ATC 52-3

Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco

Earthquake Safety for Soft-Story Buildings

Applied Technology Council

Prepared for
San Francisco Department of Building Inspection
under the Community Action Plan for Seismic Safety (CAPSS) Project

Community Action Plan for Seismic Safety (CAPSS) Project

The Community Action Plan for Seismic Safety (CAPSS) project of the San Francisco Department of Building Inspection (DBI) was created to provide DBI and other City agencies and policymakers with a plan of action or policy road map to reduce earthquake risks in existing, privately-owned buildings that are regulated by the Department, and also to develop repair and rebuilding guidelines that will expedite recovery after an earthquake. Risk reduction activities will only be implemented and will only succeed if they make sense financially, culturally and politically, and are based on technically sound information. CAPSS engaged community leaders, earth scientists, social scientists, economists, tenants, building owners, and engineers to find out which mitigation approaches make sense in all of these ways and could, therefore, be good public policy.

The CAPSS project was carried out by the Applied Technology Council (ATC), a nonprofit organization founded to develop and promote state-of-the-art, user-friendly engineering resources and applications to mitigate the effects of natural and other hazards on the built environment. Early phases of the CAPSS project, which commenced in 2000, involved planning and conducting an initial earthquake impacts study. The final phase of work, which is described and documented in the report series, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco*, began in April of 2008 and was completed at the end of 2010.

This CAPSS Report, designated by the Applied Technology Council as the ATC-52-3 Report, describes the risk of one vulnerable building type and recommends policies to reduce that risk; a companion *Documentation Appendices* volume (ATC-52-3A Report) details the technical methods and data used to develop the policy recommendations and related analyses. Several other CAPSS reports are also available in the series, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco*:

- *Potential Earthquake Impacts* (ATC-52-1 Report), which focuses on estimating impacts to the City's privately owned buildings in future earthquakes, and the companion *Technical Documentation* volume (ATC-52-1A Report), which contains descriptions of the technical analyses that were conducted to produce the earthquake impacts;
- *A Community Action Plan for Seismic Safety* (ATC-52-2 Report), which recommends policies to reduce earthquake risk in privately owned buildings of all types; and
- *Post-earthquake Repair and Retrofit Requirements* (ATC-52-4 Report), which recommends clarifications as to how owners should repair and strengthen their damaged buildings after an earthquake.

Many public and private organizations are working actively to improve the City's earthquake resilience. The CAPSS project participants cooperated with these organizations and considered these efforts while developing the materials in this report. Three ongoing projects outside of CAPSS but directly related to this effort are:

- *The Safety Element.* The City's Planning Department is currently revising the Safety Element of the General Plan, which lays out broad earthquake risk policies for the City.
- *The SPUR Resilient City Initiative*. San Francisco Planning and Urban Research (SPUR) published recommendations in February 2009 for how San Francisco can reduce impacts from major earthquakes. SPUR is currently developing recommendations on Emergency Response and Post-Earthquake Recovery.
- *Resilient SF.* San Francisco City government is leading a unique, internationally recognized, citywide initiative that encompasses the City's All Hazards Strategic Plan and seeks to use comprehensive advanced planning to accelerate post-disaster recovery. This work is coordinated by San Francisco's General Services Agency (GSA), the Department of Emergency Management (DEM) and Office of the Controller in collaboration with the Harvard Kennedy School of Government.

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Prepared for the

DEPARTMENT OF BUILDING INSPECTION (DBI)
CITY AND COUNTY OF SAN FRANCISCO
under the Community Action Plan for Seismic Safety (CAPSS) Project

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PREFACE

The leaders of the volunteer Public Advisory Committee for the San Francisco Community Action Plan for Seismic Safety (CAPSS) are excited to present this report containing significant recommendations for action. CAPSS was conceived more than 10 years ago by the Department of Building Inspection, with the objective of mitigating the effects of future earthquakes on the people of San Francisco. Nothing will have a greater impact on the City's future than large earthquakes – which we know will occur.

The CAPSS Public Advisory Committee comprises a group of diverse, community-minded volunteers who are dedicated to the collective goal of reducing the risks of future earthquakes. It is made up of many constituents, including renters, building owners, small business owners, planners, contractors, scientists and engineers. What follows is the culmination of their efforts, and represents a package of compromise recommendations for the betterment of the city's seismic safety.

Many building types are susceptible to damage from earthquakes. Mayor Newsom directed CAPSS to first address soft-story residential structures, which are known to be amongst the most vulnerable. To meet the short time frame available to prepare this study and report, the scope was further reduced, and the recommendations are focused on a more narrow category we refer to as "multi-unit soft-story buildings," which is defined as follows:

> **Wood-frame structures, 3 stories or more, with 5 or more residential units, built before May 1973, and having a "soft-story" condition on the ground floor.**

The recommendations are near-revolutionary in their approach, since they were vetted and shaped by citizen policy makers who recognize that all people who occupy buildings expect them to perform to certain minimum levels of performance. Based on that premise, the Public Advisory Committee worked with the CAPSS Project team to craft policy recommendations which focus on performance objectives instead of traditional engineering design standards. The results of this focused study received unanimous support from the highly diverse Public Advisory Committee, and will serve as the foundation for future study and recommendations as CAPSS continues.

The recommendations represent an important first step in addressing the seismic risk we all face. It is essential to emphasize that as the CAPSS project continues over the next two years, it will address other vulnerable building types that present risks to the people of San Francisco.

Significantly, the timing of the release of these recommendations coincides with the release of San Francisco Planning and Urban Research's (SPUR)'s policy white paper, *The Resilient City*. There has been significant cooperation and communication between the CAPSS Public Advisory Committee and SPUR's hazard mitigation task force. Our CAPSS recommendations are independent from SPUR's but were strongly influenced by their vision of city-wide mitigation actions to be taken to assure San Francisco's speedy recovery after a future disaster. Both documents represent the community's desire to effect action which will reduce our vulnerability to future earthquakes.

All of us on the Public Advisory Committee wish the Mayor and the Department of Building Inspection good luck in shepherding the program forward, which, when implemented, will save lives and reduce loss from earthquakes which are certain to strike our City.

We also offer our sincere thanks to all of the volunteer participants in the CAPSS Advisory Committee meetings, other project meetings, and the project workshop. The names and affiliations of these individuals are provided in the list of Project Participants section at the end of this report.

Mary Lou Zoback
Advisory Committee Co-Chair

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REPORT SUMMARY

Many of San Francisco's wood-frame buildings built before May 21, 1973 that contain three or more stories and five or more residential units would be seriously damaged in future earthquakes. A significant number could collapse. The scope of this damage could set back the City's post-earthquake recovery, could irrevocably change the character and affordability of the City, and could cause many casualties. Therefore, the Community Action Plan for Seismic Safety (CAPSS), a project of the Department of Building Inspection, recommends that owners of these buildings be required to seismically retrofit "soft-story" buildings whose capacity to resist earthquake forces is found to be inadequate. The recommendations detailed in this report are based on technical analysis and on discussions held in public meetings. This work has been guided and reviewed by a dedicated Advisory Committee composed of community members. The CAPSS project believes that establishing this earthquake safety policy is a critical step toward making San Francisco a resilient city that will be able to resume normal life quickly after the next major earthquake strikes.

Retrofitting benefits the entire City, its neighborhoods, building owners, and residential and business tenants. However, sharing the costs of retrofits among the beneficiaries—financial costs and inconveniences—raises policy issues of fundamental importance to the City. The ability to pay for retrofitting or endure disruption is not universal. Retrofitting costs would cause great hardship for some tenants and owners, especially those with limited income. The recommendations in this report recognize this issue, provide insight into the costs and the beneficiaries, and outline a flexible program with financial incentives to facilitate retrofit and protect those with hardships. Finding an equitable balance between those who benefit and those who pay will challenge San Francisco's decision makers. Ultimately, the cost of earthquakes is greater than the cost of preparing.

Retrofitting buildings advances San Francisco's commitment to reducing its carbon footprint. The investment of energy and materials to retrofit a building is a fraction of the investment needed to repair or replace damaged buildings. Retrofitting conserves resources.

Key Recommendations

This report recommends that:

- **The Department of Building Inspection should establish a program that requires owners of wood-frame buildings built before May 21, 1973 with three or more stories and five or more residential units to evaluate the seismic safety of their buildings and to retrofit them if they are found to be seismically deficient.** Many of these buildings have "soft-stories" and are highly vulnerable to damage and collapse in earthquakes. Soft-story buildings have a weak ground floor because perimeter walls have large openings for garage doors and windows, they lack interior partitions, and building materials have deteriorated over time.

- **Buildings should be retrofitted to a standard that will allow many of them to be occupied after a large earthquake.** Keeping San Franciscans in their homes averts a post-earthquake shelter crisis, lessens the demands placed upon emergency response services, and allows residents to remain in their neighborhoods and to help to revive them. It is feasible to retrofit this type of building so that many residents can remain in their homes after a large earthquake, even though there would be some damage and utilities might not function.
- **The City should immediately offer incentives to encourage voluntary retrofits.** The program described in this report will take time to launch, but the risk is urgent and should be addressed immediately. To get owners moving on making their buildings safer, the City should offer incentives to owners who retrofit, including expediting plan review, rebating permit fees, offering planning incentives, and seeking voter approval of a City-funded loan program. Buildings voluntarily retrofitted to an acceptable standard should be exempt from requirements created by the recommended program. Incentives need not be limited to the buildings addressed in this report.
- **The Department of Building Inspection should form a working group to develop a detailed plan to implement the recommended program.**

Many other types of buildings in San Francisco pose great threats to the City in earthquakes. In addition to the building types addressed in this report, the City should pursue policies to make other types of buildings at risk of major damage and collapse in future earthquakes safer.

Why Retrofits are Necessary

Retrofitting multi-unit, wood-frame buildings would reduce the consequences of earthquakes to San Francisco. It would retain significant amounts of housing, preserve architectural and cultural attributes, conserve energy and resources, and improve public safety. Retrofitting would shorten the time that the City requires to recover from the next large earthquake. Although other types of buildings are also vulnerable to earthquake damage and also need to be retrofitted, the buildings addressed in this report are particularly vulnerable and can be retrofitted relatively easily.

Many multi-story buildings have a structural weakness due to large openings in their perimeter walls and to a lack of interior partition walls at the ground level. Usually, perimeter wall openings at the ground level make way for garage doors or large windows. Interior spaces used for retail and garages often have few partition walls. The open condition makes the ground level significantly weaker and more flexible than the floors above it. This condition is called a “soft-story.” During strong earthquake shaking, these “soft” ground level walls cannot support the side-to-side or front-to-back movement of the stiff and heavy mass of the stories above them, leading to damage and, in the worst cases, to collapse. Figure A shows examples of representative San Francisco buildings that may have soft-story weaknesses.

There are approximately 4,400 wood-frame buildings built before May 21, 1973 in San Francisco with three or more stories and five or more residential units. All of

Figure A. Images of two multi-unit, wood-frame buildings that may have soft-stories.

these buildings may have a soft story condition[a]. CAPSS studied these buildings to understand better how they are being used, how they would perform in future earthquakes, how building performance could be changed through retrofitting, and what would be involved in retrofitting them.

CAPSS analyzed a subset of these buildings, to gain insight into how best to manage the larger number of potentially vulnerable buildings. CAPSS identified and evaluated roughly 2,800 buildings that have the largest perimeter wall openings and are, therefore, expected to have significant soft-story weaknesses. Findings show that dramatic damage to this subset of buildings is likely, but that vulnerability could be easily remedied:

- As they now stand, 43 to 85 percent of the multi-unit, wood-frame buildings studied by CAPSS would be posted with a red UNSAFE placard (red-tagged) after a magnitude 7.2 earthquake on the San Andreas fault. This represents 1,200 to 2,400 red-tagged buildings. Red-tagged buildings have severe damage and cannot be occupied after an earthquake until they are either repaired or replaced. Their residents would need to find new homes for those months or years that it would take to make repairs. The extensive damage predicted to these buildings suggests that buildings with smaller perimeter wall openings at the ground level would also be susceptible to significant damage.
- A quarter of these red-tagged buildings would be expected to collapse. This represents 300 to 850 multi-unit buildings. Collapses threaten lives. These buildings, most of which contain rent-controlled apartments, would be rebuilt differently, with modern materials and design. Owners might not choose to rebuild them as apartment buildings. If they did, state law dictates that the units would not be covered by rent control. The demographics and architectural character of neighborhoods that experience many collapses could change significantly.
- Nearly eight percent of the City's population, or about 58,000 people, live in this subset of buildings. The buildings house close to 2,000 businesses that employ an

[a] May 21, 1973 is the date when the San Francisco Building Code was amended to prevent design flaws that often resulted in soft-story conditions. Buildings constructed after that date, even those with open perimeter walls, should have adequate strength and stiffness at the ground level to resist earthquakes.

estimated 7,000 people. Without retrofit, the heavy damage that these buildings are likely to sustain would disrupt many neighborhoods for years after an earthquake. Tens of thousands of people would be displaced from their homes and neighborhoods and would not contribute to bringing them back to life. Small businesses along neighborhood shopping streets would suffer severe impacts.

