SEISMIC RISK MANAGEMENT 2

Chapter 2 introduces and describes seismic risk management, beginning with an overview of seismic risk, followed by discussions on the holistic nature of seismic risk management and on strategies for reducing seismic risk. These strategies fall into three categories: (1) first cost or design strategies; (2) operating cost or business strategies, and (3) event response strategies. Also included in this chapter are discussions on the selection of an optimal combination of risk reduction strategies, and example applications of seismic risk management strategies, including cost and performance considerations, described in three case studies. The chapter concludes with a discussion of the importance of seismic risk management advocacy.

2.1 SEISMIC RISK: AN OVERVIEW

In general, the term "risk" is commonly used to characterize the likelihood of an unfavorable outcome or event occurring. The term "seismic risk" is used by the scientific and engineering communities to describe the likelihood of adverse consequences resulting from the occurrence of an earthquake. Seismic risk is typically defined as a function of three elements: (1) the seismic hazard or likelihood of occurrence of an earthquake and the associated severity of shaking, (2) the seismic vulnerability or expected damage to buildings and other structures given the occurrence of an earthquake, and (3) the expected consequences or losses resulting from the predicted damage. The third term, the expected consequences, is typically used to quantify the seismic risk to an individual facility, a group of facilities, or a region. For a building, these consequences or expected losses can be broadly categorized as:

DEFINITION

Seismic Risk

Seismic Risk is typically defined as a function of three elements:

(1) the seismic hazard or likelihood of occurrence of an earthquake and the associated severity of shaking,

(2) the seismic vulnerability or expected damage to buildings and other structures given the occurrence of an earthquake, and

(3) the expected consequences or losses resulting from the predicted damage.

- Casualties – the death or injury of building occupants or passersby resulting from the building collapse, blockage of exits, or failure of life safety systems;
- Capital – the value of a building's structural and nonstructural systems, including the structural framing elements, partitions, cladding, and mechanical, electrical, and plumbing systems;
- Contents – the value of, for example, a building's fixed and movable equipment, goods for sale, laboratory and manufacturing equipment;

- Business Interruption – the financial cost resulting from loss of operations; this consequence can be expressed in a variety of ways, depending on the use of the facility, e.g., lost revenue, inability to treat patients, teach students or conduct research; and
- Market Share – the future costs of losing a competitive edge; this consequence can also be expressed in a variety of ways, including loss of clients to competitors, having staff leave to work for competitors, and losing "prestige" and the business associated with an organization's reputation.

Seismic risk, as defined above, can be reduced by a reduction in any of the three elements – seismic hazard, seismic vulnerability, and expected consequences. Seismic hazard can only be reduced by relocation of the building itself, as the likelihood of an earthquake occurring at a site and the severity of shaking is a function of the regional seismicity and local geology. If the building site is a fixed variable, seismic hazard and seismic vulnerability are often considered as one factor – the likelihood that the building will sustain earthquake damage. The combination of this factor, with the expected consequences given the occurrence of the earthquake damage, results in a measure of seismic risk. Thus seismic risk can be reduced by decreasing the likelihood of building damage (e.g., by relocating the building or by increasing the earthquake resisting capacity of the structure) or by decreasing the expected consequences (e.g., by developing a response plan, geographically diversifying operations, or purchasing insurance).

The concept of seismic risk, expressed as a function of the likelihood of damage and the expected consequences, is illustrated in Figure 2-1. The likelihood of damage is shown along the horizontal axis, increasing from left to right. As mentioned above, the likelihood of damage is a function of the seismic hazard level (expected earthquake occurrences and severity of ground shaking) and the seismic vulnerability (earthquake resisting capacity of the building). The consequences or losses resulting from the earthquake damage (or "consequence" in the more general risk term) are depicted on the vertical axis, increasing from bottom to top. The quantification of seismic risk is not a simple task; however, the graph shown in Figure 2-1 is simplified qualitatively as four distinct quadrants, each of which is described below with example scenarios.

Quadrant I, Low Risk: low likelihood of damage and low consequences; examples include:

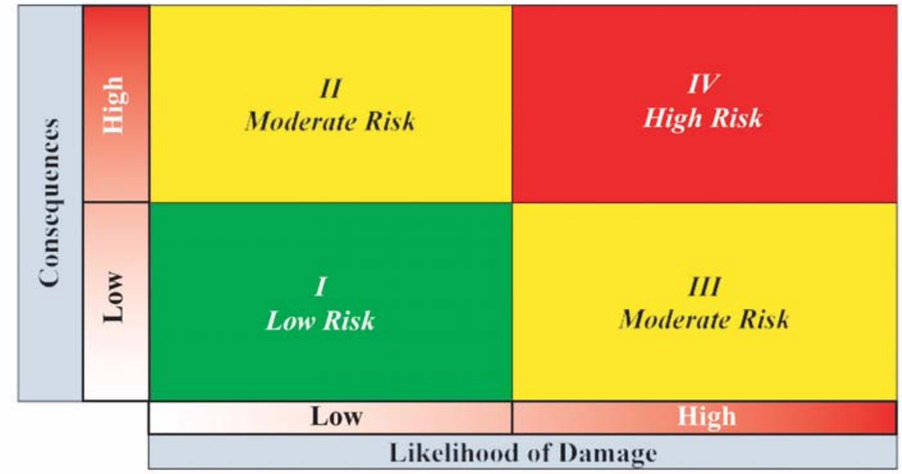


Figure 2-1 Seismic risk, expressed graphically as a function of likelihood of damage and consequences given the occurrence of the damage.

- A national chain retail store in seismically active northern California; the building has been designed to perform well during severe earthquake ground motions and potential loss of use of one building out of hundreds would not disastrously affect the owner's business.
- An abandoned warehouse in Texas; the seismic hazard is extremely low and the value to the owner is small.

Quadrant II, Moderate Risk: low likelihood of damage and high consequences; an example is:

- A well-designed hospital in South Carolina; the probability of severe earthquake ground motions is low but the hospital has 100 critical care beds and an occupancy of 2,000.

Quadrant III, Moderate Risk: high likelihood of damage and low consequences; an example is:

- A small storage facility for a national distributor located in a high seismic zone and designed to pre-1950 standards. The building is vulnerable to damage but the loss would likely be relatively unimportant to the owner.

