presented as a minor issue in one country and a major disaster in another. Each country's vulnerabilities explain the difference. 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.

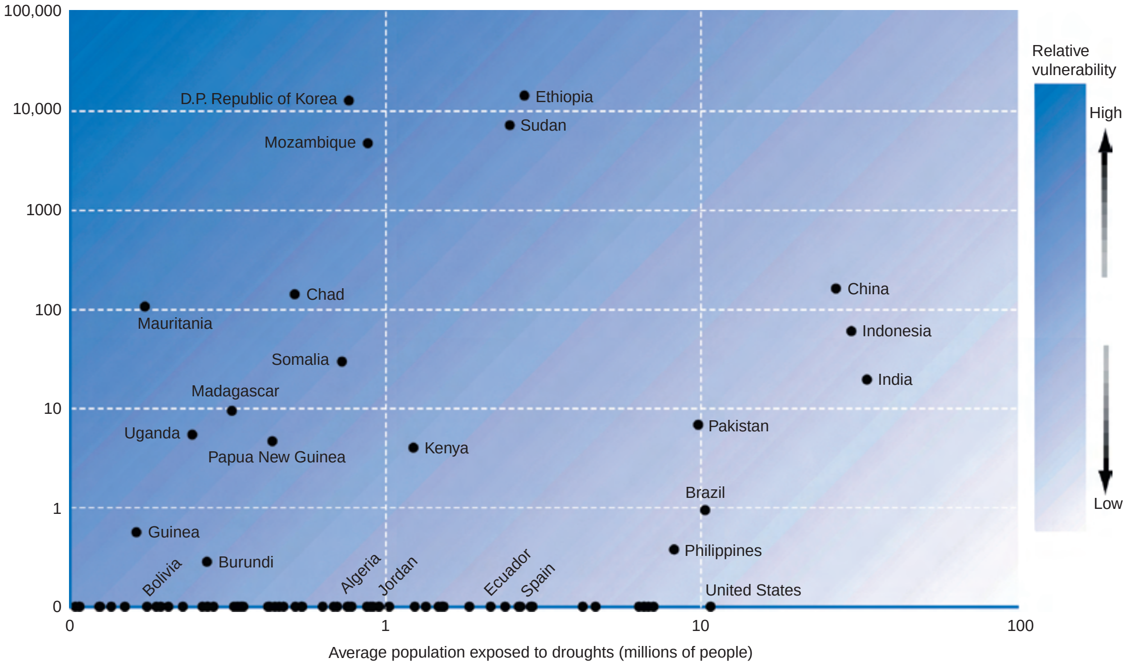

FIGURE 3–9 National vulnerabilities to drought risk as a factor of population exposure. (From the International Disaster Database, www.em-dat.net)

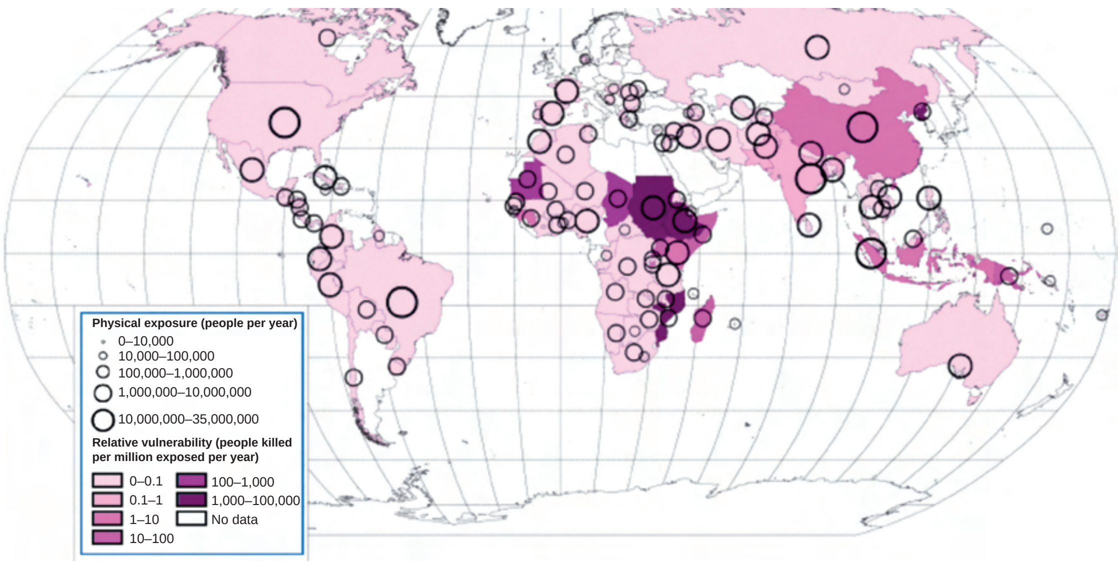

FIGURE 3–10 National vulnerabilities to drought risk as a factor of population exposure. (From the International Disaster Database, www.em-dat.net)

Physical vulnerability generally involves what in the built environment is physically at risk of being affected. The choices societies make about placing structures, transportation routes, and populations either in or out of harm's way effectively determine physical vulnerability. A majority of available mitigation measures are focused upon "hardening" these populations and structures to reduce their physical vulnerability to hazards. For instance, a building may be placed in a zone where a flood hazard is known, but raising the structure onto stilts reduces its physical vulnerability. People also are affected by physical vulnerability. As populations move into areas of high risk of disaster, their physical vulnerability increases.

Social vulnerability measures the individual, societal, political, and cultural factors that increase or decrease a population's propensity to incur harm or damage as a result of a specific hazard. Certain behaviors can contribute to or reduce that population's ability to protect itself from harm. Within populations may be groups, such as the elderly or the very young, who exhibit different vulnerability factors than the population as a whole.

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

Each of these vulnerability elements is interconnected. Economic vulnerability can lead to social vulnerability, which causes populations to build on dangerous land, causing environmental vulnerability and physical vulnerability. This is but one example, but it shows how each factor is equally important to consider when assessing the vulnerability of a country or community.

