Appendices for

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

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CONTENTS

Appendix 1: Common Types of Buildings at Risk of Collapse in Damaging Earthquakes

Buildings that collapse can cause deaths, injuries, fires, property damage, and disruption to surrounding neighborhoods and streets. Californians routinely live, work, go to school, shop, and worship in these buildings. Buildings may be vulnerable to earthquakes because they were:

- Not constructed to comply with codes and standards
- Constructed before earthquake resistance was expressly required in the 1930s, when California began to require local governments to regulate buildings for earthquake safety after the 1933 Long Beach earthquake
- Built to codes that were later found to be inadequate
- Improperly altered, repaired, or poorly maintained

These buildings may have compromised earthquake resistance. Some buildings can be exceptions to the types described in this guide, and will be typically harder to identify and systematically inventory. For example, buildings may have parts that are not well connected that can create falling risks. Seismic inventories and evaluations can identify many, but not all risks.

Five classes of buildings pose the greatest risk of collapse. Each class shares its own special set of vulnerabilities, listed below. All of these vulnerabilities can be addressed by retrofits.

Unreinforced Masonry (URM) Buildings were commonly used as fire-resistive construction in low- to mid-rise commercial and industrial neighborhoods of California until they were prohibited by the Riley Act in 1933. These buildings are relatively easy to identify, and nearly all of the unretrofitted ones pose significant risks to life. URM buildings have seven types of vulnerability:

- Unbraced parapets (tops of walls) can fall onto sidewalks, streets, alleys, and adjacent lower buildings.
- Walls that are not well connected to roofs and floors can separate and fall outward.
- Masonry walls with little or no reinforcing steel inside have low strength, especially if the mortar is deteriorated, and can quickly degrade in severe shaking.
- Ground floors with open fronts, lacking solid walls, can undergo excessive movement causing damage and collapse.
- Incomplete or inadequate seismic retrofits or subsequent deterioration can result in life-threatening damage during earthquakes.
- Mid-rise URM buildings (4 to 10 stories) may have steel or concrete frames infilled with masonry walls, which can separate and fall away from the frames. These may account for up to 5 percent of California’s URM buildings.
- Adjacent buildings are sometimes at risk of portions of taller URM buildings falling on them.

A 1986 state law requires local governments in highly seismic regions to inventory URM buildings, establish risk management programs, and report progress to the Seismic Safety Commission. In the Seismic Safety Commission's 2006 survey, 283 local governments in parts of California closest to active earthquake faults reported that 70 percent of their 26,000 inventoried URM buildings had been retrofitted or demolished, leaving about 7,800 inventoried buildings without retrofits (SSC 2006b). Buildings in regions of moderate seismicity have typically not been inventoried.

Non-ductile Concrete Buildings were built from the early 1900s to the late 1970s. Only a small and unknown percentage of the 12,000 to 15,000 non-ductile concrete buildings extant have been retrofitted (CA-OES 2013). These buildings have four areas of vulnerability:

- Columns, beams, and joints lack sufficient reinforcing steel to effectively confine their concrete.
- Concrete walls are too few in number, have too many openings, or otherwise lack strength and stiffness.
- Buildings may have weak floors and roofs, large openings in floors and roofs, and inadequate connections to walls.
- Irregular building shapes or discontinuities can aggravate other vulnerabilities.

The collapse of the Pyne Gould Building in Christchurch, New Zealand in 2011 killed 18 people. It was a non-ductile concrete building that had been partially retrofitted before the earthquake.

A relatively small fraction of these buildings clearly pose collapse risks, and detailed seismic evaluations can identify them. However, low-cost seismic evaluations could designate nearly all older concrete buildings as collapse risks, whereas more costly, sophisticated analytical techniques and actual earthquake performance would suggest that most are not. Research is underway to improve and lower the costs of seismic evaluation techniques for non-ductile concrete buildings (ATC 2014, PEER 2014).

Precast Concrete Buildings (tilt-ups) constructed before 1976 are estimated to number more than 57,000 in California. They have two areas of vulnerability:

- Connections of the walls to roofs and floors are weak and can fail, causing roofs and floors to fall down or walls to fall outward.
- Connections between segments of precast walls can be weak.

Seven local governments have completed mandatory tilt-up retrofit programs as of 2015. Similar weak wall-to-roof connections can exist in an unknown number of older reinforced masonry buildings (CA-OES 2013).

Soft-Story, Multi-unit Residential Wood Frame Buildings built before the 1990s number in the tens of thousands statewide. They share the following vulnerabilities:

- Irregular configurations with open fronts, typically at the ground floor, are designed to accommodate parking below living units or retail spaces.
- Soft (flexible) or weak wall configurations can cause buildings to move excessively during earthquakes.

About 15 local governments have conducted inventories of these buildings, and four cities (Alameda, Fremont, Los Angeles and San Francisco) require retrofits. A 2005 state law referred to a Seismic Safety Commission recommendation in 2007 that mitigation programs start by 2020, but it was replaced by a 2013 loss reduction plan without such a milestone (SSC 2013).

Steel Frame Buildings built from the 1940s to the mid 1990s have the following vulnerabilities:

- Welded connections between steel beams and columns can be brittle and crack during earthquakes.
- Diagonal braces can fail prematurely in severe shaking.

Smaller, residential dwellings have their own vulnerabilities that are listed in the *Homeowner's Guide to Earthquake Safety* (SSC 2005). Although these generally pose widespread economic losses, their risks to life and injury are smaller than for larger buildings. They are not generally considered collapse risk buildings and are not treated further in this guide. They include:

- <u>Wood frame homes:</u>
  Built primarily before the 1960s on crawl space walls that may not be braced or bolted to their foundations.

Built on unreinforced masonry or pier and post foundations before the 1940s.
Built on steep hillsides primarily before the 1990s. These can pose serious collapse risks.
With unbraced rooms over garages built before the 1980s.

- Mobile homes installed before 1995 are prone to fall off under-floor supports.

Reinforced masonry buildings such as this can have poor wall-to-roof connections that fail the same way they do in concrete tiltup wall buildings. 1992 Landers earthquake.

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Appendix 2: The Most Effective Methods of Managing Collapse Risk Buildings

Our best defense against earthquakes is regulation that ensures new construction is not prone to collapse. New buildings, as well as alterations to old buildings, require the conscientious efforts of four groups of people:

- They must be properly designed by licensed professionals.
- They must be built with approved permits by licensed contractors.
- They must be checked with thorough plan reviews and inspections by qualified regulators.
- They must be appropriately funded for safe construction and maintained by owners.

California's primary lines of defense are its local, state, and federal building departments and their regulatory effectiveness. Rigorous enforcement of design and construction relies on the comprehensive standards in the California Building Code (CBSC 2016a). This code is updated every three years to include new requirements based on testing, research and development, and observations from past earthquakes. These requirements are more stringent for buildings with essential services or large occupancies and those closest to active earthquake faults (CA-OES 2013). Buildings are regulated by one of three levels of government:

- **Local governments** regulate more than 90% of all buildings.
- **State government** regulates state-owned buildings, most mobile homes, public schools, public universities, essential services buildings, and hospitals.
- **Federal government** regulates federally owned buildings and nuclear power plants.

Regulators are responsible for preventing unlawful construction by reviewing plans and conducting inspections. Other key stakeholders in the building industry, particularly building owners and contractors, should report and discourage unlawful construction in their projects and the work of competitors.

Four Approaches to Collapse Risk Building Management

Most of California's seismic vulnerability comes from older buildings that were constructed long before our latest codes came into effect. State and local jurisdictions addressing collapse risks have generally taken one or more of the four approaches below. Each jurisdiction can tailor its programs to the unique circumstances and priorities identified by policymakers.

Approach 1: Prioritize Initiatives By Types of Buildings

This most common approach focuses on the types of building construction that are considered most vulnerable to earthquakes. Based on performance in past earthquakes, the *Commercial Property Owners Guide to Earthquake Safety* (SSC 2006) lists the following building types that have characteristics vulnerable to severe shaking in the approximate order of their risks to life:

- Unreinforced masonry buildings built primarily before the 1940s.
- Non-ductile concrete buildings built before the 1980s.
- Apartment buildings with soft lower stories built primarily before the 1980s.
- Precast (tilt-up) concrete buildings built primarily before 1995, as well as some reinforced masonry buildings of similar age.
- Other buildings with unusual configurations) built primarily before the 1990s.
- Steel-frame buildings built primarily before 1995.
- Shorter buildings of all ages that are adjacent to and within the fall zone of taller, vulnerable buildings.

For more details on these building types, see Appendix 1. Smaller residential dwellings are important in seismic risk reduction programs, but they are generally not treated as collapse risk buildings.

This list is not exhaustive, but it captures most of the poor performers observed after past earthquakes in California and in similar regions around the world.

The two main advantages of this approach are related to efficiency: (1) its scope is limited to a manageable number of buildings, and (2) it works well for building types that are easy to identify and have consistent forms of vulnerability.

Governments considering this approach should be aware that buildings of other construction types that may be difficult to inventory can also pose substantial risks. The other approaches below can help identify some of the additional risks that might not be captured by this approach.

Approach 2: Prioritize Initiatives By Parts of Buildings

The second most common approach focuses on vulnerable parts of buildings, many of which are called nonstructural components. If not properly attached, they can fall or break in earthquakes and cause casualties, water damage, fires, and other property losses. They include:

- Unbraced parapets or tops of walls
- Chimneys that can fall through roofs or onto critical surroundings
- Cladding not properly attached
- Unbraced water heaters

Other common vulnerabilities that are costly contributors to building damage are

- Sprinklers
- Partitions
- Signage
- Mechanical and electrical equipment such as light fixtures and large appliances

Nonstructural retrofits are inexpensive, nondisruptive, and can significantly reduce the risks of injuries and business interruption from earthquakes. California first regulated the earthquake safety of nonstructural systems in the 1970s. The California Building Code contains seismic requirements for nonstructural parts of buildings, and FEMA offers guidelines for the evaluation and retrofit of building contents and nonstructural building systems (FEMA 2013). Cal OES offers guidelines for evaluating and retrofitting nonstructural falling hazards common in schools (CA-OES 2011). The *Commercial Property Owner's Guide to Earthquake Safety* (SSC 2006) also contains recommendations on how to identify and retrofit contents and nonstructural systems that are vulnerable to earthquakes.

Failure of improperly attached cladding.

Bracing and flexible water pipes can prevent fires and serious water damage caused by toppled water heaters. State law requires all replacement water heaters to be braced and all existing residential water heaters to be braced when homes are sold (Health and Safety Code 1992). Water heater bracing kits that have been certified for use by the State Architect are available at most hardware stores, and strapping instructions are posted online (DSA 2014).

Failure of unbraced water heater.

Building contents are typically not regulated by government agencies for earthquake safety except those on upper shelves of racks above 12 feet high or that contain hazardous materials (FEMA 2005).

Approach 3: Prioritize Initiatives By Essential Buildings

The point of this approach is to identify and prioritize mitigation of collapse risk buildings that are most likely to create widespread secondary impacts, such as social disruption, major fires, hazardous materials releases, or disruptions to surrounding neighborhoods and streets. Schools, hospitals, other essential services buildings such as fire and police stations, and major industrial facilities are typically the focus of this strategy.

San Fernando Veterans Hospital collapse. 1971 Sylmar earthquake.

Approach 4: Prioritize Initiatives By Evaluations and Ratings

It is impractical to pre-identify all of the vulnerabilities in the building stock. The fourth approach, therefore, goes beyond focusing on only the known collapse risk building types. Instead, this approach encourages or requires seismic evaluations and resilience ratings for all major buildings with targeted occupancies, or those larger than a prescribed size or number of stories, regardless of the building type.

Retrofit Codes, Standards, and Guidelines for Reducing Collapse

Observations after recent earthquakes suggest that retrofitted buildings on the whole perform noticeably better than similar buildings that have not been retrofitted (ATC 1992, SSC 1994, and WJE 1994). But in many cases, their performance has been mixed.

California has adopted, with some amendments, a national standard, ASCE 41-13, *Seismic Retrofit of Existing Buildings*, as a retrofit regulation for acute care hospitals, public schools and state-owned buildings. California has also adopted retrofit regulations for hospitals, unreinforced masonry buildings, and wood dwellings (see CBSC 2016a, Part 10, Appendix A). The California Building Code generally allows retrofits of any nature provided that they make existing buildings no less safe. These regulations and the 2015 International Existing Building Code are available for use by all state and local regulatory agencies. They include a compilation of seismic evaluation and retrofit provisions for unreinforced masonry, tilt-up, wood-frame dwellings, and older concrete buildings. Part 8 of the California Historical Building Code contains alternative requirements for evaluating, rehabilitating, and altering historical buildings (CBSC 2016b). They became enforceable in California in January 2017.

Foundations are also vulnerable to residual ground displacements that can occur during earthquakes (e.g., landslides, liquefaction, lateral spreading and settlement of soils). Mitigation measures include strengthening foundations, locating new facilities to avoid sites with the potential for large displacements during earthquakes, and modifying soils below foundations. In addition to the standards listed above, the *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (CGS 2008) can help address foundation-related risks.

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Appendix 3: Who Is Responsible for Collapse Risk Buildings?

Building Owners

Common law, in effect throughout U.S. history, states that building owners are principally responsible for ensuring and maintaining the safety of their buildings:

> "Common law requires that an owner exercise the ordinary care that a reasonable person would use under the circumstances. Building owners are required to have the premises in a reasonably safe condition for the customer, and to warn the customer of any unsafe condition which the owner knows about or should, using ordinary care, know about." (Allen 2013)

In 2010, the state's Second Appellate Court affirmed this principle, upholding a lower court's decision that building owners were negligent when a building collapsed in 2003 notwithstanding the 2018 compliance date in the City of Paso Robles' mandatory retrofit ordinance for URM buildings (Court of Appeals 2010).

The California Building Code also requires owners to maintain buildings, structures, and parts thereof in a safe and sanitary condition (CBSC 2016, Chapter 34A Section 3401A.2, and Title 24, Part 10, Section 101.8).

Prudent owners should become aware of and actively manage the seismic risks associated with their buildings.

Collapse of the Acorn Tower Building, Paso Robles, after the 2003 San Simeon earthquake.

Each owner should consider the following steps:

- Obtain and archive a complete set of construction plans as well as those for major alterations and seismic evaluations, including specifications, and design calculations for their building. Retain copies of all plans and permit records that were approved by the government authority having jurisdiction. Store the information in a fire-safe and flood-safe, offsite location that can be quickly accessed by two or more designated facility management personnel after disasters.

- Periodically hire a design professional to conduct a seismic evaluation of the building to identify and prioritize vulnerable aspects of structural systems, nonstructural systems, contents, and nearby risks. Evaluations older than 15 years should be updated.
- Identify seismic performance objectives for the building. Develop budgets and timelines for retrofits and maintenance of building systems that will help ensure that they meet performance expectations.
- Incorporate the reduction of unacceptable seismic vulnerabilities into long-term capital outlay planning for the building.
- Obtain earthquake insurance, if found to be affordable.
- Create a Building Occupancy Resumption Program to enable rapid evaluations of damage by design professionals familiar with the building after disasters to shorten disruptions and recovery times.
- Communicate seismic risks and management practices to building occupants.
- Periodically revisit progress toward acceptable levels of risk.
- Disclose earthquake vulnerabilities to prospective buyers consistent with the *Commercial Property Owner's Guide to Earthquake Safety* (SSC 2006) and the *Homeowner's Guide to Earthquake Safety* (SSC 2005).

Government agencies that own buildings, by actively managing their own buildings in this way, can set good examples for private owners.

Several key factors tend to limit or discourage owners from actively managing the collapse risk posed by their buildings:

- Higher priorities for the use of limited funds for capital outlays
- Unawareness or discounting of seismic risks
- Fear and anxiety about earthquakes
- Feelings of helplessness and fatalism about earthquake risk
- Distrust of or lack of confidence in the ability of the building industry and regulatory agencies to ensure a safe built environment (Joffe et al. 2013)
- High costs associated with conducting seismic evaluations and alternatives such as retrofitting or replacing buildings
- Short time horizons of investors planning to liquidate their interest in particular buildings

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

Owners who are unable or unwilling to invest in managing building risk should consider selling or replacing their buildings.

Government Regulators

Although government agencies have key roles in regulating construction, many changes take place in buildings without government involvement. Minor or unpermitted work, owner or tenant alterations, and installations of equipment and unregulated contents are common occurrences that can adversely affect building safety, sometimes to the point that they affect a building's collapse risk. Governments can—and often do—leave the managing of collapse risk posed by buildings to the discretion of the building owners and tenants, and thus owners are principally responsible for building safety. Appendix 5 (Step Three, Option One) summarizes how this can be done more effectively and how mitigation progress can be monitored when relying on this option.

This relatively hands-off, attrition-based approach still leaves much for regulators to do. Many common circumstances associated with existing buildings raise challenges for the appropriate role of government regulators in ensuring the public's safety and welfare:

- Collapsing buildings can affect the public right of way when they fall onto sidewalks, streets, and adjacent lower buildings. For example, a tall building that is severely damaged in an earthquake can force the closure of a large area around its perimeter until it is stabilized. Collapse of buildings, or debris falling from them, can cause severe direct impacts to neighborhoods as well as indirect impacts to the overall well-being and security of a community, including its economy, standard of living, and vibrancy. When rights of way are disrupted, emergency responders and recovery efforts in the vicinity can be impeded.

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

- Owners don't always know if their buildings are vulnerable to collapse, or they don't warn the public about vulnerable conditions.
- Owners often defer maintenance and don't typically evaluate seismic risk. Delayed maintenance causes risk to accumulate and, in the absence of proactive intervention, can threaten lives and economic and social welfare.
- Reducing seismic risk in old buildings by attrition is typically slow. However, when regulations are effectively enforced and owners make conscientious choices about

earthquake risk, alterations and replacements can gradually change the risks posed by older buildings.

- The public is largely unaware which buildings are at risk of collapse. Yet the public has a right to know so that they can make informed decisions about occupancy and earthquake risk. Local governments have key roles in informing the public.
- Owners, regulators, and policymakers should be informed about buildings that present acceptable levels of risk, buildings with potentially vulnerable conditions that are regarded as safe enough to occupy, as well as buildings and their surroundings that may not be too unsafe to be occupied.

Precast (tilt-up) buildings, built primarily before 1995, may have reinforced concrete walls that are poorly anchored to roofs.

- While local jurisdictions have the authority to regulate the safety of new construction, as well as alterations, additions, and repairs to existing buildings, the public often incorrectly assumes that such regulations are foolproof and always ensure safe buildings. The public doesn't know how complex the problem can be—many buildings pose risks that are not known or that vary depending on the type, extent, and age of construction as well as prior alterations, additions, or repairs.
- Local government decisions regarding neighborhood revitalization, redevelopment, historic preservation, and intensification of building usage can affect the public's exposure to seismic risk in both positive and negative ways. Informed, transparent, and visionary public policy decisions will include consideration of seismic safety.

State and federal laws typically transfer the role of ensuring building safety to local governments, with a few notable exceptions enacted in state laws for mobile homes, public schools, hospitals, and other essential services buildings.