Quadrant IV, High Risk: high likelihood of damage and high consequences; examples include:

- A private day care center designed by an inexperienced engineer two miles from an active fault in a highly seismic region. Lack of knowledge of the hazards associated with near fault sites could result in injury to dozens of children.

- A high-tech chip manufacturing plant in southern California, designed and built to the minimum requirements of the current code. The likelihood that a code-minimum building will experience extensive non-structural damage is high and business interruption could be devastating to the owner.

2.2 SEISMIC RISK MANAGEMENT: A HOLISTIC APPROACH FOR REDUCING EARTHQUAKE IMPACTS

Seismic risk management is simply the act of managing activities and decision making relating to building design, construction, and operations so as to reduce the impact of earthquakes.

DEFINITION

Seismic Risk Management
Seismic risk management is the act of managing activities and decision making relating to building design, construction, and operations so as to reduce the impact of earthquakes.

One of the purposes of this document is to provide building design professionals with tools and strategies to help owners and managers make cost-effective seismic-risk management decisions. The document therefore describes and compares various strategies, including reducing the likelihood of earthquake damage and reducing consequences, or both. The document also provides information on estimating future costs resulting from earthquake damage and other impacts as well as the costs to improve performance in future earthquakes.

The likelihood of earthquake damage is a function of the seismic hazard at the site and the seismic vulnerability of the building. Seismic hazard is addressed in the context of site selection and evaluation of site-specific earthquake-related hazards, as discussed in Chapter 3. Seismic vulnerability is addressed in the context of performance-based design, a relatively new tool (discussed in Chapter 4) that engineers can use to adjust up or down the earthquake resisting capacity of a building, depending on the desired performance in future earthquakes.

Design variables and issues affecting seismic performance, along with guidance for calculating the cost of improving performance, are provided in Chapter 5. Chapter 5 also discusses the cost of improved seismic performance versus the cost of future earthquake damage and loss, including indirect costs resulting, for example, from time out of service. The means to quantify these costs are also discussed. The key to making wise investment decisions, as discussed in Chapter 5, can be found in a three-step process that consists of:

- quantifying the amount and likelihood of losses that buildings may suffer in future earthquakes,

- estimating the expected reduction in future losses that can be achieved through various risk management programs, including performance-based design, and
- calculating the costs of implementing these programs, and comparing them to the estimated reduction in losses.

As with any other investment, the building owner weighs the expected return against the possible risk of not achieving that return. Equally important is the need to weigh the cost of the lost opportunity if the investment is not made. Examples abound in decision making involving such trade-offs, whether they relate to earthquake risk or other matters.

Specific seismic risk management strategies that focus on reducing the consequences or losses associated with earthquake damage are addressed later in this chapter, in terms of financial or business strategies and response planning strategies. Examples of these strategies include:

- diversifying operations so that all of an owner's operations are not concentrated in vulnerable buildings,
- obtaining insurance or other financial instruments to cover potential losses,
- establishing options to lease or buy replacement space after an event, or to immediately bring in contractors for repairs, and
- implementing pre-event planning and developing post-earthquake response and recovery programs to speed the process of business resumption.

It is often more effective, but typically more costly, to reduce seismic risk by reducing the likelihood that the earthquake damage will occur. By reducing seismic vulnerability, the uncertainties associated with estimating consequences of the expected damage and responding after a significant event are lessened. However, the initial costs of providing improved performance may never be recovered if an earthquake doesn't occur during the functional life of the facility. Reducing seismic risk by reducing the estimated consequences of a damaging earthquake often involves lower spending on an annual basis or incurring costs to repair or restore functionality once the event occurs. Large investments are not needed up front. In this case, while the likelihood of damage is not

CASE STUDY

Examples of Risk Management Strategies

1. Most businesses, whether commercial, industrial, or non-profit, know that reducing workplace injuries reduces expected costs in the future. Experience shows that capital spent today to install safety equipment and ergonomic furniture, and to conduct safety training for employees, can generate a positive return on investment by preventing future claims and reducing insurance premiums.
2. When deciding on a structural system for a new building, an initial extra 10% investment may result in less damage in future earthquakes. The benefit of not having to suffer as high a loss of capital, contents, and business interruption over the building's life can be compared to the investment cost at a given discount rate to determine the return and value of the investment.

reduced, the intent is to reduce seismic risk by enabling a quicker response and recovery.

The move to a performance-based design philosophy is a significant advance that can assist in seismic risk management, if it can be efficiently implemented into the building code development and design process.

2.3 EVALUATING SEISMIC RISK CONSEQUENCES AS A BASIS FOR DEVELOPING A RISK MANAGEMENT PLAN

The first step in developing a seismic risk management plan is to determine the nature and magnitude of the current risks. For a building or group of buildings, structural analysis procedures can relate potential damage to the intensity of shaking for a certain size earthquake. As the size of the earthquake increases, so does the total potential direct and indirect loss. Although the size of the loss increases with increasing magnitude, the likelihood of experiencing the loss decreases with increasing magnitude as the probability of earthquake occurrence also decreases with increasing magnitude.

Based on the likelihood of potential losses, one can determine the presumed capability to manage loss. Some owners and managers might rely on government assistance in combination with in-house resources to cover potential losses. The limit of these funds to pay for recovery costs would define current manageable loss. Losses in excess of this limit would be catastrophic and threatening to the business or institution. Figure 2-2 demonstrates this concept; the horizontal line defines the boundary between manageable and catastrophic loss. The intersection of the horizontal manageable loss line with the potential total loss curve defines the likelihood or risk of catastrophic loss. If this risk is too high, it can be reduced by increasing the capability to manage loss (moving the horizontal line up in Figure 2-2) and by reducing the potential loss curve with a higher performance objective for the building. Note that in Figure 2-2, the likelihood of the potential loss occurring is directly related to the probability of the earthquake, i.e., a smaller magnitude event corresponds to a high potential for occurrence and a larger magnitude event corresponds to a low potential for occurrence.