To better understand an area's vulnerability, disaster managers must attempt to develop a profile of the country's or community's physical, social, economic, and environmental profiles. These four factors will help them determine overall vulnerability, determining what consequences are likely to occur as result of each hazard and what mitigation and preparedness measures will be most effective at treating those hazard risks. Descriptions and samples of profile components are provided in the following section.

The Physical Profile

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

The geographic components of the physical profile include 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 territory. This includes all but two of the world's 15 largest cities (ISDR, 2004). The economic and industrial benefits provided by a seaside location prompted these populations to move into such zones, but by doing so, the residents increased their exposure to many different hazards, including severe windstorms, flooding, and tsunamis. As a result, they must now accommodate that exposure by taking risk-reduction measures, or else experience increased vulnerability to those hazards.

The following list provides several examples of what factors may be seen in a study of a country's geographic makeup:

- Land cover (vegetation)
- Soil type
- Topography
- Slope
- Aspect
- Water resources (lakes, rivers, streams, reservoirs, etc.)
- Wetlands and watersheds
- Faults
- Climate (wind, rainfall, temperature)

The infrastructure components of the physical profile primarily include the interaction between people and the land. This profile is diverse, and is often generalized for regions or segments (see Exhibit 3–6). Common components of the physical profile include those listed on pages 181 and 182.

EXHIBIT 3–6: 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 between 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

(*Continued*)

EXHIBIT 3–6: SECTORING (CONTINUED)

  - 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
  - Railroads and yards
  - Airports
  - Navigable waterways
  - Dikes, dams, and flood protection
- HAZMAT facilities/public health concerns
  - Leaking underground storage tank (LUST) sites
  - 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

- 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
  - 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 looks at how people move throughout time. Disasters that occur at different times of the day often can have different consequences, and knowing where people are likely to be at certain times helps to determine vulnerability. At night, most people are likely to be in their homes, while during the weekday they will be at their jobs. For this reason, physical vulnerabilities vary throughout the day as population movements occur. Individual population factors may include:

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

The Social Profile

The social makeup of a country plays a strong role in its vulnerability. Aspects of the social profile are diverse and comprise education, culture, government, social interaction, values, laws, beliefs, and other aspects of society. Within most countries, and even within individual communities, the vulnerability of different groups varies due to a range of sociocultural factors that help or prevent them from being able to protect themselves from disasters. The prevalence of epidemics, in particular, is heavily influenced by the social factors that vary from one country to another (see Figure 3–11).

Certain religious, cultural, or 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 may have been 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 over 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. 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

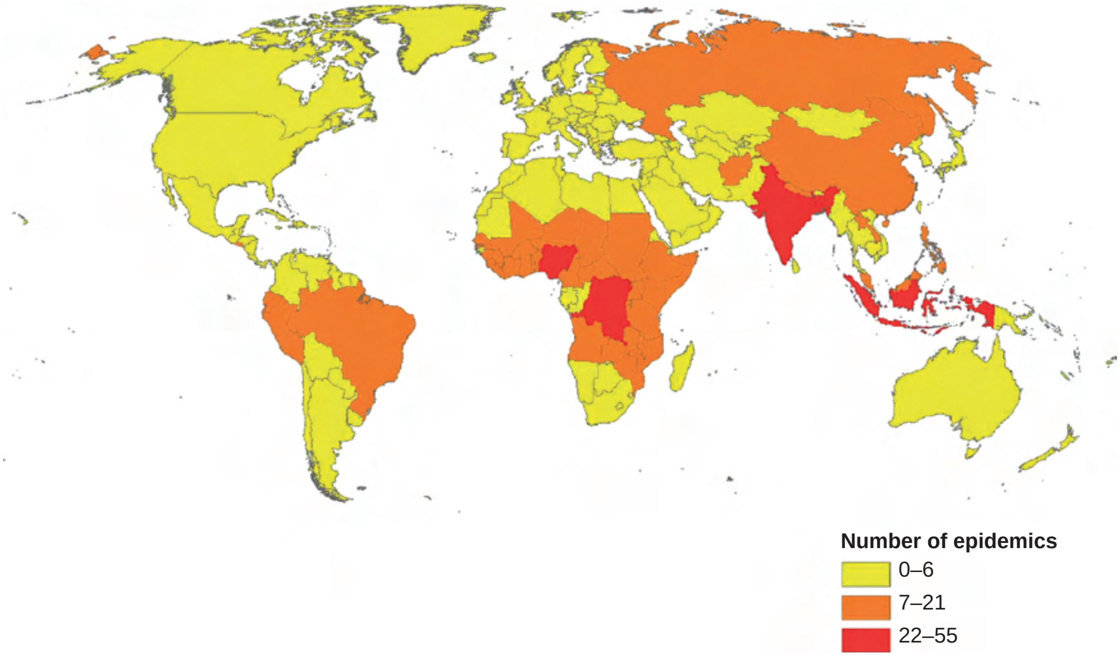

FIGURE 3–11 Number of epidemics by country, 1974–2003. (From the International Disaster Database, www.em-dat.net)

their historical bases can actually increase vulnerability due to the common but unintended consequences resulting from a social reaction in response to the change.

Examples of factors that disaster managers must consider when scoping a social vulnerability include:

- Religion
- Age
- Gender
- Literacy
- 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 3–12). It also helps to define what risk management practices and actions are possible and most effective. For instance, a mountainous country whose government does not or is not able to restrict clearcutting on unstable slopes is likely to have increased vulnerability to landslides, whereas a country that does not manage the filling in of wetlands may show an increase in flood propensity. Environments are also vulnerable to the consequences of hazards, and may increase the likelihood that a hazard event develops into a disaster.