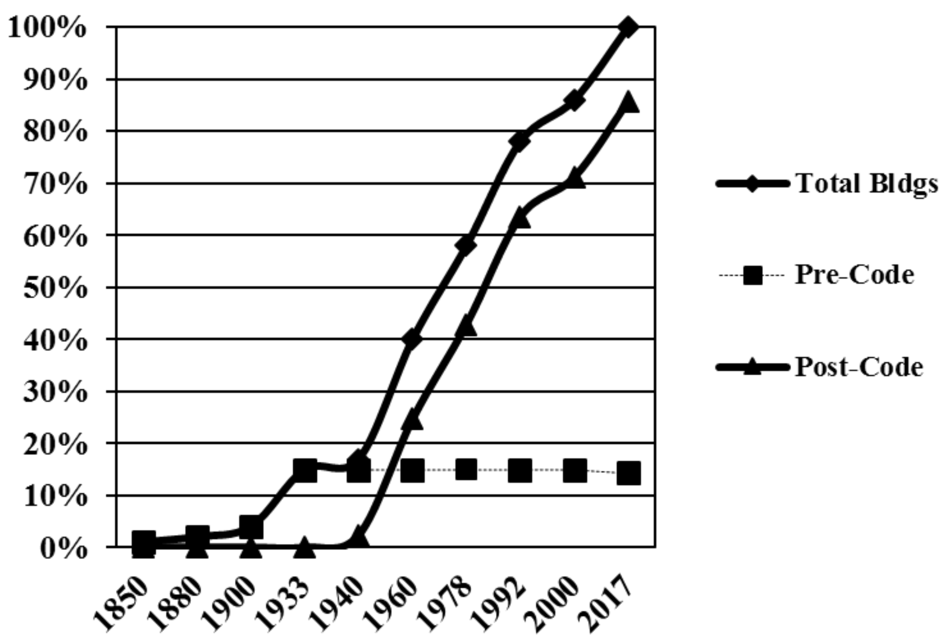
The public has multiple options. The choices for effectively managing earthquake risk are often complicated and can be quite costly, even onerous. Options often are not cost-effective to owners when only their direct costs and benefits are considered. Policymakers can more effectively compare alternatives when they consider not only the owners' interest but also the public's interests, including the community-wide interests of other stakeholders:

- Potential for saving lives
- Reducing the cost of injuries

- Reducing delays in recovery and business interruption in the neighborhood
- Accounting for the time value of funds invested in improving buildings
- Historic and cultural preservation
- Averting social and economic impacts including loss of tourism or tax revenue after damaging earthquakes

Buildings that collapse are horrendous experiences causing traumatic disruptions to communities after earthquakes. It can take days to extricate victims, weeks to determine the causes of collapse, and months to clear the debris. Resilient communities that avoid collapse can recover as quickly as possible after disasters and minimize long-term adverse effects.

Another major consideration affecting seismic risk is California's population, which has increased the state's building stock dramatically (see the figure below).



Growth of California's building stock from 1850 to the present.

As a result, California's building stock is relatively young and earthquake-resistant compared to many other regions of the world. Approximately 85 percent of the state's growth has occurred since most local governments began to require earthquake resistance in building construction in the 1930s. California's population and building stock have grown more than 20 percent since the 1994 Northridge earthquake. California's growth continues to be robust, so strategies should capitalize on market forces and population growth to help reduce seismic risk.

It is important for local government agencies to work together to develop and enforce appropriate seismic risk management priorities and regulations. Their focus should be on speeding the improvements, reducing costs, and minimizing disruption to owners, occupants, and surrounding neighborhoods.

Successful seismic risk management initiatives depend on:

- Knowledge and experience of building owners, contractors, and design professionals selecting the most cost-effective alternatives for the future built environment
- Technical and economic feasibility
- Meaningful incentives and other supportive government policies (SSC 1987)
- Effective regulation of construction through plan reviews and inspections

Local governments can measure the rates of investment devoted to building retrofits or replacements. Understanding the percentages of vulnerable buildings that are gradually replaced or retrofitted each year will give communities a tool to gauge the adequacy of current seismic risk policies and to help determine whether other approaches will speed up or hinder progress. Since the public demands safe buildings and values seismic retrofits and replacements, governments should measure and periodically report progress on those efforts.

Communities in regions of high seismicity are encouraged to explore three classes of difficult choices:

- Do nothing more than existing policies
- Make modest initial investments in earthquake risk management and information outreach that rely primarily on passive, market-driven approaches
- Make larger, more assertive risk management investments to further reduce vulnerabilities and future casualties, minimize social and economic disruption, and speed recovery after future earthquakes

These options are treated in detail in Appendix 5. Several factors tend to limit or discourage local governments from actively managing the collapse risk posed by buildings in their jurisdictions:

- Higher priorities for the use of limited funds and time on policy-setting agendas
- A lack of awareness of the risks
- Fear and anxiety about earthquakes
- Feelings of helplessness and fatalism about earthquake risk
- Distrust or lack of confidence in the ability of the building industry and regulatory agencies to ensure a safe built environment (Joffe et al. 2013)
- High costs associated with conducting inventories, seismic evaluations, and scoping of alternatives such as retrofitting or replacing buildings
- Short time horizons that preclude government policymakers and key staff from making decisions directed at long-term risks such as earthquakes

The choices for how to ensure safe buildings are best left to each building owner and jurisdiction to tailor to their unique circumstances they face. Given the great variation in risks and social and economic conditions across the state, uniform statewide approaches are typically not optimal.

Liability Considerations for Building Owners, Governments, Contractors, and Design Professionals

> "The question of tort liability for building owners is determined on a case-by-case basis by a judge or jury based on the following standard: Did the owner or operator of the building (that is, the person or entity having control over the facility) act as a reasonable person would have to prevent the harm? Many factors might be considered, including actual or imputed knowledge of the risk, the cost to mitigate the risk, the expected degree of harm, timing of corrective actions, alternatives available to the owner or operator of the building, and the ability of occupants or others impacted by the collapse to avoid the harm." (San Francisco 2014)

Local and state governments have immunity from liability unless they are found to be grossly negligent in carrying out their regulatory duties. However, such immunity does not extend to the owners of buildings, whether they are public or private entities (Government Code Section 818). While immunity may generally offer some protection to government staff members, time-consuming criminal and civil trials could force agencies to document and defend past regulatory decisions that may or may not have been significant over the life of a building that collapses. Moreover, post-earthquake recovery will be significantly delayed by criminal and civil investigations of building collapses, undertaken to determine the causes collapses and responsible parties. The costs of legal defenses are typically borne by both owners and government agencies and are not necessarily recoverable.

Contractors and design professionals may be found liable for actions or inaction associated with a building that has collapsed. It can take years to conduct a defense or negotiate a mutually agreeable settlement with those who have been harmed.

Finally, the public has a right to know about the vulnerability of the buildings they occupy or are exposed to, and owners have a duty to disclose those vulnerabilities (SSC 1992).

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Appendix 4: Nexus for Public/Private Partnerships to Manage Collapse Risks

Most buildings are privately owned, but if they were to collapse, they would adversely impact public spaces and neighboring buildings, create demands on government emergency and recovery services, and disrupt social and economic activities. So both building owners and government agencies have major stakes in managing earthquake risks. Building owners stand to lose property values and governments stand to lose tax revenues after earthquakes. It is in everyone's best interests for governments and building owners to collaborate in identifying vulnerable buildings, improve their earthquake resistance, or replace them.

The Seismic Safety Commission has observed efforts to address collapse risk by building owners and local governments across the state for the past several decades. Progress appears to be greatest when private owners and governments both foster active dialogue, commitment, mutual understanding, and collaboration. Governments have critical roles in informing the public, encouraging talk about risk reduction, and easing efforts by building owners. Collaborations to identify risk reduction priorities, funding mechanisms, time frames for accomplishing retrofits and replacements, financial incentives, and removal of disincentives are most effective when they reflect the collective interests of stakeholders. This appendix contains a set of case studies, from cities in all parts of California, that may serve as examples of success stories.

In efforts to reduce the threat of collapse risk buildings, all parties are bound by state laws and their associated regulations, of which the following may be applicable:

- Business and Professions Code 10147 *et seq* "Seismic Safety Commission publishes Commercial Property Owner's Guide to Earthquake Safety"
- Education Code 17280 and 81130 *et seq* "Field Act for Public School Construction"
- Health and Safety Code 16000 *et seq* "Essential Services Building Seismic Safety Act"
- Health and Safety Code 18950 *et seq* "State Historical Building Code"
- Health and Safety Code 19000 *et seq* "Riley Act Requiring Local Governments to Issue Permits and Regulate New Construction"
- Health and Safety Code 17320 *et seq* "Private Schools Building Safety Act of 1986"
- Health and Safety Code 19160 *et seq* "Earthquake Hazardous Building Reconstruction"
- Government Code 8870 *et seq* "California Earthquake Hazards Reduction Act of 1986"
- Government Code 8875 *et seq* "Unreinforced Masonry Building Law"
- Government Code 8876.1 *et seq* "Enabling Legislation for the Pacific Earthquake Engineering Research Center at UC"
- Government Code 8893.1 *et seq* "Eligibility for State Assistance Programs for Earthquake Repairs"
- Government Code 8893.2 *et seq* "Commercial Property Owner's Guide to Earthquake Safety"

- Government Code 8894 *et seq* "Buildings Enclosing More than 20,000 Square Feet of Concrete or Reinforced Masonry Column or Wall Construction Seismic Retrofit Standards"
- Health and Safety Code 55000 *et seq* "Seismic Safety Rehabilitation Loans"
- Constitution, Article 13A, Section 2 "Property Tax Exclusion for Seismic Retrofits"
- Public Resources Code 2621 *et seq* "Alquist-Priolo Earthquake Fault Zoning Act"
- Public Resources Code 2624 *et seq* "Seismic Hazard Mapping Act, Disclosure to Buyers of Property"
- Public Resources Code 2700 *et seq* "Strong Motion Instrumentation Program"
- California Building Standards Code, Title 24, Parts 2, 8, and 10, California Code of Regulations

These are easily consulted at leginfo.legislature.ca.gov/faces/codes.xhtml.

Governments also have several incentive programs available that can be applied to collapse risk reduction projects.

Federal tax credits: Pursuant to the 1986 Tax Reform Act, the federal government offers tax credits of up to 10 percent of a seismic retrofit construction cost for pre-1936 non-residential, non-historic buildings and up to 20 percent for historic buildings that are listed on the National Historic Register. For more information: www.nps.gov/tps/tax-incentives.htm

Federal tax credits were used to retrofit this theater in a Los Angeles hotel.

Mills Act agreements**:** These are contracts with minimum 10-year terms that are individually negotiated between local governments and owners of historic buildings. Generally, in exchange for property tax relief, owners agree to restore, maintain, and protect their buildings in accordance with specified historic preservation standards and other conditions. Local jurisdictions typically commit to periodic inspections to ensure adherence to the contract. Local governments can also impose penalties for failure to protect the buildings. Contracts are transferable to new owners when a property is sold. Over 90 local governments have Mills Act participants. For more information: ohp.parks.ca.gov/?page_id=21412

Property tax exclusions for seismic retrofits: Some seismic retrofits can be excluded from property tax assessments, helping minimize the overall cost to building owners. Owners contemplating seismic retrofits can notify their county tax assessor prior to, or within 30 days of, completing a seismic retrofit project. Documents supporting claims for property tax exclusions must be filed within six months after completion of the retrofits. The local building department that issues a permit for retrofit construction must report the cost of the retrofit portion of the projects to the county tax assessor. The State Board of Equalization has more information on this exclusion, and the claim form "BOE-64 Claim for Seismic Safety Construction Exclusion from Assessment," at www.boe.ca.gov/proptaxes/pdf/lta10036.pdf

Following is a list of earthquake risk reduction incentives and the cities that have adopted them (EERI 2006). Each city should be contacted for more information. The Seismic Safety Commission maintains information on each local government in highly seismic regions of California and can direct inquiries into various alternatives for incentive management.

- **Waiver of permit fee for seismic retrofit:** Albany, Berkeley, Fremont, Livermore, Los Gatos, Morgan Hill, Oakley, San Rafael, Sonoma, St. Helena.
- **Permit fee reductions**: Pittsburg, San Leandro, St. Helena.
- **Local tax breaks**: St. Helena's Mills Act, Redwood City's Mills Act.
- **Federal mitigation incentives:** The Disaster Mitigation Act of 2000 allows for enhanced eligibility for post-disaster mitigation funds for jurisdictions that have effective mitigation programs established prior to disasters.
- **Grants:** Brentwood, Colma, Emeryville, Morgan Hill, Napa, Pinole, St. Helena, Windsor.
- **General obligation bonds:** San Francisco. These bonds can be used for retrofitting privately owned buildings when the local jurisdiction declares such work is in the public interest.
- **Other incentives:**
  - Berkeley: Its transfer tax incentive enabled Berkeley to achieve more than three times the number of retrofitted homes as adjacent cities. However, this incentive only applies to jurisdictions like Berkeley that levy transfer taxes when buildings are sold.
  - Dixon: $3 per square foot of floor area for URM retrofits.
  - Fremont: Low-interest loans for redevelopment area.
  - Los Gatos: Parking waivers.
  - Napa: Redevelopment funds for retrofit designs.
  - Palo Alto: Allowances for additions waivers.
  - San Leandro: Special assessment district loan program.

- San Mateo: Storefront improvement loans and grants.
- Santa Clara: Loans of 5 years at 3 percent interest for engineering analysis.
- Sonoma: Grants for retrofit designs.
- Vacaville: Redevelopment loans of 25 years at 3 percent interest.
- Vallejo: Up to $40,000 per building from Community Development Block Grants.
- Property Assessed Clean Energy (PACE) financing: Offered by AllianceNRG through the California Statewide Communities Development Authority's OpenPACE program, a nonprofit organization. Although only two seismic retrofit projects have been financed so far by this program, it is available at owners' discretion in 59 cities and 11 counties as of February 2017.

Local Government Case Studies

St. Helena's Financial Incentives

Recognizing that its old brick and stone buildings along Main Street, Highway 29, were critical to the city's tourism and cultural identity, St. Helena:

- Waived building permit fees for seismic retrofits
- Established Mills Act agreements with owners to help preserve historical facades in exchange for reductions in property taxes
- Encouraged the use of Federal Tax Credits for retrofit work on Nationally Registered historic buildings
- Allowed for building permit renewal extensions to give owners more time to finance the retrofits
- Streamlined the design review process
- Provided small grants to fund architectural and engineering services to those owners who had financial difficulties to help pay for retrofits

While city funds invested in these incentives were relatively small compared to the investments in retrofits by the owners, the lengthy discussions that led up to the City Council enacting these incentives and the government's clear expression of commitment to helping building owners with this effort sent a strong message of priorities and a desire to collaborate in reducing earthquake risk. After 12 years of investments and retrofit efforts, 33 unreinforced masonry buildings were eventually retrofitted.

Fremont's Soft Story Apartment Building Program

In 1999, Fremont's building department inventoried its soft story apartments and its city council ordered notices sent to 30 owners of soft story apartments that their buildings were vulnerable to collapse. The city also established a goal of voluntary retrofits within a year. However, only two owners voluntarily retrofitted. In light of the lack of progress in 2007, Fremont amended its ordinance and required retrofits of the remaining 28 buildings within five years. The city allowed owners to apply for deadline extensions by demonstrating financial hardships. The city also waived plan review and building permit fees as long as owners met the timetables in the ordinance. As of September 2014, reportedly 80 percent of the buildings had been retrofitted (www.mercurynews.com/business/ci_26449983/thousands-bay-area-apartment-houses-need-quake-fix).

A copy of Fremont's ordinance is available at www.fremont.gov/377/Earthquake-Hazard-Reduction-Ordinances

Los Angeles' Unreinforced Masonry Building Retrofit Program

Los Angeles had more unreinforced masonry buildings than any other local government in California, but they represented just 1.3 percent of the city's stock of 700,000 buildings back in the 1970s (Spangle 1990). The city inventoried 9211 buildings and adopted two programs, one in 1981 for buildings with load-bearing walls and another in 1993 for non-load-bearing infill masonry wall buildings with steel or concrete frames. At the time the M6.8 Northridge earthquake struck in 1994, over 6000 of the buildings had been retrofit and approximately 2000 had been demolished or replaced. Fortunately, no one was killed by falling masonry from the buildings, in part, because the earthquake occurred early in the morning. However, had the earthquake occurred at another time of day, lives could have been lost from the partial collapse of retrofitted buildings. The retrofit efforts clearly demonstrated that such buildings are not earthquake-proof, but that they significantly reduced losses and accelerated recovery compared to nearby unreinforced masonry buildings that were not retrofitted.

The city considered financial incentives, but "enactment of Proposition 13 virtually eliminated the possibility of substantial assistance from the city. New initiatives were not forthcoming from either the federal or state government. Public funding programs were being cut; not expanded. However, in the end, the City Council acted on the ordinance without resolving the issue of financial assistance to owners or tenants" (Spangle 1990). Nevertheless, the City's Community Development Department later funded 27 retrofits using $29 million in federal Community Development Block Grants. Los Angeles used $32 million in redevelopment funds to offset seismic retrofit costs for 50 unreinforced masonry buildings. Two seismic retrofit projects were funded by tax-exempt revenue bonds authorized by the state legislature in 1984. The city's attempt to enact a bond program in 1989 just missed getting the required two-thirds vote of its electorate (Spangle 1990). Some owners took advantage of a state law that exempts seismic retrofits from property tax increases, and other owners of unreinforced masonry buildings took advantage of Federal tax credits (both described in this Appendix). Out of the roughly $1.7 billion spent on retrofits and replacements in Los Angeles, less than 10 percent came from government finances.

Soft story apartment building with a retrofit underway.

The city has a form of rent control, and in 1998 it approved rent increases for seismic retrofits that averaged $64 per month. The city also required owners to provide tenants relocation assistance of up to $5000 per unit when seismic retrofits required tenants to move out. Most of the remaining costs for seismic retrofits were paid by owners of buildings.

San Luis Obispo's Downtown Revitalization Program

San Luis Obispo's downtown had 126 unreinforced masonry buildings. Progress on the city's 11-year old retrofit program was slow at the time the M6.5 San Simeon earthquake occurred in 2003. After the earthquake, the City Council shortened the deadline for strengthening from 2018 to 2012. The city's economic development department established a Seismic Task Force that included building owners, small business owners who typically rent space from owners, and city staff to encourage a dialogue on how to best manage the seismic retrofit effort and minimize impacts to the fragile economy downtown while encouraging revitalization. After three years, the Task Force developed a program that included no-cost building permits, waiving of sewer and water costs during construction, favorable retrofit contractor parking fees, and small grants to fund portions of the work. After seven years of monitoring progress, the city reconvened the Task Force to revise the compliance deadlines and financial incentives. A new fee structure was established for building permits and construction parking. No additional grants were provided. Placards warning the public of potential risks to life in the event of earthquakes were added to the ordinance. Penalties for noncompliance including fines, administrative citations, and injunctive relief were also included. The city streamlined entitled reviews for façade changes to historic buildings. A Seismic Coordinator was assigned to provide individual support to each retrofit project, improve communication, and keep the public abreast of progress, while highlighting successful efforts by individual owners. Time extensions for compliance were granted in 2010. Completion of the retrofits is anticipated in 2018. The city learned that the proximity of deadlines is key to motivating owners to retrofit. The Seismic Coordinator serving as an internal advocate and catalyst was also a key factor. Lastly, a few willing building owners set good examples to get other owners to join them and commit to investing in building retrofits. Progress varied over the years in large part as a reflection of local economic conditions, so it may be best to allow deadlines to be adjusted over time to prevent undue hardships and sustain economic revitalization (Clark 2012).