- Seismic retrofits make a big difference and would dramatically reduce the number of collapsed buildings. With retrofit, collapses could be reduced to less than one percent of these buildings.
- Retrofitting all of the buildings in this subset to a recommended level that would allow most of them to be occupied after a large earthquake would cost approximately $260 million[b]. These retrofits would eliminate $1.5 billion in damage after a magnitude 7.2 earthquake on the San Andreas Fault. Even so, many retrofitted buildings would still require costly repairs.
- Seismic retrofits at the recommended level are likely to cost in the range of $60,000 to $130,000 per building for direct construction costs. Retrofit construction would last for two to four months and could be limited to the ground floor level, meaning that residents of upper level apartments could stay in their homes. However, construction could have significant impacts on residents and small businesses located at street level in these buildings. Ground floor tenants might temporarily need to close, relocate or deal with considerable construction inconvenience. Tenants occupying the upper floors would experience noise, dust, vibrations and other inconveniences during construction.
- The subset of buildings studied can be found throughout the City but are most common in the Mission, Western Addition, Richmond, Pacific Heights, North Beach, and Marina neighborhoods.

The Report

The following sections of this report include detailed information about the analysis and recommendations of the CAPSS Project:

- Chapter 1: San Francisco's Multi-Unit, Wood-frame Buildings

  This chapter provides details on the characteristics of these buildings, how many exist, how they are used, and where they are located.

- Chapter 2: The Risk in Doing Nothing

  This chapter outlines the damage that could occur to these buildings in future earthquakes if no action is taken.

- Chapter 3: The Consequences of Retrofitting

  This chapter describes the benefits and costs of retrofitting these buildings.

- Chapter 4: Options to Reduce The Risk

  This chapter reviews the many options available for a policy to reduce the risk to these buildings. It discusses pros and cons of various options.

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[b] The dollar values mentioned were calculated during the Fourth Quarter of 2008.

- Chapter 5: The Recommended Program

  This chapter describes the policy that the CAPSS project recommends to make multi-unit, wood-frame soft-story buildings safer and to improve San Francisco's earthquake resilience.

This report is accompanied by a companion volume, *Earthquake Safety for Soft-Story Buildings, Documentation Appendices* (ATC-52-3A Report), which details the technical methods and data used to develop the analysis and recommendations presented in this report.

This report and its recommendations address only one type of building in San Francisco. Other building types that could be damaged by earthquakes will be covered in subsequent reports of the CAPSS project. Some other building types, such as smaller wood-frame buildings, are more numerous than the subset addressed in this report. Others, such as older concrete buildings, are more subject to catastrophic failure. The CAPSS project focused first on multi-unit, wood-frame buildings not only because they are known to be highly vulnerable to earthquake shaking, but also because they are easy to identify and to retrofit. It makes sense for San Francisco to begin addressing these buildings now.

The 1989 Loma Prieta earthquake, centered about 60 miles to the south of San Francisco, caused dramatic damage and seven collapses to multi-unit, wood-frame buildings in the Marina district, including the damage shown in Figure B.

Figure B. Damage to a multi-unit, wood-frame soft-story building on Beach Street in the Marina District due to the 1989 Loma Prieta earthquake. Image by Raymond B. Seed, Courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley.

An earthquake centered closer to the City would cause far greater damage. It is time to take action to protect San Francisco's unique character, to improve its ability to respond to and recover from earthquakes, and to improve public safety by retrofitting buildings throughout the City that are similar to those that failed in the Marina District.

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CHAPTER 1: SAN FRANCISCO'S MULTI-UNIT, WOOD-FRAME BUILDINGS

During the 1989 Loma Prieta earthquake, a number of multi-unit, wood-frame soft-story buildings in the Marina district either collapsed or were heavily damaged (Figure 1). Thousands of similar buildings exist in neighborhoods throughout the City. The epicenter of the Loma Prieta earthquake was about 60 miles south of San Francisco. Larger or closer earthquakes, which are considered likely by seismologists, could cause much stronger shaking in many parts of the City than was felt in the Marina District. This means that thousands of buildings that house many city residents and small, local businesses are at risk.

Figure 1. Two multi-unit, wood-frame soft-story buildings that collapsed in the Marina District during the 1989 Loma Prieta earthquake. For both buildings, the second story is at street level due to the complete collapse of the first story. Image courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley.

Multi-unit, wood-frame soft-story buildings are not the only building type that would be heavily damaged in future earthquakes, but they are clearly vulnerable. This type of building houses many San Francisco residents. Many of these buildings are old and architecturally interesting; 65 percent were built before World War II. Ninety percent are occupied by renters, who have little ability to find out about or to remedy their building's seismic deficiencies. Compared to other structure types, these buildings are easy and cost-effective to make safer. For all of these reasons, it makes sense for San Francisco to address the seismic safety of these buildings now.

Soft-Story Buildings

A common building weakness is called "soft-story." The term "soft-story" describes one level of a building that is significantly more flexible than the stories above it and the floors or the foundation below it. In San Francisco's multi-unit, wood-frame buildings, weakness at the ground level stems from a lack of strong walls, both because of large openings in perimeter walls and because of few existing interior partition walls. Usually perimeter openings are for garage doors or large windows. In addition, ground floor uses such as parking or commercial space, require fewer partitions than the residential uses in the floors above. During strong earthquake shaking, the ground level walls cannot support the stiff and heavy mass of the stories above them as they move back and forth. The ground level walls can shift sideways until the building collapses, crushing the ground floor.

Figure 2 shows representative examples of what multi-unit, wood-frame buildings that probably have soft-stories look like in San Francisco. These buildings have either garage doors or large windows for commercial establishments at the ground floor. It is not possible to know for certain that a building is a soft-story building simply by looking at it from the street. Large openings at the ground level are a strong indicator that a building might have a soft-story, but many characteristics affect a building's response to earthquake shaking, and only a building-specific analysis conducted by an engineer can determine if a particular building is a soft-story building.

Figure 2 Sketches of four typical examples of multi-unit, wood-frame buildings that are likely soft-stories.

Number and Locations of These Buildings

San Francisco has many thousands of wood-frame buildings with an open ground floor and residential space on higher floors. This configuration is characteristic of the construction of buildings ranging from single-family homes over a garage to large, multi-unit structures. This report focuses on wood-frame buildings with three or more stories. In previous earthquakes, buildings with three or more stories have been observed to sustain greater damage than buildings with one and two stories. Local experts believe that they pose a higher risk than similar buildings with two stories. The buildings of most concern are those built before May 21, 1973. After that date, the San Francisco Building Code was changed to prevent soft-story weaknesses in wood-frame buildings.

In 2007-2008, the San Francisco Department of Building Inspection conducted a sidewalk survey of wood-frame buildings with three or more stories and five or more residential units[1]. This survey focused on buildings with five or more units, because the five-unit cutoff has been used by other City programs, such as the unreinforced masonry retrofit program and various code triggers, and because these buildings house more occupants than do buildings with fewer units[2]. This survey provides information about important characteristics that contribute to vulnerability, such as the amount of openness in ground floor exterior walls and whether buildings are located on a corner or mid-block. The Department survey identified approximately 4,400 wood-frame buildings with three or more stories and five or more residential units built in San Francisco prior to the building code change in 1973.

The CAPSS project decided to analyze a subset of these buildings, those with the largest ground floor openings, which are believed to be most vulnerable to damage. For the purposes of this project, significant ground floor openings were defined as openings (garage doors, windows, entry ways, or other openings) that span 80 percent or more of one side of a building, or 50 percent or more of two sides of a building. The Department's survey found approximately 2,800 buildings that have this level of openness. Building with less open areas can also be vulnerable.

Figure 3 illustrates how the Department survey estimated the percentage of openness of each building side. The openness criteria used to select buildings for the CAPSS analysis are not an indicator of whether a building is "safe" or "unsafe;" rather, the criteria reflect a decision to capture those buildings with the largest openings that are likely to have higher overall vulnerability. Many buildings with fewer openings in their perimeter walls were excluded from the CAPSS analysis but could also have soft-stories and could be vulnerable to significant damage and collapse.

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[1] This survey was conducted by building inspectors, and members of two professional organizations: the Earthquake Engineering Research Institute and the Structural Engineers Association of Northern California. Results from the survey include important data that were used to make analysis assumptions for this report. The survey results are not a list of vulnerable buildings, and include no information about some important factors that contribute to whether a building is a soft-story, such as interior partitions, strength of walls and whether a building has already been retrofitted.

[2] There are an estimated 2,600 four-unit buildings and 3,400 three-unit buildings in San Francisco with three or more stories. Many of these buildings have similar risk to buildings with five or more units. It is reasonable to assume that larger buildings are often more vulnerable and, on average, buildings with five or more units are larger than those with three or four units. The CAPSS project does not have detailed data about three and four unit buildings, so they are not included in the analysis presented in this report.

Figure 3. An example building image with lines indicating what is considered open and what is not in the Department of Building Inspection survey.

It is interesting to note that most of San Francisco's multi-unit, wood-frame buildings have large openings on at least one side. Figure 4 shows the number of buildings with varying degrees of openness on their most open side.

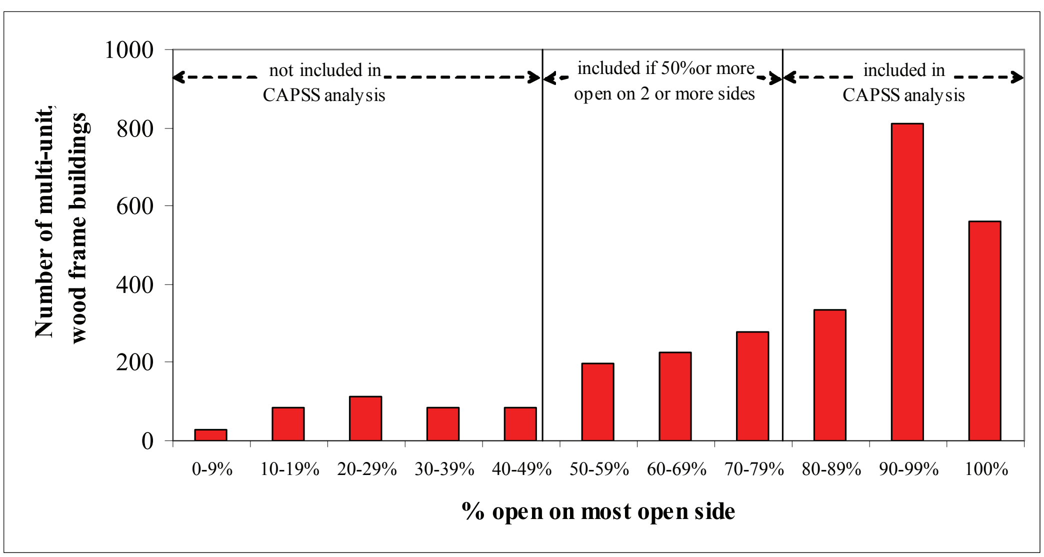

Figure 4. Range of openness of most open side of all wood-frame buildings with three or more stories and five or more residential units.

The buildings studied by CAPSS are dispersed across a number of city neighborhoods. Figure 5 shows the locations of all wood-frame buildings with three or more stories and five or more units. The subset analyzed by CAPSS, those buildings with the largest ground floor openings, are concentrated in the same neighborhoods as the larger set of buildings.