The health and vitality of the natural environment of a country or community are critical when measuring its vulnerability to each specific hazard. A healthy and productive natural environment provides 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 the hazard's potential 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 3–13, 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. Measuring the health of the country's natural environment is vital in understanding the role that the natural environment can play in protecting a community and reducing the impacts from hazard events (see Figure 3–14). 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

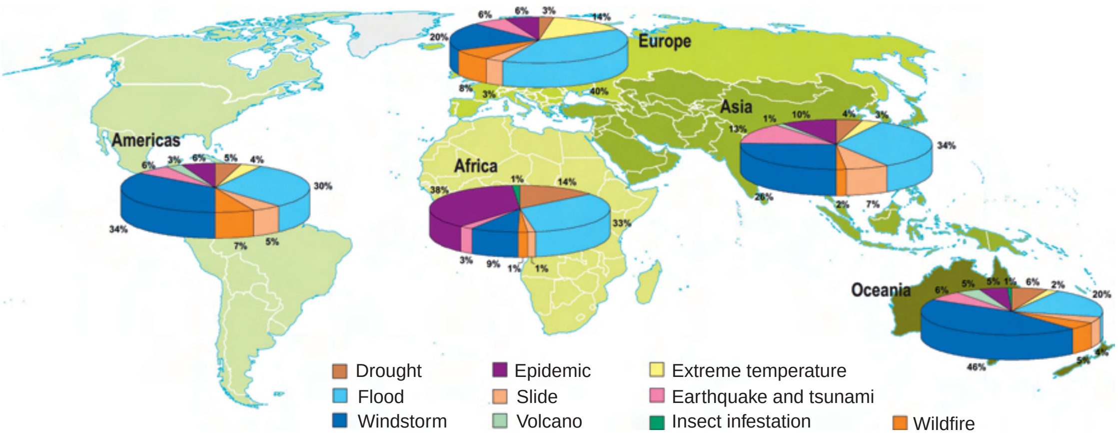

FIGURE 3–12 Regional differences in hazard portfolios (1991–2005). (From the International Disaster Database, www.em-dat.net)

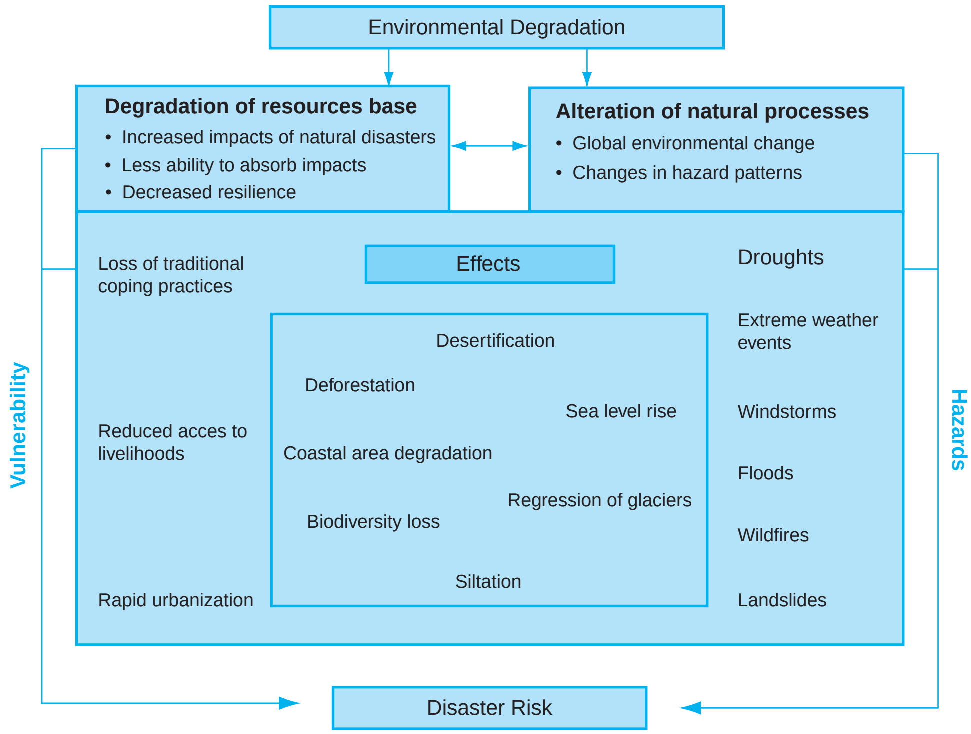

FIGURE 3–13 The link between environmental degradation, natural disasters, and vulnerability. (From ISDR, 2004)

Human practices that affect the environmental profile of a country (see Exhibit 3–7) include:

- Diking or damming of rivers and creeks
- Filling in wetlands for development
- Channeling of coastal areas such that marsh and wetlands areas are destroyed
- Clearcutting of forests
- Mismanagement of forests such that dead wood builds up (serving as fuel for a forest fire)
- Destruction of coastal dunes