San Francisco's Earthquake Safety Implementation Program

San Francisco has long encouraged stakeholder feedback for its earthquake risk management programs. In the 1980s and 1990s, the Seismic Investigation and Hazards Survey Advisory Committee helped set priorities for unreinforced masonry buildings. In 1998, the city launched a new effort called the Community Action Plan for Seismic Safety (CAPSS) that was funded using $1 million from the state-mandated fees collected by San Francisco for the Strong Motion Instrumentation Program. Many volunteers also helped develop the plan over nine years. The building inspection department developed and proposed in 2010 a 30-year Earthquake Safety Implementation Program to carry out the recommendations of CAPSS. A key part of this program is the city's Earthquake Safety Working Group, which provides public policy advice and feedback from stakeholders. First steps for the program include reducing the collapse risks from the city's most vulnerable soft story apartment buildings. Next in line are older private schools, chimneys, and non-ductile concrete buildings. As the program ramps up, three additional working groups are being formed around the topics of facade maintenance, neighborhood support centers, and earthquake safety for private schools. This structure allows the city to focus volunteer time commitments on targeted efforts, and it expands the number and diversity of participants.

San Diego's Downtown Parapet Bracing Program

San Diego was not part of the state legislature's vision for the Unreinforced Masonry Building Law of 1986. That law was limited to regions of high seismicity, and San Diego was thought to be outside California's region of principal active earthquake faults. However, in the late 1980s more studies of the Rose Canyon Fault elevated the expected seismicity in San Diego. City Council members, the city's building department, and local engineers began to consider the implications of damaging earthquakes occurring along the Rose Canyon Fault and identified the collapse of unreinforced masonry walls in older portions of San Diego as one of the city's greatest risks. So San Diego developed a scaled-down, partial retrofit program for bracing the parapets on older brick and stone buildings. San Diego's parapet bracing program was not as comprehensive as mandated retrofit programs enacted by other local governments in regions of higher seismicity. Yet it can serve as a model for jurisdictions throughout California that do not have effective programs. Bracing was accomplished with historic preservation in mind, maintaining the aesthetics of the brickwork and ornamentation. Risks posed by other vulnerable aspects of the masonry were judged not to be cost effective to address given the relatively low seismic hazards and corresponding benefits compared to higher seismicity regions of California.

Much of the work was funded by a redevelopment investment program in the downtown area. As of 2006, 728 buildings had been inventoried, 218 had parapets braced for partial retrofits, 144 had been demolished, and 24 were fully retrofitted to comply with state standards in the California Existing Building Code (SSC 2016).

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Appendix 5: Four Steps to Managing Collapse Risk Buildings

There are a variety of ways to approach the issue of managing collapse risk buildings. The Seismic Safety Commission recommends that local governments become familiar with common options and with what other jurisdictions have already learned in their efforts to identify and reduce collapse risks. The four-step approach detailed in this Appendix summarizes information from the Commission's monitoring of useful approaches and experiences of hundreds of local government efforts since the 1970s.

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

Helping the public to learn about earthquakes, temper their fears, overcome the sense of helplessness, and recognize how they can take steps to ensure that buildings are safer and more resilient will benefit the community. Local political leaders should be closely involved in this process because decisions will require commitments of time and resources, balancing community goals and priorities, and choosing from controversial alternatives.

The city council or board of supervisors should direct staff to:

- Consult with the city's or county's attorney for advice on due process and notifications to ensure timely and appropriate public participation in developing risk management alternatives to address collapse risk buildings.
- Actively inform the public about the issues and the alternatives to be considered, including public notices for initial discussions on the agendas of councils, boards, and commissions that have responsibilities in the matter.
- Listen and provide responses to community views.
- To help eliminate surprises and ensure timely input, place priority on a collaborative process that gives ample opportunities to review and comment, so that stakeholders are kept informed about how and when decisions will be refined and adopted.
- Consider creating a task force involving community leaders to help develop and guide deliberations.
- If an interest emerges to explore alternatives in greater detail, consider appointing a coordinator or staff point person to solicit opinions and obtain background information in a timely manner.
- Minimize delays, complaints, and lawsuits by engaging in dialogue with the public that includes multiple opportunities to solicit and consider differing points of view and options.
- Deal with policy and financing challenges arising from the dialogue.

Consideration of the issues deliberately, incrementally, and from a variety of perspectives is a proven, effective management technique. Several departments and divisions within local governments have stakes in collapse risk buildings and will need to work together to generate effective changes. These include the building and planning department, community, finance, and economic development authorities, the fire department, emergency management, legal counsel, the historical preservation commissions, public works, and parks and recreation departments. If initial dialogue finds merit in considering alternatives, a lead agency should be designated to reach out to more stakeholders and coordinate the communication campaign and decision process.

Elements of effective communication campaigns include a description of the risks, the alternatives that owners and government agencies should consider to manage the risks, past retrofits and building replacements that highlight success stories, and the opportunities for public participation in the discussion.

Efforts should be made to address the public's natural fears and anxieties about earthquakes, to counterbalance fatalism, and to promote participatory and community-based approaches that will be effective for minimizing losses and speeding recovery after future earthquakes. Confidence-building messages to the public emphasizing that risks posed by vulnerable buildings can be effectively managed are preferable to anxiety-provoking messages that evoke denial and inaction (Joffe et al. 2013).

Initial attempts at reaching out to stakeholders may primarily engage the most adversely impacted, who may focus on opposing the costs that could be imposed on building owners. Local engineers and architects will also likely be among the first to show an interest. So governments should plan to make extraordinary efforts to create more communication opportunities by engaging other stakeholders that may experience indirect costs and benefits from risk management decisions. Neighborhood groups, business improvement associations, and other entities such as nongovernmental organizations, chambers of commerce, social and professional organizations, and other charitable and business groups should be engaged.

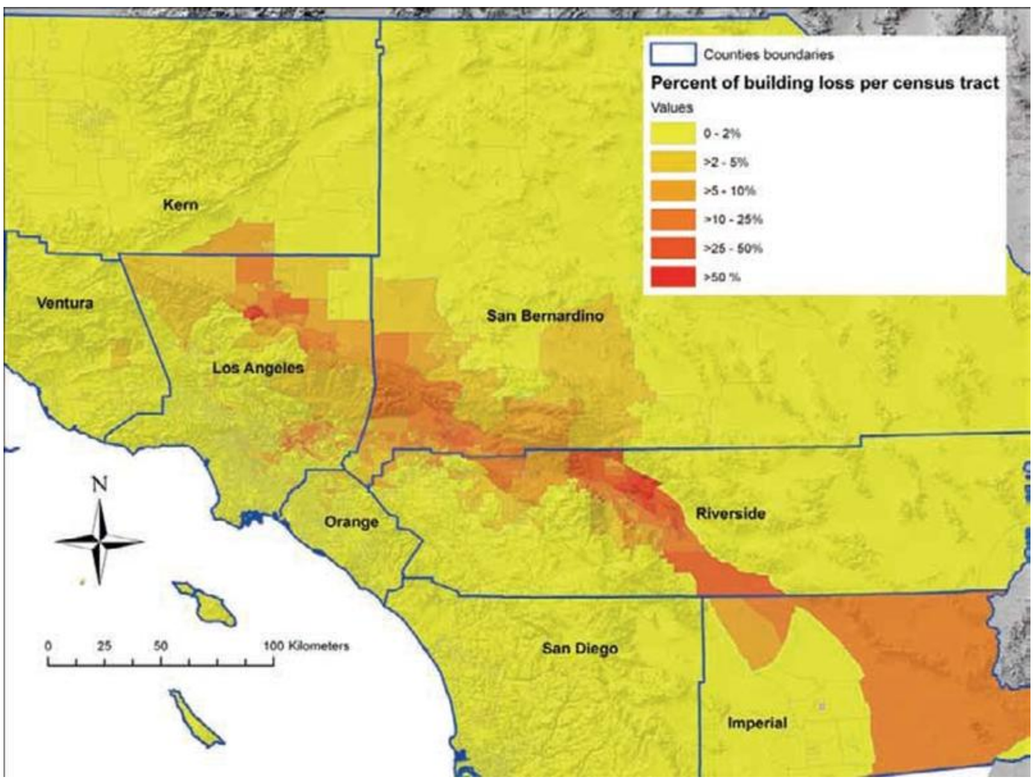
Step Two: Estimate the Size and Nature of Collapse Risks

Earthquakes are unlike most other hazards since they can occur with no warning or at best only seconds of warning. Collapse risk is a special category of hazard in the long list of earthquake consequences. Hazards that are directly caused by earthquakes include severe ground shaking, landslides, liquefaction, lateral spreading of soils, tsunamis and seiches in bodies of water, and fault rupture. Indirect, triggered hazards include fire following earthquakes and the failure of dams and levees. Of all these, severe ground shaking is the most likely cause of building collapses, and losses due to building collapse tend to dominate the losses from other types of hazards in the absence of major conflagrations. These facts are the backdrop to the need for comprehensive estimates of collapse risks. No actions can be rationally planned without such estimates.

Causes of Building Vulnerability to Earthquake Damage

Compared to other earthquake vulnerabilities, buildings pose the largest risks to life, health, property, and economic welfare. California has approximately 14 million buildings, with an average of 2.7 occupants per building. Approximately 95 percent are low-rise (1 to 3 stories), 5 percent are medium-rise (4 to 7 stories), and 0.03 percent are high-rise buildings (8 or more stories). Observations after earthquakes indicate that building safety is most often compromised by poor quality in design and construction, inadequate maintenance, lack of code enforcement at the time of original construction, and improper alterations to buildings (CA-OES 2013).

Approximately 15 percent of California's buildings were constructed before 1933, when explicit requirements for earthquakes first began to be incorporated into building codes and the state first required local governments to create building departments and issue permits. Pre-1933 brick buildings pose well-known collapse risks (CA-OES 2013).



Loss estimation from the 2008 Southern California ShakeOut Scenario.

A somewhat less common cause of damage is the poor performance of older buildings constructed to earlier, less stringent seismic codes. About 17 percent of California's buildings were constructed before the advent of strong-motion recording in 1940. About 40 percent of the state's buildings were constructed before the Structural Engineers Association of California published the first statewide consensus on recommended earthquake provisions in 1960. About 60 percent were built before improved lateral force requirements began to be enforced throughout the state in the mid to late 1970s. California did not require uniform adoption of the same edition of building codes in every jurisdiction until the early 1990s. The result is that well over half of all existing buildings in California are built to earlier standards that may result in extensive damage or otherwise inadequate earthquake performance (CA-OES 2013).

Fortunately, the vast majority of buildings in California are small wood-frame structures that are inherently earthquake-resistant. However, a small yet significant percentage, perhaps on the order of 2 percent of all buildings, pose collapse risks that can conceivably be identified by systematic inventories and seismic evaluations.

Techniques for Estimating the Number of Vulnerable Buildings

Accurate data collection and how data are transmitted to the public are two of the most important steps in a successful program; government staff should ensure that procedures are transparent and the data are beyond reproach. Rough estimations that include identifying the neighborhoods with concentrations of collapse risk buildings, without necessarily listing individual addresses, can help governments take first steps to identify priorities and begin to evaluate potential losses, costs, and benefits of risk management alternatives. Estimates of the number, size, story heights, occupancy, and socio-economic conditions including rental rates, can be generated using a variety of indirect and direct techniques (Anagnos 2012). These include:

- Drive-by and walk-by surveys
- Online maps with street views can depict building heights, shapes, and proximity to neighboring buildings and public rights of way
- Consultations with building officials, their staffs, and their permit records
- Old Sanborn maps that depict building construction types
- Tax assessor data
- Various sources of information and databases at libraries and on the internet
- Archives of civil, architectural, and structural engineering firms
- Loss estimation programs
- Building stock sampling and databases that can be used to infer building stocks elsewhere
- Building Occupancy Resumption Program data
- Transportation corridor studies
- Redevelopment studies

Information about old buildings is often poorly documented.

- Historical building registries and historic district surveys
- Rapid visual screenings

A somewhat more detailed approach than indirect estimation is the FEMA 154 method, described in *Rapid Visual Screening of Buildings for Potential Seismic Hazards* (FEMA 2015). In the FEMA 154 method, civil or structural engineers conduct field surveys and fill out one-page forms that generates a basic score for each building. The results can help classify buildings into common types and determine if more detailed evaluations are warranted. FEMA 154 evaluations are much less detailed than ASCE 41 Tier 1 Evaluations, which are intensive procedures better suited to Step Three in the four-step process, under Option Four.

Using Earthquake Scenarios to Describe the Risk to a Community

Recently developed scenarios can be used to describe the effects of major earthquakes striking metropolitan regions. For instance, the *2008 Southern California Shakeout Scenario* (USGS 2008) describes anticipated losses from a major earthquake on the southern segment of the San Andreas Fault. Another scenario published in 2006 describes losses to be expected from a repeat of the 1906 earthquake (Kircher et al. 2006). It is reasonable to estimate the increase in losses by multiplying the scenario's losses by ratios reflecting population and cost of living increases in the time since these scenarios were developed.

Although these regional scenarios are useful for public presentations of large-scale earthquake risk, they lack sufficient detail to allow individual jurisdictions or subregions to define their specific losses. The regional scenarios can be supplemented with more detailed loss estimates for smaller study areas as described in the next section.

Techniques to Estimate Earthquake Shaking Losses from Collapse Risk Buildings

A low-cost, federally funded computer program called HAZUS (2014) can be used to generate aggregate loss estimates for large groups of buildings within a region. Based on default data on vulnerability for common building types, HAZUS also allows users to input custom building location and vulnerability estimates and subject them to either probabilistic ground motions or scenario earthquakes. The results can include the numbers and types of casualties, dollar losses, and volumes of debris that would be generated by scenario earthquakes. Jurisdictions have used HAZUS and other similar loss estimation tools to conduct what-if scenarios to judge how much and how soon retrofits or replacements would reduce aggregate losses.

Because HAZUS uses simplified and limited input information, its results are not meant for judging the adequacy of individual buildings, but the results can be quite suitable for estimating aggregate, region-wide losses from many buildings. Rough estimates of the number and sizes of collapse risk buildings have limited uses. For example, without a more detailed building-by-building inventory, there is no way to tell the percentage of collapse risk buildings that have been previously retrofitted, and default HAZUS loss modeling may not be reliable enough to be quotable in a public hearing. Nevertheless, such initial estimates of the size and nature of the building stock are effective, low-cost ways to develop a feel for the challenges that may lie ahead. Emergency managers, fire officials, and other first responders can also use these estimates to conduct table-top disaster response exercises.

If a jurisdiction chooses to release rough estimates to the public, the limitations and uncertainties associated with the estimation should be described in the release and emphasized. Publishing ranges of estimates can also be an effective way to characterize the uncertainty.

Whether a jurisdiction decides to take no further action during Step Three below, as in Option One, or to explore more assertive alternatives such as those in Options Two through Seven, 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 Mitigating Collapse Risks

Mitigation of collapse risk buildings is a long and complex task. Once a process is in place to obtain and absorb stakeholder input (Step One) and once the scope of the problem has been preliminarily assessed (Step Two), jurisdictions should formally lay out detailed options to guide and manage their efforts. This section describes seven options, differing in their degree of intervention, that California jurisdictions have typically considered.

Whatever path jurisdictions take, it is critical that the process be transparent and that the public is aware of opportunities to participate in deliberations, both before policies are implemented and while their progress is being tracked.

At the end of this section, Exhibit A presents a complete checklist including the details of the specific tasks presented in all seven options. It includes a set of 12 tasks, which represent the current state of practice for most California jurisdictions.

Option One: Rely on Attrition and Current Triggers for Alterations, Additions, and Repairs in the Building Code

This option reflects the current practice in nearly all California jurisdictions. Collapse risk buildings are occasionally identified and retrofitted or replaced voluntarily. The two most commonplace triggers for these actions are (1) disclosures of earthquake vulnerabilities at the time of sale and (2) major repairs, alterations, or additions sometimes triggered by requirements in the California Building Code. In addition, population growth can drive building replacements. Smaller buildings that are vulnerable to collapse can be replaced with larger, more earthquake-resistant buildings with smart growth.

The *Commercial Property Owner's Guide to Earthquake Safety* (SSC 2006) summarizes state laws that encourage sellers to promptly disclose typical earthquake weaknesses to buyers. Similar laws requiring disclosure for residential dwellings are summarized in the *Homeowner's Guide to Earthquake Safety* (SSC 2005). Real-estate agents are motivated to minimize their liability by making these guides available to their clients and by encouraging sellers to comply with prudent disclosure practices.

These disclosure practices often result in adjusting market prices for buildings downward to reflect the costs of seismic retrofits. Owners may choose to retrofit or replace buildings before they sell or instead to offer the buildings on an as-is basis. Similarly, buyers may choose to lower their offering price or plan to finance their own retrofit before moving in to newly purchased buildings.

Chapter 34A and Parts 8 and 10 of the 2016 California Building Code have requirements for existing buildings that undergo voluntary additions, alterations, repairs, or retrofits. Owners who apply for building permits for minor changes to the building are typically not required to consider seismic vulnerability as long as the building will not be made more unsafe. However, major changes to buildings as defined in Chapter 34A and Parts 8 and 10 will trigger such considerations. The code defines limits on increases in building weight, reductions in building strength, and the extent of building damage being repaired. Many owners limit their proposed alterations to avoid such triggers. Moreover, recent code changes require consideration of the cumulative effects of all major alterations and additions since original construction. These too can have the effect of discouraging owners to alter, repair, or add on to buildings. They can also encourage unpermitted, illegal construction.

Reroofing should trigger reevaluations of parapet bracing at tops of walls.

Local governments are authorized to amend the California Building Code for geologic reasons that include earthquake risk, provided they report such amendments to the Building Standards Commission (Health and Safety Code Section 18941). This is one mechanism that local governments can use when exercising their regulatory authority to more proactively manage and reduce collapse risk.

Voluntary seismic retrofits can be undertaken with limited performance objectives, or without any explicit objectives, as long as the buildings are no less safe than they were before the retrofits. Some retrofits might focus on improving nonstructural systems or portions of buildings. Other retrofits might address only structural systems.

Seismic retrofits are often included in projects that have other objectives such as modernization, so in many jurisdictions their records do not indicate which projects include seismic work or what were the performance objectives for the seismic improvements.

The primary advantages of this option are that it offers owners the most discretion and is the least confrontational, that it is completely market-driven, and that it is generally more consistent with the policies of neighboring jurisdictions.

The main disadvantage of this option is that most jurisdictions do not currently monitor and periodically report on the incremental progress that occurs at the time of sale or following Chapter 34A, Parts 8 and 10 triggers. Nor are jurisdictions necessarily capable of fully documenting previous alterations and additions to existing buildings. So to maximize the effectiveness of this option, jurisdictions should consider enhancing their accounting practices so that seismic improvement information can be tracked and periodically reported.

Tracking can help policymakers determine if this market-driven approach is generating an adequate pace of seismic investments. After several years of data are collected, building departments can report accurate information to policymakers about annual progress on both major retrofits and the cumulative pace of smaller alterations and additions. Such refined data will also inform decisions on adopting another of the seven options and improve the reliability of future earthquake loss estimates. By tracking and reporting their progress, jurisdictions will be showing the public that it values seismic safety and is encouraging the market to make improvements, albeit gradually, to address the risks of collapse and increase resiliency.

Political and budgetary support for building code enforcement capabilities such as civil service and consultant personnel qualifications, training, continuing education, licensure, and credentialing are also critically important to ensure that this option is effective.

Even if other options are more assertive in addressing the most vulnerable building types, this option has the virtue of applying to all building types regardless of their vulnerabilities. Over decades, conscientiously applied, this option can significantly reduce risks in all building types.

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

Local governments will find that if they cannot produce a detailed inventory of pre-defined classes of collapse risk buildings, it is difficult to monitor their progress or take advantage of synergy with other efforts such as economic revitalization, green building initiatives, or flood or fire prevention programs. Although jurisdictions might be aware of some of the buildings that have been retrofitted or replaced, their records may not be systematic or complete. A detailed inventory is critical to knowing how big the risk is, where such buildings are primarily located, and how much progress has been made to date. In other words, monitor and manage this risk using progress metrics.