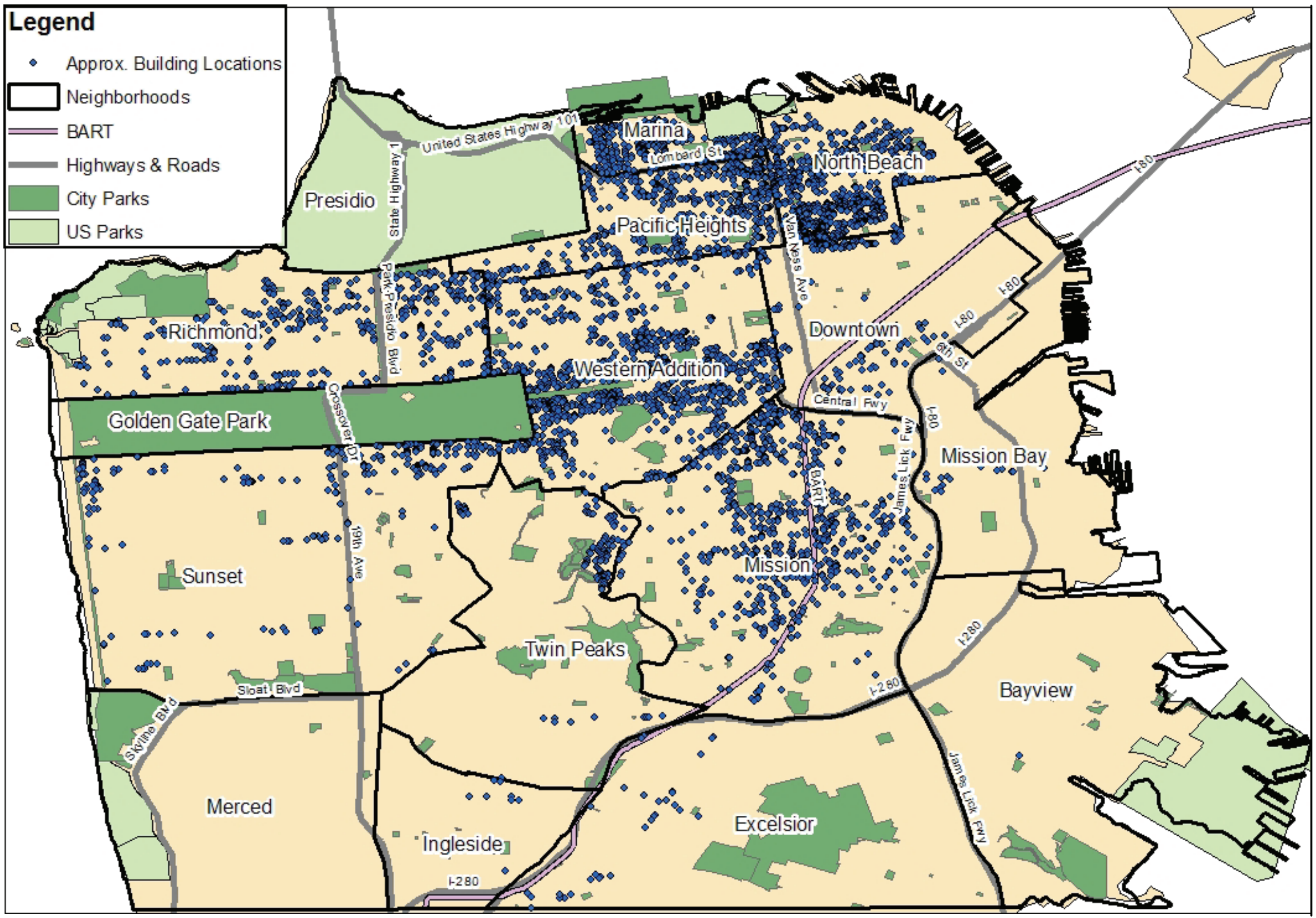

Figure 5. Locations of wood-frame buildings with three or more stories and five or more residential units.

Characteristics that Contribute to Vulnerability

A number of characteristics contribute to the vulnerability of multi-unit, wood-frame buildings. Those include the following:

- **Size of openings in ground floor perimeter walls.** Buildings with large openings at the ground level generally are more likely to be vulnerable to earthquake damage than those without large openings. Large windows or garage doors often mean that the interior also lacks partitions.
- **Length, strength, stiffness and location of interior walls and partitions.** Buildings with open ground floor areas (for parking or commercial uses) that lack structurally strong walls and partitions are more likely to be vulnerable to earthquake damage than those that have numerous walls and partitions.

- **Position within a block.** Corner buildings are generally more vulnerable than mid-block buildings. Mid-block buildings with a gap between themselves and neighboring buildings are more vulnerable than those that have buildings directly abutting them on each side. This is discussed further below.
- **Number of stories.** Taller buildings and those with more stories are heavier and, generally, more vulnerable, because the ground story walls have to support more mass. In the buildings studied by CAPSS, roughly 40 percent have three stories, 58 percent have four stories, and two percent have five or more stories.
- **Condition of wood.** Buildings with significant wood rot or pest damage have less capacity to resist earthquake forces than buildings without these problems.
- **Local soil conditions.** Buildings situated on soft soils or on artificial fill are generally damaged more than those that are located on firm soils or on rock. Soil conditions affect building performance in two ways. First, soft soils amplify ground shaking intensity, so that the amount of damage is increased. As example, during the Loma Prieta earthquake, the Marina district experienced shaking ten times stronger than neighboring Pacific Heights, due to differing soil characteristics[3]. Second, certain saturated soils can fail due to a phenomenon called "liquefaction" during earthquakes; liquefaction causes soil to spread and/or settle differentially, leading buildings to tip on their foundations. Figure 6 shows the California Geological Survey Seismic Hazard Zones map of San Francisco, indicating areas that may be susceptible to liquefaction or landslides. Other maps are available that show different soil characteristics.
- The most dramatic earthquake damage to soft-story buildings that was observed in the 1989 Loma Prieta earthquake occurred in buildings that were located at the corner of a block. Six out of the seven buildings that collapsed in the Marina were corner buildings of the type discussed in this report[4]. Corner buildings in San Francisco are typically more vulnerable to earthquake damage for a variety of reasons than are buildings in the middle of a block. Corner buildings tend to have larger ground floor openings than do buildings in the middle of a block. For example, many corner buildings have garage doors on both sides that face a street. Corner buildings with street level commercial spaces in them often have large windows that extend for much of the street frontage on both sides. These larger openings make corner buildings vulnerable to damage in earthquakes.
- In San Francisco, many midblock buildings abut their neighboring buildings with only a few inches or less between them. During an earthquake, neighboring buildings can crash into each other, in a phenomenon known as pounding, which can cause some damage. However, many experts believe that neighboring buildings also help to hold each other up by limiting side-to-side shaking. Midblock buildings without directly adjacent neighbors and corner buildings face a higher risk of damage, because they don't have the benefit of support from their next-door building.

[3] Boatwright et al., 1992.

[4] Harris and Egan, 1992.

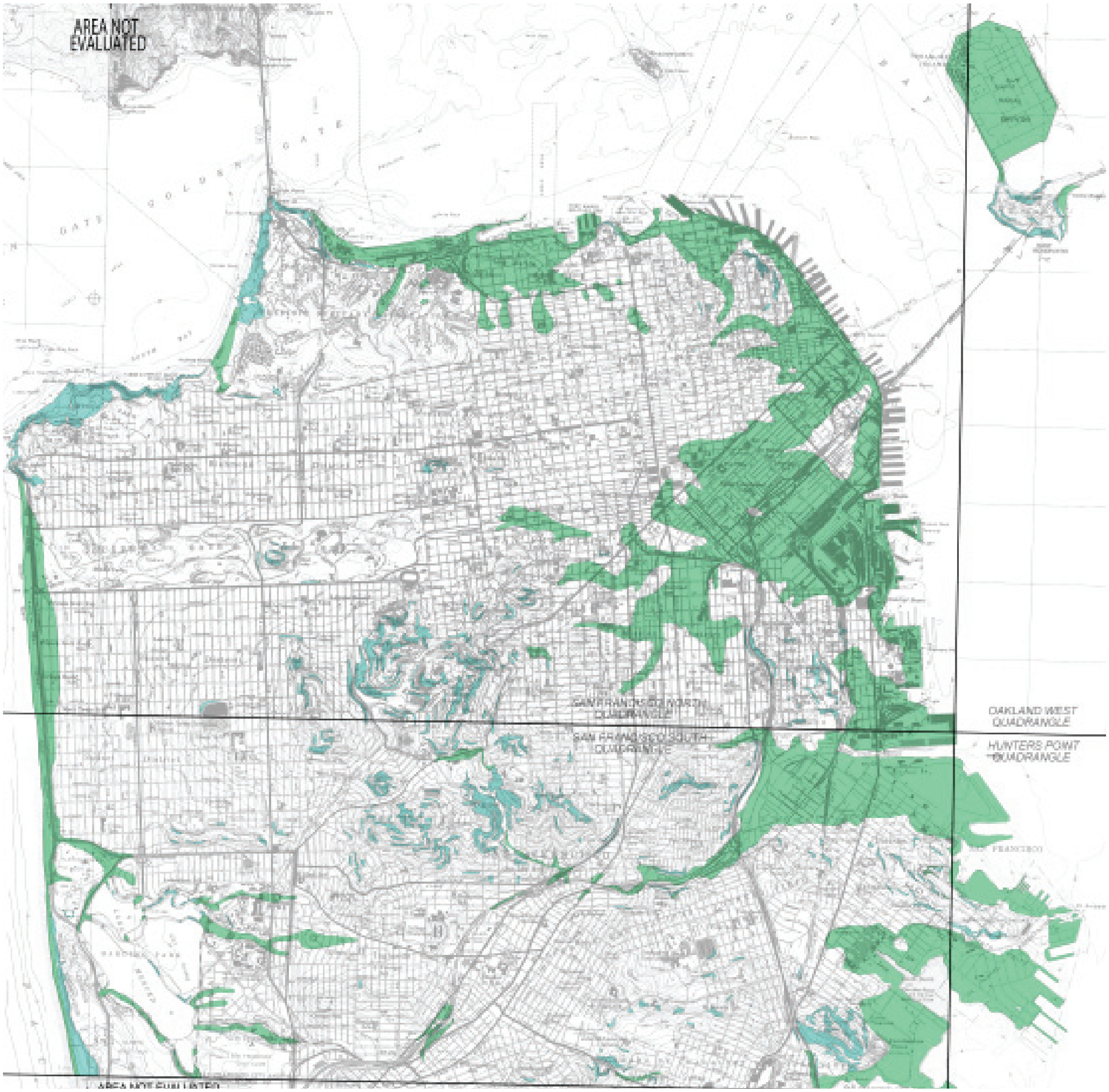

Figure 6. California Geological Survey Hazard Zones Map of San Francisco.

Uses and Occupants of These Buildings

Residents

Wood-frame buildings with three or more stories and five or more residential units contain a significant share of the City's residential units. These buildings house approximately 45,000 units or thirteen percent of the City's housing stock. An estimated 89,000 residents, or eleven percent of the City's total population, live in these buildings.

A considerable percentage of San Francisco residents live in the 2,800 buildings analyzed by CAPSS. These buildings contain 29,000 residential units and an estimated 58,000 residents, or eight percent of San Francisco's total population. The Western Addition, Mission, Pacific Heights, Marina, and Richmond neighborhoods have the highest concentration of residential units in these buildings. As shown in Figure 7, these five neighborhoods contain more than 70 percent of the people living in multi-unit, wood-frame buildings with significant ground floor openings.

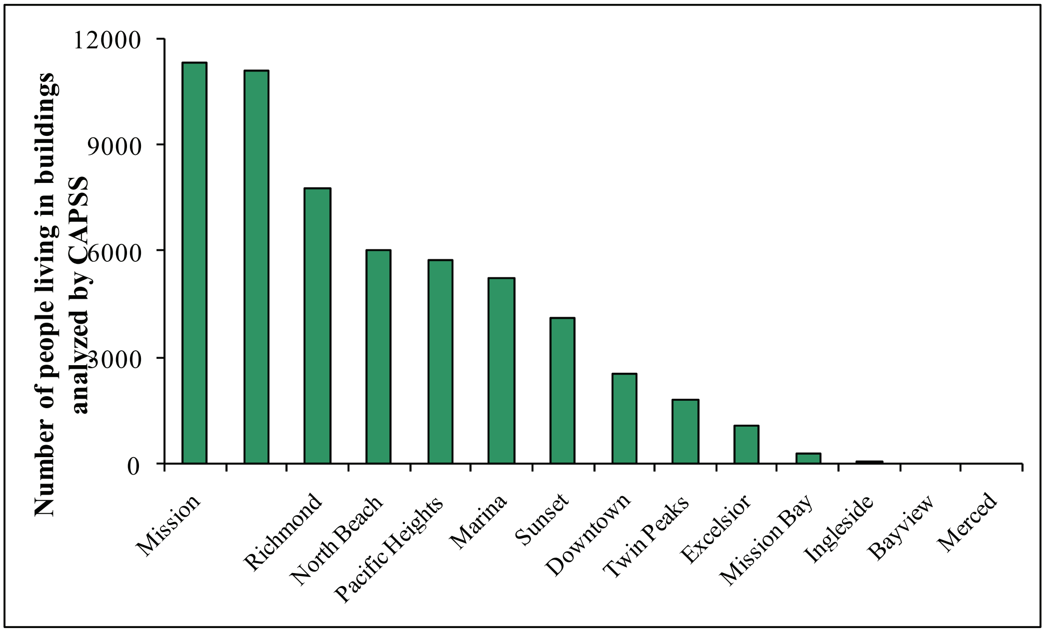

Figure 7. Estimated number of people living in the 2,800 buildings analyzed by CAPSS, by neighborhood.