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

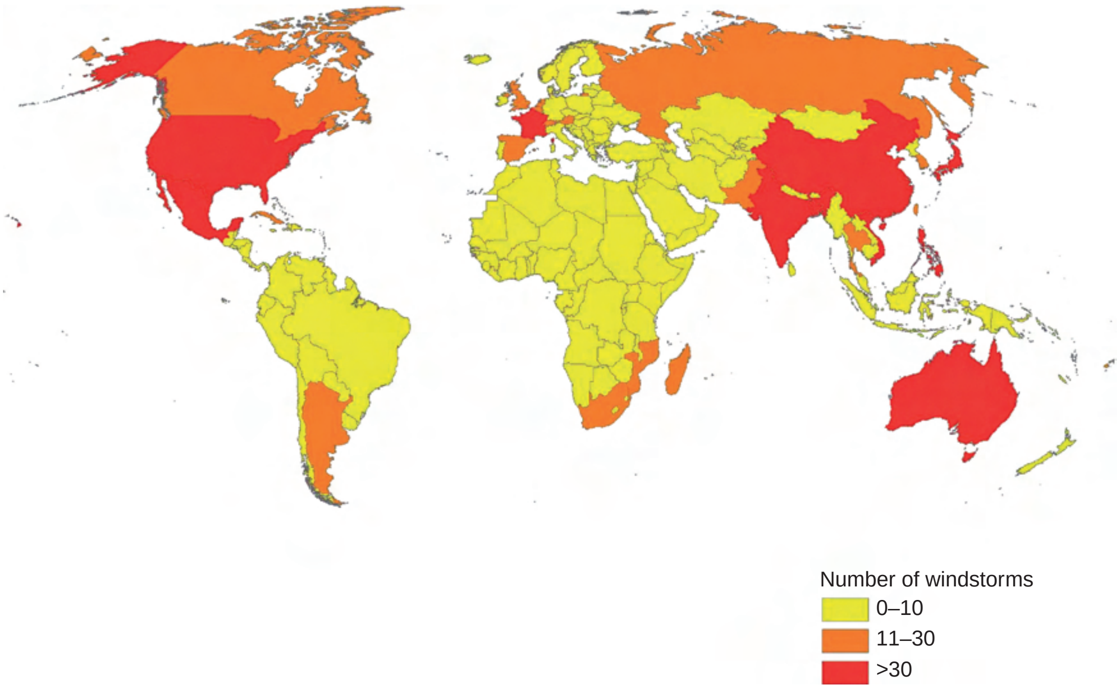

FIGURE 3–14 Number of severe windstorm events by country, 1974–2003. (From the International Disaster Database, www.em-dat.net)

The Economic Profile

The financial status of a government and its populations deeply affects their ability to protect themselves from the consequences of disaster. Financial well-being, however, does not indicate that they *will* protect themselves; rather, it is just a measure of their ability to do so. Other factors may be learned from this 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 that are unable to withstand environmental pressures. They are more likely to have zero tolerance to delays in basic necessities that often follow disasters.

Factors involved in the economic profile that affect vulnerability include:

- Gross domestic product
- Debt
- Access to credit
- Insurance coverage
- Sources of national income
- Funds reserved for disasters
- Social distribution of wealth
- Business continuity planning

EXHIBIT 3–7: 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 December 26, 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 10-m (30 foot) wave swept 1.5 km (1 mile) inland, carrying a passenger train about 50 m (200 feet) off its tracks, with a death toll of 1700.

Yet, a mere 3 km (2 miles) south, in Hikkaduwa, the tsunami measured just 2–3 m (7–10 feet) in height, traveled only 50 m (200 feet) inland, and caused no deaths.

The researchers found 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 km 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 concluded that waves 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 concluded 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 2 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 noted 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).

It is recognized that poor countries experience more disasters than the wealthy ones. Figure 3–15 illustrates this. 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. Because of their strong economic standing, wealthy nations are better able to develop the preparedness, mitigation, response, and recovery mechanisms before events occur, and thus are able to manage them effectively once they do happen. Identical events that occur in a high-income country and a low-income country may be recorded as a

