Guide to Identify & Manage Seismic Risks of Buildings for Local Governments

March 9, 2017

SSC 17-01

CONTENTS

Overview

California has some of the most modern and earthquake-resistant buildings in the world. However, most of our older buildings could be damaged by severe shaking in a major earthquake, and a small percentage of them could partially or completely collapse. Many Californians live, work, go to school, shop and worship in these buildings. "Collapse risk" buildings present the greatest risk of death and injury from earthquakes. They can also cause fires, damage or disrupt surrounding properties, and threaten neighborhoods and public rights of way. Together, these effects may cost hundreds of billions of dollars after the largest foreseeable earthquakes. Moreover, they will draw worldwide scrutiny about why the collapses happened, who was responsible for the risks, what measures were taken to manage them prior to the collapses, and what will be done about similar buildings. Mitigation of this risk is an expensive project, but much cheaper than the costs of collapse.

The California Seismic Safety Commission considers these buildings a top priority in seismic risk mitigation efforts across the state. Given sufficient time, effort and luck, many collapse risk buildings can be retrofitted or replaced before they cause harm in the next damaging earthquake. The Commission encourages a long-term outlook and commitment, because even under the best conditions it will take generations to achieve the ultimate goal of an earthquake-resilient society.

Every jurisdiction has an obligation to determine its degree of exposure to risk from building collapses in earthquakes, but there is more than one way for a jurisdiction to handle the threat. This guidebook presents a broad four-step process, with many different options, to help local governments identify and reduce the risks presented by these buildings. It also summarizes California's relevant laws and regulations. Along the way, it presents examples of successful approaches that have been taken by different California cities to address collapse risk buildings. Because each jurisdiction faces its own unique circumstances, each summary section of this guide is expanded in the Appendixes.

The advice in the Appendixes can be considered a toolbox from which local governments can draw and adapt to their community's unique circumstances. Checklists, success stories, financial incentives, and references for more detailed information might prove useful to local governments when designing initiatives to manage collapse risks.

The California Seismic Safety Commission has drawn from the experiences of hundreds of local governments to generate this Guide and Appendixes. Your feedback is welcome and essential for the Commission to make periodic improvements and corrections. Please send your comments to feedback@stateseismic.com

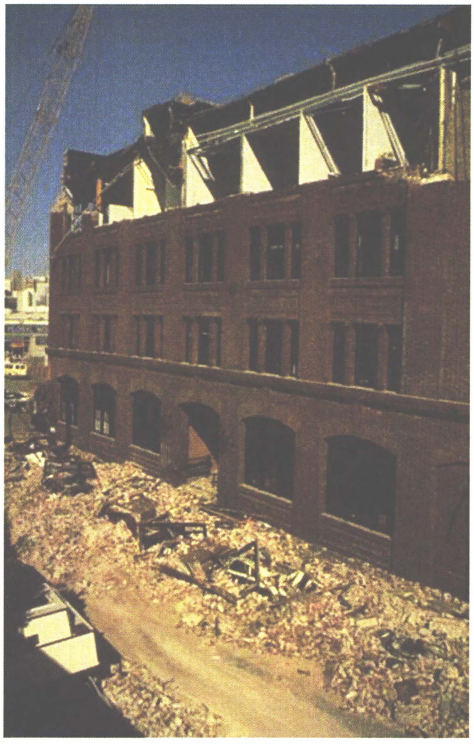
What Are Collapse Risk Buildings?

No building is without any risk of collapse during a very strong earthquake, but some have much greater risk than others. Buildings may be vulnerable to collapse because they were:

- Not constructed to comply with codes and standards, or
- Constructed before earthquake resistance was required in the 1930s, or
- Built to codes that were later found to be inadequate, or
- Poorly maintained or improperly altered, repaired or retrofitted.

Experience in California near active earthquake faults has shown that the following types of buildings generally pose exceptionally high risks of collapse:

- Pre-1940s unreinforced masonry, primarily brick, buildings
- Pre-1980s concrete frame buildings
- Pre-1980s buildings with soft or open lower stories, unbraced crawl space walls below first floors, or irregular shapes, including those on steep hillsides
- Pre-2000s buildings with precast concrete tilt-up walls or masonry walls, and precast concrete parking structures



Collapse of inadequately retrofitted brick building onto cars in San Francisco after the 1989 Loma Prieta earthquake.