The capability to manage risks depends on the combination of several investment strategies on the part of facilities owners and managers. The first source of recovery funding is out-of-pocket expenses using in-house

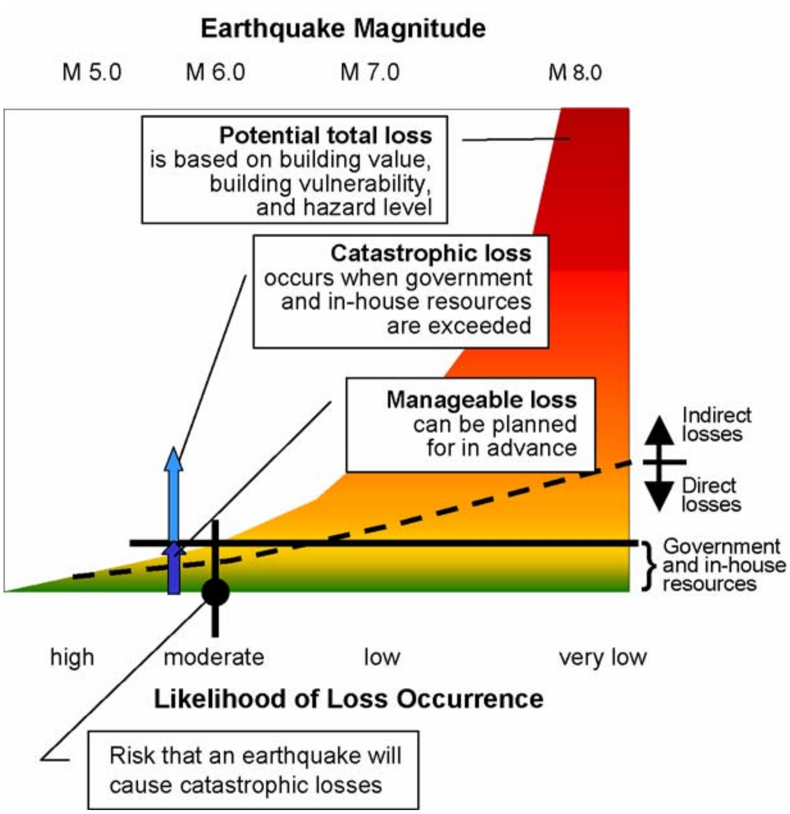


Figure 2-2 Illustration of risk of experiencing catastrophic earthquake losses. Concept assumes building, or inventory of buildings, is located close to earthquake source region.

resources to cover losses. This may be supplemented by some sort of government disaster assistance. For example, Stanford University covered all of its costs resulting from the 1989 Loma Prieta earthquake with its own funds, supplemented by funds from the Federal Emergency Management Agency and the California State Office of Emergency Services. Small businesses may be able to obtain low interest recovery loans to increase their own resources.

Conventional insurance is a fairly common means of increasing manageable loss levels. This may be appropriate for smaller owners, whereas capacity might be a problem for a large institution such as a major university or hospital organization. Insurance rates fluctuate with the perceived market, and settlement delays can be quite costly in some cases. The capital markets may offer the flexibility to design financial instruments directly to suit an owner's specific needs using catastrophe bonds, which are effectively a combination of a loan and insurance. Conventional insurance and capital market investments can be used to increase the capability to manage loss. As discussed in Section 2.5, the optimal combination of these alternatives depends on insurance market conditions, interest rates, bonding capacity of the building owner, and other factors. Increasing the manageable loss level reduces the risk of catastrophic loss by elevating the horizontal loss limit line as illustrated in Figure 2-3.

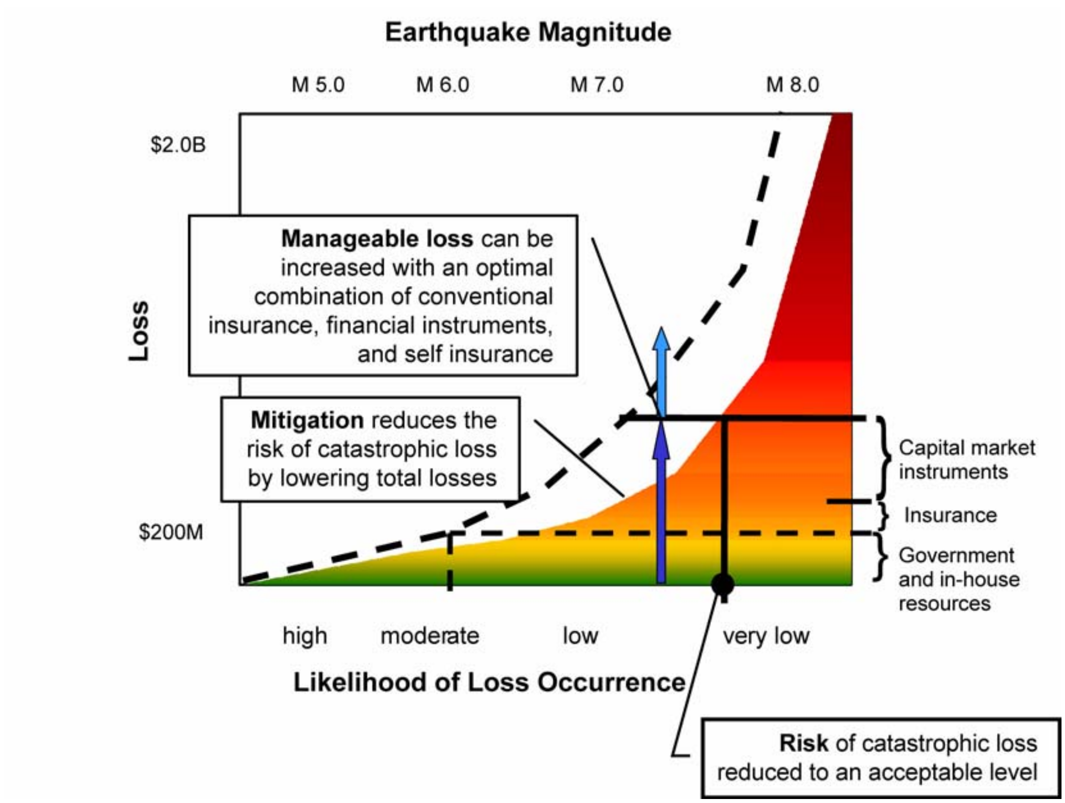


Figure 2-3 Illustration of reduction in risk of catastrophic earthquake losses.

Other strategies that can increase the level of manageable risk include the establishment of postearthquake response and recovery programs, which may reduce the amount of lost operations time through rapid engineering inspection and construction or repairs, or by obtaining alternate operating space quickly after an event. This is discussed further in Section 2.6.