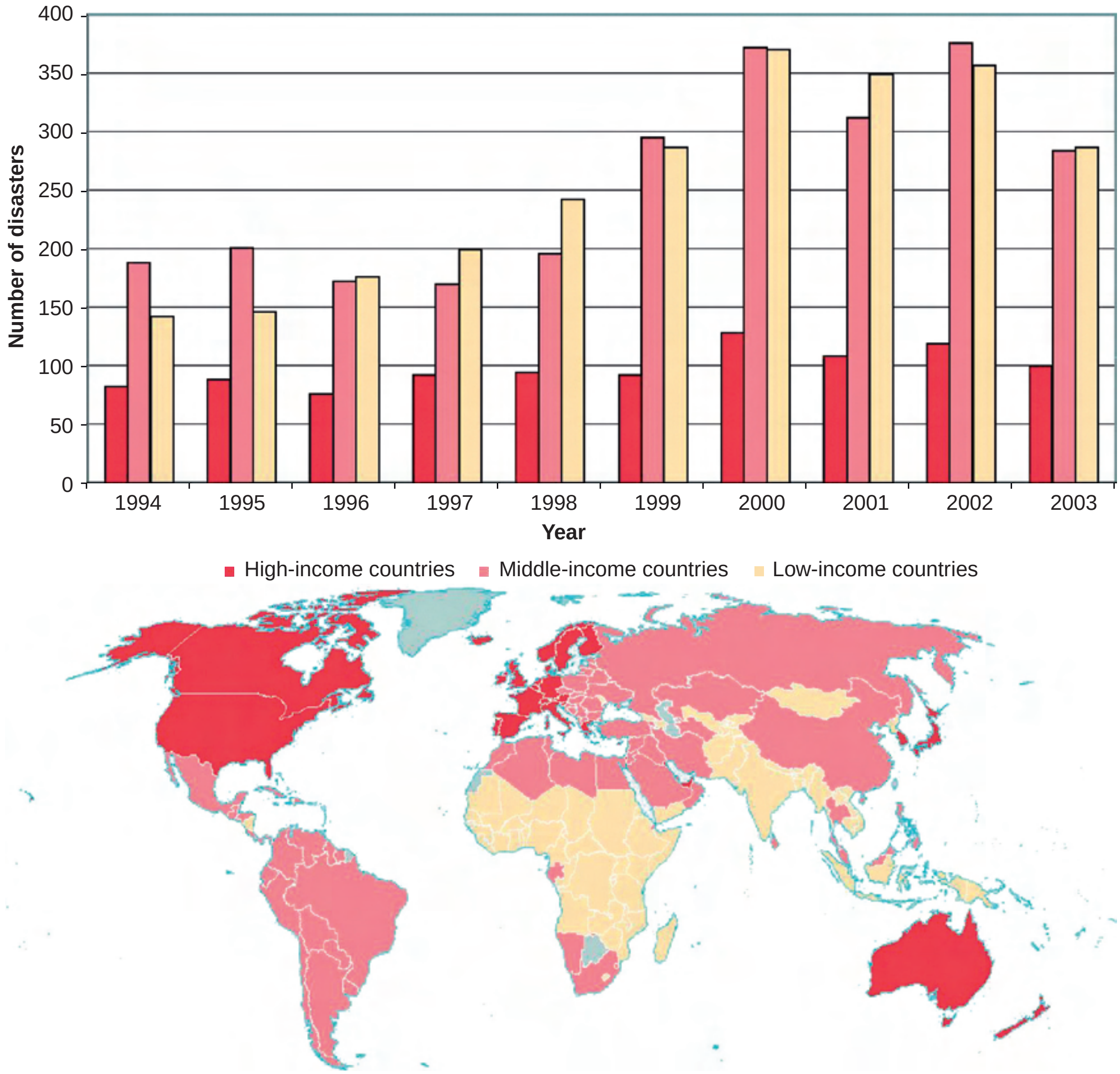

FIGURE 3–15 Total number of disasters by year, 1994–2003 (by income; reference map provided). (From the International Disaster Database, www.em-dat.net)

routine event in the high-income country while resulting in a full-scale disaster in the poor country. The income of these countries, therefore, results in their discrepancy in vulnerability.

Another income-related factor that determines how significantly an event affects a country is the gross domestic product (GDP), which 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 great deal of information about how badly the country overall was affected. However, when presented as a percentage of GDP, this consequence figure gives much greater perspective on how deeply the nation's economy feels the impact. For example, a disaster that causes $2 billion in damages may represent upwards of 38% 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 their entire economy. Wealthy nations with strong economies can absorb the effects of disasters, and many even have reserve funds set aside for expected events. Poor countries, however, often must borrow significant amounts of funding while concurrently cutting vital social programs to pay for the relief and recovery from a major disaster. As a result, development continues to lag long after the disaster has struck, as debt payments draw heavily off of annual budgetary spending. Figures 3–16 and 3–17 illustrate how disaster events differently affect economies of different sizes.

Risk Factors That Influence Vulnerability

The United Nations Development Programme (UNDP, 2004), in their report *Reducing Disaster Risk: A Challenge for Development*, identifies two main factors that influence risk levels of nations and their populations: urbanization and rural livelihoods. Each factor contains associated processes that further influence a combination of the vulnerability factors previously discussed.

Urbanization

Populations are concentrating in urban centers throughout the world. The UN estimates that by 2007, more than half the world's population will live in cities. This trend toward the development of large "megacities" is evident upon examination of the world's great metropolises. Between 1950 and 1990, the average population of the largest 100 cities on the planet grew from 2.1 to 5.1 million. There are now six times as many cities with more than 1 million people in the developing world as there were in 1950, and 41 cities had populations that exceeded 5 million in 2000 (UNDP, 2004).

Urbanization, especially rapid urbanization, presents significant challenges for disaster 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 (e.g., unstable slopes, in floodplains, and on seismically unstable soil). Governments may not be aware for months or years that these groups are at such high risk without current census data and risk assessment.

In addition to concentrating populations, urbanization concentrates national wealth and resources into small, often vulnerable pockets. When disasters occur, the likelihood that a significant portion of the nation's infrastructure, industrial output, and governance will be affected greatly increases. Housing, distribution of food, transportation, communications, public health, and many other resources and services can be affected to a much greater degree as urbanization increases.