Surveying buildings to identify those prone to collapse involves the first eight of the 12 tasks listed in Exhibit A. They cover a suggested set of tasks involved in gathering existing records in the office, conducting field surveys, and compiling and maintaining a building inventory. Jurisdictions will typically modify them depending on their local conditions.

Task One: Office Planning

During office planning, existing records including street views, aerial photography, footprint maps, Sanborn maps, building permits, and construction plans can be identified and located. Each set of records should be sampled for a preliminary assessment of its state of thoroughness and reliability. Below is a list of possible office resources.

Online overhead and oblique street views	Sanborn maps
Online maps of building footprints	Online aerial photography maps
GIS, planning, and zoning maps	Fire zone maps
Assessor’s parcel/block maps	Building department permit files
Historical building surveys	Building department plan archives
Redevelopment agency records	Fire department records
Previous codes and ordinances	Utility company plans
Public works agency records	Special district records

Once all available office resources have been identified and sampled, local officials can decide which ones have the most useful information. Next, they should meet with inspectors who will have a good idea which areas of the jurisdiction have the majority of collapse risk building types. These may be the areas to target first in the field survey.

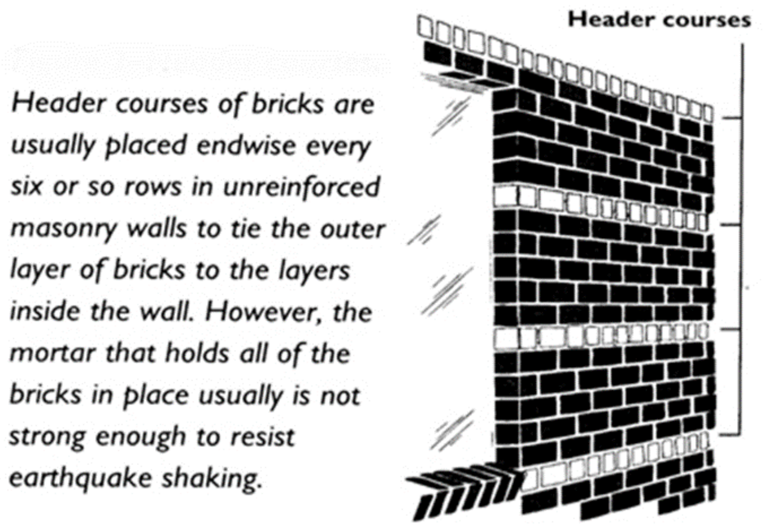
Task Two: Field Survey and Report

Next, a field survey is done, beginning in selected neighborhoods. As part of the survey, a set of basic data can be generated for each potential collapse risk building that is tentatively identified, and a preliminary inventory may be compiled.

The purpose of the field survey is to create a list of addresses of collapse risk building types. Survey personnel inspect neighborhoods where hazardous buildings are expected and walk the streets and alleys of these areas, looking at each building. It is critical for local government personnel to articulate and clarify the intent of the field survey to ensure the public’s understanding. Policy scoping studies like those described here are very different from hard data collection. Policy scoping data can differ considerably from future, more complete inventories.

Building officials, in consultation with experienced plan review engineers, should develop a summary of how to identify types of collapse risk buildings, their common characteristics, architectural eras, and decorative finishes, and where to typically find them. With that summary, field surveyors can make one of the following determinations:

- The building is **definitely a type commonly considered a collapse risk:** In this case, its address is added to the list and a Building Survey Form is filled out.
- The building is **definitely not a type commonly considered a collapse risk:** In this case, the building is not added to the list and a form is not filled out.
- It is **not certain whether the building is a collapse risk type:** In this case, the building's address is added to the list and the Building Survey Form filled in as completely as possible.



Some building types are easy to reliably identify from the street or sidewalk, such as unreinforced masonry buildings.

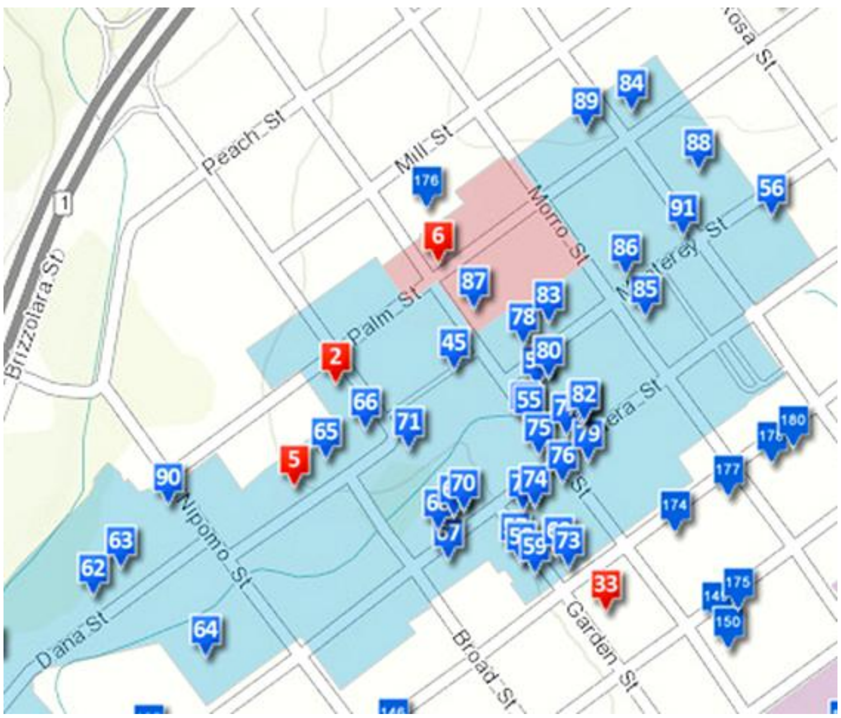
The survey should probably be a very rapid visual investigation, primarily of building exteriors. In some cases, access to the buildings' interiors will be necessary to determine if a building is of a collapse risk construction type. Survey teams should proceed methodically, block by block. Field procedures will vary depending on the number of collapse risk buildings anticipated. Before the survey is begun, personnel should thoroughly understand its objectives. Some building inspectors and most plan review engineers will have adequate backgrounds to conduct the survey. If less experienced personnel are used, they may need special training. The level of detail sought should be appropriate to the goals of the anticipated type of mitigation option.

Plaster, veneer, and other building finishes often cover the structural system of buildings. Looking at the alley sides of buildings or peering between closely spaced buildings may reveal unfinished surfaces. Knowing the typical characteristics of collapse risk building types will help personnel conduct the field survey more reliably.

After completing the field survey, compile the list of addresses of collapse risk buildings and create a map, preferably digital, depicting their locations. It is important that the jurisdiction maintains organized databases. Folders should be set up for each building, sortable by address, assessor's parcel number, neighborhood, historical status, occupancy type, and other identifying characteristics. A filled-out Building Survey Form should be included in each folder. A summary file with lists of confirmed and uncertain collapse risk buildings should also be maintained.

Task Three: Office Verification

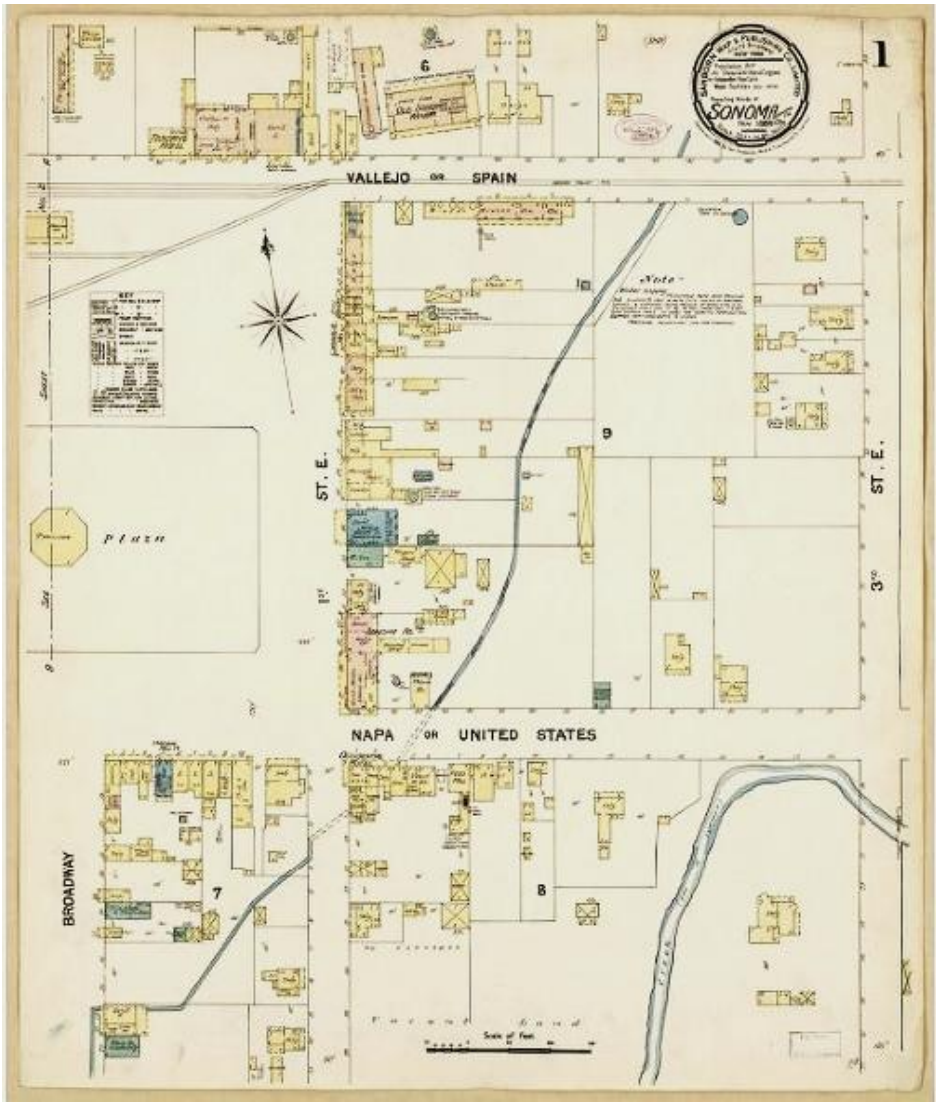
Personnel will verify the field survey findings using existing documents in city files to verify if the buildings identified in the field survey are really collapse risk building types. Once a collapse risk building type is identified, its date of construction is a key factor in determining what codes it may have complied with. A jurisdiction's history of code adoption can indicate cutoff dates after which construction of certain types of collapse risk buildings was no longer allowed. Buildings constructed before the cutoff date should be added to the list unless a search of building permits and construction plan archives shows that they were retrofitted.



Maps of historic districts and information about individual buildings
in the district can help identify vulnerable building types

Buildings that are on a list of national, state, or local historical resources have been reviewed for their architectural importance, but possibly not for their seismic vulnerability. Information about structural and nonstructural systems and other pertinent data about historical buildings should be reviewed. Nationally registered surveys of historical buildings or districts will contain detailed information about their ages and construction types.

Early zoning maps can depict older areas of commercial development that may differ from current zoning. County assessor's records may include information on buildings' construction materials, dates of construction, or uses. Sanborn Maps, produced for fire insurance companies beginning in the late nineteenth century, can help date buildings and provide more information about their features and construction.



Sanborn maps can be used to identify building construction type, age, and footprint.

After finishing the office verification, survey personnel may need to return to the field to revisit certain buildings. When in doubt, a building should be put on the list and its owner asked for information.

It is important that the jurisdiction continue to maintain organized files. The completed Building Survey Forms should be kept in folders in a database after the field survey and office verification.

Task Four: Contacting Building Owners

The jurisdiction should notify owners of potential collapse risk buildings that their buildings are on a preliminary list. They may respond with information on seismic evaluations or retrofits.

Building officials should contact the owners by email or letters. Exhibit B, at the end of Step Three, includes a sample letter that can be used or adapted. The letter should state that the jurisdiction may be considering options to manage or reduce the risks of collapse, and it should ask owners to help verify the construction types and retrofit status of their buildings within a reasonable timeframe. A copy of the letter should be included in the building's folder in the database. Owners may have evidence that their building has been retrofitted, is capable of meeting an earthquake performance objective, has been misclassified, or is of a type of construction that is outside the scope of the jurisdiction's inventory. Exhibit C, at the end of Step Three, is a sample response letter for building owners.

Task Five: Revising the Draft Inventory

All information from building owners should be carefully reviewed. If warranted, officials may decide to take certain buildings in or out of the draft inventory. Attention to this task will prevent time-consuming revisions later.

Task Six: Publishing the Draft and Operational Inventories

Once a draft inventory has been completed and vetted with input from owners, it should be made publicly available and a reasonable amount of time granted for public review and comment. This may generate additional information, particularly from neighbors, construction contractors, and design professionals, that can improve the inventory.

After the review and comment period, an operational inventory should be released. It should include a proviso that the jurisdiction expects to make further refinements to the inventory as additional information becomes available. This inventory should be readily accessible online and updated periodically by responsible parties. Policymakers should inform the public that risk reduction efforts relying on inventories are not going to be perfect or address all collapse risks, since other vulnerable buildings can exist outside the inventories.

After a reasonable amount of time for owner and public input—perhaps six months to a year—a final inventory can be published. Experience from past, established programs indicates that up-to-date information with public access is a major asset for monitoring progress and measuring the reliability and progress of risk reduction efforts.

Task Seven: Analyzing the Findings

The list of likely collapse risk buildings should be analyzed to determine community impacts before beginning to select risk management options. It may be useful to categorize structures in terms of total number, type of use, occupancy, role in emergency response or economic livelihood, social services, and other criteria. This information will be of value to stakeholders including agencies and nonprofits responsible for emergency services and recovery after earthquakes.

Detailed estimates of likely earthquake losses can be made using inventory data to generate a more nuanced and reliable sense of the potential impacts and casualties from future earthquakes. With refined information from the inventory including specific building vulnerabilities and locations, occupants exposed to collapse risk, and variations in the uses of buildings depending on time of day, loss estimates can characterize the risk of casualties in much greater detail than HAZUS estimates that rely on default assumptions.

All of the summary information generated in this task will be essential for the next phase of work: considering options for a risk management program.

Task Eight: Periodically Refining the Inventory

Building departments should plan to update and refine the inventory periodically, as it is likely additional buildings that were overlooked will occasionally come to their attention. Department personnel should be trained to look out for such buildings whenever future construction projects may bring them to their attention.

Jurisdictions, particularly where large numbers of buildings have been inventoried, should recognize that inventory processes are imperfect and plan accordingly. New information can emerge at any time that may alter the status of buildings on the inventory. Owners of newly discovered vulnerable buildings should be granted a reasonable time in which to take actions consistent with that required for other owners.

CITY OF [illegible]

INVENTORY OF POTENTIALLY HAZARDOUS BUILDINGS

The following list represents those structures defined as potentially hazardous in accordance with the provisions of A.B. 547. The structures identified herein are those of unreinforced masonry construction known to have been constructed prior to 1933 and not subsequently strengthened to an acceptable level.

Building Address	Current use	Daily Occupant Load*
6737 [illegible] Ave.	Vacant	30
6751 [illegible] Ave. (et al.)	Retail/service	17
7028 [illegible] Ave.	Retail/service (currently vacant)	44

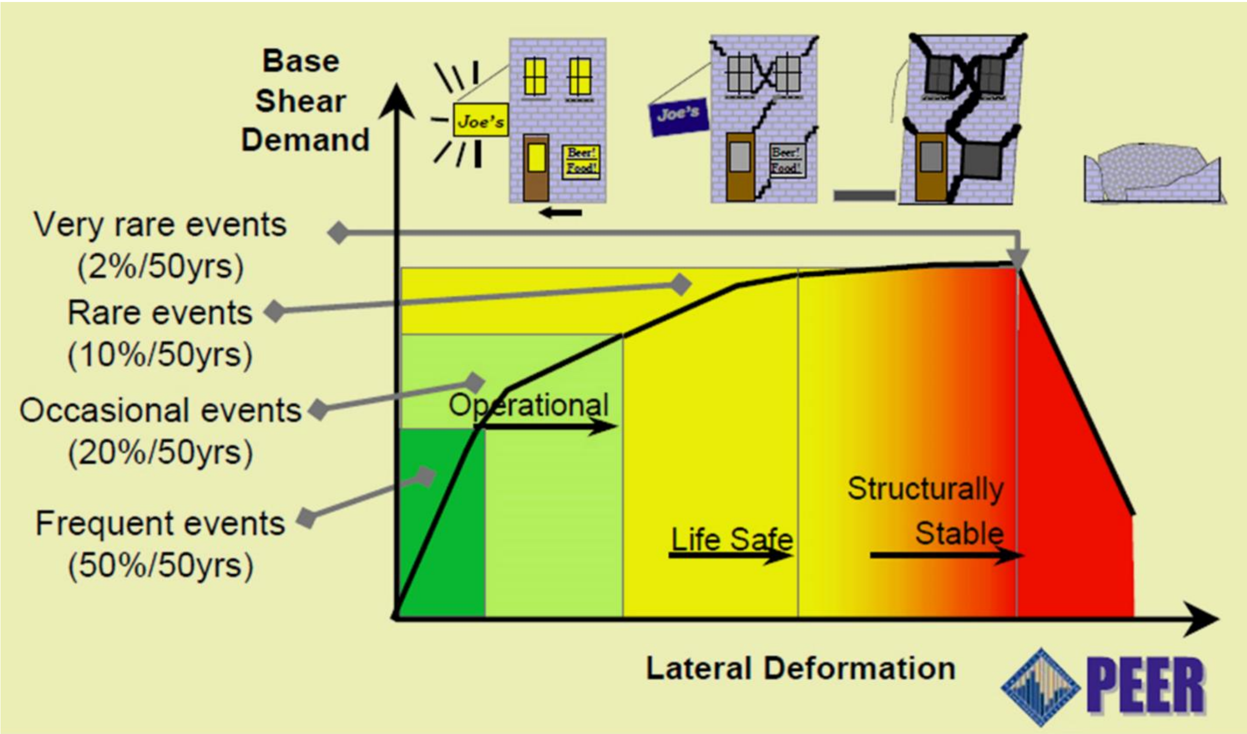
Publishing an inventory of collapse risk buildings is an iterative process warranting periodic re-evaluation and amendments.

Updated inventories are critically useful after damaging earthquakes. Building officials should generally be prepared at any time to issue reports to the public, with minimal delay, on the status of efforts to inventory and retrofit vulnerable buildings, including when they were retrofitted or demolished.

Option Three: Develop Seismic Performance Objectives

Once they have a robust and well-maintained inventory of collapse risk buildings, jurisdictions will have the information needed to consider a variety of seismic performance objectives. A performance objective can be described as an expected level of performance for buildings in response to defined earthquake ground motions. Both the performance levels and the severity of the ground motion can be varied to generate a suite of options—some basic, others enhanced—and still others that are more limited in scope. State and national building codes and referenced national standards allow for the following alternatives, which are listed in rough order of increasing cost:

- Limited objectives—such as parapet bracing
- Partial retrofit objectives—such as work done in phases
- Reduced performance objectives
- Basic performance objectives for existing buildings
- Objectives similar to those required for new buildings
- Enhanced objectives—such as those for fully resilient buildings (PEER 2014)



Owners and policymakers need to talk about and decide what performance objectives are minimally acceptable for buildings.