Analyzing the demographic and economic characteristics of areas with the highest concentration of units in these buildings provides the following insights about households in those neighborhoods:

- **They generally have higher median incomes than the City as a whole.** Conversely, households in areas without these buildings have lower median incomes. High concentration areas have a median household income of $74,700, compared to $61,800 in areas without these buildings and $68,300 among households citywide. The geographic distribution of these buildings throughout the City explains, in part, these trends. As noted above, more affluent neighborhoods such as Pacific Heights, the Marina, and North Beach contain a major portion of San Francisco's multi-unit, wood-frame buildings, while lower-income neighborhoods such as Bayview and Ingleside contain relatively few.
- **Residents are slightly younger than the City as a whole.** Residents in high concentration areas have a median age of 39.2 years, compared to 40.2 years among residents citywide and 40.6 years among residents in low concentration areas.
- **They have lower homeownership rates than the City as a whole.** Only 19 percent of households in high concentration areas are homeowners, compared to

44 percent among households in areas without these buildings. Citywide, 35 percent of households own their home.

- **They have a higher proportion of White residents and lower proportions of African American, Asian American, and Hispanic residents than the City as a whole.** Approximately 66 percent of residents in high concentration areas are White, compared to just 32 percent in areas without these buildings and 44 percent in San Francisco as a whole. Again, this finding is largely due to the underlying demographic profile of the neighborhoods that contain a large share of these buildings.

Most of the people who live in multi-unit, wood-frame buildings are renters. Assessor's data indicate that 90 percent of these buildings are used as rental apartments, with the remaining buildings classified as condominiums or other uses. In addition, all apartment buildings built before June 1979 are subject to San Francisco's Rent Stabilization Ordinance, commonly known as rent control. All multi-unit wood-frame apartment buildings of concern are covered by rent control, because the Building Code change adopted in 1973 should prevent newer buildings from having a soft-story condition. However, due to San Francisco's high rate of apartment turnover, many of these rent-controlled units are likely to be at or near market rate rent levels[5].

Businesses

Close to 2,100 businesses operate in approximately 900 of the multi-unit, wood-frame buildings analyzed by CAPSS. This means that roughly one third of the 2,800 buildings studied contain commercial tenants. Businesses and workers located in these buildings represent a small percentage of all businesses and workers in San Francisco. Of the 73,000 businesses in San Francisco, less than three percent operate in these buildings. These businesses employ 6,900 people, accounting for one percent of jobs in the City.

The Western Addition, Mission, North Beach, and Pacific Heights contain the largest portion of businesses operating in this type of building.

Businesses housed in these buildings are concentrated in the retail, services, and food service industries. This reflects the fact that small retail shops and restaurants, along with professional and personal service establishments, often locate in mixed-use buildings along commercial corridors in San Francisco.

An extremely high percentage of the businesses located in the 2,800 buildings studied by CAPSS are small businesses. As shown in Figure 8, 84 percent of businesses in these buildings employ fewer than five people, compared to 76 percent of all San Francisco businesses. An additional 11 percent of them have between five and ten employees. The small size of businesses in these buildings suggests that many are independent, locally owned enterprises.

[5] See Chapter 3 and the Documentation Appendices for more details on this topic.

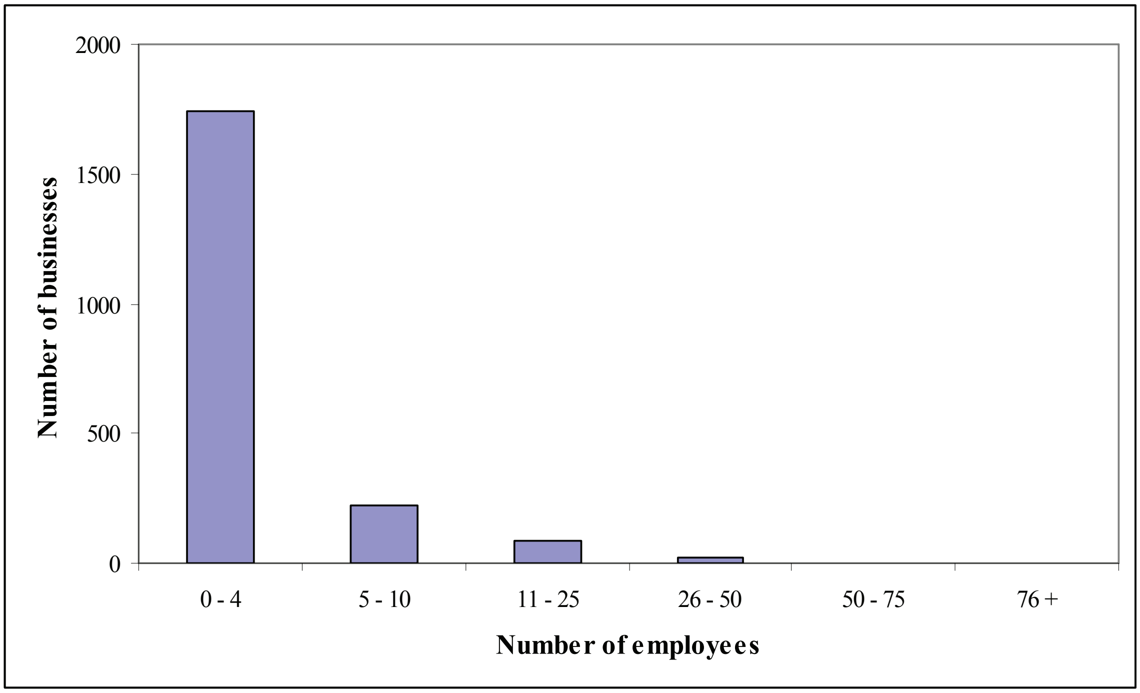

Figure 8. Size of businesses in the 2,800 buildings analyzed by CAPSS.

Architectural Character

The multi-unit, wood-frame buildings addressed in this report are common in many San Francisco neighborhoods. They shape the character and fabric of San Francisco's residential and commercial streets. If San Francisco lost many of these buildings in future earthquakes, the character of the City would change dramatically.

Many of these buildings are old, as shown in Figure 9. Sixty-five percent were built before World War II. Some of them survived the 1906 earthquake, although this does not mean that they are "safe". They may have been elevated since then, to add garages at their ground level, thereby changing their structural integrity. Many may suffer from

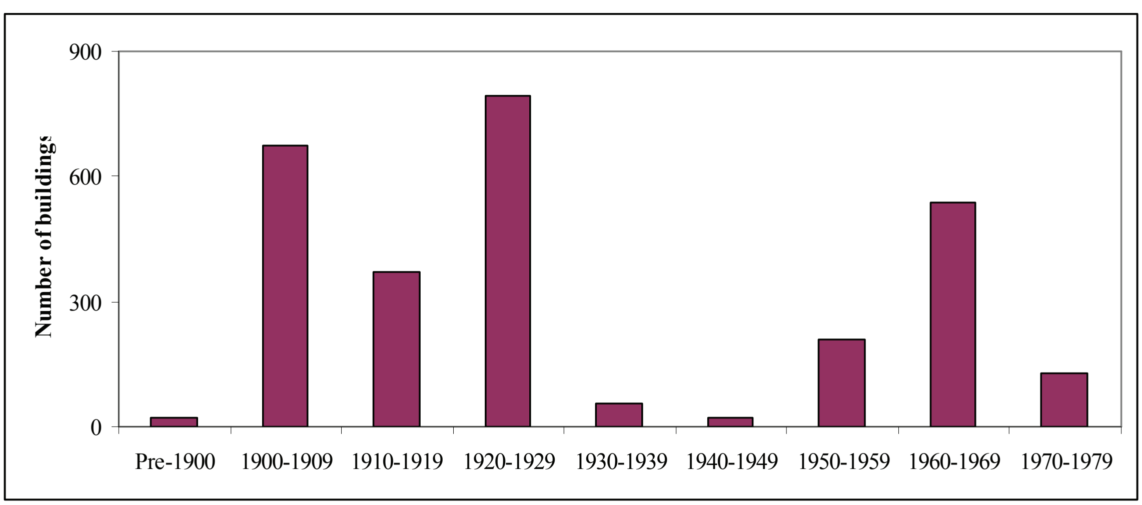

Figure 9. Decade of construction of multi-unit, wood-frame buildings studied by CAPSS.

wood deterioration that weakens their ground floor. Older buildings are not inevitably weaker; some older buildings were built with excellent quality materials. Older buildings are also not necessarily more architecturally important than newer buildings, but they are different. The materials, appearance, scale, and relationship to the streetscape of older buildings differ from those of buildings built today.

A few dozen of these buildings are officially designated (locally or on the state or national registers) as historic. These buildings cluster primarily in the Mission, Western Addition and Richmond neighborhoods. The San Francisco Planning Department is currently working to survey the historic importance of more buildings and neighborhoods, and it is likely that this number will increase. Whether or not they are officially designated as historic, these older buildings set the style and feel of many areas in San Francisco. Many include architectural articulation typical of their time of construction, such as that shown in Figure 10.

Figure 10. Close up of architectural detail on a multi-unit wood-frame building.

Multi-unit wood-frame soft-story buildings are an important part of San Francisco's neighborhoods. Those with the largest ground floor openings house nearly 60,000 people, eight percent of the City's population, most of them in rent-controlled units. They comprise a meaningful portion of the City's rental housing stock. They are often older buildings that hold an important place in the neighborhood residential and commercial streetscape. If the City lost many of these buildings to future earthquakes, it would cause dramatic social, economic and physical changes. As the next chapter makes clear, this level of damage is likely if the City takes no action to improve these buildings.

CHAPTER 2: THE RISK IN DOING NOTHING

Large earthquakes would seriously damage many of San Francisco's 4,400 multi-unit, wood-frame buildings, and a significant number could collapse. The actual number of severely damaged multi-unit, wood-frame buildings would depend on the earthquake that strikes and on other factors, but damage to buildings with soft stories would cause casualties and economic losses. The ripple effects could hinder the City's post-earthquake recovery process and could irrevocably change both the character and the affordability of the City.

Future Earthquakes

No one knows when the next large earthquake will strike San Francisco, but it is certain that a big one will come. The last significant earthquake to shake the City was Loma Prieta, which occurred on October 17, 1989. This magnitude 6.9[6] earthquake was centered about 60 miles south of San Francisco, near Santa Cruz. Despite being relatively distant from the City, this quake caused enough shaking in San Francisco to kill seven people, cause seven buildings to collapse in the Marina district, damage many more buildings, spark dozens of fires, and significantly damage the elevated Embarcadero freeway.

San Francisco is flanked by active earthquake faults. The San Andreas fault lies just off the City's western shore, and the Hayward fault cuts through the East Bay at the base of the foothills. Both of these faults are equidistant, about 10 miles, from the foot of Market Street in downtown San Francisco.

It is reasonable to expect an earthquake that is closer and, perhaps, larger than Loma Prieta to strike San Francisco soon. A recently released statewide assessment of the likelihood of earthquakes estimates that there is a 63 percent chance of at least one magnitude 6.7 or greater earthquake in the Bay Area some time in the next three decades. The Hayward-Rodgers Creek and San Andreas fault systems have the highest probabilities of generating large earthquakes in that time period[7].

The CAPSS project studied the impacts of four large and likely earthquakes in order to better understand the risks that earthquakes pose to San Francisco's multi-unit, wood-frame soft-story buildings. All of these potential earthquakes would produce shaking over large areas of the City that is two to four times stronger than the shaking that occurred in the Marina District during Loma Prieta. In other words, these

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[6] All earthquake magnitudes in this report are moment magnitudes. Moment magnitude represents the total amount of energy released in an earthquake and is the preferred scale used by earth scientists. This is similar to Richter magnitude, which is related to the peak horizontal acceleration caused by an earthquake.

[7] 2007 Working Group on Earthquake Probabilities, 2008.

potential earthquakes are significantly stronger than any earthquake that the City has experienced in over 100 years. These earthquakes are:

- **A magnitude 6.9 earthquake on the Hayward fault**. This event would rupture the entire length of the Hayward fault.
- **A magnitude 6.5 earthquake on the Peninsula segment of the San Andreas fault**, located on the portion of the San Andreas fault offshore San Francisco.
- **A magnitude 7.2 earthquake on the Peninsula segment of the San Andreas fault**. This earthquake is located on the San Andreas fault, extending north of the 1989 Loma Prieta rupture zone to Marin County.
- **A magnitude 7.9 event on the San Andreas fault**, which would be a repeat of the 1906 earthquake. This is the largest known earthquake to have occurred in northern California on the San Andreas fault.