Another important element of a risk management plan involves increasing the expected earthquake performance of the building, thereby lowering the potential loss curve. Mitigation reduces the risk of catastrophic loss by lowering the likelihood that the design earthquake would cause losses that exceed the manageable loss limit. The implementation of a mitigation strategy may include, as described in Section

2.4, designing new facilities to higher performance objectives, in order to limit losses over the building's life. This can apply to the replacement of outdated facilities or new facilities required as a result of company expansion needs.

The technical and financial parameters of a risk management plan all have associated uncertainties. Selecting the optimal combination of risk management strategies requires consideration of these uncertainties to assess the reliability of the decision making process. In addition, an integrated financial and technical model is necessary to test alternative strategies. The end result is a risk management plan that maximizes the return on investment to manage losses and reduce risk to an acceptable level over a fixed future time period. The flowchart shown in Figure 2-4 illustrates the various strategies that comprise a typical risk management plan and the options, or steps, for evaluating the strategies to select the optimal risk reduction solution. These three groups of strategies and related steps (outlined in Figure 2-4) are discussed in the next three sections.

2.4 FIRST COST OR DESIGN STRATEGIES

First cost or design risk reduction strategies are techniques that reduce the likelihood of damage to a structure. The term "first cost" is generally defined as an investment requiring a large capital outlay, whether or not it is truly spent near the start of a project. A capital investment of $10 million on a new building will most likely be amortized over some length of time, typically much longer than that actually required to construct the building. The owner is still responsible for the entire debt principal once the loan is secured, and often the debt goes "on the books" as a reduction in the amount of capital available for other investments.

First cost strategies reduce damage potential by either reducing the site hazards associated with a building or by increasing the expected performance of the building.

Reduce Site Hazards

An owner can reduce site hazards by reducing the intensity of earthquake shaking expected at the building site over the life of the structure, and by eliminating or reducing the potential for other seismic hazards, such as fault rupture, liquefaction, landslide, and inundation. Several techniques for accomplishing this are described below.

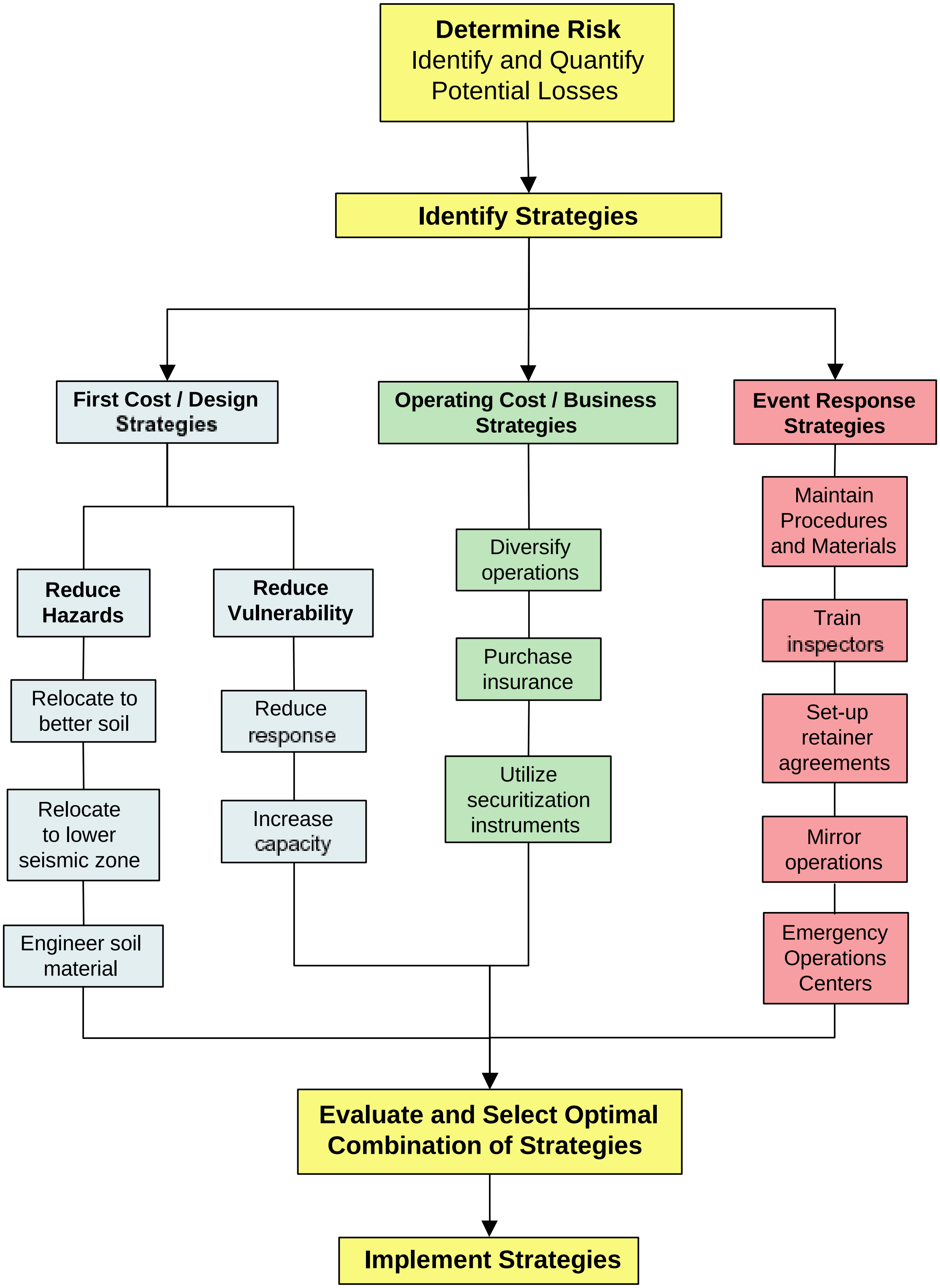
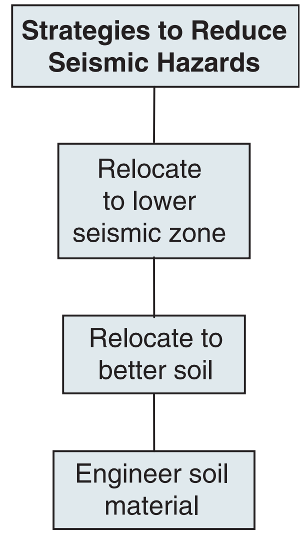


Figure 2-4 Flow chart for identifying, evaluating, and selecting risk-reduction strategies to develop a risk management plan.