Performance choices can also differentiate between structural systems and nonstructural systems, or address both at once. Structural performance levels take the following forms, listed in order of increasing cost and performance:

- **Not considered**
- **Collapse prevention**, which may still pose significant risks to life
- **Life safety**, which offers an additional margin of performance beyond collapse prevention but does not expect that the building be occupiable immediately after earthquakes
- **Immediate occupancy**, where functionality above and beyond life safety typically depends on nonstructural systems and building contents

Nonstructural performance levels include the following:

- **Not considered**
- **Life safety**, where nonstructural building components may dislodge during earthquakes but won't generally pose significant risks to life or injury
- **Position retention**, where building components are unlikely to be dislodged but may still be damaged and not fully functioning
- **Operational**, where nonstructural systems and critical building contents are expected to fully function after earthquakes

The severity of earthquake ground motions may be selected from a range of mean return periods and probabilities of exceedance. These are, in order of increasing costs and performance:

Mean return periods for ground motions		Probability of exceeding ground motions
Very frequent	43 years	50% probability of exceedance in 30 years
Frequent	72 years	50% probability of exceedance in 50 years
Less frequent	224 years	20% probability of exceedance in 50 years
Pre-2000 building code	475 years	10% probability of exceedance in 50 years
Rare	975 years	5% probability of exceedance in 50 years
Maximum considered	2475 years	2% probability of exceedance in 50 years

A jurisdiction's conversations with stakeholders should include consideration of these options as well as expected future losses, retrofit costs, and the benefits associated with each option.

Note that partial retrofits have been observed to have mixed and less reliable performance than complete retrofits, so retrofit designs that address the complete performance of the building are to be preferred in terms of safety, resilience, and reliability. It is generally not feasible or economically viable to retrofit buildings such that their performance matches that required for new buildings, so often owners and jurisdictions are faced with selecting lower performance objectives, weighing tradeoffs in light of the costs and benefits. For some vulnerable buildings, it is more cost effective to replace than to retrofit them.

For example, most URM building retrofits have historically focused on collapse prevention as a structural performance level for relatively moderate ground motions with short durations. Moreover, these retrofits typically addressed only some of the nonstructural risks, such as parapet bracing. As a result, many URM buildings will likely be severely damaged and unrepairable after severe ground shaking, even though their risks to life will be significantly reduced when compared to unretrofitted URM buildings.

Before selecting performance objectives for one building or an entire inventory, it is good practice to obtain a more detailed understanding of the deficiencies posed by vulnerable buildings. Seismic screenings and evaluations, described in Options Four and Five below, address this need.

Option Four: Undertake Seismic Screenings

The FEMA 154 rapid screening method (FEMA 2015) was recommended for the initial surveys in Step 2. For a more rigorous screening, the appropriate tool is a more detailed and costly protocol in the national standard *Seismic Evaluation and Retrofit of Existing Buildings*, ASCE 41-13 (ASCE 2014). Its Tier 1 Screening relies on civil or structural engineers determining building types, visiting buildings, investigating as-built conditions, and reviewing plans if available, to fill out a checklist that identifies potential deficiencies common to the building type. Tier 1 screenings of a sample subset of an inventory of collapse risk buildings will be informative for understanding the risks to the public and for setting priorities for other options.

Project: ______________________ Location: ______________________

Completed by: ______________________ Date: ______________________

16.12LS LIFE SAFETY STRUCTURAL CHECKLIST FOR BUILDING TYPES PC1: PRECAST OR TILT-UP CONCRETE SHEAR WALLS WITH FLEXIBLE DIAPHRAGMS AND PC1A: PRECAST OR TILT-UP CONCRETE SHEAR WALLS WITH STIFF DIAPHRAGMS

Low Seismicity

Connections

C NC N/A U WALL ANCHORAGE: Exterior concrete or masonry walls that are dependent on the diaphragm for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections shall have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 4.5.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1)

Moderate Seismicity: Complete the Following Items in Addition to the Items for Low Seismicity.

Seismic-Force-Resisting System

C NC N/A U REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1)

C NC N/A U WALL SHEAR STRESS CHECK: The shear stress in the precast panels, calculated using the Quick Check procedure of Section 4.5.3.3, is less than the greater of 100 lb/in.^{2} or $2\sqrt{f'_c}$. (Commentary: Sec. A.3.2.3.1. Tier 2: Sec. 5.5.3.1.1)

C NC N/A U REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area is not less than 0.0012 in the vertical direction and 0.0020 in the horizontal direction. (Commentary: Sec. A.3.2.3.2. Tier 2: Sec. 5.5.3.1.3)

C NC N/A U WALL THICKNESS: Thicknesses of bearing walls shall not be less than 1/40 the unsupported height or length, whichever is shorter, nor less than 4 in. (Commentary: Sec. A.3.2.3.5. Tier 2: Sec. 5.5.3.1.2)

Checklists in national standards can be used to identify critical vulnerabilities in buildings. C is “Compliant,” NC is “Non-Compliant” and U is “Unknown”.

A drawback of Tier 1 screenings is that they are not entirely reliable, and the actual performance of buildings can depend on other factors not identified in the screenings. In addition, this option provides no consistent way of disclosing the results of the screenings to the public. Quality assurance of such screenings can be problematic and may lead to a loss of confidence by the public if such results were made widely available. This drawback is addressed in Option Five.

Beyond Tier 1 screenings, ASCE 41-13 includes deficiency-based retrofits for simple buildings using its more detailed Tier 2 evaluations. Complex buildings with irregular configurations or unusual performance objectives may require Tier 3 evaluations. These tiers can help provide preliminary and conceptual bases for scoping retrofit costs and disruptions to occupants.

Detailed evaluations for a sample or subset of an inventory of collapse risk buildings can help in generating more reliable estimates of the performance of similar unretrofitted buildings as well as likely scopes and costs of their retrofits.

Option Five: Require Seismic Evaluations and Ratings of Buildings

Once ASCE 41-13 evaluations are completed, buildings can be rated using criteria developed by the U.S. Resiliency Council (USRC 2015). Its five-star Certificate of Resilient Engineering (CoRE) rating system is a consistent way to measure and communicate risk and expected building resilience. A five-star building is expected to be life safe and have repairable losses of less than 5 percent of the building's replacement value, and be immediately occupiable and fully functional after repairs within 72 hours after the occurrence of shaking with a return period of 475 years. A one-star building is a collapse risk. Such ratings can be posted at building entrances, either voluntarily by owners or as a requirement of the jurisdiction to effectively communicate risks to the public.

There are significant costs associated with assigning USRC CoRE ratings to buildings, including training and accreditation for engineers, peer reviews for quality assurance, and an appeals process.

USRC CoRE ratings coupled with detailed seismic evaluations are defendable ways to convey results to the public in an effective, simple, and consistent manner. Such disclosures may alter the use of buildings. Vacancy rates and commercial activity may change as a result of people choosing buildings on the basis of resilience ratings. Building occupants who become aware of poor ratings may

place pressure on owners to address risks in a timely manner. However, evaluations and ratings alone will not significantly reduce collapse risks in the short term.

Options Six and Seven describe more active measures to further encourage voluntary retrofits or require mandatory retrofits and replacements.

Option Six: Encourage Voluntary Seismic Retrofits or Replacements

After compiling an inventory of collapse risk buildings, jurisdictions can consider measures to reduce their risks. The most viable approaches will depend on each jurisdiction's risk perception, social and economic circumstances, historical preservation objectives, and other factors. A voluntary retrofit or replacement program is less confrontational and objectionable than a mandatory retrofit or replacement program. In most respects except their timelines, voluntary programs are similar to mandatory programs.

Four tasks beyond the eight tasks of Option Two are generally used to implement a retrofit or replacement program.

Task Nine: Considering the Circumstances

Reviews of other laws, policies, plans, and socio-economic circumstances are warranted before developing the specifics of an earthquake risk reduction program. For example, the California Environmental Quality Act must be applied when such a program would create adverse impacts on historical buildings to ensure that a variety of alternatives are considered. A jurisdiction's growth projections, historical preservation policies and priorities, and development and economic revitalization plans should be consulted. If opportunities arise, changes can be suggested to such plans to address or encourage considerations of seismic safety. Some jurisdictions also face related vulnerabilities from tsunami and seiche inundation, flooding, landslides, liquefaction, or subsidence. Because these can be exacerbated or triggered by earthquakes, they also warrant considerations.

Task Ten: Selecting Specific Requirements of the Retrofit/Replacement Program

Voluntary retrofit or replacement programs in the past have included some or all of the following components:

- Minimum seismic performance objectives for both evaluations and retrofits
- Financial incentives and removal of disincentives
- Required seismic evaluations of collapse risk buildings within prescribed time frames
- Time frames for owners to report back to the jurisdiction describing their intentions to carry out retrofits voluntarily
- Appeals provisions
- Notification of owners and other stakeholders (see Task Eleven)
- Periodic monitoring of progress and reports to policymakers (see Task Twelve)

Task Eleven: Notifying Building Owners and the Public and Implementing the Program

Before implementing their programs, some cities and counties have used an effective strategy of publishing a draft inventory of buildings to notify the public and engage stakeholders. Maintaining complete contact information for stakeholders that could be impacted by a proposed program will help ensure they have an opportunity to participate in its development and implementation. Six months to a year may be appropriate for this task. Other stakeholders such as chambers of commerce, business improvement districts, neighborhood watch groups, and neighborhood emergency response teams should also be contacted and kept abreast of steps toward implementing the program.

Task Twelve: Periodically Monitoring and Reporting on Progress

It will take several years before a voluntary program begins to show quantifiable results. The public discourse should explore the likely extent to which owners will voluntarily commit to reducing their buildings' risks and to what degree financial incentives or removal of disincentives will stimulate their progress.

Stakeholders should also discuss and periodically reassess the pace of compliance. In voluntary retrofit programs, owners should be asked to commit to self-determined time frames, so that policymakers can evaluate progress.

Retrofits often involve scaffolding, work in cramped spaces, and many safety precautions and inspections.

In mandatory retrofit programs, the pace of progress should also be monitored to help jurisdictions respond to changes in political, social, and economic conditions. Judging the adequacy of the pace of retrofits or replacements should take into consideration the risk of damaging earthquakes occurring before the program is fully effective.

Option Seven: Consider Requiring Seismic Retrofits or Replacements

Some jurisdictions have found it politically viable and less confrontational to begin with a voluntary retrofit program. But invariably, a large percentage of owners will not retrofit or replace their buildings until they are required to do so. Mandatory seismic retrofit programs should contain many of the characteristics of voluntary programs, listed in Exhibit A, along with time schedules for owners to comply with evaluations, retrofits, or demolitions and replacements.

Mandatory retrofit or replacement programs in the past have generally included the following components:

- Procedures to ensure notification of the owners and stakeholders (see Task Eleven)
- Minimum seismic performance objectives for both evaluations and retrofits
- Placing a certificate of collapse risk on the deed of the property that can be removed after a retrofit or replacement is completed
- Financial incentives and removal of disincentives
- Required seismic evaluations, retrofits, or replacements of collapse risk buildings within prescribed time frames
- Procedures to ensure effective program enforcement, including demolition as a last resort
- An appeals process to address disputes and provide relief in the event of hardships
- Provisions for monitoring progress, including the frequency of periodic progress reports to policymakers (see Task Twelve)

Ordinances should grant considerable discretion to building officials for administering and extending timelines for compliance, as this has proved to be an appropriate and necessary practice. Flexibility enables building officials to regulate retrofit progress in response to varying circumstances, economic conditions, and availability of qualified contractors. Jurisdictions should plan to stagger timelines for compliance so that owners don’t all try to hire retrofit designers and contractors at the same time. It is best to spread out a program over several years, perhaps a decade in larger jurisdictions, to maintain manageable levels of design, construction disruption, and enforcement activity over time. It is more important to complete retrofit work thoroughly than to rush to meet arbitrary deadlines at the expense of quality of construction or thoroughness in enforcement of retrofit safety.

Exhibit A: Checklist for Inventorying, Seismic Evaluations, and Retrofits

<u>Option One</u>: Rely on Attrition and Current Triggers for Alterations, Additions and Repairs in the Building Code

a) Audit building department personnel qualifications, licensure, certifications, and continuing education.
b) Develop a tracking system to record when additions, alterations, repairs, seismic evaluations, seismic retrofits, demolitions, or replacements of collapse risk buildings occur that includes listing the seismic performance objectives for retrofits.
c) Periodically report to policymakers on mitigation progress, expressed as the sum of retrofitted and demolished or replaced buildings divided by the inventory or estimates of the number of collapse risk buildings in the jurisdiction.
d) Periodically advise policymakers that the rate of progress will substantially reduce the collapse risk in ____ years based on current rates of mitigation progress.

<u>Option Two</u>: Develop Reliable, Detailed Inventories of Collapse Risk Buildings

Task One: Office Planning

a) Identify possible office resources.
b) Determine which available resources are most useful, complete, and current.
c) Have inspectors, plan review engineers, and others meet to discuss which neighborhoods are most likely to have collapse risk buildings.
d) List buildings thought to be a collapse risk type.
e) Develop a sample Building Survey Form for use.

Task Two: Field Survey and Report

a) Develop procedures and estimate hours for a field survey.
b) Train survey personnel.
c) Proceeding block by block, examine buildings in neighborhoods expected to have collapse risk buildings.
d) Proceeding block by block, create a preliminary list of collapse risk buildings. If in doubt, put questionable buildings on the preliminary list.
e) For each building on the list, fill out the Building Survey Form.
f) Compile and refine a draft list of collapse risk buildings from multiple neighborhoods.
g) Create a folder in a database for each collapse risk building on the list.
h) Add a copy of each Building Survey Form to the folder.

Task Three: Office Research and Verification

a) Develop procedures and estimate hours for office verification of the draft list of collapse risk buildings.
b) Review local building codes and ordinances to determine the dates that seismic design requirements were first enforced for the collapse risk building types. Consider that some

buildings in more recently annexed areas of the jurisdiction may have been built to different editions of the code than other buildings.

c) Review existing building permit files, construction plans, specifications, calculations, and seismic evaluations to refine the list of collapse risk buildings, and to add buildings not initially observed in the field. Start the process by reviewing documents and mapping resources that are the most useful, current, and complete.
d) For each building listed in the field survey, confirm whether or not it should remain on the draft inventory of collapse risk buildings.
e) Depict collapse risk building locations on a map.
f) Sort buildings by address and assessor's parcel number.
g) Fill out the rest of the Building Survey Form.
h) Revisit buildings in the field for follow-up investigations, if warranted.

Task Four: Contacting Building Owners

a) Draft a form letter to be sent to building owners.
b) Ask legal counsel to review the draft form letter.
c) Send out certified letters to each owner of collapse risk buildings.
d) Add a copy of the sent letter to the folder for each building in a database.
e) Receive responses from owners.

Task Five: Revising the Draft Inventory

a) Review owners' responses. If warranted, add or remove buildings from the draft inventory of collapse risk buildings.
b) Conduct follow-up investigations to confirm the revised information.

Task Six: Publishing the Draft and Operational Inventory

a) Establish a reasonable time frame and notification procedure for public input including provisions for updating the inventory upon receipt of public input.
b) Develop a statement to be released with the draft inventory that describes its limitations, the potential for errors and omissions, and opportunities for the public to help correct and refine the record.
c) Coordinate release of the draft inventory with education and public outreach efforts to encourage public awareness.
d) Issue an operational inventory with a proviso that the jurisdiction reserves the right to periodically amend the inventory as new information becomes available.

Task Seven: Analyzing the Findings

a) Sort and categorize the buildings by age, size, number of stories, number of occupants, occupancy types, retrofit status, and historic status.
b) Map the buildings to enable consideration of adjacency risks and effects on concentrations of buildings with similar vulnerabilities.

c) Merge the refined inventory data into a loss estimation program like HAZUS and develop new estimates of property and casualty losses.
d) Report on analysis findings periodically to policymakers and the public.

Task Eight: Periodically Refining the Inventory

a) Train building department personnel to keep on the alert for changes in collapse risk building status (retrofitted, demolished, or replaced) and to detect additional buildings that may not have been identified in the initial survey efforts.
b) If new buildings are added to the inventory, provide their owners comparable time frames in which to respond to inquiries and participate in policy deliberations.
c) Plan to periodically summarize adjustments to the inventory and the status of buildings for the benefit of policymakers and the public.

Options Six/Seven: Consider Voluntary or Mandatory Seismic Retrofits or Replacements

Task Nine: Considering the Circumstances

a) Determine how to comply with the California Environmental Quality Act (CEQA) and coordinate CEQA requirements in developing the mitigation program.
b) Review existing policies and socio-economic circumstances of the neighborhoods that could be affected by a collapse risk building mitigation program:
    i. How are collapse risk buildings distributed or clustered? Are busy streets, sidewalks and other public rights of way exposed to risks adjacent to collapse risk buildings?
    ii. Determine the nature of the occupancy types in collapse risk buildings. Does the population within and around buildings vary during the day or seasonally?
    iii. Determine the patterns of building neglect such as lack of maintenance by owners.
    iv. Consider future planning and revitalization characteristics in the jurisdiction and how seismic risks can be incorporated into priorities for those plans.
    v. Determine the locations and extent of historic districts in neighborhoods with collapse risk buildings. How would historical resources be impacted by their severe damage or collapse?
    vi. Where are collapse risk buildings located relative to commercial, industrial, tourism, residential, and institutional centers?
c) Review these and other seismic risk issues:
    i. Do some neighborhoods have a greater potential for severe ground shaking because of soft soil conditions than others with stiffer soils or rock?
    ii. Are areas with collapse risk buildings at risk of soil liquefaction?
    iii. Are areas prone to lateral spreading of soils?
    iv. Are areas prone to landslides?
    v. Are areas prone to tsunamis from the ocean, seiches in lakes, or dam inundations?

Task Ten: Selecting the Specific Requirements of the Voluntary or Mandatory Program

a) Draft options and detailed provisions of a retrofit program considering whether or not to include:
   i. Specific design criteria for seismic evaluations and retrofits including performance objectives.
   ii. Draft timetables for conformance.
   iii. Deed restrictions to inform potential buyers that a building is a collapse risk, and provisions for revising or removing these deed restrictions once buildings have been retrofitted to meet a defined performance objective.
   iv. Financial incentives and removal of disincentives.
   v. Procedures to ensure effective enforcement of the program, including an appeals procedure for owners who have difficult, unusual, or unforeseen problems with compliance.
   vi. Provisions for monitoring progress, reporting to policymakers, and making adjustments downstream.

b) Evaluate the proposed retrofit program by addressing the following questions:
   i. Does it address important buildings such as schools, police, fire, and other critical government and institutional facilities in a timely manner?
   ii. Does it address buildings of certain occupancies in a rational and equitable order?
   iii. Does it consider impacts on and accommodate housing needs?
   iv. Does it make sense with current and future redevelopment plans for the jurisdiction?
   v. Does it adequately balance competing goals of preserving cultural and historical features and safety?
   vi. Does it make sense when environmental risks are considered?
   vii. Does it make sense when land-use and growth patterns are considered?

c) Estimate costs and durations of disruptions for building owners.

d) Estimate costs to the jurisdiction for managing the program and to address collapse risks of government-owned and leased buildings.

e) Formalize a draft of the proposed retrofit program and alternatives.

f) Have the draft reviewed by other departments with stakes in its outcome.

g) Hold public hearings, as well as informational and outreach meetings.

h) Revise the draft proposed program to address persuasive public comments.

i) Prepare information to provide to owners of collapse risk buildings and others potentially affected by the program.

j) Ensure legal review of the final proposal and supporting documentation, including notifications, disclosure provisions, compliance orders, noncompliance orders, and progress monitoring provisions.

k) Inform stakeholders and jurisdiction policymakers of all details of the proposed program.

l) Present the final proposal to policymakers for their consideration and action.

m) Plan for additional public outreach at periodic intervals throughout the duration of the program, not just during initial phases.
n) Facilitate interaction with property owners, design professionals, contractors, and lenders to help connect owners with qualified professionals with experience in managing collapse risk buildings.