Figure 11 shows the rupture zone of each of these scenario earthquakes. Larger magnitude earthquakes rupture a greater length along the faults. All of these earthquakes would emanate from fault segments much closer to San Francisco than the Loma Prieta earthquake.

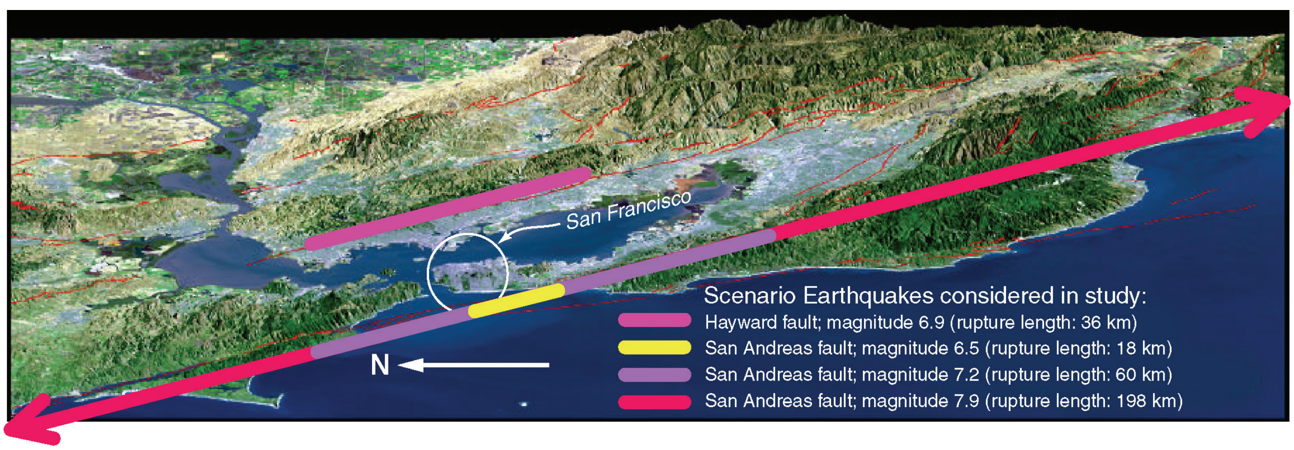

Figure 11. Rupture zones of four scenario earthquakes studied by CAPSS. Fault map courtesy of the US Geological Survey and Pacific Gas and Electric Company.

Likely Damage in Future Earthquakes

An estimated 4,400 wood-frame buildings in San Francisco with three or more stories and five or more residential units were built before the City changed the Building Code in May 1973 to prevent soft-story construction. The CAPSS project selected 2,800 of these buildings that have the largest ground floor openings for analysis. This subset of buildings is presumed to face the highest risk of damage in future earthquakes; examining this group in detail provides insights into the scope of damage that other similar buildings might experience in future earthquakes. It is important to remember that buildings with two stories, fewer units or smaller openings could also experience heavy damage in future earthquakes.

Because loss studies are uncertain by their very nature, this report presents potential losses as a range. The initial loss estimates were calculated using a numerical model derived from the nationally recognized loss estimation software developed by FEMA known as HAZUS-MHTM, which is based on earth science, engineering, and observations made following damaging earthquakes, combined with assumptions regarding the scenario earthquake, site conditions and responses of representative buildings. HAZUS-based loss estimations can have uncertainties of a factor of two. CAPSS convened the Project Engineering Panel to review this analysis. This Panel, whose members are intimately familiar with numerical modeling and first-hand observation of earthquake damage, advised that policy makers would be better served if the results were expressed as a range rather than single numbers. The panel members developed the ranges.

Damage to these buildings was calculated for four scenario earthquakes and is presented in Table 1. While no future earthquake would be precisely like the scenarios studied, this analysis illustrates the range of possible damage for the selected scenarios.

Table 1 Estimated Damage to a Sample of 2,800 Unretrofitted Multi-Unit, Wood-Frame Soft-Story Buildings in Four Scenario Earthquakes

Scenario	Dollar Loss* ($Billions)	Estimated Distribution of 2,800 Buildings with Large Openings by Post-earthquake Safety Tagging Category			
		Green Tag (% of Buildings)	Yellow Tag (% of Buildings)	Red Tag – No Collapse (% of Buildings)	Red Tag – Collapse (% of Buildings)
Magnitude 6.9 Hayward Fault	$3.2	33 - 49	19 - 27	18 - 30	6 - 18
Magnitude 6.5 San Andreas Fault	$3.6	22 - 42	17 - 27	23 - 39	8 - 23
Magnitude 7.2 San Andreas Fault	$4.1	6 - 35	9 - 23	32 - 54	11 - 31
Magnitude 7.9 San Andreas Fault	$4.4	1 - 33	2 - 18	37 - 62	12 - 35

* The total estimated value of these buildings and their contents is approximately $14 billion. This excludes the value of the land.

M: Magnitude

Economic damage was also estimated using a model based on the HAZUS software. These estimates are subject to the same uncertainty described previously and can vary considerably. The estimated damages, expressed in dollars, are given as a single number because they are intended to be compared and each figure is derived from the same model and assumptions.

Building damage results are presented in terms of the expected safety tag (placard) assigned to buildings by inspectors after an earthquake, which are defined as follows[8]:

- **Green Tag (INSPECTED):** No apparent hazard is found although repairs might be required. Residents should be able to continue to occupy these structures.

[8] ATC-20-1, 2005.

- **Yellow Tag (RESTRICTED USE):** A hazardous condition exists or is believed to exist that requires restrictions on the occupancy or use of the structure. Residents might be able to continue to occupy some, but not all, of these structures, with restrictions.
- **Red Tag (UNSAFE):** Extreme structural or other hazard is present. There might be imminent risk of further damage or collapse from creep or aftershocks. Occupants cannot use any of these buildings. Some are collapsed. Some would need to be demolished, but others can be repaired.

Each of these potential earthquakes varies in size and location and, thus, the estimated damage that each would produce also varies; however, the overall pattern is similar for each of these events:

- Less than half of multi-unit, wood-frame buildings analyzed are expected to be green tagged and fully usable after any of these four scenarios.
- In the least damaging scenario event, about a quarter of these buildings are expected to receive red tags, which would mean that they cannot be occupied after an earthquake. In the most damaging scenario, more than 90 percent would be red tagged. These buildings house tens of thousands of residents, who would probably have to leave their neighborhoods for months or years, if not permanently, while these buildings were repaired or replaced. This could create blight in neighborhoods where many buildings would lie vacant for an extended period. This level of damage would place a significant burden on City emergency response personnel who provide rescue, fire fighting, shelter, and building inspection services.
- From 6 to 35 percent of these buildings would collapse. This outcome threatens the lives of the people who live in and use these buildings. It also would mean that rent-controlled apartments in these buildings would be permanently lost to the City. The look and feel of neighborhoods that contain these buildings would change, as the buildings were rebuilt with modern materials and design.
- For more insights, it is helpful to take a closer look at the damage that would occur due to a magnitude 7.2 earthquake on the San Andreas fault. This size earthquake would produce shaking in many parts of the City that would be similar to the "design level" shaking that San Francisco's building code requires engineers to consider when designing new buildings. In a magnitude 7.2 quake, this subset of 2,800 buildings would experience the following damage:
    - 43 to 85 percent of buildings—from 1,200 to 2,400 multi-unit buildings—would be red-tagged. This means that residents could not use them until they were repaired or replaced, which could take years. For this structure type, most of the buildings that do no collapse should be repairable, although repairs may be expensive. These red-tagged buildings contain from 12,000 to 25,000 residential units.
    - A quarter of these red-tagged buildings would collapse, from 300 to 850 buildings with approximately 3,000 to 9,000 residential units. Collapses threaten lives. They also mean that San Francisco permanently loses these buildings, their architectural character, and the rent-controlled apartments in them. When they are replaced, owners may choose to rebuild them as condominiums, and even if they are rebuilt as apartments, they will no longer be covered by rent-control under state law.

- Over $4 billion dollars in damage to building structures and their contents would be incurred. Few multi-unit buildings carry earthquake insurance, so the majority of these losses would be borne by the buildings' owners and occupants.

Figure 12 illustrates the proportion of green, yellow and red tags, including collapses, for this earthquake.

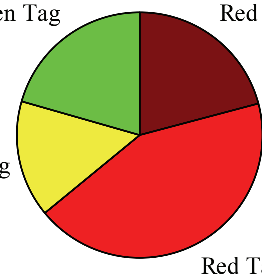

Figure 12. Approximate distribution of safety tagging of buildings studied by CAPSS for a magnitude 7.2 scenario earthquake on the San Andreas fault. The number of tags in each category could vary as shown in Table 1.

The damage estimates presented in this report do not include the impacts of post-earthquake fire. Earthquake shaking sparks fires in many ways, but a significant source of fire risk comes from damaged buildings. Wracked building walls can sever gas lines where they enter the buildings. Collapsing buildings can tip appliances with pilot lights or can drag down power lines. The heavy damage estimated for this category of building suggests that they could be responsible for sparking a number of fires. The fire in the Marina District that followed the Loma Prieta earthquake was sparked by the collapse of a multi-unit, wood-frame soft-story building[9]. Whether these fires spread into a citywide conflagration, as occurred after the 1906 earthquake, or are extinguished quickly depends on many factors, including the number of ignitions, the weather and the actions of local residents and fire fighters.

What This Damage Would Mean to San Francisco

The estimated damage to multi-unit, wood-frame soft-story buildings in each of the scenarios examined is devastating. It is important to recognize that this damage from a particular sample of buildings would be part of a larger catastrophe: many other types of buildings in San Francisco would also be damaged; other Bay Area communities would suffer similar damage; water, telephones, transportation networks, and other utilities would not be usable; and people would be killed, injured and frightened. Repairing damaged buildings and replacing destroyed buildings will consume resources and energy that would be conserved if buildings were retrofitted to resist strong ground shaking. The sections that follow examine only the impacts of damage to the 2,800 buildings studied in this report.

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[9] Scawthorn, Porter and Blackburn, 1992.

Impacts on Building Residents

Residents of multi-unit, wood-frame soft-story buildings would be severely impacted by the heavy damage that these buildings would experience in a large earthquake. These impacts include:

- **A high risk of death or injury,** especially for people in ground level stores, restaurants, apartments or parking areas.
- **A high likelihood of displacement.** Without retrofit, only 1 to 49 percent of these buildings are expected to receive green tags, meaning that they can be continuously occupied. Some, but not all, yellow-tagged buildings can also be continuously occupied. In the least damaging scenario studied, over 13,000 residents would need post-earthquake shelter, many for years. Residents would face dislocation, expense, separation from neighborhood services, and possible difficulty in accessing schools and jobs due to this relocation.
- **Damage or destruction of personal possessions.** Residents could lose many or all of the things that they own and be forced to bear the cost and hassle of replacing them. Insurance may cover some losses for some residents.

Natural disasters have a particularly negative effect on lower-income households and on other vulnerable populations, such as seniors and the disabled. Lower-income households typically have fewer resources to manage their losses, to recover from economic and geographic displacement, and to return to their homes. Furthermore, many lower-income residents live in multifamily buildings, which historically have been rebuilt at slower rates than single-family units. Although on average, the residents living in the buildings studied in this report are not low-income, it is likely that many of these buildings do house long-term low-income tenants, such as seniors who live on a fixed income.

A 2006 study of New Orleans after Hurricane Katrina suggests that lower-income areas have been slower to repopulate, due to a lack of access to transportation among poor households, fewer resources to repair damaged property, and the ongoing lack of employment prospects in the City's disrupted economy[10]. The study also states that lower-income households may not be able to afford the higher rents in reconstructed buildings in New Orleans. As a result, the study predicts major demographic and socioeconomic disparities in the City's repopulation.

Research on the impacts of the Loma Prieta earthquake in Santa Cruz County shows that seniors are similarly affected by natural disasters. The elderly are less mobile and need to be near social services, grocery stores, pharmacies, shopping, entertainment, and existing community networks. These factors, combined with the general loss of affordable housing, make it particularly difficult to find replacement housing for lower-income seniors who lose their homes after a disaster.

Impacts on Housing

Multifamily housing is slow to recover following an earthquake. A 1994 study on residential rebuilding efforts after the Loma Prieta Earthquake found that one year after the earthquake, 90 percent of the multifamily units destroyed or rendered

[10] McCarthy et al., 2006.

unserviceable in the Bay Area were still out of service. Four years later, 50 percent of these units had not been repaired or replaced[11].