- *Locate the building in a region of lower seismicity*, where earthquakes occur less frequently or with typically smaller intensities. This option is generally the most effective strategy solely in terms of reducing the potential for earthquake damage to a facility, whether it be caused by ground shaking, fault rupture, liquefaction, landslide, or inundation. Locating a building in Dallas, Texas, for example, will almost guarantee that it will never be damaged by an earthquake. Of course, this option isn't possible for many building owners.

  While certainly less desirable, and possibly quite costly from a market share and cost of operations standpoint, universities, manufacturing facilities, commercial offices and, to some degree, commercial retail owners, can use this strategy to manage their risks. Although it may not be practical for a university to build a new classroom facility across the country, locating some services off the main campus may be an option. For example, a university on the San Francisco peninsula located near the San Andreas Fault has considered siting a rare books depository approximately 75 miles south of campus, in an area of significantly less seismicity. It is also fairly common for high technology manufacturing plants to be located far from their headquarter locations, at sites with low seismicity such as Texas, Massachusetts, or Idaho. While it would be very rare for a retail establishment to make a siting decision based on seismic risk over the demographics of the market in a particular region, moving a store even a few miles in some cases can make a measurable difference in seismic hazard, e.g., moving a proposed building location from within a mile of a major fault to five miles away.



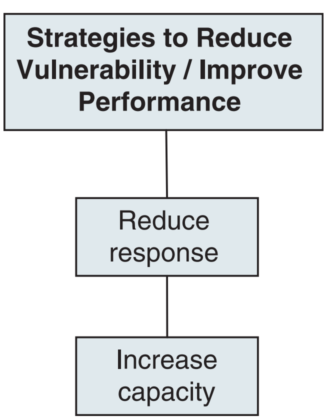
- *Locate the building on a soil profile that reduces the hazard.* Local soil profiles can be highly variable, especially near water, on sloped surfaces, or close to faults. In an extreme case, siting on poor soils can lead to liquefaction, landsliding, or lateral spreading. Often, as was the case in the 1989 Loma Prieta earthquake near San Francisco, similar structures located less than a mile apart each performed in dramatically different ways because of differing soil conditions. Even when soil-related hazards are not present, the amplitude, duration, and frequency content of earthquake motions that have to travel through softer soils can be significantly different than those traveling through firm soils or rock.

  An owner who is concerned about the effects of soil properties on risk should be encouraged to consult geotechnical and structural engineers to gauge the potential hazards associated with differing site conditions. These should be weighed against the costs, both direct and indirect, of locating the facility on soils that will result in better performance.

- *Engineer the soil profile to increase building performance and reduce vulnerability.* If relocating to a region of lower seismicity or to an area with a better natural soil profile is not a cost effective option, the soil at the designated site can often be re-engineered to reduce the hazard. On a liquefiable site, for instance, the soil can be grouted or otherwise treated to reduce the likelihood of liquefaction occurring. Soft soils can be excavated and replaced, or combined with foreign materials to make them stiffer. The building foundation itself can be modified to account for the potential effects of the soil, reducing the building's susceptibility to damage even if liquefaction or limited landsliding does occur.

  The owner should weigh the additional costs of modifying the soil profile or the building foundation (which may be quite significant in certain cases) with the expected reduction in damage and loss.

Improve Building Performance



An owner can reduce vulnerability by increasing the performance of the building, thereby reducing the damage expected in earthquakes. There are two methods by which this is typically accomplished:

- *Reduce the response of the building to earthquake shaking.* An earthquake generates inertial forces in a building that are a function of the structure's mass, stiffness, and damping, and of the acceleration and frequency of the earthquake motion. The parameters associated with the earthquake can only be altered by reducing hazards, as described above. While the actual mass of the building (the weight of the structure, contents, and people) typically cannot be significantly altered, the effective mass can be changed by providing special devices, such as passive or active mass dampers, that can effectively reduce the overall mass that is accelerated by the earthquake. Stiffness can be altered by modifying the structural system (e.g., concrete shear wall, steel moment frame) or by using braces and seismic dampers. The building's fundamental period, which is an important parameter in determining building response, can be significantly increased (and resulting forces reduced) by providing seismic isolating devices at the building foundation.

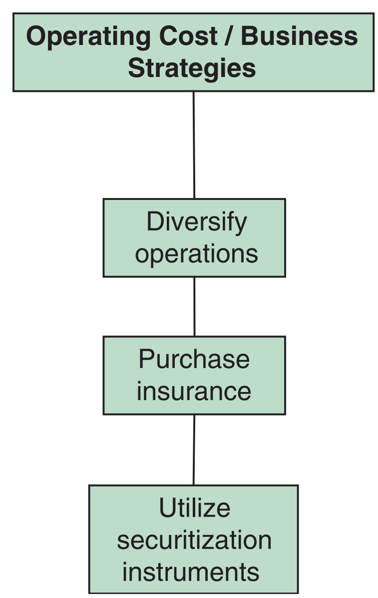
Engineers familiar with the use of these response-modifying devices can relatively easily quantify both the costs and benefits of employing them in buildings. When these types of products were new to the building industry, they were generally expensive. Today, with competition in the marketplace, they are much more common and costs have dropped dramatically.

- *Increase the capacity of the building to resist earthquake forces.* The most traditional method for decreasing vulnerability of buildings is to make them "stronger." By increasing the forces that a building can resist, such as by providing larger structural elements or increasing the amount of bracing for nonstructural systems, less damage would be expected. This strategy can be costly and, in some cases, may not be the most efficient means of increasing performance. Another option is to increase the ductility of the structural or nonstructural systems, improving their ability to absorb the energy of the earthquake without permanent damage.

  Increasing the capacity of the building may be the most difficult strategy to quantify reliably because of the inherent complexity of most structural and nonstructural systems. However, the range of possible solutions (and costs) for increasing capacity is relatively large, thus this strategy is the often employed because it allows the engineer to fine-tune a design approach to meet an owner's budget and risk management criteria.