Task Eleven: Notifying Building Owners and the Public and Implementing the Program

a) Send out a letter to each owner of collapse risk buildings (see Exhibit B).
b) File a copy of each letter sent in a database folder for each building.
c) Assign staff to answer questions from the public.
d) Provide information to owners and others.
e) Provide multiple opportunities to remove unintended buildings from the program, and clearly explain the type of buildings intended to be included in the scope of the program.
f) Ask owners to respond with information about past alterations or retrofits, if any.
g) Consider holding an Earthquake Retrofit Fair to encourage vendors, contractors, financiers, and design professionals to share information with owners about retrofit designs, financing, and construction alternatives (San Francisco, ESIP 2016)

Task Twelve: Periodic Monitoring and Reporting on Progress

a) Develop and issue (by certified mail) compliance orders for owners.
b) Log in seismic evaluations and retrofit plans and permit applications to the jurisdiction's database.
c) Review evaluations and plans calculations using qualified, licensed plan review engineers.
d) Issue permits.
e) Monitor the list of collapse risk buildings for compliance.
f) Carry out enforcement procedures in cases of noncompliance.
g) Inspect retrofit, demolition, and replacement construction.
h) Maintain records including inspection and testing reports.
i) Issue compliance and completion notices.
j) Present annual progress reports to policymakers for their reviews, comments, and periodic reconsideration of the provisions of the program in light of progress.
k) Make recommendations to policymakers for adjustments to the program that will improve its effectiveness.
l) Coordinate with the local real estate community to create clear disclosure requirements for collapse risk properties at the time of sale.

Exhibit B: Sample Form Letter to Building Owners

<Date>

<Owner Name>
<Owner Address>
Re: Property Located at: <Address of Collapse Risk Building>

Dear <Mr. Ms. >:

Widespread concerns over earthquake safety caused the City/County of <Jurisdiction Name> to create a draft inventory of collapse risk buildings. Our survey results indicate that your building is likely a <collapse risk building type> that is expected to perform poorly in future damaging earthquakes and pose significant risks to occupants, nearby buildings, and/or adjacent public spaces.

The state, through its multi-hazard mitigation plans, encourages local governments to enact risk management programs to identify and significantly reduce the risks posed by collapse risk buildings. The City/County of <Jurisdiction Name> is in the process of developing a <seismic evaluation/disclosure/retrofit program> that may require <________________________>. It is expected that a proposed <program/ordinance> will be presented for public review and comment on <date(s)>. Before such a <program/ordinance> goes into effect, you and other members of the public will have opportunities to participate in public hearings before formal action is taken on this proposal.

The City/County of <Jurisdiction Name> has compiled a draft inventory of approximately <_____ > collapse risk buildings. The building referenced above is tentatively on the draft inventory. Before this draft inventory of <__________________> collapse risk buildings is finalized, the <name of agency> wants to be sure that the inventory is accurate. If you believe that your building is not a <collapse risk building type> or that the building has already been evaluated or retrofitted, or is planned to be replaced or otherwise determined not to pose significant risks, please check the appropriate box on the attached form, and return it to our office within two weeks. Please include information to support your opinion.

Sincerely,

<Building Official Name>
<Building Official Title>
<Building Official Name>
<Building Official Title>
<Building Department Address>

Exhibit C: Sample Form Letter from Building Owners to Building Official

<Date mailed or emailed>

Dear <Building Official Name>:

My property at <Address of Collapse Risk Building>

☐ is not a <collapse risk building type>.

☐ has been seismically evaluated that demonstrates compliance with a seismic performance objective of < >.

☐ has been seismically retrofitted to provide a seismic performance objective of < >. The date of retrofit completion was ______________________.

Comments and supporting material are ☐ attached / ☐ not attached.

<Owner Name>
<Owner Address>

Step Four: Other Key Management Considerations

This section includes a wide range of topics that are not universally applicable. One size does not fit all, and no single approach to managing risk has been suitable to the wide variety of seismic risks and social and economic circumstances of California's 482 cities and 58 counties. However, some of the subjects treated here may be high priorities for your particular jurisdiction, and all of them should be reviewed before each major stage of developing earthquake risk reduction plans.

Benefits and Pitfalls of Typical Approaches

Many adaptable lessons can be drawn from past efforts to manage earthquake risk. The following points of advice are derived from several decades of observations by the Seismic Safety Commission. They appear at various places in Steps One through Three, stated in various ways, but are summarized here for convenience.

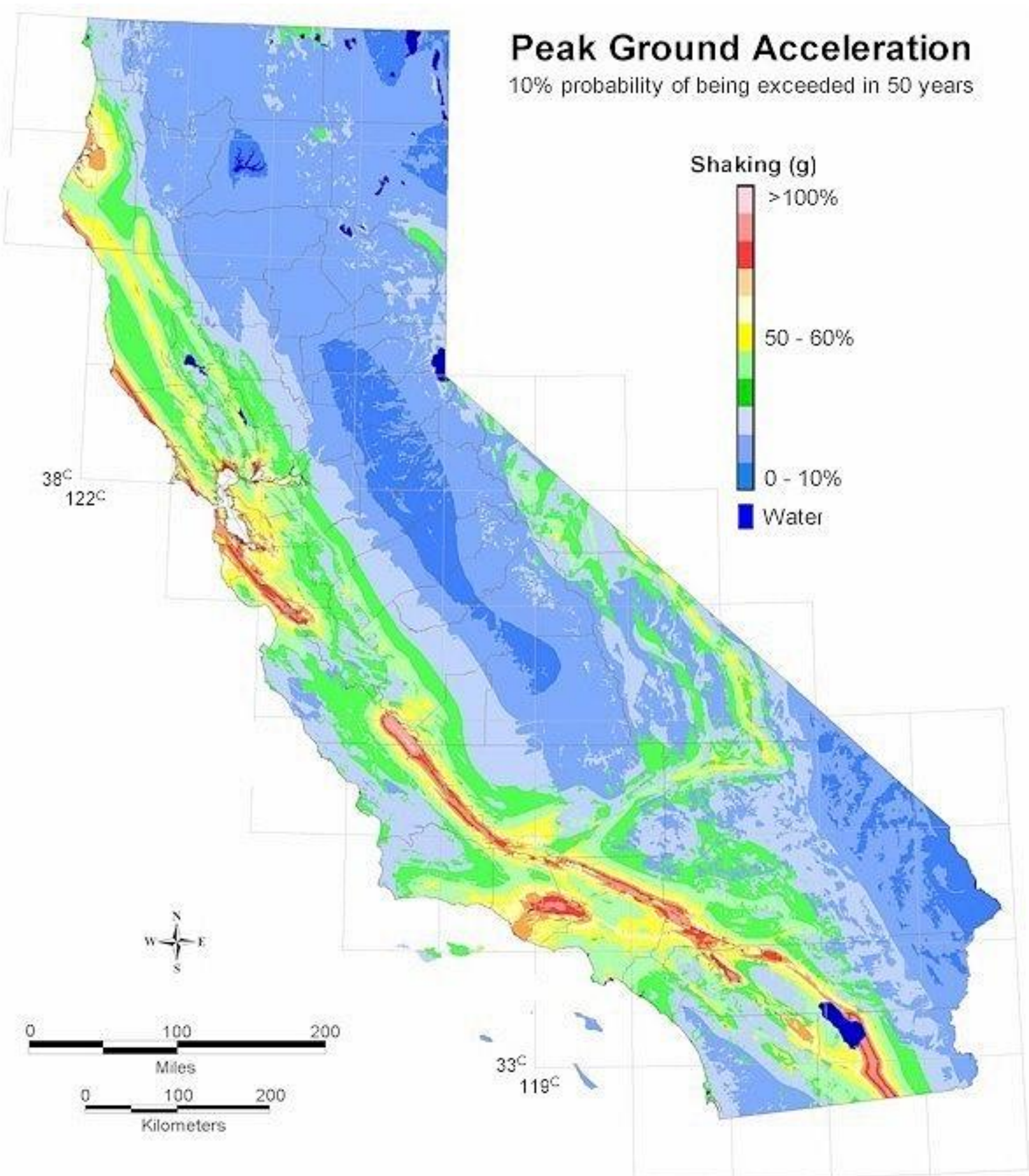
- ***Look around***—Local governments are encouraged to learn from similar communities that have pioneered past efforts and then tailor and adapt from their experiences.
- ***There are limits***—Voluntary retrofit programs can work if communities require seismic evaluations, have vibrant economic conditions as well as sufficient incentives and progress monitoring measures in place, but they can create inequitable conditions where some owners cooperate and others don't.
- ***The details matter***—Mandatory retrofit programs can be confrontational and unenforceable unless there is economic viability and manageable time frames for compliance.
- ***Be flexible***—Extending deadlines for mandatory retrofits produces better results than forcing owners to abandon buildings or cut corners on retrofits simply to meet unrealistic deadlines. Staggering and adjusting deadlines for compliance based on actual experience in the community produces better results than setting arbitrary deadlines and forcing compliance regardless of the side effects.
- ***Ill-conceived efforts can backfire***—Programs such as simply notifying owners that their buildings are prone to collapse are typically ineffective and can have slower mitigation rates than relying only on natural attrition from additions, alterations, repairs, and sales that can trigger voluntary retrofits.
- ***Beware of simplistic fixes***—Programs that have relied primarily on placarding collapse-risk buildings to warn the public have been difficult to enforce over time and have generally been ineffective.
- ***Don't bank completely on the unknown***—For example, programs that rely on seismic ratings of buildings have little or no track record yet for motivating owners to retrofit or replace vulnerable buildings.

- ***History is a compelling motivator*****—**Regions of California that have recently experienced damaging earthquakes nearby tend to manage earthquake risk more assertively than regions that have not. Anniversaries of historical earthquakes can be effective occasions for raising and sustaining motivation about seismic safety in the community.
- ***Gestures can be motivational even without much substance*****—**Financial incentives generally have been too small to provide meaningful motivation for building owners to accdelerate their retrofits. However, the discussions that lead to local governments making the commitment to financial incentives can be useful as a tool to engage stakeholders, convey the commitment and priorities of policymakers, and encourage cooperation.
- ***General interests can't be met with one solution*****—**The needs of individual owners and neighborhood economic conditions vary greatly, so many jurisdictions can help by developing a suite of financial incentives and the removal of disincentives that best suit the jurisdiction's needs. Uniform statewide solutions tend to be inflexible or inadequately funded to be effective for a large number of owners and jurisdictions.
- ***Special interests are often the focus*****—**Some financial incentives may be quite effective for narrow segments of eligible building owners (such as federal tax credits for nationally registered historical buildings). They should not be neglected.
- ***Avoid too many strings*****—**Eligibility conditions and red tape required to apply for some financial incentives have at times created so many restrictions that owners have opted not to apply. Startup and management costs incurred by local governments to administer some incentive programs can cost disproportionately more than the benefits accrued. Changes in tax laws or market conditions can render financial incentives inflexible or underused if they cannot be updated.

Hazards Vary for Each Jurisdiction and Over Time

California's earthquake hazards vary greatly from region to region depending on proximity to known, active faults. On one extreme, the triple junction region near Cape Mendocino where the Pacific, North America, and Juan de Fuca plates intersect is one of the most active regions in the contiguous United States. In contrast, parts of eastern California are relatively stable with quite modest hazards. This is one reason why uniform seismic risk management policies are generally not appropriate for statewide adoption. Regulations across the state currently vary consistent with known variations in hazards.

Some regions have recently experienced damaging earthquakes and are now in a period of relative quiescence as stress rebuilds within the earth's crust before future earthquakes occur. So the absence of earthquakes in recent decades may not be a reliable indication of actual hazards. Also, recent small to moderate earthquakes may not be reliable indicators of future earthquakes that can be much larger, somewhat closer, and more damaging. Just because your city or county may have "survived" past earthquakes, that is not necessarily an indication of future losses. Much of our knowledge about earthquake histories, earthquake cycles, and earthquake interactions is provisional, and the scientific community continues to learn useful lessons from major seismic events in California and around the world. The Seismic Safety Commission plans to remain open to these lessons on an ongoing basis and incorporate them as appropriate in its guidelines.



Seismic hazard varies greatly across California depending on distances from active faults and soil conditions.

Many California earthquakes in the past half-century have occurred at relatively fortunate times of the day when people were less exposed to casualties from falling buildings. No two earthquakes will necessarily be alike. Parts of California have been lucky in this respect.

Major Secondary Effects of Building Collapse

Impacts with Regional, National, or International Significance

Buildings that house assets with regional, national, or international significance should warrant higher priority consideration than other buildings.

For example, in small jurisdictions, vulnerable buildings whose damage could disrupt traffic flow along major transportation arteries can justify contingency planning. Are detours feasible around such buildings to maintain traffic flow? Can hard barriers be readily installed before repairs or demolitions to maintain traffic flow?

In large jurisdictions, it can be prudent to evaluate concentrations of multiple assets within a few blocks of development. Their co-location risks should be considered in the event that one or more buildings that are severely damaged or collapsed could indirectly disrupt entire neighborhoods and regional economies. It may be desirable to pre-identify and pre-plan for vulnerabilities and impediments that could inhibit safety and recovery. This can be done through multi-agency table-top exercises that address traffic flow considerations. Ad hoc task forces can characterize the risks of tall buildings and envision plausible “red zones” around them. Economic impact studies could also help postulate the range of indirect effects of such impacts and identify risk management alternatives to speed recovery.

Fire Following Earthquakes and Fire Protection Needs

Recent earthquake scenarios (USGS 2008, 2015) as well as many older scenarios—and historical experience—have identified the potential for conflagrations following earthquakes to generate far greater losses than the shaking. Major variables are how much wind is blowing once fires start and how easily fire is likely to spread to adjacent buildings. Studies suggest that the number of fires will greatly exceed local and regional fire fighting resources, thus requiring mutual aid from other regions and states. However, mutual aid can take many hours to arrive when it may be needed the most, leaving fires to spread unabated or victims trapped in collapses.

Fires spread faster when shaking damage compromises a building’s fire resistance and enables its spread, as shown by this recent test on a shaking table (UC San Diego 2012).

Risk managers for jurisdictions can generate shaking loss models (HAZUS 2014) and fire spread models to help characterize this risk and evaluate the relative effectiveness of various risk reduction alternatives.

Water Damage

Damage to functions, nonstructural systems, and building contents from broken sprinkler systems, toppled water heaters, and flooding from these and other piping has the potential to rival shaking-related losses in many buildings. Recent enhancements in building code requirements for new buildings will help reduce future losses, but the vulnerability of older buildings to post-earthquake water damage persists. Retrofits for sprinkler systems, water heaters, and pipe bracing can be accomplished through periodic, routine maintenance programs that significantly reduce this risk. Training occupants to quickly identify and shut off water sources can also help minimize losses.

Nonstructural Losses and Building Contents Losses

The vast majority of buildings are not expected to collapse, but typically nonstructural systems (ceilings, external cladding, windows, mechanical and electrical equipment, and partitions) will result in greater costs and disruption to functions than compared to losses from structural systems. Post-1980 buildings are expected to have more earthquake-resistant nonstructural systems than older buildings because of enhanced requirements in building codes and standards since then. (See also Approach 2 in Appendix 2.)

Ceilings that move during earthquakes can shear off sprinkler heads, causing water damage.

Facade Risks and Maintenance Programs

Facades of existing buildings are subject to weathering and deterioration. They can benefit from periodic inspections to ensure that cladding, window systems, and ornamentation are (1) adequately connected to structures, (2) monitored to identify corrosion and other signs of maintenance needs, and (3) maintained to reduce their risk of falling in earthquakes. Well-maintained facades will help reduce deaths and injuries on sidewalks and public rights of way as well as reduce disruptions to adjacent buildings and roadways. Some jurisdictions, redevelopment and business improvement districts, and historic buildings with Mills Act agreements have or are planning to implement facade maintenance programs that encourage or require building owners to more actively and consistently manage this risk.

Infrastructure Vulnerability

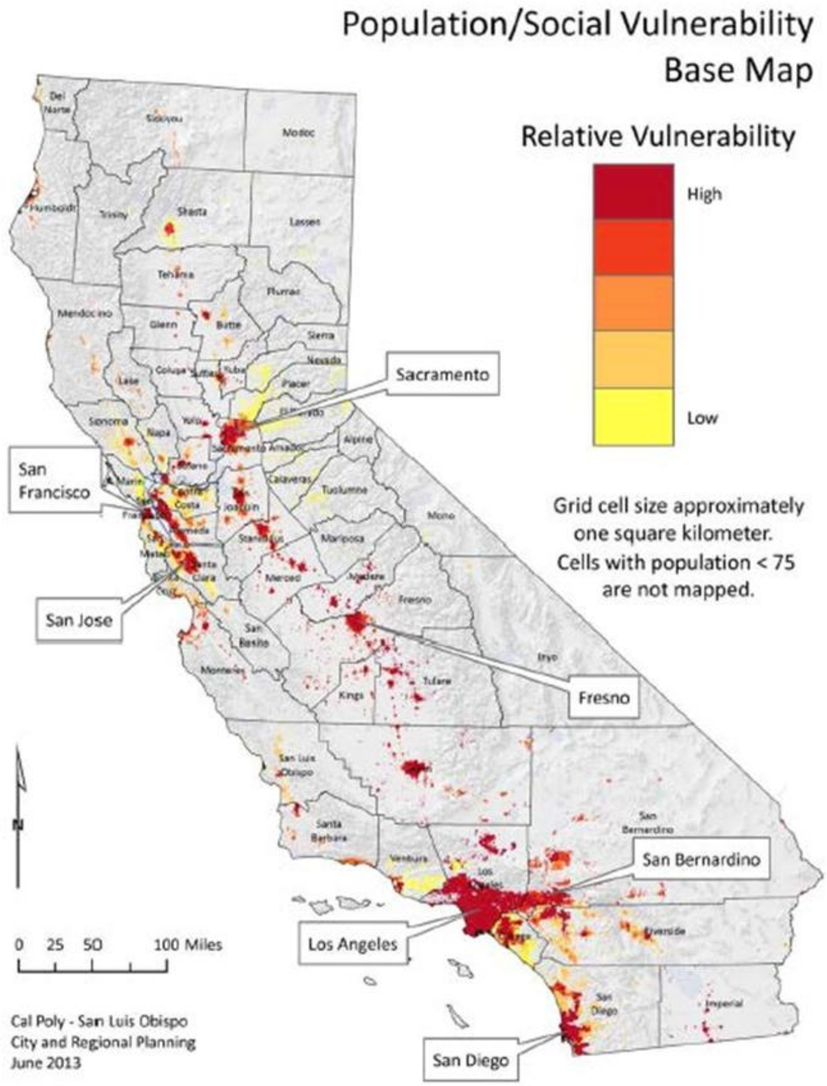
Building functions depend on external infrastructure: electricity, gas, water, and telecommunications. The failure of one or more of these can cause indirect losses (including social, economic, and unemployment effects) much greater than the direct losses from shaking. Major utilities have implemented earthquake risk reduction programs. But many smaller utilities have chronically underinvested in such efforts.

Internal damage to nonstructural and structural systems of buildings that are the responsibility of building owners and beyond the control of utilities can also interrupt electrical, telecommunication, and other utilities. Seismic evaluations and retrofits should include consideration of these effects.