When multifamily properties are demolished after an earthquake, the market favors those properties being reconstructed as condominiums, rather than apartments. Development economics generally find that condominiums generate greater financial returns to developers than do apartments, even in high-priced rental markets such as San Francisco. When demolished apartments are reconstructed, the new construction is not subject to the City's Condominium Conversion Lottery, and the lost rental units may therefore be replaced as ownership units. Similarly, new apartments replacing demolished units are not subject to the City's Rent Stabilization Ordinance, commonly known as rent control. For an owner of an apartment building, the incentive to rebuild is connected to his or her ability to enhance cash flow and to service debt. Owners have little incentive to rebuild, if construction costs cannot be recovered through rents. For units serving lower-income households, access to construction financing is even more difficult. In sum, if the building owner is carrying a large debt load relative to the building's value, is making little or no profit from rental income, and if the cost to repair is high, then incentives to re-construct the property as condominiums are greater.

The current credit market would limit access to construction financing for any new residential development in the short-term. Lenders now apply tight underwriting criteria and stringent financing terms to new construction of any kind. Interviews with developers indicate that lenders are currently offering loans in amounts up to 50 percent of the building's value, compared to historical norms of 70 to 90 percent.

Affordable housing is particularly slow to recover after natural disasters. For example, after Hurricane Katrina, federal and state allocations would only suffice to replace two out of five affordable rental units in the state of Louisiana, and one out of three affordable rental units in the city of New Orleans. What is more, of the 24,600 units projected to receive assistance, only 11 percent were open for occupancy as of 2008[12].

The Loma Prieta Earthquake particularly impacted lower-income housing stock. The 1994 study of the Loma Prieta earthquake found that 75 percent of the 6,300 San Francisco units destroyed or damaged after the earthquake were rental units, and 66 percent of those units were rented by low- and moderate-income households[13]. The study also showed that federal recovery assistance was less effective at meeting repair needs for multifamily buildings and for affordable housing, in particular. While owners of multifamily buildings in strong San Francisco submarkets could rely on rental income to access rebuilding loans, owners of more marginal properties had little cash flow to leverage to secure financing.

Impacts on Owners

Building owners would bear most of the financial losses to these buildings, a figure estimated at $3.2 billion to $4.4 billion for the four scenario earthquakes studied.

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[11] Camerio, et al., 1994.

[12] Rose et al., 2008.

[13] Camerio et al., 1994.

Discussions with building owners suggest that few owners of multi-unit apartment buildings currently carry earthquake insurance. Insurance for this type of building is expensive and does not provide comprehensive coverage.

The federal government offers limited resources for rebuilding rental housing. The Federal Emergency Management Agency (FEMA) and Small Business Administration (SBA) offer a small number of programs to homeowners for rebuilding their properties following a disaster. In general, FEMA offers more financial assistance to homeowners than to renters due simply to the greater cost of reconstructing or repairing a home. Homeowners also may qualify for months of rental assistance while repairing their property.

For owners of rental properties, the SBA serves as the primary source of financial assistance for rebuilding. The SBA offers Business Physical Disaster Loans with interest rates ranging from 4.0 to 8.0 percent and with a maximum term of 30 years, although applicants who have access to credit through other means are only eligible for a maximum three-year term. Loans are limited to $2.0 million and cannot exceed the verified uninsured disaster loss.

Following Hurricane Katrina, smaller building owners could access forgivable loans through the Department of Housing and Urban Development's (HUD) Small Rental Repair Program. In contrast to the upfront grants available to homeowners for property reconstruction, the Small Rental Repair Program reimburses owners after repairs are completed and tenants are in place. A recent study found that building owners have had trouble taking advantage of the Small Rental Repair Program's reimbursements, due to difficulties in accessing private financing for repairs[14].

Building owners are obligated to act in a prudent manner to protect their building's occupants from injury, and they may be liable for damages if they know that their building has a soft-story that may be hazardous. Liability issues for older buildings are not clear-cut, but every damaging earthquake generates lawsuits relating to deaths, injuries and/or damage to personal property. A retrofit program could establish a reasonable standard for owners to meet.

Impacts on Businesses

Small businesses are more vulnerable than large firms are following a natural disaster. Small business owners often do not own their building, seldom carry insurance, and are rarely diversified in terms of the products and services that they offer. They also lack the resources to address equipment and inventory damage and interruptions in utility and transportation lifelines. Small and locally-owned businesses are therefore less likely to recover from disasters than are their chain competitors, whose profits do not depend on a single store. Given the number of small businesses located in multi-unit, wood-frame soft-story buildings, the City's economic recovery after an earthquake would be impacted by heavy damage to these buildings.

For small businesses located in older areas, structural damage can cause a number of problems that further delay and hamper recovery, such as release of hazardous materials and failure of older utility pipes, ducting, and sprinkler systems, which can cause flooding and interior damage. Small businesses often lack the resources to

[14] Rose et al., 2008.

address the damage that can occur in older buildings. If other nearby businesses and residences suffer similar damages, then customer traffic in the area may decrease, compounding the economic hardship that the neighborhood confronts.

In the case of the Northridge earthquake, businesses reported that for some time after the earthquake, residents changed their spending patterns, which further disrupted business operations. The highest job loss levels that resulted from the Northridge earthquake were in the retail industry (24 percent of total job losses). Some small businesses failed as a result of the Northridge earthquake as late as two years after the event[15].

A study of the 2001 Nisqually Earthquake in Washington State similarly highlighted the vulnerability of small retailers[16]. Of 13 industries surveyed, retail businesses reported higher rates of direct physical losses (buildings and equipment) and reduced revenue as a result of lost inventory. This was attributed to the fact that retailers have a higher percentage of their assets invested in inventory than do most businesses.

Even businesses that qualify for federal lending assistance eventually bear the full losses themselves. The SBA offers loans to businesses for the repair or replacement of real estate, inventories, machinery, equipment, and all other physical losses following a disaster. The SBA does not provide disaster grants.

While the damage to multi-unit, wood-frame soft-story buildings would impact the small businesses located in these structures most heavily, businesses of all sizes and in all locations would be affected. These buildings house people who work in many San Francisco businesses. No business can succeed without its employees.

Impacts on Neighborhoods

Evidence suggests that major earthquakes can lead to significant neighborhood transition. A study of the 1994 Northridge earthquake reported that an estimated 60,000 people migrated out of the San Fernando Valley as a result of the damage done to homes and businesses. That area had already been suffering an economic decline, due to contraction of the defense industry and to falling home values. In the years following the disaster, approximately 20,000 new residents moved into the area. Most of the newcomers were younger and poorer than the previous population had been. These new residents had different spending habits and needs, and their influx greatly altered both the retail fabric and the overall social structure of neighborhoods[17].

In some Los Angeles neighborhoods, the Northridge earthquake had an even more striking impact on neighborhood transition. In many areas that had once been middle-income neighborhoods, the damage rendered structures uninhabitable and forced some tenants to abandon their units. These neighborhoods subsequently became targets of looters, squatters, and street gangs, whose presence further undermined the quality of the neighborhood. In an already weak housing market, it was not economically viable to reconstruct the damaged housing stock, and low-income units

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[15] Petak and Elahi, 2000.

[16] Meszaros, Jacqueline and Mark Fiegener, 2002.

[17] Petak and Elahi, 2000.

were especially difficult to finance. In time, this led to a spiraling decline in affordable housing stock and to an overall decline in property values[18].

San Francisco is celebrated for the unique character and ambiance of its neighborhoods. That character is largely due to the style, scale, articulation, narrow parcels and patina of buildings that were built generations ago. Most of those buildings are wood-frame, and many have soft-story conditions. Buildings define neighborhoods, give identity to residents, create communities and attract tourists.

In a magnitude 7.2 earthquake on the San Andreas fault, from 300 to 850 of the 2,800 buildings studied are expected to collapse. The structures that replace them would be determined by the choices and the financial wherewithal of their owners. One thing is certain: the newly constructed buildings that replace those that collapse would look different from what stands today. The new structures would be built using modern materials and design aesthetics and reflecting the economic realities of the times. Their use, look, size, floor height, size of residential units and relationship to the street would all change. In some cases, owners might combine parcels to build larger developments.

The next major earthquake to strike San Francisco would cause heavy damage to multi-unit, wood-frame soft-story buildings. This damage would have serious impacts on all San Franciscans. However, as discussed in the next chapter, many of these impacts can be avoided or reduced if these buildings are seismically retrofitted.

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[18] Petak and Elahi, 2000.

CHAPTER 3: THE CONSEQUENCES OF RETROFITTING

Seismic retrofits greatly reduce the likely level of damage that multi-unit, wood-frame soft-story buildings will experience in future earthquakes. Retrofitting would save lives, reduce collapses, and allow thousands of residents to remain in their homes and neighborhoods after an earthquake and contribute to reviving their community. It would preserve many units of rent-controlled housing and would maintain the vitality, character and demographic mix of neighborhood residential and commercial areas. Fewer buildings would need to be razed and replaced and resources and energy would be conserved.

These safety increases come with costs. Building owners would need to bear the costs of retrofit construction, typically $60,000 to $130,000 per building for direct construction costs[19]. Roughly 30 percent of buildings studied by CAPSS have commercial or residential uses at the ground level. Retrofit construction could require these tenants to vacate or to deal with considerable inconvenience for two to four months during construction. This could cause hardship, especially to small businesses and owners. All of these costs would be immediate and tangible. Their scale, however, is dwarfed by the costs that would be borne by all of these parties after a large earthquake, if retrofits do not occur.

Damage Avoided by Seismic Retrofits

Wood-frame soft-story buildings can be retrofitted to improve their performance in earthquakes. Retrofitting these buildings generally involves installing shear walls, steel frames or steel cantilevered columns, such as those shown in Figures 13 through 15.

However, not all retrofits are the same. The CAPSS project selected four representative buildings with large ground floor openings to evaluate the benefits and costs of retrofitting. For each building, three different retrofit designs were made, ranging from a basic retrofit to a retrofit requiring more extensive work[20]. The three retrofits were intended to achieve three different levels of performance when exposed to strong shaking:

- **Retrofit Scheme 1:** This is a minimal retrofit approach intended to reduce harm to those who live and work in or frequent the building. Collapse would be prevented, and occupants should be able to escape the building safely, but the

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[19] These costs are for direct construction only and do not include other costs owners will incur. These estimated costs are explained later in this chapter.

[20] Details about the representative buildings studied and the various retrofit schemes are available in the Documentation Appendices.

Figure 13. An example shear wall.

Figure 14 An example steel moment frame. Photo courtesy of Anderson Niswander Construction.

Figure 15 An example of steel cantilevered columns.

building might not be repairable or fit for occupancy after an earthquake. Rent-controlled apartments could be permanently lost.

- **Retrofit Scheme 2:** This is a moderate retrofit level that is intended to avoid demolition. It would allow significant damage, and the occupants could become homeless after a major earthquake and need to seek other lodging for the years it could take to repair the building. Repaired rental units would remain under rent control restrictions, and neighborhood character would be protected.
- **Retrofit Scheme 3:** This scheme is similar to Retrofit 2, except that it uses different structural steel members. It is intended to allow the residents to remain in their units after a major earthquake. A building retrofitted to this standard would be damaged after a major earthquake, but would be expected to withstand strong aftershocks. There might be significant damage to nonstructural building elements, utility services might not function, and some areas of the building might be off limits.

Retrofit schemes 2 and 3 use different structural systems. The differences make them difficult to compare directly because the two schemes, steel frames and steel cantilevered columns, differ in where they would be preferred. The appropriate system depends on engineering judgment about each specific building. The differences in approaches and small differences in estimated construction costs are less important than learning that retrofitting using these systems can result in retrofitted buildings that could be occupied following earthquakes.

In reality, no retrofit can guarantee any specific performance. Any well-engineered retrofit makes it more likely that a building would be safe, repairable and fit for occupancy after an earthquake. An extensive retrofit makes these things more likely than a basic retrofit. After an earthquake, the performance of each building would vary based on the strength, duration and direction of shaking experienced at its particular location, the local soil it sits on, unique characteristics of its construction, and many other factors. If many buildings were retrofitted to one of the schemes described above, the majority of them would be expected to have the described performance, but some would fare better and some would fare worse.

All retrofits examined by the CAPSS project limited construction work to the ground floor. Construction work in upper floors would increase the costs of seismic retrofits considerably, as well as requiring upper level residential tenants to temporarily relocate. For most buildings, it should be possible to achieve the performance described above without extending work into the upper floors. The retrofits do not, however, mitigate against liquefaction damage. While the retrofits would increase the safety of buildings that experience liquefaction, it cannot be assumed that the buildings could be occupied or repaired after liquefaction. This level of performance would require costly upgrades to foundations.