2.5 OPERATING COST OR BUSINESS STRATEGIES

Operating cost or business risk reduction strategies are techniques that primarily enhance the capacity to manage losses, by effectively reducing the consequences of damage. The term "operating cost" is generally defined as an investment made on an annual or other regular basis.



Diversify Operations

An owner with geographically-dispersed buildings, or with an inventory consisting of buildings of various ages and seismic performance characteristics, can reduce overall earthquake risk by moving certain operations to buildings located in regions of lower seismic hazard or to buildings of higher seismic performance. This strategy can be fine-tuned when different operations carry different earthquake risks in terms of business disruption, loss of contents, or other impacts. For example, high resource operations, such as manufacturing or administration, can be relocated to new, higher performing buildings, while archival storage can be moved to older, more vulnerable ones. This can be done incrementally as new buildings are brought on line or over a defined timeframe so as to minimize the impact on operations.

Consider the following example of two manufacturing businesses. One runs 100% of its production from a single building in San Francisco. The other runs 50% each from one building in San Francisco and from one building in Seattle. There is a one percent annual chance in each city of an earthquake large enough to cause complete loss to the buildings.

Company A
100% operations in San Francisco
1% annual risk of complete loss to San Francisco building
Overall result: a 1% annual risk of complete business loss

Company B
50% operations in San Francisco
50% operations in Seattle
1% annual risk of complete loss to San Francisco building
1% annual risk of complete loss to Seattle building

Overall result:

- *a 1% annual risk of 50% business loss due to San Francisco event*
- *a 1% annual risk of 50% business loss due to Seattle event*
- *a 2% annual risk of 50% business loss*
- *a 0.01% annual risk of complete business loss (1% × 1%)*

As the number of sites grows, the risk of suffering a catastrophic loss to the business drops exponentially, even though the risk of suffering some loss grows. This assumes, of course, that the sites are independent. Having two similar buildings in San Francisco, within a mile of each other might not decrease the risk as substantially since a single earthquake could affect both. This methodology is used by insurance companies regularly to spread out their risk and reduce the potential for a single disaster causing more claims than they can settle.

Obtain Higher Levels of Insurance

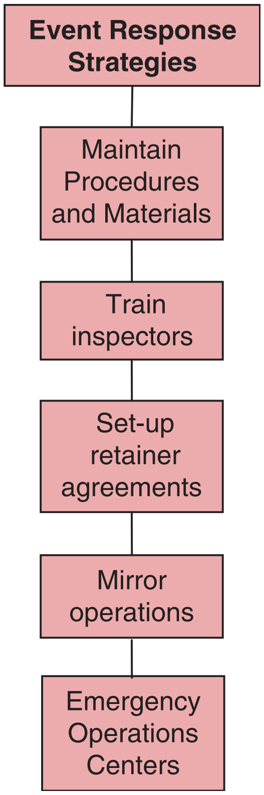
An organization should ensure that it has a sufficient amount, and type, of insurance coverage to adequately protect against losses. This determination is typically made by an owner's risk manager (or the insurance broker, acting on behalf of the owner). The risk manager must assess the cost of insurance relative to the potential costs of accepting the risk without insurance coverage. In most cases, investments in risk reduction (e.g., improving building performance or relocating to a lower risk area) will also result in insurance premium reductions. The risk manager must balance these different options by assessing the life cycle costs and benefits of each option. In order for the overall risk management plan to be effective, it is important for the organization's risk manager to become an integral part of the management team making facility decisions, and that communications with the facility manager and the design team be open and complete.

Using Securitization Instruments

Conventional insurance is typically best suited for incidents that occur regularly, although possibly infrequently, such as fire and worker injury. Conventional insurance is also appropriate for losses that are easily quantifiable, such as losses to capital and inventory. For very rare or catastrophic losses, however, obtaining insurance coverage can often be cumbersome or costly. It becomes difficult to price insurance when the rates of incidents are uncertain and when coverage for indirect losses from business interruption or loss of market share is needed.

A newer instrument, commonly called a Catastrophe Bond (Cat Bond) has recently garnered some attention. Sold on the open market, the proceeds of these bonds (typically in the range of $10 million to $100 million) are held in a financially secure trust. If an earthquake occurs within the period of the bond, and if the earthquake meets certain criteria in terms of size, location, or loss, some or all of the bond's principal or interest is forfeited to the seller to assist recovery. While generally limited to reinsurance companies, a small number of large, private corporations have started offering Cat Bonds. When insurance rates are low, Cat Bonds are generally less attractive. However, when insurance rates are high, as is common after a disaster, bonds become more economical.

Large investment banks are generally the best source to help an owner explore securitization options. The owner should have adequate understanding of his or her expected losses in different events, however, so that the amount of the bond and the interest payments can be as small as possible and yet still cover potentially catastrophic damage. Design team members well versed in performance-based design, risk assessment, and loss estimation, can be a valuable resource to owners in this effort.



2.6 EVENT RESPONSE STRATEGIES

The goal of event response risk reduction strategies is to manage potential losses through quick recovery and response to damage caused by earthquakes. Similar to operating cost or business strategies, event response focuses on reducing the consequence of damage and loss, rather than reducing the likelihood of damage and loss occurring. Relative to first cost or design strategies, event response typically requires much lower initial costs, as well as lower annual operational costs. While event response does not typically reduce capital losses or the amount of repair that may be needed, it can speed up the process of recovery through effective pre-event planning.

Emergency Response Procedures and Materials

The simplest form of an event response strategy can consist of maintaining procedures, equipment, and materials on-site for aiding the evacuation of building tenants. Most companies and institutions have at least a basic emergency kit and response procedures for evacuating people from a potentially hazardous building after an earthquake or during a fire. This level of planning can be implemented at a minimal cost. It may aid in the evacuation of the building and the treatment of injuries, but will not reduce capital or business interruption losses.

Pre-Event Disaster Training and Inspection Services

A second strategy is to develop and provide formal disaster training for employees and building personnel. Many large companies have instituted basic emergency response training for their employees, which includes basic safety and medical training. It may also include primer level education on how buildings respond in earthquakes and what telltale signs of building damage might indicate potential safety or operational hazards. These programs are generally not technically sophisticated, and are not intended to be a substitute for professional emergency response or engineering personnel. They can, however, reduce lost time in the event that damage is minimal and if building occupants are efficiently organized in the recovery effort.