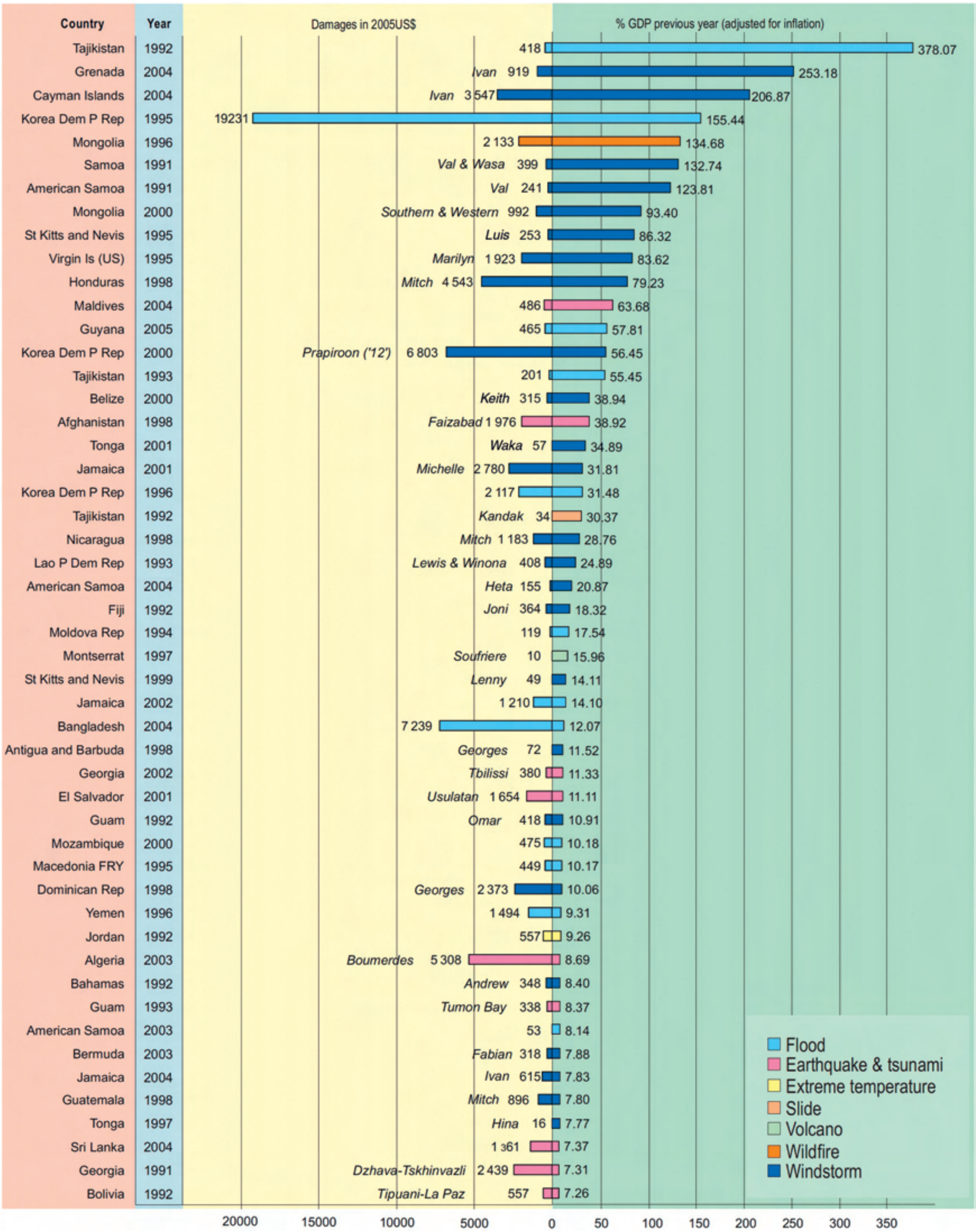

FIGURE 3–16 Disaster damages as a percent of GDP, 1991– 2005. (From the International Disaster Database, www.em-dat.net)

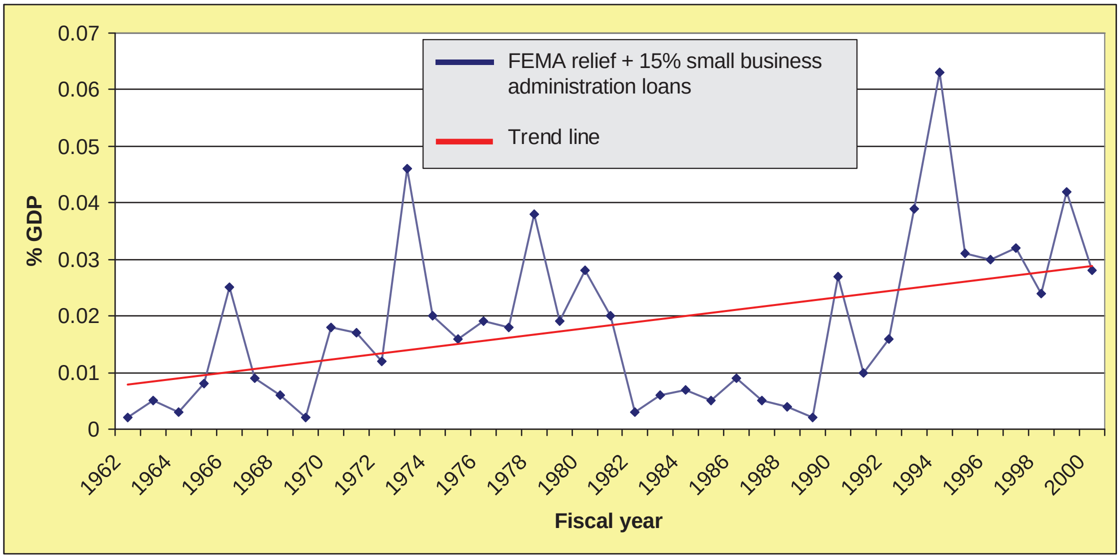

FIGURE 3–17 Disaster relief costs as a percentage of GDP in the United States. (From the Congressional Natural Hazards Caucus and Princeton University, 2001)

Governments' ability 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 and emergency management services must grow with populations to ensure adequate protection. Even wealthy countries often have a lag in services as recognition and funding catch up, but in poor countries the situation can be much worse because political pressure and the competition of financial interests often rob disaster management programs of much needed funding.

The UNDP identified several characteristics of urbanization that contribute to risk and vulnerability, 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 the disasters that resulted 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 (2005), more than 70% 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, as identified by the UNDP:

- *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 can all lead to an increase in the likelihood or consequence factors of risk. In these cases, it is common for regular events, such as annual rains, to result in disasters that did not normally affect the region; for example, mudslides and flash floods.
- *Nondiversified economies.* Many rural areas rely on just a few sources or even one source of income. This increases the chance that a hazard will result in the destruction of much of the area's income-generation abilities. A plant epidemic is one example of a hazard that causes a disaster that would not have occurred with a more diversified range of resources. Shifts in global market prices can result in a drop in local income, increasing the vulnerability of the area's population. The worst-case scenario, which involves a drop in global prices in conjunction with a disaster, has happened on multiple occasions in the recent past.
- *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 disasters do occur, it can be days or weeks 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

An important component of disaster management is the 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 laypeople, 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 Chapter "Rating the Risks," acclaimed risk perception experts Paul Slovic, Baruch Fischhoff, and Sarah Lichtenstein begin, "People respond to the hazards they perceive" (Slovic, Fischhoff, & Lichtenstein, 1979). This statement is important for two reasons. First, its opposite is true. People generally do not respond to the hazards that they do not perceive. Second, it has been found that these stated perceptions are based primarily upon 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. People tend to fear a specific risk less as they become better informed with 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) stated, "the more of a gamble something is," the more people will fear it. In the face of uncertainty, people will consciously or subconsciously make personal judgments based upon very imperfect information to establish some individual concept of the risk they face. Judgments based upon 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 over 7 years, people have overestimated their personal risk from violent crime by up to 86%. 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 responded with an 80 to 100% 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.

   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 from 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. Laypeople's risk perceptions are based in part on frequencies of death with some striking discrepancies. It appears that the concept of risk for laypeople 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 over- rather than underestimate their vulnerability. Economists have classified this tendency to overestimate unknown or unclear risks as "risk-ambiguity aversion" (*The 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 an individual, even if they are a risk "expert." Few people can conceptualize the difference between a "one-in-a-million" and a "one-in-one-hundred-thousand" chance of occurrence (Jardine & Hrudey, 1997).