The CAPSS project examined how earthquake damage would lessen in four scenario earthquakes, if all 2,800 multi-unit, wood-frame buildings with three or more stories, five or more residential units, and large ground floor openings were retrofitted to each of the three retrofit schemes. The results, presented for all scenarios in Table 2, show that seismic retrofits greatly reduce the damage expected in these buildings, although damage is not entirely eliminated. As discussed in the previous chapter, these results, based on numerical analysis and professional judgment, are presented as a range due to the uncertainty inherent in these types of estimates. The most meaningful way to interpret the economic losses, which, although not expressed as a range, also have uncertainty, is to compare the various scenarios and retrofit schemes.

A closer look at the impacts of retrofitting in one of these scenarios, a magnitude 7.2 earthquake on the San Andreas fault, provides additional insights. Key points that emerge include:

- Retrofitting would greatly reduce collapses in a magnitude 7.2 earthquake on the San Andreas. If all 2,800 buildings were retrofitted using scheme 3, collapses would be reduced to less than one percent of buildings, from an estimated 11 to 31 percent with no retrofits. Retrofit schemes 1 and 2 would also reduce collapses significantly.
- The number of buildings that receive red tags would also be significantly reduced, although many buildings would still be heavily damaged. Red-tagged buildings cannot be occupied after an earthquake and, if not collapsed or demolished, generally require costly and lengthy repairs. For this structure type, most red-tagged buildings that do not collapse can be repaired. Retrofitting all 2,800 buildings reduces red tags to 6 to 36 percent of buildings, depending on the level of retrofit, down from an estimated 43 to 85 percent red-tagged with no retrofit.

Table 2 Expected Damage Before and After Three Retrofit Schemes for a Sample of 2,800 Multi-Unit, Wood-Frame Soft-Story Buildings in Four Scenario Earthquakes

Scenario	Retrofit	Dollar Loss (Billions)*	Estimated Distribution of 2,800 Buildings with Large Openings by Post-earthquake Safety Tagging Category			
			Green Tag (% of Buildings)	Yellow Tag (% of Buildings)	Red Tag – No Collapse (% of Buildings)	Red Tag - Collapse (% of Buildings)
Magnitude 6.9 Hayward Fault	As-is	$3.2	33 – 49	19 – 27	18 – 30	6 – 18
	1	$2.4	72 – 75	18 – 20	4 – 8	1 – 2
	2	$1.8	84 – 86	10 – 11	3 – 6	0.2 – 0.3
	3	$1.7	88 – 89	9 – 10	2 – 3	0.1 – 0.2
Magnitude 6.5 San Andreas Fault	As-is	$3.6	22 – 42	17 – 27	23 – 39	8 – 23
	1	$2.7	61 – 66	23 – 26	6 – 13	2 – 4
	2	$2.2	76 – 79	15 – 17	4 – 9	0.3 – 0.5
	3	$2.1	79 – 81	15 – 16	3 – 6	0.2 – 0.3
Magnitude 7.2 San Andreas Fault	As-is	$4.1	6 – 35	9 – 23	32 – 54	11 – 31
	1	$3.4	36 – 48	28 – 34	14 – 28	4 – 8
	2	$2.9	57 – 64	24 – 27	9 – 18	0.5 – 1
	3	$2.6	67 – 71	21 – 23	6 – 12	0.3 – 0.7
Magnitude 7.9 San Andreas Fault	As-is	$4.4	1 – 33	2 – 18	37 – 62	12 – 35
	1	$4.0	13 – 35	21 – 32	26 – 52	7 – 14
	2	$5.4	23 – 40	27 – 35	24 – 47	1 – 3
	3	$4.0	28 - 44	26 - 33	22 - 44	1 – 3

*The total value of these buildings and their contents is estimated at $14 billion. This does not include the value of the land.

Figure 16 illustrates how post-earthquake safety tagging would change if buildings were retrofit to various levels (see previous chapter for a description of post-earthquake safety tagging).

The loss estimates for this project do not consider the risk of post-earthquake fire. However, damaged buildings are a major cause of fire ignitions. Retrofitting buildings reduces their damage and, consequently, reduces the number of fires that are likely to ignite.

Costs of Retrofitting

Retrofitting clearly reduces damage and collapses, but that increased performance comes at a cost. Part of this cost can be quantified in terms of financial impacts. Other elements of the cost are not financial, at least not directly, but still constitute real impacts that the community would experience over the course of retrofitting these buildings.

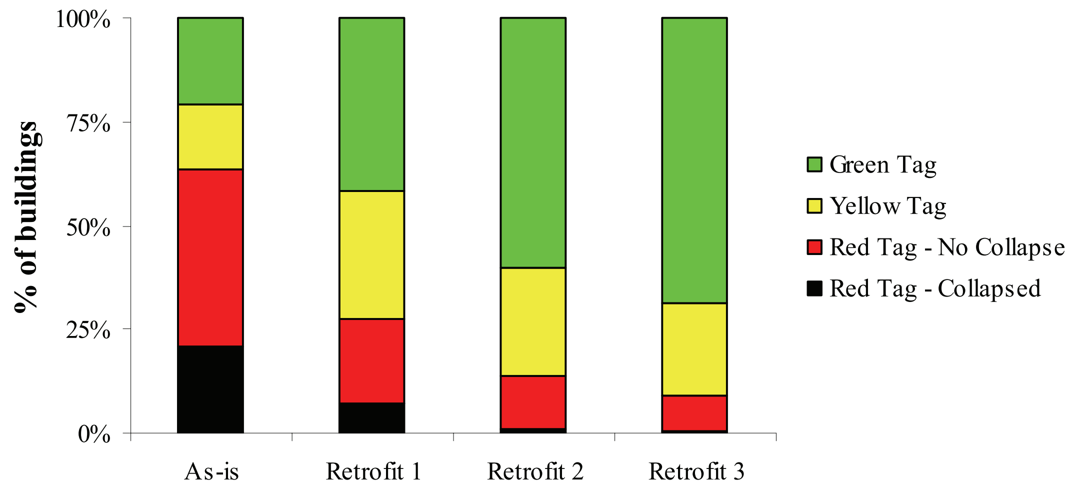

Figure 16. Approximate distribution of damage tags before and after three retrofit schemes in a scenario magnitude 7.2 earthquake on the San Andreas Fault. The number of tags in each category could vary as shown in Table 2.

Direct Construction Costs

The CAPSS project took a detailed look at the direct construction costs of each retrofit scheme for four representative San Francisco buildings. Although the actual costs of retrofitting any specific building would vary depending on the unique circumstances of each project, the cost estimates produced for these retrofits provide guidance about the overall range that should be expected and the differences in cost associated with achieving different performance levels.

Table 3 presents cost estimates for direct construction costs based on an analysis of retrofits for four representative multi-unit, wood-frame soft-story buildings. These

Table 3 Direct Construction Costs Estimated for Four Representative Multi-Unit, Wood-Frame Soft-Story Buildings for Each Retrofit Scheme

	Per Building		Per Residential Unit		Per Square Foot	
	Average	**Range**	**Average**	**Range**	**Average**	**Range**
Retrofit Scheme 1	$65,000	$49,000 to $79,000	$11,000	$9,000 to $13,000	$6.60	$3.00 to $9.40
Retrofit Scheme 2*	$105,000	$59,000 to $132,000	$17,000	$15,000 to $20,000	$10.00	$5.70 to $12.10
Retrofit Scheme 3*	$93,000	$58,000 to $114,000	$16,000	$13,000 to $19,000	$9.00	$4.60 to $11.10

* Although retrofit scheme 3, which provides the better performance, is less expensive than retrofit scheme 2, in general it costs more to get better performance. Retrofit 2 uses steel moment frames and plywood shear walls. Retrofit 3 uses steel cantilevered columns and plywood shear walls. Cantilevered columns generally are less expensive to construct than are moment frames, but are not always appropriate to use. Many structural engineers prefer frames to cantilevered columns. The costs of retrofitting any building will vary based on its unique circumstances. This analysis shows that a range in performance is available at a range of costs.

estimates include direct construction costs and permit fees. They do not include architectural or engineering design fees, costs of relocating any conflicting utilities, or costs associated with other circumstances described below. Engineering fees would vary, but would represent at least 10 percent of construction costs.

These costs do not include the costs of other work that might be triggered by this construction. In particular, buildings with commercial use are subject to Title 24, California Building Code, which implements the Americans with Disabilities Act (ADA). When upgrades or repairs exceeding a threshold of $119,000 are made within a particular commercial space, cumulative over a three-year period, then significant upgrades must be made to make that area of the building more accessible to the disabled. When the three-year cumulative costs of upgrades and repairs do not exceed the threshold, then the project must spend an additional 20 percent to improve handicapped access. These requirements cannot be waived for seismic safety projects. If the Title 24 threshold is triggered, the overall costs of construction rise considerably, and a number of changes might be required that impact the businesses in the affected space. For example, a restaurant with a small bathroom might be required to upgrade the bathroom to a larger size, which would reduce the amount of floor space available for customer seating. The Department of Building Inspection vigorously enforces Title 24, because it protects important civil rights.

Construction costs could be higher for many other reasons, as well. Buildings with ground floor commercial spaces may be able to keep those tenants in place by carrying out construction during off-hours, but this increases costs. Owners of historic or architecturally important buildings could see their construction costs rise by an estimated 20 to 50 percent due to efforts to maintain the architectural integrity of the building[21]. Buildings with occupied commercial or residential spaces at the ground floor could see costs rise if significant demolition and replacement of interior finishes are required. In some cases, other fire and life safety upgrades relating to issues such as egress, parapets, and façade materials could be triggered, which would add to costs. None of these issues are included in the cost estimates shown in Table 3.

Costs to Owners

Building owners would bear most of the costs of seismic retrofit construction. The financial impact of these costs on owners would vary according to each owner's particular economic circumstances. A major property owner with a diversified investment portfolio might be able to bear the costs of retrofits to this type of building without suffering significant adverse consequences. By contrast, a "mom and pop" owner who relies on the property as a major source of income, who has a significant amount of outstanding debt, or who is heavily invested in the property, could be more negatively affected by retrofit costs.

In most cases, San Francisco building owners do not rely on their properties as a primary income source. The San Francisco Board of Supervisors commissioned a survey in 2003 of owners and tenants of multi-unit rental building in San Francisco[22]. The survey revealed that most building owners were employed and tended to work in executive or professional occupations in San Francisco. Most of

[21] Tennebaum, 2009.

[22] Bay Area Economics. 2003. Survey respondents totaled 693 multi-unit rental building owners, representing six percent of the total rental housing stock in San Francisco.

the survey respondents did not work primarily as property owners or managers. Owners had relatively high household incomes in comparison with San Francisco renters, with all San Francisco households, and with property owners nationwide. The owners' median annual household income was estimated at $90,900, compared to $44,800 for tenants, and $55,200 for San Francisco households overall. Most owners received the majority of their income from sources other than their rental properties in the City; only one-fourth relied on these properties for half or more of their income. The most frequently stated reason for purchasing property was to receive income from rents, and only 16 percent of owners reported purchasing the property for retirement security. Less than one-fifth of the owners indicated that they were merely breaking even or were losing money on their properties, which is nearly the same as rates nationwide, where a far lower proportion of units are covered by rent control.

In the near term, restrictive credit markets might limit the ability of landlords to secure financing for seismic improvements. Due to ongoing turmoil in the national and international credit markets, landlords could encounter difficulty in securing affordable financing for seismic improvements. Literature reviews also indicate that lenders often provide less favorable financing terms for seismic improvements, which do not increase a property's value (i.e., allow for higher rents). In fact, experience in other cities has shown that when seismic upgrading is required, owners use the retrofit as an opportunity to address other code violations and to carry out cosmetic rehabilitation work, allowing them to command higher rents as turnover occurs[23].

According to City Assessor's data, approximately 90 percent of these buildings are categorized as rental apartments, with the remaining buildings identified either as condominiums or as having other uses. Buildings that contain condominiums or tenancy-in-common units might have more difficulties in arranging financing, due to complications that arise when a building has multiple owners.

The San Francisco Rent Stabilization Ordinance governs owners' ability to pass seismic retrofit costs on to residential tenants. The Ordinance allows landlords to pass through the full cost of any seismic retrofit that is required by law, with a maximum increase of 10 percent of the tenant's base rent in any 12-month period, amortized over 20 years.

Capital improvements that are not required by law are subject to a different set of pass-through regulations. For properties with one to five residential units, 100 percent of the certified capital improvement costs can be passed through to tenants. For properties with over five units, only 50 percent of the certified capital improvement costs can be passed through to tenants. Therefore, under current law, landlords of buildings with six or more units would only be able to pass through 50 percent of total retrofit costs, if retrofits are not mandated by the City.