A key component of event response is the ability to adequately identify what building damage means in terms of occupant safety and building functionality. To be done reliably, this requires the use of professional engineers and architects who have taken comprehensive training in the evaluation of earthquake damaged structures. Building owners and tenants can not reasonably be expected to accept the liability of deciding whether a building is safe to occupy. Thus, post-event engineering inspections are an important tool in an overall event response strategy. Large organizations will typically keep architects or structural, mechanical, and electrical engineers on retainer to quickly respond after a major event. They will be authorized to make safety inspections of owner's facilities using guidelines typically established by the local jurisdiction, such as the ATC-20 post-earthquake building safety evaluation procedures (ATC, 1989, 1995, 1996). They will then make recommendations to the building owner and put up signs noting whether the building is safe to enter, unsafe, or has restricted access in some fashion.

For owners or tenants of several buildings, this strategy should include the entire network of buildings that could be affected by an earthquake. Inspectors will be used most efficiently if they are sent to the buildings that are most severely damaged. For critical facilities, such as hospitals, it is advantageous to predict in advance the expected safety inspection postings—INSPECTED (green placard), RESTRICTED USE (yellow placard), and UNSAFE (red placard)—for all buildings on site. Procedures to be followed in developing and using such posting predictions are provided in the ATC-51-1 report, *Recommended U.S.-Italy Collaborative Procedures for Earthquake Emergency Response Planning for Hospitals in Italy* (ATC, 2002)

RESOURCES

Pre-Event Disaster Training and Inspection

1. ATC-20, *Procedures for Postearthquake Safety Evaluation of Buildings* (ATC, 1989),
2. ATC-20-1, *Field Manual: Postearthquake Safety Evaluation of Buildings* (ATC, 1989),
3. ATC-20-2, *Addendum to the ATC-20 Postearthquake Building Safety Evaluation Procedures* (ATC, 1995).
4. ATC-20-3, *Case Studies in Rapid Postearthquake Safety Evaluation of Buildings,* (ATC, 1996)
5. ATC-51-1, *Recommended U.S.-Italy Collaborative Procedures for Earthquake Emergency Response Planning for Hospitals in Italy* (ATC, 2002)

On-Retainer Temporary Space and Repair Contractors

A relatively new strategy being employed by some businesses is to obtain disaster lease or repair options for their facilities. Organizations may execute agreements with local contractors and property owners to provide them with a choice of available temporary space and for the labor necessary to repair damaged facilities. If an organization's buildings are damaged to the point that they are not functional and need significant repair, the owner would have the first right of refusal on any available space that a landlord has, at an agreed-upon set of pre-event prices, and on the use of personnel from local contractors. The organization, in return, provides a yearly retainer for the service.

Contingency planning companies offer building owners a service referred to as a "hot site." This is typically a fully equipped and functional facility (usually office space) that can be occupied fairly rapidly, whenever the owner's facility becomes unusable as the result of a natural or man-made disaster. Such a service can significantly reduce or eliminate the costs of business disruption resulting from earthquake damage. The service does not usually include the repair of the owner's damaged facility.

Facility and Data Mirroring

A formal business occupancy resumption program may include developing procedures by which critical information and the ability to conduct business are backed up or duplicated at alternate sites. This can range from electronically backing up and storing computer data at an off-site location to supplying company-wide transportation assistance to and from the employees' place of business, to having a plan to swiftly relocate operations to other offices or locations. Depending on the nature of the business, one or more of these options may be applicable.

Emergency Operations Centers

An emergency operations center is typically a hardened facility in which managers can conduct the emergency response and recovery effort. This facility will be constructed or located so that it can be operational after a major event. It should house emergency communications equipment, information on buildings and their contents, and have access to maps and information detailing the extent of damage both to the owner's facilities and the surrounding areas. The emergency operations center should be stocked so as to remain operational for at least 72 hours. For owners with large inventories of buildings or where a complex network of inspection and recovery is needed, the creation of an emergency operations center can be an effective strategy to ensure that building safety is rapidly evaluated and business resumption can occur as soon as it is safe and possible to do so.

2.7 CHOOSING AN OPTIMAL COMBINATION OF RISK REDUCTION STRATEGIES

RISK CONSIDERATION

Steps to Identify an Optimal Combination of Risk Reduction Strategies

1. Identify potential losses
2. Quantify losses
3. Identify risk reduction strategies
4. Select and implement strategies

Choosing an optimal combination of risk reduction strategies among those described above involves weighing the costs and potential savings associated with each option. The goal is to determine which combination results in the best return on investment. The basic steps that should be taken to identify an optimal combination of risk reduction strategies include the following.

1. ***Identify potential losses.*** These losses include, as described earlier, capital, contents, casualties, business interruption, and market share. A qualitative description of the type of damage that could be suffered is an appropriate starting point. This should include the use of engineering evaluation and performance-based design (see Chapter 4). For a range of earthquake scenarios or probabilities, a description of the type of capital and contents damage, estimates of casualties, and estimates of the duration of business interruption can be made by evaluating the structural and nonstructural behavior of the building under the given shaking intensity (See Section 5.7 for additional discussion). The design team and facilities staff should work as a team to identify, as examples, how long building operations will be shut down if shear walls in a building are cracked to the extent that structural repair is necessary, or what the average continuous occupancy of a classroom is over the course of a month.

2. ***Quantify losses.*** After the losses are qualitatively identified, they need to be translated into a common quantitative measure. The total value of both anticipated direct and indirect losses should be determined. In some cases, indirect losses will need to be converted into a direct cost equivalent through a value-based conversion; e.g., total manufacturing days lost, or hospital bed days lost.

3. ***Identify risk reduction strategies.*** Once losses have been quantified, the design team and owner's representatives should explore methods for reducing these losses, using the strategies described above; i.e., first cost or design strategies, operating cost or business strategies, or event response strategies. The team should identify as many options within each method as practical, estimating the cost to implement each and the expected savings in terms of reduced losses.

   For first cost or design strategies, various performance objectives should be considered for the new building. For example, the baseline scheme would be a building that meets the minimum provisions of the applicable building code. A higher performance objective might be one in which the building is not necessarily functional after the design event, but in which operations can be restored within a relatively short period of time. A still higher performance objective may be a building that is designed to remain fully functional in the design event. For each higher performance option, a conceptual level of structural and nonstructural design should be performed to determine an approximate cost difference above the baseline option. It is generally sufficient to make rough order approximations of costs.