People tend to need other clues to help them put these numbers into perspective. Many tend to view their chance of being affected by rare but spectacular hazards in a comparable fashion to how people believe that they can beat long odds to win a state lottery. James Walsh wrote 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). 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 $57 \times 52 \times 100 \times 100 = 29{,}640{,}000$.

It is the qualitative factors that people consider most heavily when weighing their personal risk. Slovic, Fischhoff, and Lichtenstein (1980) proposed that there are 17 risk characteristics that influence public risk perception. These characteristics fall under two subgroups (called "factors"): factors related to dread (Factor 1) and factors related to how much is known about the risk (Factor 2). A third factor, encompassing a single, eighteenth characteristic, which measures the number of people exposed to the hazard, will not be 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

- *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).
- *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.
- *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 the effects a conventional war taking place in a country other than one's own.
- *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.
- *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 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.
- *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.

- *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 within our own lifetime. The most apparent example of this is nuclear radiation, which can remain dangerous for thousands of years. Because of this extended danger, there still are no agreements on where spent nuclear fuel will be stored in the United States after it is no longer useful for power generation.
- *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.
- *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.
- *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).
- *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.
- *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

- *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.
- *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.

- *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.
- *New risk versus old risk*. Risks we are facing for the first time are much scarier than risks that 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.
- *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," evidence that is sometimes impossible to obtain in an accurate or timely manner (Slovic et al., 1979).

    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% gave odds of 100:1 that their answer was correct, and 30% gave odds of 50:1 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 3 (Twomey, 2001).

Paul Slovic wrote 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 that they know, they can begin to question the validity of their views.

Elspeth Young of the Australian National University described social constructs of risk. These are human attributes that define how different people assess risk and determine personal vulnerability. They include:

1. *Socioeconomic characteristics (including 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" (Young, 1998).
2. *People's knowledge of the environment and the hazards that the environment poses to them (traditional ecological knowledge).* "Traditional ecological knowledge 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)" (Young, 1998).
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" (Young, 1998).
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" (Young, 1998).
5. *Their ability to access help from outside.* "Having confidence makes asking for assistance much easier" (Young, 1998).

The ways in which hazard risk is presented or reported greatly influence how people perceive the hazard. For instance, Slovic and Weber (2002) described several ways that a risk manager could describe 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 & 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) described 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. These compared risks are provided as Exhibit 3–8.

Risk comparisons can also cause incorrect perception of risk if they are not presented in an appropriate manner. Kenneth Warner (1989) described 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.

EXHIBIT 3–8: RISKS THAT INCREASE CHANCE OF DEATH BY 0.000001 (1 IN 1 MILLION), FOLLOWED BY THE 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 min 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 (cancer caused by cosmic radiation)
- Living 3 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 ounce cans of diet soda (cancer caused by saccharin)
- Living 5 years at the boundary of a typical nuclear power plant in the open (cancer caused by radiation)
- Living 20 years near a PVC plant (cancer caused by vinyl chloride)
- Living 150 years within 20 miles of a nuclear power plant (cancer caused by radiation)
- Eating 100 charcoal-broiled steaks (cancer from benzopyrene)

Source: Adapted from Wilson (1979).

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)

Warner described 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 attributed to the effects of these fear-inducing reports the fact that in surveys conducted after 9/11, Americans felt they faced a 20% chance of being a direct victim of future attacks, and felt that the "average American" faced a 48% chance of being a victim (Vedantam, 2003).

Lerner found that women tended to respond with more fear to terrorism risk-related articles, while men tended to respond more with anger. She contended, "the government and the media can unwittingly alter risk perception by making people either fearful or angry," and further stated, "[u]sed responsibly, that connection could also be used to better communicate the real degree of risk" (Lerner et al., 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 wrote 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) wrote:

> *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 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 that 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) wrote:

> *Perceptions of risk play a prominent role in the decisions people make, in the sense that differences in risk perception lie at the heart of disagreements about the best course of action between technical experts and members of the general public, men vs. women, and people from different cultures. 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.*

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 provided 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. It was called a crime wave because the media labeled it as such.

Objectively speaking, 10 murders of 41 million visitors did not even constitute a ripple, much less a wave, especially considering that at least 97% 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 upon 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.

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 upon 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, 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 or floods.

Conversely, disaster 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 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 & 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) contended 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 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) contended 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

Risk and vulnerability reduction is paramount to reducing injuries, deaths, and damages associated with disasters. All nations may significantly reduce their risk and vulnerability, no matter their wealth or facilities. Yet for most nations, disaster management emphasis focuses only upon the post-disaster functions of response and recovery, rather than pre-disaster mitigation and preparedness. Fortunately, nations such as Australia, New Zealand, and the United States and international organizations such as the United Nations are working hard to reverse these reactive attitudes.

References

Alesch, D. (2001). *Acceptable risk: What is it and how do we measure it?* Presentation at the University of Colorado, 2001 Hazards Workshop, Boulder. June.

American Geophysical Union. (2005). *Illegal destruction of coral reefs worsened impact of tsunami*. Press Release, August 15.

Ansell, J., & Wharton, F. (1992). *Risk: Analysis, assessment, and management*. Chichester, UK: John Wiley & Sons.

Barnes, P. (2002). Approaches to community safety: Risk perception and social meaning. *Australian Journal of Emergency Management* (Autumn), 15–23.

Cameron, G. (2002). *Emergency risk management: What does it mean?* Presentation at ATEM-AAPPA 2002 Conference, Brisbane, Australia, September 29–October 2. www.aappa.com/infoservices/papers/2002_AAPPA_Brisbane/G_Cameron.pdf.

Centers for Disease Control (CDC). (2002). *Suicide in the United States*. www.cdc.gov/ncipc/factsheets/suifacts.htm.

Congressional Natural Hazards Caucus and Princeton University. (2001). *US vulnerability to natural hazards*. www.hazardscaucus.org/USHAZPOSTER.pdf.

Crowe, T. D. (2000). *Crime prevention through environmental design: Applications of architectural design and space management concepts*. Boston: Butterworth-Heinemann.