Other types of buildings pose risks that are significant, but generally lower or harder to identify:

- Pre-2000s steel buildings
- Buildings of all ages that are inadequately constructed, repaired or maintained
- Buildings on sites subject to fault displacement, landslides, or soil liquefaction

Smaller, residential buildings, such as those with up to two stories and four units or less, and various specific building components have their own sets of vulnerabilities, but they present a relatively low risk of death and injury and are not considered further here.

In setting priorities among their collapse risk buildings, jurisdictions may choose from three basic approaches. The first focuses on the specific building category that poses the greatest risk.

The second addresses vulnerable buildings in order of their size. The third prioritizes buildings by their importance. Many jurisdictions combine two or more of these in a hybrid approach.

See **Appendix 1** for more detail on this topic.

The Most Effective Methods of Managing Collapse Risk Buildings

The best defense against building collapse during earthquakes is strong standards and professional practices. Ensuring that building construction and alterations are properly designed by licensed professionals, using plan reviews and inspections by qualified regulators, is the most effective way for governments to identify and reduce the risks of collapse.

Nearly all of this responsibility falls upon local governments. They review construction plans, issue building permits and inspect construction for more than 90 percent of buildings, including local essential service facilities such as fire and police facilities. State agencies check plans for and inspect most mobile homes, public schools, hospitals and other essential services buildings. Federal agencies regulate building safety for federally owned buildings and support research to improve building standards. Regulatory permits are required from all appropriate agencies for new buildings as well as alterations and seismic retrofits of existing buildings.

Jurisdictions have generally chosen one or more of four different priority-based approaches to address collapse risks. They may prioritize specific vulnerable building types, vulnerable nonstructural components, essential buildings, or buildings greater than a certain size. Each jurisdiction can tailor its programs to the unique circumstances and priorities established by policymakers.

See **Appendix 2** for more detail on this topic.

Who Is Responsible?

The responsibility for collapse risk buildings is generally well defined, but not always widely understood. For effective cooperation, building owners and regulators need to be aware of each other's obligations and concerns.

Building owners are responsible for ensuring their buildings are safe and are responsible for disclosing a building's vulnerabilities to occupants. Regulators leave certain matters to the discretion of building owners (tenant alterations, minor repairs and so on) that may affect the collapse risk of buildings. Owners are not obliged by law to go beyond the ordinary care exercised by a reasonable person; however, there are many extra options that prudent owners can take in their own self-interest. These include:

- Arranging for professional seismic evaluations and retrofits where warranted
- Storing construction records securely
- Creating a Building Occupancy Resumption Plan to ease disruption after a disaster
- Obtaining earthquake insurance

Government agencies can also set examples of prudence in managing buildings.

Because decisions made by building owners usually affect others, many circumstances associated with buildings may involve government regulators in their role of ensuring public safety. For example:

- A building at risk of collapse may endanger neighboring structures and rights of way, blocking emergency response efforts.
- Owners might not inform building occupants—or not even know—about the vulnerable condition of their buildings.
- The public may assume that the existence of regulations ensures the safety of a building even if its owners are negligent.
- Local government policies aimed at population growth, preservation, redevelopment or revitalization of neighborhoods may affect the public's exposure to seismic risks in ways that should be considered during decision-making.

Collapse of the Alexandria Building after the 2014 South Napa earthquake.

These circumstances tend to accumulate with time, increasing levels of risk, unless they are addressed through proactive intervention by regulators and effective action by policymakers.

The public is a stakeholder in questions of collapse risk buildings. Collapsed buildings cause major disruptions that affect the whole community. Retrofitting policies should focus on speeding improvements, reducing their costs, and minimizing their disruption to all parties: owners, occupants and surrounding neighborhoods. The best initiatives go beyond technical feasibility by respecting owners' knowledge and experience, selecting cost-effective alternatives, and demonstrating that local governments are serious about ensuring their success.

Because California's jurisdictions vary so greatly, a uniform statewide approach is not optimal. In deciding on levels of investment in retrofit programs and the urgency with which to pursue them, local governments have difficult choices to make in balancing the risks against their resources. Internal factors affect these choices, such as the confidence of leadership, funding priorities, relationships with other stakeholders, staff costs and expertise, and time horizons. Governments should acknowledge these factors as they work to best ensure safe buildings.

See **Appendix 3** for more detail on this topic.

Nexus for Public/Private Partnerships to Manage Collapse Risks

Most buildings are privately owned, but their risk of collapse affects occupants as well as the public. Both building owners and government agencies therefore have a stake in managing earthquake risks. It is in everyone's best interests for governments and building owners to collaborate in identifying vulnerable buildings and improving their earthquake resistance. After several decades of witnessing such collaborations, the Seismic Safety Commission has observed that fostering active dialogues, mutual understanding, and commitment are key to helping these efforts succeed. A few of the many success stories from California jurisdictions are presented here in sidebars.