For each design strategy, the performance of the building is then translated into an expected loss (both direct and indirect) in a range of earthquake scenarios with different probabilities of occurrence. To facilitate comparisons, these should be translated into an expected annual loss and converted to a present value at an assumed discount rate.

For operating cost or business strategies, different options such as insurance, securitization, and lease/repair options should be explored. The annual premiums to obtain specified amounts of insurance can be calculated with the help of the owner's insurance brokers. It is important to understand whether the insurance will also cover business interruption losses, or only capital and contents. For larger owners, catastrophe linked securities can also be considered. Typically, the coverage provided by such securities ranges from $10 million to $100 million, so smaller entities would not find these products appropriate. Lease/repair options can be developed with contractors and landlords in the nearby vicinity of the building, typically for an annual retainer fee. For all of these options, annual costs should be converted to a present value in order to facilitate a comparison with the other strategies.

For event response strategies, the design team should develop an outline of some specific options, such as a post-earthquake inspection program or the establishment of an emergency operations center. Annual or initial costs can be relatively easily estimated from this, as they will typically be small relative to the other strategies. The main benefit of this strategy will be to reduce down time as a result of better pre-event planning. The resulting savings should be approximated in terms of the daily cost of lost operations, multiplied by the expected reduction in lost time. These costs and savings should also be annualized and converted to a present value for comparison purposes.

4. ***Select and implement strategies.*** Once the various options within each strategy group have been evaluated and quantified, the team should consider permutations of each to determine the ones with the overall greatest benefit-to-cost ratios. Other factors may make certain strategies less desirable (such as the difficulty of a local school commission passing a bond measure for a seismic improvement capital outlay). Where appropriate, each option should be given a weight-

ing factor to express its desirability apart from purely economic factors. Once the optimal combination of strategies is selected, the owner and design team should develop a plan to implement them as part of the overall design process.

2.8 EXAMPLE IMPLEMENTATION OF A RISK MANAGEMENT PROGRAM

The following example illustrates how a hypothetical company might develop a risk management program.

Description of company

A Hayward, California company manufactures computer memory boards for large computer makers. The company's annual revenues are $100 million. All manufacturing is done in a single building with administration in a separate facility located in the same office park about three miles from the Hayward Fault. The company is planning to expand in the next three years, to double its annual revenues. It will buy a second manufacturing facility and construct a new office building.

Establishment of risk tolerance

Because the company currently has only four major clients it has determined that the risk of losing a substantial amount of revenue due to being dropped by a client is intolerable. It has decided to permit no more than 5% annual chance that lost client revenue exceed 10% of its revenue. Being near the Hayward Fault, the company concludes that it should not arbitrarily tolerate a large earthquake risk.

Current seismic risks

The company has conducted an engineering analysis of its current buildings and calculated the seismic risk. In a Hayward Fault event with a 5% annual chance of exceedence, capital and contents losses could reach $10 million. Loss of operations could cost another $25 million. The total direct losses of $35 million exceeds 10% of the company's revenue.

Risk Management Strategies

First cost / design strategies – The company can either buy new properties in the same office park or across the San Francisco Bay. By grouping all the buildings in the same location, the seismic hazard remains unchanged. However, the consequence of an earthquake on the Hayward Fault is increased because all of the buildings are likely to be affected. By separating the buildings geographically, the vulnerability of all four buildings being damaged by an earthquake in a year becomes negligible, although the chance that at least two of them will be affected by any event goes up. Engineers calculate that diversifying the regional location of operations reduces the overall risk most effectively. This results in reduced capital, contents and business interruption losses associated with a 5% annual chance of exceedence to $31 million, or 15.5% of the now doubled $200 million annual revenues.

Operating cost / business strategies – The company considers two operating cost options to further reduce the risk to its target tolerance. It can either obtain insurance to cover the remaining losses not managed by the improved first cost strategies, or it can implement a program of incremental retrofit of the two manufacturing buildings, to reduce their vulnerability. The company decides that the most cost effective option is to obtain insurance to cover (after deductibles) $5,000,000 of remaining potential losses above its tolerance. This represents 2.5% of the company's annual revenues

Event response strategies – The company decides to establish a post-earthquake response program, whereby it contracts with local engineers and contractors to provide immediate post-event inspections and repair design. The annual cost of developing and maintaining the program is $40,000 per year for the four buildings. The company conservatively estimates that in a moderate-to-large earthquake it could save at least a week-and-a-half of lost operations by having an engineer on board immediately. This equates to $6 million, or 3% of the annual revenue.

The three strategies together result in the following risk management program that meets the company's tolerance.

Vulnerability assumes hazard with 5% annual chance of exceedence:

First cost strategy:	Total losses = $31 million (15.5% of revenues)
Operating cost strategy:	Reduces total losses by $5 million, to $24 million (11% of revenues)
Event response strategy:	Reduces business interruption and total losses by $6 million, to $20 million (10% of revenues)

2.9 SEISMIC RISK MANAGEMENT ADVOCACY

Corporate cultures, especially those related to perception and tolerance of risk, are difficult to change. As a result, encouraging a corporate or institutional mindset to place a higher emphasis on seismic risk management will usually require one or more “champions” who can work from both within and outside the organization.

From within an organization, the organization’s risk manager or a top level staff member from the facilities department is the likely most appropriate in-house champion, as these individuals are likely to have both a broad understanding of the company’s corporate and business goals, and detailed knowledge of the design and construction process. The in-house champion will be expected to introduce seismic risk management standards, establish design priorities, quantify the consequences of losses, develop ongoing risk reduction processes, and keep the facilities department staff aware of their activities and findings. This champion must also be able to persuade upper level management of the need for such changes in policies and procedures. This will often require that the in-house champion “speak” in two languages – one technical and the other financial.

The design team should also act to champion the seismic risk management cause at early stages of discussion regarding a new building. In current practice, most design teams are organized under the direction of the project architect, who typically has a direct relationship to the building owner. Therefore, the external champion may be someone from within the project architect’s office.

It is important that both internal and external champions believe that seismic risk management truly adds value to their services and to the overall design process. Additionally, the external champion should establish a relationship with the internal champion, in order to leverage and support each others efforts, and to further the risk management process.