Social Implications of Risk Management Alternatives

The most vulnerable population groups including the elderly, poor, disabled, and non-English speaking, experience disproportionate losses in disasters. These groups often occupy low-income housing that tends to be more vulnerable than other housing. The need for emergency shelters and interim housing after future earthquakes will be dominated by these vulnerable populations. After some major metropolitan earthquakes, government-subsidized housing is expected to dramatically increase to help replace possibly over 100,000 uninhabitable housing units, and could last for many years (ABAG 1996, 1999).

The state's *Multi-hazard Mitigation Plan* (CA-OES 2013), which summarizes "social vulnerability" by census tracts, shows that the greatest concentrations are in Southern California and the San Francisco Bay region. Given the limitations of the statewide map, local governments are encouraged to conduct similar studies of social vulnerability as the basis for their local multi-hazard mitigation plans. Studies combining social vulnerability data with local inventories of collapse risk buildings can generate considerable insights. Such information was compiled for San Francisco and Ventura regarding URM buildings in environmental impact reports (San Francisco 1990, Ventura 1991).



Social vulnerability in the Coastal and Southern Inland Empire regions is correlated with high earthquake hazards (CA-OES 2013)

Financial Implications of Risk Management Alternatives

For most building owners, seismic retrofits pose new expenses without clear opportunities for increased revenues to pay for them. Rental rates are often set by the market irrespective of whether individual buildings are retrofitted. Older buildings often house marginal occupants or are only partially occupied, so in many cases they may have already exceeded their economic life. Retrofitting or replacing these buildings can eliminate the businesses and institutions that occupy them, causing economic problems such as loss of jobs in the segments of society perhaps least able to bear them. Moreover, many older buildings possess architectural and character-defining features that lend charm, historical significance, and distinct identities to communities. Adaptive reuse and modernization of buildings can maintain and enhance the positive qualities that they possess (SSC 87-020).

Neighborhoods and their individual buildings typically fall into one of three tiers of economic vitality:

- **Top Tier** buildings retain consistent growth in equity, command high rents, and are fully occupied. These are excellent candidates for seismic retrofits and adaptive reuse since owners typically have the ability to refinance and generate funds to pay for improvements.
- **Middle Tier** buildings are being used for more marginal businesses or as housing for low-income people that are already being rented at or near the prevailing rates in their area. Financing for seismic retrofits for these buildings can be difficult. Such buildings often have been owned by a single family for a long period, and the owners don't have the funds or inclination to spend money on them. Even if they are upgraded and modernized, the buildings cannot command much, if any, more rent given market conditions in their neighborhoods. Banks will loan on the middle tier if they can be confident that projects will be completed on time and within budget, and that revenue streams and the owner's other assets are reliable enough to protect their equity from default. They can be marginal candidates for seismic retrofits or good candidates for replacements, depending on a wide variety of factors.
- **Lower Tier** buildings have long exceeded their economic life. They are often vacant or partially vacant and no longer generate sufficient revenues. Owners are banking on the value of the land, more than the building itself, or hoping that speculators will take them off their hands. Gradual demolition by neglect and blight is commonplace. These properties are primarily candidates for replacement since they often require much greater investments than seismic retrofits to restore them to the Middle Tier. Such investments are generally not cost-effective.

Mandatory seismic retrofit ordinances that don't provide adequate time for owners to comply can leave many owners with untenable choices. They can make the improvements with private financing and try to pay for them by increasing rents, or they can try to disinvest and sell the properties to others who may be willing to invest in retrofits. Some owners will milk their buildings for all they are worth until ordered to vacate, then, through demolition by neglect, hope to convert the sites to other and more economical uses.

Owners, governments, and other stakeholders should adopt realistic expectations when managing the building stock. It is realistic to assume that the use of top and middle tier and perhaps a few lower tier buildings can be extended or adapted. However, many lower tier buildings should probably be replaced unless sustainable financial mechanisms can be found. Consider that thousands of severely damaged buildings will be demolished after future metropolitan earthquakes. So policies that gradually replace vulnerable, under-used buildings over decades can be preferable to policies that expect all lower tier buildings to remain in use for generations to come.

Seismic risk management approaches including incentives, compliance time frames and expectations can be tailored to each tier since their circumstances and financial and social needs are so different.

Retrofits can be part of a facade improvement effort.

Ranges of Current Retrofit Costs for Building Owners and Occupants

Costs per square foot of floor area for seismic retrofits vary widely, depending on a host of factors:

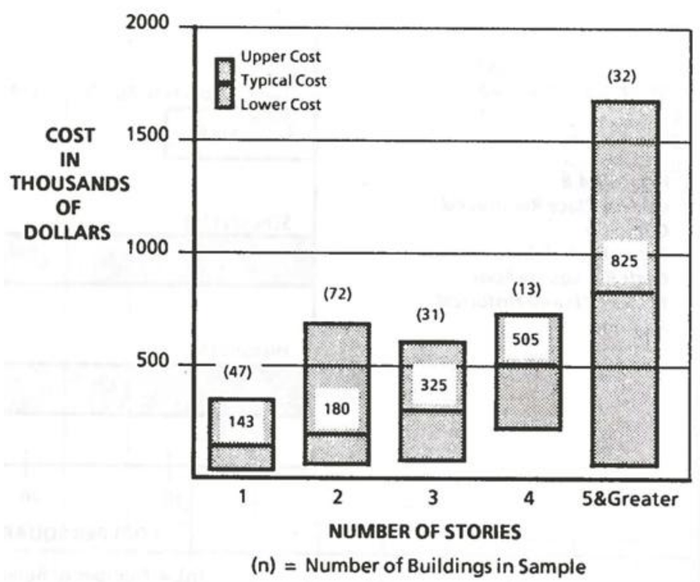
- Size of the building (smaller buildings are costlier)
- Number of stories
- Building shape and regularity of configuration, since irregular buildings will generally experience higher retrofit costs compared to buildings with simple shapes
- Quality of the original building design and construction
- State of repair and deferred maintenance of the building
- Skill and experience of the retrofit design professionals
- Skill and experience of the retrofit contractors and their personnel
- Location of the building and proximity to other buildings that may pose constraints for construction workers during the retrofit
- Local wage rates and how the retrofit is financed
- Whether building owners can manage any of the design or construction coordination themselves
- The seismic performance objective or standard that the retrofit is expected to meet
- Whether innovative technologies are used for the retrofit

- Whether other improvements such as modernizing the building's access, energy consumption, mechanical or electrical systems are planned to be done at the same time as the seismic retrofit

The Seismic Safety Commission does not maintain a database of current retrofit costs. The Federal Emergency Management Agency sponsored the last known effort to provide a cost database using an inventory of retrofits conducted primarily in the 1980s and 1990s (FEMA 1995, 2013). Although costs have changed significantly since then, these databases provide a sense of the great variability of retrofit costs and the factors that contribute.

Experiences with government retrofit programs suggest that retrofits are often less than half the total value of typical modernization projects.

Local governments are encouraged to track and share with other jurisdictions and the Seismic Safety Commission their permit valuations for such work and, where possible, to segregate out the cost of bare-bones seismic retrofits from other unrelated alteration costs. This information, particularly the variations and trends in costs, is critical for judging the cost-effectiveness and life-cycle costs of seismic retrofits.



Retrofit costs are known to vary greatly. Federal cost databases were last updated in 1994 (FEMA 1995).

Ranges of Current Costs to Local Governments

Some vulnerable building types are relatively easy to identify and inventory. For example, URM buildings and soft story apartments can typically be identified and inventoried by sidewalk and alleyway surveys in well under an hour per building. Unretrofitted URM buildings almost always pose collapse risks or serious parapet falling risks. In contrast, many soft story apartments may have irregular lateral force resisting systems that can protect against collapse. In this case, more detailed seismic evaluations of apartments could find them to be earthquake resistant and removed from final inventories of collapse risk buildings.

Many concrete buildings have architectural finishes that obscure the structural system, making them harder to quickly and reliably identify as risks for collapse. Many were built in accordance with some earthquake resistance requirements, and most have concrete walls that can enhance resistance compared to buildings without walls. After simple sidewalk surveys place these in a preliminary inventory, detailed seismic evaluations that include reviews of original construction plans will likely indicate that many, perhaps most smaller concrete buildings do not pose significant collapse risks.

As a result, the costs to identify and inventory buildings depend greatly on the types and numbers of buildings to be addressed. Only when such buildings are few in number will building code enforcement agencies be able to fit these costs within existing budgets. In most other cases, agencies will need additional funds to conduct systematic inventories and review seismic evaluations. Local building departments should anticipate long durations, perhaps 5 to 25 years, for internal program management when estimating staffing demands.

Local governments are encouraged to track their costs and share this intelligence with other similar jurisdictions and the Seismic Safety Commission.

Retrofits often include adding new connections of walls to roofs.

Benefit-Cost Comparisons

A few local governments have conducted benefit-cost studies for URM buildings (San Francisco 1990, Ventura 1991). These can inform considerations for future benefit-cost studies, since they articulate alternatives and offer advice on how to account for variability in losses including the changes in expected losses if earthquakes occur at different times of the day.

A 2005 benefit-cost study by the National Multi-hazard Mitigation Council suggested that each dollar spent on multi-hazard mitigation provides the nation about $4 in future benefits, and typical benefit-cost ratios for earthquake mitigation were in the range of 1.5 to 1. However, that study's interest rate used to compute the present value of future benefits was called into question by the Congressional Budget Office (CBO 2007). If the CBO's adjustments are considered, benefit-cost ratios for some past earthquake mitigation projects fall below 1.0 and thus do not appear to have been cost effective unless other indirect and qualitative benefits can be considered.

There are no known recent benefit-cost comparisons that account for the latest changes in seismic evaluation and retrofit codes and standards.

Life-cycle studies are another variation of benefit-cost study. Building owners may conduct life-cycle studies, at times in connection with obtaining insurance, to estimate the potential returns on their investments if they were to voluntarily retrofit their buildings. Vulnerable building types for which earthquake insurance is readily available or affordable may benefit from potential net savings in avoided business interruption, life loss, injuries, or property losses even when taking into account the infrequency of earthquakes and the time value of money.

Investment and Tax Losses due to Earthquakes

Many jurisdictions have invested in redevelopment projects by forgoing property tax increments or by providing subsidies or other incentives to finance renovations and attract investors. These public investments can be at risk as well as private investments if collapses were to occur in older neighborhoods. Building owners, business improvement districts, chambers of commerce, and communities as a whole should consider alternatives for how to best protect prior and future investments from earthquake losses. Projections of future tax revenue typically assume that buildings will continue to function and owners will be paying property taxes. However, if these assumptions do not reflect the vulnerability of those assets, financial contingency planning by local governments should include the potential for loss of tax revenues after earthquakes.

Model Ordinances and Other Approaches Adopted by Local Governments

Some agencies have already adopted programs that can serve as models for other jurisdictions. Most performance objectives for seismic retrofits are considerably lower than those required for new construction due to high costs. They usually intend to significantly reduce risks to life, but not necessarily eliminate the risks. Typical seismic retrofit objectives do not attempt to limit property damage or ensure repairability of damaged buildings after earthquakes. State law authorizes local governments to adopt retrofit standards that do not fully comply with requirements for new buildings (Health and Safety Code 19160 *et seq.*). This law also provides certain liability immunities to local governments, discussed in Appendix 3.

The Seismic Safety Commission monitors and keeps a database of local government retrofit programs. Local governments are encouraged to contact the Commission to get information about what similar agencies have accomplished or are proposing elsewhere in California. To share the lessons learned from prior efforts, the Commission provides a clearinghouse of information to help risk management practices take advantage of the experiences gained by others.

In the past, the Seismic Safety Commission has encouraged statewide organizations such as the California Building Officials, the California Council of the American Institute of Architects, and the Structural Engineers Association of California to work together to develop recommended model ordinances. These documents can improve enforceability and consistency by encouraging jurisdictions that adopt them to take advantage of vetted and consensus experience from other members of the organizations. At present, a model ordinance only exists for unreinforced masonry buildings (SSC 2006b). As the needs and consensus arise, the development of other model ordinances may be pursued.

Incentives and Reduction of Disincentives

Adaptability and Sustainability of Incentives

Whether incentives used by one jurisdiction can be adapted by others depends greatly upon the similarity of their economic and real estate conditions, the owners' willingness to pay in response to the incentive, and competing lending rates or other alternatives currently available.

Changes in tax laws over the years have rendered many earlier incentives, such as the Marks Historical Bond Act and some types of special assessment districts such as Mello-Roos, either non-applicable or less feasible. Some incentives are not readily adaptable by other jurisdictions unless tax laws are similar, because new taxes require a two-thirds vote of the electorate. Such is the case for Berkeley's real estate transfer tax, since most other jurisdictions don't have a transfer tax. Many incentives have a limited life or effectiveness. For example, special assessment districts may be created once and not allow for additional participants at later dates. Some below market-rate loans may become unattractive with changes in the market or for owners unable to take on additional loans.

As a result, governments should periodically review existing incentives and options for new or revised incentives to allow for changed conditions in the economy as well as local, state, and federal laws. (EERI 2006) Two out-of-date publications summarize financial incentives and their limitations (EERI 1998, ABAG 1992).

Market-Driven Incentives to Attract Tenants and Obtain Loans

Some proponents of seismic retrofits have adopted a strategy that safer buildings will be more competitive in the rental market, perhaps resulting in lower vacancy rates and commanding higher rents. Visible indicators of seismic retrofits, such as prominent walls or diagonal braces in storefronts, have been architecturally emphasized in some projects as an attraction to owners and potential tenants. On the other hand, there is little evidence that owners have been able to reliably charge higher rents for retrofitted buildings. Anecdotal observations suggest that rents are not greatly influenced by individual building safety or perceptions of safety.

Probable Maximum Loss (PML) estimates are generally required by lenders of commercial mortgages. Some lenders will not issue mortgages if PMLs exceed 20 percent of replacement value. Seismic retrofits can substantially reduce PMLs and enable some owners to get access to market-rate loans. However, PMLs are often overly simplistic, inaccurate, or inconsistent indicators of building risk. And retrofits with low performance objectives may only address life loss, but still pose substantial risks to business interruption and loss of property value after damaging earthquakes. Consider using a more comprehensive rating system as an alternative to PML's such as the USRC's CoRE rating system (see Option Five in Step Three) or FEMA P58.

Reduction of Disincentives

Some disincentives for retrofits or demolitions, such as compliance with the federal Americans for Disability Act, cannot be removed or altered. However, dialogue with building owners, community development directors, and other stakeholders can sometimes identify other disincentives that local governments might be able to remove or adjust. Examples include parking or density restrictions and other growth control policies, reductions of fees, and expedited plan reviews.

Other Benefits that Can Be Triggered by Retrofits

The California Building Code contains specific triggers for additional work beyond seismic retrofits, including asbestos abatement, improving disabled access, adding fire sprinklers, carbon monoxide detection, and other life safety requirements. Most owners take the opportunity to include modernization and other improvements in conjunction with seismic retrofits. It can be more cost-effective to make several kinds of improvements to buildings when undergoing seismic retrofits. On the other hand, the costs associated with complying with other non-seismic requirements can often exceed the seismic-only costs of a retrofit.

Including Seismic Objectives in Other Planning, Zoning and Development Initiatives

Since earthquake risk management is typically not a community's highest priority until damaging earthquakes occur, local governments can find it effective to include seismic issues when developing and implementing other initiatives. "Pre-Earthquake Planning for Post-Earthquake Rebuilding" (Spangle 1986) has been used as a technique to visualize the nature and extent of future losses and to identify opportunities that will promote seismic resilience indirectly through change spurred by other initiatives that involve planning, revitalization, inducing growth, zonation, and historic preservation.

Economic development: It is best to include considerations of seismic risk when making decisions about enhancing a community's economic vitality. Communities should avoid overdependence on vulnerable buildings unless reinvestment plans include seismic evaluations and retrofits where needed.

Urban revitalization and reducing social vulnerability: Streetscape and facade improvements on buildings may become good investments when their collapse risks are addressed at the same time. Repairing single-room occupancy apartments for low-income residents should also include retrofits. California earthquakes have partially destroyed earlier redevelopment investments that did not include comprehensive retrofits, for instance in Whittier in 1987, Santa Cruz in 1989, and Paso Robles in 2003.

Transportation management, smart growth, and green growth: Intensifying new developments or investments in older buildings near transit hubs and population centers should avoid overreliance on collapse risk buildings. Growth priorities should target the replacement or adaptive reuse of lower and middle tier buildings at risk of collapse. Resilience should be promoted in new construction and retrofits since greener, smarter buildings are earthquake-resilient.

Zoning incentives: Owners can be encouraged to intensify or change the uses of their buildings with parking waivers, transfers of building height allowances to other owners, easing of nighttime use restrictions, allowing certain occupancies, and other types of zoning changes. Seismic evaluations and, if warranted, retrofits should be considered as a condition for eligibility for these incentives.

Efforts to reduce fire, flood, climate change, and terrorism risks: Land use planning decisions should best incorporate seismic considerations along with the management of other natural hazards.

It also may make sense to include building seismic risk management as a major subset within an overall, multi-hazard resilience program. Societal expectations for resilience can often exceed the capabilities of the built environment, so there is considerable risk that the public could assume expectations for resilience in damaging earthquakes that are not realistic for many existing buildings. Yet it is prudent to include earthquake considerations in resilience efforts. The focus of resilience programs is on enhancing the reliability and continuity of functions after disasters and measuring performance across multiple scales.

The United Nations' "Making Cities Resilient" campaign is underway and growing in popularity across the world (see www.unisdr.org/we/campaign/cities). Such efforts were advocated in the latest Sendai Framework for Disaster Risk Reduction and have been encouraged by the federal Department of Homeland Security and the state Office of Emergency Services. A similar effort is the "100 Resilient Cities" program, sponsored by the Rockefeller Foundation (www.100resilientcities.org), which includes Berkeley, Los Angeles, Oakland and San Francisco.

Earthquake Insurance as a Tool to Transfer Liability

The California Department of Insurance has stated that as of 2015, only about 8.5 percent of all commercial property in California is insured for earthquake losses (CDI 2015). Generally premiums are affordable for building classes that have a good record of performance in past earthquakes. Unreinforced masonry buildings are typically uninsurable. Local governments are sometimes self-insured or participate in a pool of insurance with other governments. Building owners should be encouraged to periodically explore insurance alternatives, including the impact seismic retrofits will have in reducing future losses and premiums. Some insurance companies offer incentives to owners to evaluate buildings and reduce their risks.

Preservation of Historical Buildings

Retrofitting historical buildings while preserving their character-defining features improves the likelihood that they can be repaired after damaging earthquakes. The California Historical Building Code provides acceptable alternatives to the codes and standards that are intended for non-historic buildings. These include an objective to prevent partial or total structural collapse such that the overall risk of life-threatening injury as a result of structural collapse is low. It is intended to promote sustainability, provide cost-effective approaches to preservation, and to provide for reasonable safety. Records of appeals to the State Historical Building Safety Board can provide examples of how difficult retrofit decisions were resolved in the past (CBSC 2016).

Historical buildings that are damaged in earthquakes cannot by law be construed as imminent threats requiring rapid demolition if the risks posed by the damage or the archaic building system can be addressed by shoring, stabilization, barricades, or temporary fences (CBSC 2016).

Limitations of Retrofits—They Are Not "Earthquake Proof"

Most complete seismic retrofits are designed to significantly reduce the risks to life of the public exposed to collapse risk buildings, but some retrofits are limited in this respect. A partial retrofit may reduce only some of the risks and leave the remainder of the building to perform as poorly as an unretrofitted building. Older retrofits, particularly those for URM buildings, were completed long before performance-based earthquake engineering and likely did not address the potential for loss of building functions. Owners and jurisdictions should consult with structural engineers to gain an understanding about the limitations of retrofit performance and the cost tradeoffs for achieving improved performance. Owners should also take steps to inform building occupants so that they too can make informed risk management decisions about the future use of buildings.