Davis, A. (2002). New alarm heats up debate on chemical risks. *Arizona Daily Star* (May 30). www.azstarnet.com/attack/indepth/wsj-chemicalrisks.html.

de Becker, G. (1997). *The gift of fear: Survival signals that protect us from violence*. Boston: Little, Brown and Co.

Derby, S. L., & Keeney, R. L. (1981). Risk analysis: Understanding 'how safe is safe enough?' *Risk Analysis*, *1*(3), 217–224.

Dickey, T. S. (1980). *Bank robbery—Architectural implications from the criminal's point of view*. Unpublished Master's thesis, Georgia Institute of Technology College of Architecture.

Dresher, M. (1961). *Games of strategy: Theory and applications*. Englewood Cliffs, NJ: Prentice-Hall.

Dubner, S. J., & Levitt, S. D. (2006). How many lives did Dale Earnhardt save? *The New York Times* (February 19), http://www.nytimes.com/2006/02/19/magazine/19wwln_freak.html?pagewanted=print.

Economist, The. (2002). *The logic of irrational fear* (October 19), 29–30.

Emergency Management Australia (EMA). (2000). *Emergency risk management: Applications guide*. Dickson, Australia: Author.

Federal Emergency Management Agency (FEMA). (2001). *How-to guide #3*. www.Fema.gov/FIMA/planning_howta3.shtm.

Federal Emergency Management Agency (FEMA). (1997). *Multi-hazard: Identification and risk assessment*. Washington, DC: Author.

Glassner, B. (1999). *The culture of fear*. New York: Basic Books.

ICESI. (2002). *Primera Encuesta Nacional sobre Inseguridad Publica en las Entidades Federativas*. Mexico City: Instituto Ciudadano de Estudios Sobre la Inseguridad A.C.

International Strategy for Disaster Reduction (ISDR). (2004). *Living with risk*. Geneva: The United Nations Inter-Agency Secretariat.

Jardine, C. G., & Hrudey, S. E. (1997). Mixed messages in risk communication. *Risk Analysis*, *17*, 489–498.

Lerner, J. S., Gonzales, R., Small, D., & Fischoff, B. (2003). Effects of fear and anger on perceived risks of terrorism. *American Psychological Association. Psychological Science*, *14*(2).

Lunn, J. (2003). Community consultation: The foundation of effective risk management. *Journal of Emergency Management*, *1*(1), 39–48.

Massachusetts Precautionary Principle Project (MPPP). (1999). *Risk assessment & risk management*. Boston: Massachusetts Precautionary Principle Partners.

Mumpower, J. (1986). An analysis of the *de minimis* strategy for risk management. *Risk Analysis*, *6*, 437–445.

Pesticide Management Education Program (PMEP). (1997). *The Delaney Paradox and negligible risk 8/91*. http://pmep.cce.cornell.edu/issues/delaney-negrisk-891.html.

Pitzer, C. J. (1999). New thinking on disasters: The link between safety culture and risk-taking. *Australian Journal of Emergency Management* (Spring), 41–50.

Ravid, I. (2001). Theater ballistic missiles and asymmetric war. Unpublished manuscript.

Roderick, L. M. (1998). Slips, trips, and falls. *Safety and ergonomics manual*. www.trinity3.com/lmr/slipstripsfalls.htm.

Ropeik, D. (2001). *"Fear factors" in an age of terrorism* (October 15). www.msnbc.msn.com/id/3077306/.

Slovic, P. (1986). Informing and educating the public about risk. *Risk Analysis*, *6*(4), 403–415.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1979). Rating the risks. *Environment*, *21*, 14–20, 36–39.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1980). Facts and fears: Understanding perceived risk. In *Societal risk assessment: How safe is safe enough?* New York: Plenum.

Slovic, P., & Weber, E. (2002). *Perception of risk posed by extreme events*. Presented at Risk Management Strategies in an Uncertain World, Palisades, New York, April 12–13.

Smith, K. (1992). *Environmental hazards: Assessing and reducing disaster*. London: Routlege.

Twomey, J. (2001). Media fuels fear about youth crime. *Baltimore Sun* (May 13), 1C.

United Nations Development Programme (UNDP). (2004). *Reducing disaster risk: A challenge for development*. New York: Bureau for Crisis Prevention and Recovery.

United Nations Development Programme (UNDP). (1994). *Vulnerability and risk assessment*. www.proventionconsortium.org/files/undp/VulnerabilityAndRiskAssessmentGuide.pdf.

Vedantam, S. (2003). More afraid than we should be. *The Washington Post* (March 31), A6.

Viscusi, W. (1996). Economic foundations of the current regulatory reform efforts. *Journal of Economic Perspectives*, *1*(3), 119–134.

Walsh, J. (1996). *True odds: How risk affects your everyday life*. Santa Monica, CA: Merritt Publishing.

Warner, K. E. (1989). The epidemiology of coffin nails. In *Health risks and the press: Coverage on media coverage of risk assessment and health*. Washington, DC: The Media Institute.

Wiggins, C. (2002). Warm waters attract people and sharks. *Standard (Baker County)* (March 27). www.bcstandard.com/news/2002/0327/community/007.html.

Wilson, R. (1979). Analyzing the daily risks of life. *Technology Review*, *81*(4), 41–46.

World Bank. (2005). *The World Bank and agriculture and rural development*. World Bank News and Broadcast. September.

World Health Organization (WHO). (2009). *Global status report on road safety: Time for action*. Geneva: World Health Organization. www.who.int/violence_injury_prevention/road_safety_status/2009.

Young, E. (1998). Dealing with hazards and disasters: Risk perception and community participation in management. *Australian Journal of Emergency Management*, (Winter), 14–16.

Zimmerman, R., & Bier, V. (2002). *Risk assessment of extreme events.* Columbia-Wharton/Penn Roundtable on Risk Management Strategies in an Uncertain World, April 12–13. www.ldeo.columbia.edu/CHRR/Roundtable/Zimmerman_WP.pdf.