This retrofit project in Eureka took over 25 years to complete. It relied on federal tax credits for historical buildings and a loan from the city's Community Development Block Grant.

All parties, public and private, are bound by many state laws and their associated regulations, which may apply to a given collapse risk reduction project. Governments also have incentive programs at their disposal, from federal tax credits to property tax exclusions to special measures for historically significant buildings, that can be used to promote progress.

See **Appendix 4** for more detail on this topic.

Four Steps to Managing Collapse Risk Buildings

There are many options for governments to manage the risk presented by buildings that are prone to collapse. They range from passive approaches that may gradually reduce collapse risk for some buildings over decades to active approaches that require seismic evaluations and retrofits within a few years. This guidebook summarizes knowledge gained from monitoring hundreds of local government efforts.

The public often assumes, incorrectly, that government agencies require existing buildings to be earthquake resistant. Many people are surprised to learn that some earthquake safety regulations only apply to existing buildings when they undergo major alterations, additions, or repairs.

Owners may not know or may be reluctant to find out about the earthquake resistance of their buildings. As a result, many buildings have never been seismically evaluated or upgraded. Pre-1930s buildings were likely constructed without considering earthquake resistance since California's building codes did not include earthquake safety requirements until 1933.

Success Story

St. Helena's Unreinforced Masonry Building Program

St. Helena has 33 buildings in its inventory, and the owners have retrofitted all of them. The city provided numerous incentives including building permit fee waivers, creation of a historic district to take advantage of a 20% federal tax credit, use of the state's Mills Act to preserve facades and reduce costs, and a streamlined design review process.

There may be only a few key opportunities to address the collapse risk of a building during its useful life, such as major alterations or changes in use. These opportunities set the baseline pace for risk reduction in a jurisdiction. In dealing with collapse risk buildings, policymakers should decide whether to speed up this pace and how much to do so. This section outlines ways to organize that decision-making process.

When buildings are sold, the California Seismic Safety Commission's *Commercial Property Owner's Guide to Earthquake Safety* and the *Homeowner's Guide to Earthquake Safety* encourage or require sellers to disclose typical earthquake weaknesses to buyers. When major buildings are refinanced, lenders and insurers may require seismic evaluations as a precondition. When buildings undergo major alterations, additions or repairs, local governments may require seismic evaluations or retrofits when issuing construction permits.

If a community relies on building owners to manage their own risks, conscientious owners who have long-term interests in their community and are aware of earthquake risks may eventually replace or retrofit their vulnerable buildings when they find it convenient. But risk reduction progress is expensive and will typically be slow and uneven. In the meantime, those who

occupy collapse risk buildings and rely on streets and sidewalks nearby are exposed to their risks while facing the prospect of years of disruption after a major earthquake.

In the face of this situation, three public policy questions warrant consideration by governments, building owners and the public:

1) How effective are our current policies regarding earthquake safety?

2) How many years will these policies take to significantly reduce collapse risks in our community?

3) What alternative policies might we consider?

Communities assume that their government officials will take initiatives in long-term planning and place earthquake safety priorities into context with other competing priorities. And California has many examples of government agencies that have undertaken earthquake risk management initiatives.

Next we present the four necessary steps of a successful initiative to manage earthquake risks associated with buildings most likely to collapse.

See **Appendix 5** for more detail about this topic.

Success Story

Fremont's Soft Story Apartment Building Program

In 2007, Fremont required owners of 30 apartment complexes to retrofit. The city designed its ordinance to result in no occupants being relocated from their units during construction. Fremont also reimbursed owners for all plan check and permit fees once the retrofits were completed. Owners could apply for time extensions due to financial hardship. Fremont demonstrated remarkable success, albeit for a relatively small portion of its apartment building stock.

Step One: Create Opportunities for Education, Dialogue, and Public/ Private Participation in Decisions about Buildings

Before anything else, governments should make a commitment to ensure sound decision-making. The right process will avoid surprises and minimize delays, complaints and lawsuits after a course of action has been set. Considering issues deliberately, incrementally and from a variety of perspectives is a proven, effective management technique.

It is important at the start for departments within local governments to work together to generate effective changes. At the right time, a lead agency should be named to communicate issues in a timely manner to the public. Messages can be crafted that evoke confidence in carrying out risk reduction rather than provoke anxiety and fatalism.