Pre-Earthquake Preparedness

Building owners should develop emergency response plans that incorporate the vulnerabilities identified by seismic evaluations. Such plans should be periodically evaluated using table-top exercises. Annual ShakeOut exercises on the second Thursday of each October to practice "drop, cover and hold on" responses can also be excellent opportunities to familiarize key building personnel and occupants with these plans.

Local governments should also maintain and periodically exercise their emergency response and recovery plans. Effective procedures for responding to severely damaged and collapsed buildings are key to ensuring a safe and rapid recovery. With specific inventories and locations of buildings that are prone to collapse, emergency plans can incorporate realistic estimates of deaths and injuries, disruption, and dollar losses. Planners can help decision-makers compare emergency resources with anticipated demands after earthquakes.

Ensuring that all building occupants are trained to drop, cover and hold on could save many lives, even in buildings that pose collapse risks. It is safer for occupants to stay inside buildings under sturdy furniture than to attempt to leave buildings during shaking. Assigning trained coordinators for each floor to help occupants respond effectively can help create a culture that values safety, reduces casualties, and speeds recovery.

Post-Earthquake Recovery

Post-earthquake Safety Assessment Program

The State of California has trained over 6000 building inspectors and volunteers to conduct safety assessments following disasters and assign red (unsafe), yellow (restricted use), or green (inspected) placards on damaged buildings. After damaging earthquakes in major metropolitan areas, safety assessments can take weeks to months and can be expedited by owners who have arranged for Building Occupancy Resumption Plan agreements with their jurisdiction. Buildings with red placards are not necessarily repairable, but neither are they necessarily required to be demolished. Green-tagged buildings may be later found not to be repairable. Such decisions must rely on more detailed seismic evaluations and repair considerations that are the primary responsibility of owners and their design professionals. Neighboring buildings that are placarded red or yellow may adversely impact the use of green or undamaged buildings in the vicinity. For that reason, owners should be concerned about the seismic vulnerability of not only their own buildings, but also others in their neighborhood.

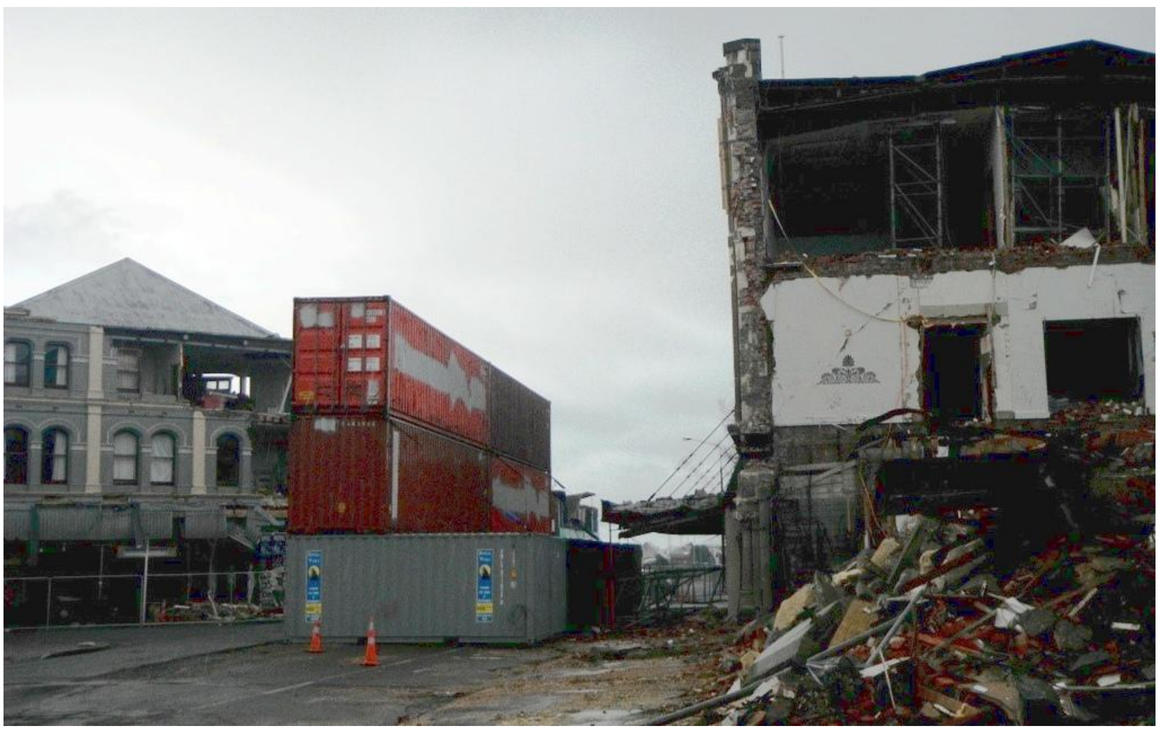
Building Occupancy Resumption Program

Owners should consider creating a Building Occupancy Resumption Plan (BORP 2016) in cooperation with their city (or county in unincorporated areas) to accelerate post-earthquake seismic evaluations, and repairs after future damaging earthquakes. These plans encourage owners to hire structural engineers to conduct seismic evaluations between earthquakes. Such plans help owners maintain relationships with their consultants, who have first-hand knowledge of each building's characteristics and seismic vulnerability, so that they can be engaged without delay to conduct safety assessments, evaluate damages, and generate repair plans after future earthquakes.

Evaluation, Stabilization, and Repair of Damaged Buildings

Despite all efforts, some of California's buildings, even retrofitted ones, may not survive future damaging earthquakes. Labeling retrofitted buildings "resilient" can be an exaggeration. In many cases, prior retrofits may be capable of resisting only one moderate earthquake with a short duration of severe shaking. Afterward, they may pose greater risks in aftershocks unless they are stabilized and extensively repaired. Hundreds of local governments in California have significant concentrations of collapse risk buildings that could place extraordinary demands on government staff and owners during emergency response and recovery. The California Building Officials group has developed *Interim Guidance for Barricading, Cordoning, Emergency Evaluations and Stabilization of Buildings with Substantial Damage in Disasters* (CALBO 2013).

After major damaging earthquakes, local governments should anticipate dramatic impacts on the built environment, including collapses and potentially hundreds of buildings requiring major stabilization, repairs, demolition, and replacement.



Hard barriers such as containerized cargo units can be quickly installed to keep damaged buildings from falling onto streets in aftershocks.

When major metropolitan regions are damaged by earthquakes and aftershock sequences, the Office of Emergency Services expects local governments to request mutual aid from undamaged jurisdictions elsewhere in the county. The agency also manages a building safety assessment program that relies on private-sector volunteers as well as mutual aid from other government agencies to evaluate and placard damaged buildings and ensure that occupants do not enter unsafe areas. It also calls for the creation of specialized strike teams to address the special needs associated with essential services facilities, hazardous materials, tall and mid-rise buildings, housing, low-rise buildings, schools, and infrastructure as well as geotechnical/geological strike teams for landslides, liquefaction, lateral spreading, and foundation settlement. In particular, the demands of assessing, barricading, and stabilizing damaged buildings, particularly tall and mid-rise buildings, will far exceed the capabilities of local government staffs.

Government agencies are encouraged to periodically conduct table-top exercises to understand and anticipate responses to damage that will be unique to their communities. Such exercises offer ways that agencies such as fire, police, public works, and social services can become familiar with their response roles as they relate to vulnerable building inventories, locations and occupancies. Advanced preparations, dialogue, and relationships improved through these exercises will pay off in the event of actual disasters.

Managing Aftershock Risks

Most earthquake sequences include many episodes of damaging ground motion. Some vulnerable building types may perform adequately during one earthquake, but accumulated damage after multiple earthquakes can reduce their strength, expose occupants to additional hazards, and cause delays before decisions about repair or demolition can be made. Aftershocks can be stronger or more damaging than foreshocks. Many owners may mistakenly believe that if their building survived the last earthquake in their region, they can expect it to survive intact in future earthquakes. But no two earthquakes or aftershocks are alike, so past performance is not necessarily an indication of future performance. Comprehensive seismic evaluations that consider the potential for losses from aftershocks can be informative risk management tools. Owners should also be prepared to stabilize their damaged buildings and protect occupants and surroundings from the potential for additional falling risks in aftershocks.

Severely damaged, tall buildings can force the closure of entire city blocks until they are stabilized or demolished. This building took 5 months to demolish.

Earthquakes with an extended aftershock sequence can greatly discourage interest in reinvesting in damaged communities and other economic activities, such as tourism, until aftershocks subside. In some cases aftershock sequences can last for many years. Aftershocks can also adversely affect the public's perception about the effectiveness of regulatory efforts to ensure safety. Operational Earthquake Forecasts will likely be issued after significant, damaging earthquakes to describe increases in hazards in regions experiencing aftershocks. Jurisdictions should become familiar with managing these potential long-term impacts.

Identifying Recovery Priorities and Avoiding Long-Term Catastrophic Effects

If owners have basic information about the vulnerability of their buildings and infrastructure, they can begin to visualize recovery priorities and take steps to minimize the prospect of long-term catastrophes. Jurisdictions can do the same for their key neighborhoods. Their options include (1) retrofits between earthquakes to reduce risks, (2) replacements with earthquake-resistant construction between earthquakes, and (3) repairs after future earthquakes. They should consider the owners' abilities to pay and survive disruptions associated with each option as well as a community's overall expectation of supporting recovery and risk reduction efforts.

Building Department Personnel Qualifications and Training

Building department staffs are typically qualified and experienced in the regulation of new construction, remodels and, with varying skills, seismic alterations to existing buildings. However, seismic evaluations and retrofits include specialties and rely on materials and systems that are unfamiliar to many building department staff members. It is in the best interests of local governments to support education and training programs for building department staff to ensure effective monitoring and regulation of seismic evaluations and retrofits. Training is essential for familiarity with the provisions of Chapter 34A and Parts 8 and 10 of the 2016 California Existing Building Code, and the inspection and testing protocols that can apply to existing buildings.

A shortcoming of some past seismic retrofits has been inadequate and uninformed design and construction, resulting in disappointing performance in past earthquakes. Rigorous plan reviews of retrofit designs and thorough inspections during construction by regulatory authorities help minimize poor quality and improve performance. Consider the example of water heaters. Water heater braces and gas piping are in every building, but they can easily be installed incorrectly. Seeing to it that building inspectors are capable of identifying properly installed gas piping and water heater bracing to prevent toppling will reduce fire and water damage in future earthquakes.

Adopting a Long-term Perspective

Local governments should plan for and budget periodic efforts to report their progress in seismic evaluations, retrofits, and replacements to policymakers. Local multi-hazard mitigation plan updates, which are provided to OES every five years, should ideally include such progress summaries. OES should consider supporting consistent reporting protocols so that it can more readily compile and interpret statewide progress. The familiar reporting protocols for URM buildings can be readily adapted to other types of buildings, using the “mitigation rate” statistic described in the “Management by Metrics” subsection below. In turn, the state can update its Multi-hazard Mitigation Plan every five years to report on and compare regional, incremental progress.

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.

Experience has shown that progress should be measured in decades, not years, to effectively track seismic retrofit and replacement initiatives involving private and public buildings.

- It took California 44 years, from 1933 to 1977, to complete the first cycle of seismic retrofits and replacements of public schools, for grades K to 14. Now some school districts are embarking on a second generation of retrofits of early Field Act buildings and prior retrofits.
- The Hospital Seismic Retrofit Program started in 1995, after a decade of surveys and seismic evaluations, and is expecting completion 35 years later in 2030.
- In the 20 years from 1986 to 2006, 55 percent of the URM buildings inventoried by 283 local governments were retrofitted, and 15 percent were demolished.
- Retrofit programs have been underway since the 1970s at the University of California and at the California State University campuses since the 1990s.

By no means will these programs be able to declare 100 percent completion—managing seismic risks tends to be an ongoing, iterative endeavor. The public school experience shows that many earlier retrofits should periodically be reevaluated and, if warranted, retrofitted again or replaced.

Building owners and local governments should adopt similar long-term perspectives to manage their collapse risk buildings. While the risk that earthquakes will occur before all retrofits can be completed is significant, that risk should be balanced with the limitations of financing major investments, to spread out the costs over time and avoid placing too great a short-term burden on the limited resources of owners and the design and construction industry.

Reevaluating Progress Periodically, Especially after Future Earthquakes

By investing in mitigation progress monitoring, policymakers can periodically revisit and reevaluate each community's pace and overall adequacy as well as gaps and other shortcomings of their initiatives. They can also make comparisons with progress in nearby jurisdictions and statewide. In this vein, monitoring and reporting conveys to the public that jurisdictions recognize the importance and value of seismic risk management.

The public will typically expect authorities to reconsider progress and critique the actual performance of retrofitted buildings after future damaging earthquakes. This expectation may also arise after a large earthquake elsewhere in California or the rest of the world. Local government staffs should anticipate this and be prepared to reevaluate policies without delay. If governments invest in maintaining inventories and progress records, they can readily summarize the size and nature of the concerns associated with particular types of collapse risk buildings, what has been done about them so far, how much they cost, what remains to be done at the current pace of progress, and how long the current phase of retrofitting and replacing will take.

The best time to identify collapse risk buildings and determine which buildings were retrofitted is between earthquakes. The work local governments do between earthquakes will leave them prepared to provide timely and accurate information about aspects that are fundamental to the safety of buildings after future earthquakes.

Many local governments in California have experienced changes in priorities. Since 1975, the Seismic Safety Commission has maintained records of such deliberations by local governments and the State Legislature. Local governments are encouraged to consult with the Commission if locally maintained records don't extend back to 1975.

Management by Metrics

Because the issues raised by collapse risk buildings typically must be resolved in a long time frame, risk managers and policymakers should consider adopting a system of metrics, periodic monitoring, and benchmark goals to maintain progress in a coherent way. Management by metrics proceeds by periodically addressing several key questions, as follows.

How big is the threat posed by collapse risk buildings? Questions about the size and nature of the threat can be addressed by developing estimates or more detailed inventories of classes of known vulnerable building types, estimates of retrofit and replacement costs, and estimates of losses for earthquake scenarios or probabilistic studies.

What are we currently doing to address the threat, and how many years will current policies take to reduce the threat to acceptable levels? These questions can be addressed by developing a detailed inventory of buildings (Option Two in Step Three) and by monitoring the progress of individual building retrofit and replacement projects over decades, including information about the range of seismic performance objectives for the retrofits. Overall progress can be reported as a mitigation ratio: the sum of retrofitted and replaced buildings divided by the number of inventoried buildings in a jurisdiction's vulnerability class. Mitigation ratios for URM buildings averaged 70 percent in regions of high seismicity when last surveyed in 2006 (CSSC 2006b).

A common risk reduction metric to measure progress:

$$\textbf{Mitigation Ratio (\%)} = \frac{\textbf{(\# Buildings Retrofitted + \# Buildings Demolished)(100\%)}}{\textbf{(\# Collapse Risk Buildings in Inventory)}}$$

Option One in Step Three, which relies on current triggers for voluntary retrofits and replacements, will likely reduce collapse risks at a relatively slow pace, perhaps 0.2 to 2 percent per year. Progress under this option must be measured over a period of several generations, ranging from 50 to 250 years depending upon market conditions and how often buildings are sold and renovated.

With these long-term projections in hand, policymakers and stakeholders can compare the rate of progress with the expected rate of future earthquakes to generate a sense of how many damaging earthquakes might be experienced before the great majority of a class of collapse risk building types is retrofitted or replaced. A jurisdiction that determines that Option One provides an acceptable rate of investment in managing this risk could decide to take no further action, except perhaps to monitor and report on progress periodically. If Option One is determined to leave a community vulnerable to damaging earthquakes and unacceptable losses for too long, the expected mitigation rates can be estimated for more aggressive options. Options Four, Five, and Six, which require seismic evaluations, can generate more specific information about the extent and severity of the collapse risks and prompt more owners to voluntarily take steps to reduce them. Option Seven, with mandatory seismic retrofits, will produce the fastest progress but still require multi-year implementation periods, so progress monitoring remains a useful tool for all options. Mandatory retrofit and replacement programs that allow for varying the rate of compliance in response to local economic and social conditions have been used by local governments over the past several decades. In a few cases, mandatory programs have become stalled due to local political influences or economic conditions. Maintaining the monitoring and reporting on mitigation progress can be a prudent way of fostering momentum if the public and its electorate value risk reduction and meeting resilience goals.

How does our progress compare with neighboring jurisdictions and the statewide average? Every five years, local governments are required to update their progress on multi-hazard mitigation plan initiatives to the state Office of Emergency Services. These updates should routinely include progress on retrofits and replacements of collapse risk buildings. Once enough local governments provide this data, OES should be able to aggregate and analyze these updates for the state's Multi-hazard Mitigation Plan, depicting regional variations and averages.

This type of analysis is already possible for URM building programs, as shown in the table below. As of 2013, notification-only programs for URM buildings generated mitigation rates of 0.65 percent per year, or 13 percent retrofitted or replaced over two decades. Voluntary strengthening programs for URM buildings generated mitigation rates of 1.2 percent per year, or 24 percent retrofitted or replaced over two decades. In contrast, mandatory URM strengthening programs generated mitigation rates of 4.3 percent per year, or 87 percent retrofitted or replaced over four decades. Curiously, local governments that chose not to adopt a URM program have had higher mitigation rates than governments with ineffective programs. In many of these cases, planned redevelopment initiatives and other voluntary efforts were underway when those governments decided not to adopt more proactive measures such as mandatory strengthening (SSC 2006, CA-OES 2013).

URM program type	Annualized mitigation rate	Cumulative mitigation rate after 20 years
No program adopted	1.5%	31%
Notification of owners only	0.6%	13%
Voluntary retrofit		from 39 programs
Without incentives	1.1%	23%
With incentives	1.3%	26%
Other program types	1.3%	26%
Mandatory retrofit	4.3%	87% from 134 programs, some more than 40 years old

The actual annual mitigation rates can also be compared with recommended rates in California's model mandatory retrofit ordinance (SSC 2006b) once owners are sent notices requiring retrofits:

Low-risk buildings	14.3% completion within 7 years
High-risk buildings	33.3% completion within 3 years

The state's experience with URM buildings also demonstrates that such decisions are best left up to local governments rather than dictating uniform acceptable levels of risk statewide. Local governments are best suited to determine the public's tolerance for risk, to account for local economic and social circumstances, and set goals and priorities for managing collapse risk. It also shows that after over 40 years of effort, many unretrofitted URM buildings remain, approximately 4000 out of the 26,000 inventoried.

However, consider with caution the potential for misleading conclusions that this management by metrics approach can generate. For example, achieving an "apples-to-apples" comparison may be difficult when earthquake risks or socio-economic makeups differ greatly between neighboring jurisdictions. Exceeding the performance of neighboring jurisdictions can provide a false sense of accomplishment to a jurisdiction with a situation that calls for even better performance. A more prudent approach might be to compare the current state to an optimal state of progress as defined by policymakers.

Does our jurisdiction have a management team in place with appropriate professional licensure, training, and continuing education to effectively implement policies? The Building Code Effectiveness Grading System as well as surveys of building department staff that have periodically been conducted by the California Building Officials organization (calbo.org) can be used to benchmark salary structures, staffing ratios based on population and permit valuation, and training budgets to ensure that an effective team with adequate resources is managing earthquake risk.

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