Along with the private sector, government building officials, emergency managers, city councils, and boards of supervisors should actively engage and inform the public about the issues related to collapse risk buildings and the alternatives for managing their risks.

Stakeholders should be kept informed about who makes decisions, when, and how they can participate and influence policymaking. Building owners should be informed about the variety of seismic upgrade options available to building design professionals. Stakeholders can respond well to specific approaches pitched to their interests and allies.

Step Two: Estimate the Size and Nature of Collapse Risk

Buildings offer different levels of collapse risk, depending on their construction type, age, and occupancy. Inventories of buildings thus can provide detailed insights into a community's vulnerability. A jurisdiction can make a useful beginning with indirect surveys based on agency records, online street views, Sanborn maps, other archives and similar resources. There are several more robust approaches that can be considered as part of **Step Three**. Agencies may benefit from comparing efforts in other similar communities that have conducted such studies.

Success Story

San Diego's Downtown Parapet Bracing Program

The City of San Diego includes parapet bracing as a key part of its downtown redevelopment effort. In light of the city's somewhat lower risk than in other parts of California, the city government considered the risks posed by other vulnerable aspects of brick buildings to be too costly to address. Bracing was accomplished with historic preservation in mind so that the aesthetics of the brickwork was not adversely impacted by the installation of new wall anchors.

Learning basic information about the ages, occupancies, sizes, locations, and states of repair of the buildings in the jurisdiction will help quantify the potential for deaths, injuries, downtime, economic and social losses from damaging earthquakes. Reviewing long-term plans for economic improvement, historic preservation, transportation, and redevelopment will help identify opportunities and constraints for reducing earthquake risks while accomplishing other objectives. Inventories will also help identify buildings that have already been retrofitted or replaced and the rate at which changes are already taking place.

Even if no further steps are contemplated, community leaders, emergency managers, and building officials will gain a better sense of what to expect and how to respond to future earthquakes. Getting rough estimates of collapse risk buildings—their numbers and sizes—is a critical first step to effectively manage them.

Step Three: Develop and Consider Options for Identifying and Mitigating Collapse Risks

In this section we present seven options to manage collapse risks. These range from implementing existing regulations to enacting mandatory retrofit programs. They are ranked below from lowest to highest according to their difficulty to implement and their potential for resistance from building owners.

Option 1: Rely on Attrition and Current Triggers for Alterations in the Building Code

Older buildings are periodically replaced by newer, typically more earthquake-resistant buildings as communities grow. This attrition typically occurs at rates of less than 2 percent of the building stock per year. Most California jurisdictions rely on attrition as a risk reduction strategy. It offers owners the most discretion, is the least confrontational, is market-driven, and is consistent with the policies of neighboring jurisdictions. However, most jurisdictions are not making use of the information coming in from attrition-related activity.

Chapter 34 of the California Building Code requires owners to consider seismic safety in existing buildings when major alterations, additions, and repairs are contemplated. However, these regulations tend to discourage owners because they can cause uncertainties and triggered costs like fire safety and accessibility upgrades. The cumulative effects of prior alterations are required to be considered when altering or constructing additions to existing buildings. Voluntary seismic improvements are encouraged by the building code, which allows owners discretion when proposing improvements.

State laws require disclosures of typical earthquake weaknesses at the time of sale for certain dwellings and encourage disclosures for certain commercial buildings. These disclosures can trigger voluntary retrofits.

This option is consistent with policies in most jurisdictions except for unreinforced masonry buildings in regions of high seismicity. A community's building official will have more information and a sense of how effectively and at what rate attrition and voluntary seismic improvements are taking place.

Option 2: Develop Reliable, Detailed Inventories of Collapse Risk Buildings

Any risk reduction program that goes beyond attrition will require detailed inventories as a foundation. Starting from information gathered in **Step Two**, these inventories can rely on:

- Records of building permits for past seismic evaluations as well as triggered and voluntary seismic retrofits

- Samplings of buildings to infer characteristics of a larger inventory
- Online street views and other geographic information systems
- Sanborn maps that depict construction types
- Building permit and tax assessor data
- Archives of architectural, civil, and structural engineering firms
- Redevelopment plans or transportation corridor studies
- Maps of liquefaction zones and areas with landslide potential
- Registers of historical buildings and surveys of historic districts
- Adopted versions of the building code in effect when buildings were constructed or retrofitted

These can help determine construction types, sizes, heights, and occupancy classifications and overall vulnerability to earthquakes. Software is available that can help analyze building inventories and make preliminary estimates of possible earthquake losses.

Success Story

Los Angeles's Unreinforced Masonry Building Retrofit Program

The City of Los Angeles spent over a decade requiring owners to retrofit or replace over 8000 unreinforced masonry buildings. At the time of the Northridge earthquake in 1994, over 6000 had been retrofitted and 2000 replaced. Fortunately, no one was killed in these buildings during the earthquake. While not all retrofits were entirely successful and lives could have been lost if the earthquake had occurred at another time of the day, the city's recovery efforts were accelerated by reduced damage and disruption in these buildings.

Option 3: Develop Seismic Performance Objectives

Governments and other stakeholders can consider a variety of alternatives for describing how buildings can be expected to perform in earthquakes. These seismic performance objectives, which are issued separately for structural and nonstructural parts of buildings, can then be used for retrofits or replacements.

The process of considering seismic performance objectives will enable a dialogue in the community about acceptable levels of risk, recovery costs, and durations of social and economic interruption. Discussions can highlight the differences between the expected performance of newer buildings compared with the performance of existing buildings.

Typical structural performance descriptions or objectives are:

- **Not Considered or Unknown**
- **Immediately Dangerous** – and not safe to occupy
- **Significant Collapse Risk** – considered safe enough to occupy

- **Collapse Prevention** – with little or no margin of safety
- **Life Safety** – with larger margins of safety beyond collapse although buildings may not be occupiable after damaging earthquakes
- **Immediate Occupancy** – although not necessarily operational due to damage to building contents, nonstructural systems, or lifelines

Typical performance objectives for nonstructural portions of buildings such as equipment, electrical, plumbing and ventilation systems, ceilings, partitions, and cladding are:

- **Not Considered or Unknown**
- **Life Safety** – to avoid death and injury, but not necessarily keep systems in place
- **Position Retention** – to keep systems in place during shaking, but not necessarily operational
- **Operational**

Success Story

San Luis Obispo's Downtown Revitalization Program

The City of San Luis Obispo requires that all of its 126 unreinforced masonry buildings be retrofitted. The city provided free downtown parking for contractors, $5000 incentives for each owner that retrofits, grants for up to $25,000 for some owners, and permit fee waivers. Most importantly, the downtown business community is experiencing a major revitalization with enhanced foot traffic, retail and restaurant activity partly as a result of the improvements, which will be complete in 2018.

Option 4: Undertake Seismic Screenings

Selective screening of collapse risk buildings will be informative for setting priorities for other options and aiding public understanding of the risks. This option doesn't necessarily involve formal quality assurance or public disclosure of screening results.

Two standard techniques for screenings are available:

- *Rapid Visual Screening of Buildings for Potential Seismic Hazards* (FEMA 154, a national guideline) is a simple procedure that can be accomplished with smartphones from the sidewalk and no access to interiors.
- *Seismic Evaluation and Retrofit of Existing Buildings – Tier 1 Seismic Screening* (from ASCE 41-13, a national standard) is a somewhat more in-depth procedure that can be accomplished in less than a day for most buildings with interior access.

The results of these screening techniques can be incorporated into community-specific vulnerability databases for more reliable loss estimates for large cities and counties. Loss estimates can also help generate what-if scenarios for an expected range of earthquakes as well as annualized losses based on screening data unique to each community.

Option 5: Require Seismic Evaluations and Ratings of Buildings

More stringent ASCE 41-13 Tier 2 or 3 evaluations of buildings that have a particular type of exceptionally high risk construction will provide comprehensive insights into vulnerabilities. These are typically done for buildings that face retrofits. This information can help scope retrofit costs and disruptions to occupants and neighbors. The results of ASCE 41 evaluations can also be used to generate safety ratings and compare them with the performance provided by standards for new construction.

A number of jurisdictions have opted to subsidize owners' costs of these evaluations.

Option 6: Encourage Voluntary Retrofits or Replacements

Communities can take steps to accelerate the baseline rate of attrition through programs that make retrofits or replacements more attractive to building owners. The success of these programs will be influenced by:

- Real estate market conditions including property values, rents, and vacancy rates
- Frequencies of changes in occupancy
- Code-based triggers of seismic evaluations and retrofits including those for alterations, additions, or repairs
- Changes in stakeholder awareness when ratings and disclosures become known pursuant to previous options
- Ordinances that require owner notification of exceptionally high risk buildings and specify seismic performance objectives
- Redevelopment and intensification of properties
- Incentives such as reducing building permit fees, or reduction of disincentives such as waiving parking requirements

An important part of such programs is asking owners to commit to a self-defined time frame for action. It may be more politically acceptable and less confrontational to start a voluntary retrofit program first, but typically a large percentage of owners will not retrofit or replace their buildings until they are required to do so.

Success Story

San Francisco's Earthquake Safety Implementation Program

San Francisco engaged its citizens in collaborative ways to develop a Community Action Plan for Seismic Safety to reduce vulnerabilities with priorities tailored to the City's unique building stock and socio-economic conditions. The plan's recommendations are now being managed through a new 30-year Earthquake Safety Implementation Program. First steps include addressing the most vulnerable soft story apartment buildings. Next in line are older private schools, and plans are being put in place to address non-ductile concrete buildings later.

Option 7: Require Retrofits or Replacements

Mandatory retrofit ordinances will generally require retrofits by owners within time frames of multiple years. Ordinances will typically include:

- Notification of owners of exceptionally high risk buildings near active earthquake faults
- Minimum seismic performance objectives and retrofit requirements
- Financial incentives and removal of disincentives
- Procedures for regulators to record certificates of collapse risk and compliance on property deeds
- Ways to ensure effective enforcement of evaluations, retrofits or replacements within prescribed time frames
- Procedures to accommodate changing economic conditions, respond to unexpected construction costs and delays, and allow time for buildings to be sold to others more willing to retrofit
- Guidelines for preserving qualified historical resources
- Language specifying demolition and replacement of high risk buildings as a last resort when retrofit alternatives are infeasible
- Requirements to monitor and report progress to policymakers

California jurisdictions have enacted successful ordinances of this type for unreinforced masonry structures. In extending them to other building types, flexibility and creativity are essential for success. Communities considering this option should closely study existing programs in this state and elsewhere.

Step 4: Other Key Management Considerations

Only rarely can collapse risk buildings be dealt with in isolation. Other issues always complicate the process of seismic risk reduction, but the specifics are unique to each jurisdiction. To help avoid unforeseen difficulties, the following issues should be evaluated as part of the planning checklist for each of the three previous steps.

- Hazards arise from nearby active faults, including the extent and expected rate of occurrence of damaging ground motions, landslides, liquefaction, tsunamis, and other geological effects. The exact mixture of these hazards is unique to each community.
- Fire protection needs, electrical and communications networks, and infrastructure of regional significance each require special attention.

- Earthquakes induce major secondary effects such as water damage, nonstructural damage and damage to building contents.
- Costs are always significant. It is imperative to balance them against realistic estimates of benefits, affordability and the time needed to reduce collapse risks effectively.
- Financial, zoning and use incentives can make a significant difference in helping owners invest in building safety.
- Seismic safety objectives should mesh with other planning, zoning, economic, social development, and historic preservation initiatives.
- Seismic retrofits can trigger other requirements such as disabled access compliance, fire resistance and repairs that can substantially increase project costs and discourage building owners from taking action.
- The community's tax base will be affected, both by altering the building stock and by damaging earthquakes.
- Post-earthquake recovery times, and the extent to which they might be reduced by pre-earthquake risk reduction, should be carefully considered.

A final challenge to communities is reconciling the human and geological timescales. Damaging earthquakes may occur at any time and cannot be predicted. But they are relatively rare, so communities may have the advantage of many years, possibly decades, before the next one. But retrofits and replacements of collapse risk buildings are quite costly, so they can't be readily accomplished in the short term. Therefore, adopting a long-term perspective is typically sound practice. These are the essential elements:

- Building safety regulatory oversight by well-trained and qualified professional inspectors and plan reviewers, who are generally licensed or certified, to ensure that new buildings are earthquake resistant and every opportunity is taken to effectively reduce the risks posed by older buildings
- Preparedness, public education, and emergency management measures including barricading, stabilization and having repair ordinances in place to address the anticipated risks that damaged buildings can pose
- Management by metrics, using periodic progress reports to keep the public and policymakers abreast of the size and nature of the collapse risks posed by buildings, what has been done about them over time, how soon will such risks be significantly reduced to manageable levels, and how the rate of retrofit and replacement progress compares with the expected rate of occurrence of future earthquakes
- Incorporation of retrofit and replacement initiatives into a community's multi-hazard mitigation plans and coordination with other long-term planning and growth objectives
- Periodically reevaluating progress and revising priorities and strategies, especially after damaging earthquakes