Table 4 compares the monthly debt service of a seismic retrofit to the permitted capital improvement pass-through to tenants who pay the average monthly rent for an example property. The analysis assumes a retrofit cost of $132,000, based on cost estimates prepared by the CAPSS team and assuming a 20-year amortization period, an 8.0 percent interest rate, and a six-unit building[24]. Rent data are drawn from

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23 Comerio, Mary. 1987.

24 The amortization period and interest rate are based on Rent Stabilization Ordinance requirements.

RealFacts, a private subscription data service. Under these assumptions, the building owner would have a monthly debt-service of $184, which falls well within the $240 monthly pass-through allowance for a tenant who pays the average monthly rent.

Table 4 Allowable Rent Increase for Retrofit Versus Monthly Debt Service

Cost Category	Amount
Average monthly rent in San Francisco per unit*	$2,400
Maximum allowable increase (10% of base rent)**	$240
Estimated retrofit cost†	$132,031
Monthly debt service (amortized over 20 years at 8% interest)	$1,104
Monthly debt service per unit (6 unit building)	$184

* Average rent for third quarter 2008.

** Assumes Rent Stabilization Ordinance allows 100% of qualified retrofit costs may be passed through to renters.

† Conservatively assumed highest cost estimates from CAPSS analysis. Estimates range from $49,000 to $132,000.

Basic economic principles of real estate dictate that the market establishes the maximum rent that a landlord can charge. Therefore, when rents in a building are already at market rates, a landlord who attempts to pass through seismic retrofit costs risks losing tenants. Currently, an estimated 40 to 60 percent of San Francisco apartments have rents at or close to market rate. Therefore, landlords have a limited ability to pass through costs to residential tenants. As a result, landlords might forgo a capital improvement pass-though petition with the Rent Board if roughly half of the units in a given multi-unit building could not absorb a rent increase. Under these constraints, landlords would have to absorb a large portion of the retrofit costs.

Building owners would incur expenses beyond those directly related to retrofit construction. Landlords might need to reduce rents and/or compensate tenants for lost parking and storage space during the course of construction. If ground floor commercial or residential tenants need to relocate temporarily, then the landlord might also have to compensate those tenants.

Once completed, the retrofits will have a minimal impact on leasable area. Retrofits generally should not require any permanent loss of floor space or parking space or any blockage of windows. Some structural changes, such as steel frames, might be visible inside at the ground floor. This would generally not be a concern for buildings with garages at the ground level, but extra design care might be required for buildings with street level commercial space or architectural importance.

Financial impacts to owners could be partially mitigated if the City offers certain types of incentives recommended by the CAPSS program. These incentives include rebating permit fees, allowing use changes, easing parking requirements, allowing increases in usable floor space, and offering City-funded loans, and are described in more depth in Chapter 5.

Costs to Residential Tenants

Most residential tenants would bear little disruption due to seismic retrofits. Construction for retrofits of multi-unit, wood-frame soft-story buildings can generally be limited to the ground floor. Therefore, residential tenants living above the ground floor are protected from displacement during construction. However, construction would likely affect ground floor parking and storage for a period of two to four months. Tenants might need to seek alternative solutions for parking and storage during that time, but they might be compensated for this by their landlord. During construction, there would be some noise and other disruptions typical of construction projects.

Fourteen percent of the buildings studied by the CAPSS project had one or more residential units at the ground level. Tenants in these units might need to relocate temporarily and to deal with the resulting expense and hassle, although in some cases retrofit designs might be able to avoid construction inside these units. Under San Francisco law, tenants have the right to reoccupy their unit once construction work is complete.

Costs to Business Tenants

Commercial tenants in the ground floor of these buildings can expect to experience a greater impact from retrofits than their residential counterparts do. The seismic work would be likely to disturb operations significantly for a period of two to four months. Many small businesses lack the financial wherewithal to recover from closing for a few months. Small businesses make up a major share of commercial tenants in multi-unit, wood-frame soft-story buildings; almost 95 percent of these businesses have ten or fewer employees. With limited savings, small profit margins, and dependence upon a steady revenue stream to pay for inventory and to service debt, many small businesses, particularly those in the retail and food service industry, do not have the resources to withstand a prolonged closure. Construction can be scheduled to minimize, but not eliminate, ground floor disruption.

Because rent control laws do not apply to commercial tenants, lease rates are already at market or are limited by long-term lease provisions, and landlords have limited ability to pass through seismic retrofit costs. A 1990 study reporting on the impacts of the Los Angeles Earthquake Hazard Reduction Ordinance, Los Angeles' program to retrofit unreinforced masonry buildings, found that few owners were able to pass through costs to commercial tenants, because rents were already as high as the market could bear[25]. In the few cases in which rents were raised, the increase did not cover the full cost of seismic rehabilitation.

During construction, businesses can expect a substantial amount of noise, space constraints, visual disturbance, and dust, disrupting normal operations. In the 1990 Los Angeles study, building owners noted that it was in their best interest to retain tenants and rental income, and thus they tried to do the work in phases so as not to disturb business. Despite these efforts, however, the retrofit activity did force many businesses to close during construction.

Seismic retrofit ordinances have a limited impact on the mix of local land uses. The 1990 Los Angeles study developed detailed case studies of four different neighborhoods to examine the effect of Los Angeles' unreinforced masonry building program on local land uses. The study ultimately regarded the shifts in occupancy as a normal pattern of land use change in these neighborhoods, rather than change that reflected a direct impact of the City's program. Building owners reported that when tenants moved out permanently, new tenants with similar businesses took their place.

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[25] Blair-Tyler, Martha and Penelope A. Gregory 1990.

In some neighborhoods, the rate of turnover was approximately the same as for non-unreinforced masonry buildings. While local businesses were sometimes supplanted by national chains, this trend was already occurring throughout the neighborhood, and the seismic work provided an opening for changes that might have occurred in any case.

Benefits of Retrofitting

The costs of retrofitting are short-term and readily apparent. Most of the benefits of retrofitting, however, are not evident until after an earthquake strikes. The benefits of retrofitting are realized as losses that are avoided when earthquakes strike. Avoided repairs and/or business interruptions have direct monetary value; many other benefits of retrofits—such as avoided deaths, injuries and trauma, avoided loss of housing resources, and maintained neighborhood cohesion—cannot be so easily monetized.

Benefits to Owners

Retrofitting multi-unit, wood-frame soft-story buildings directly saves building owners money by avoiding damage, reducing the cost of post-earthquake repairs and avoiding business interruption (loss of rent). The estimated savings due to retrofit varies depending on the intensity of the earthquake and on the level to which a building has been retrofitted. In the four scenario earthquakes examined by the CAPSS project, building owners as a whole save between $400 million and $1.5 billion, depending on the level of retrofit, in reduced damage to building structure and contents. The costs of all retrofits citywide would total about $260 million, to achieve a performance that would allow most residents to remain in their damaged but safe homes after an earthquake.

From the perspective of an individual owner, resources invested in retrofit result in significant savings after an earthquake. Table 5 shows the average loss per residential unit in damage to the building structure and its contents that would be avoided if the building was retrofitted and then shaken by a magnitude 7.2 earthquake on the San Andreas Fault.

Table 5 Average Loss Avoided Through Retrofit Per Residential Unit in a Magnitude 7.2 Earthquake on the San Andreas Fault

	Average per unit $ loss avoided to structure and contents
Retrofit scheme 1	$24,000
Retrofit scheme 2	$41,000
Retrofit scheme 3	$52,000

Retrofitting increases the odds that a building can be continuously occupied or reoccupied quickly after an earthquake. This means that owners can continue to receive income from their property after an earthquake.

After every damaging earthquake, tenants file lawsuits against building owners for deaths, injuries, and damage to tenants’ possessions. Owner liability for seismic safety issues of older buildings is not clear-cut. However, conducting seismic retrofits would reduce building damage, limit whatever liability building owners have to their tenants, and lower the number of lawsuits filed.

It is important to note, nonetheless, that many retrofitted buildings could require costly repairs after an earthquake. As a general rule, the financial benefits of retrofitting decrease as the size of an earthquake increases. An extremely large earthquake, such as the magnitude 7.9 event, would cause heavy damage to buildings with or without retrofit. While retrofits would greatly reduce collapses during this size earthquake, owners could still be left with damage that could cost more than half of the value of their building to repair.

Benefits to Residents and Neighborhoods

Occupants of multi-unit, wood-frame soft-story buildings clearly benefit from retrofit. Some of their many benefits include the following:

- They are less likely to be killed or injured in an earthquake;
- Their possessions are less likely to be damaged or destroyed;
- They are more likely to be able to remain in their homes and to avoid the trauma and expense of long-term displacement; and
- They are more likely to remain close to their jobs, to services that they need to access, and to valued family or community members.

Neighborhoods benefit from retrofitting. Following earthquakes, if residents can stay in place, then they can contribute to helping to bring the community back to life. The demographic and economic mix of residents is less prone to change. Neighborhoods avoid the many negative consequences of having buildings stand vacant for extended periods of time. Neighborhood-serving businesses are more likely to survive. By reducing the number of buildings that need to be demolished, retrofits maintain the look and feel of neighborhoods. The architectural styles, scale and mix of uses are retained. Historic and interesting buildings remain. All of these benefits contribute to the resilience of the City and are critical to helping the City as a whole recover quickly from a major earthquake and avoid the long-term disruption and change that accompanies extensive loss.

Benefits to Businesses

Businesses—both those located in multi-unit, wood-frame soft-story buildings and those in other building types—also benefit from seismic retrofits. As previously discussed, most of the businesses located in multi-unit, wood-frame soft-story buildings have fewer than 10 employees. Some of the many benefits of retrofits that these businesses experience after an earthquake include the following:

- Employees and customers are less likely to be killed or injured by an earthquake;
- The business is more likely to be able to remain in its current location and to reopen quickly; and
- Inventory, equipment and supplies are less likely to be damaged or destroyed.

Neighborhood-serving businesses need a functioning neighborhood to serve. All businesses in neighborhoods that contain numerous multi-unit, wood-frame soft-story buildings benefit from retrofit, because less damage means that more people remain in or quickly reoccupy their homes, shop in neighborhood stores, eat at neighborhood restaurants, and seek out the services of local businesses.

All San Francisco businesses, even those sited in neighborhoods with very few of this type of building, need places where their employees can live safely. By preserving housing stock, retrofits help to keep San Francisco's work force in San Francisco.

Perhaps the most important benefit to the San Francisco community is that less damage means that all of the people, causes and programs that make San Francisco a special place can get back up and running again quickly. The next chapter describes a range of policy options to make these buildings safer.

CHAPTER 4: OPTIONS TO REDUCE THE RISK

San Francisco could take a variety of approaches to reduce the seismic risk to its multi-unit, wood-frame soft-story buildings. This chapter outlines the range of options available to the City to manage this risk.

Elements of a Seismic Safety Program

Five key elements can be used to frame how best to develop a seismic safety program to reduce the risk to buildings. Different policy directions might be adopted for each of these interlinking elements. These elements are:

- **Performance Objective**—What level of damage to privately owned wood-frame residential and multi-use buildings is acceptable after a large earthquake?
- **Approach**—What should the City require of owners of seismically deficient buildings?
- **Scope and Priorities—**Which buildings should be covered by a program? Which should be addressed first?
- **Implementation Period**—How long should building owners be given to comply with a program's requirements?
- **Incentives**—What measures should the City offer to encourage or ease the burden of retrofitting by building owners?

Options for each of these key elements are described in depth in the sections that follow.

Performance Objectives

A performance objective defines the desired performance of a group of buildings in an earthquake. Put more simply, it defines the acceptable level of damage to the building stock after a large earthquake. Selecting a performance objective has broad implications on any policy that the City may adopt. This choice affects the number of buildings that will be considered seismically deficient (that is, buildings that will perform worse than the desired performance). It affects the extent—and cost—of seismic retrofits that buildings will need to undergo to meet the minimum standard. If heavy damage to these buildings were considered acceptable, then a modest number of buildings would need to be upgraded to a modest level. If little damage were considered acceptable, then many buildings would need to be retrofitted to a higher and costlier level.

Buildings with different uses or characteristics might be assigned different performance objectives. For example, the City might demand a higher level of performance (that is, less damage) for highly important or heavily occupied buildings than for buildings that are rarely occupied. The buildings addressed by this report function chiefly as rental housing, condominiums, small businesses, and parking. It is possible, but unknown, that some of these buildings have other uses considered especially vulnerable, such as elder care homes, childcare centers, private schools, kidney dialysis centers, or medical clinics.

Options for Performance Objectives

The CAPSS project identified five possible performance objectives, to provide a range for consideration. These are based on performance objectives developed by San Francisco Planning and Urban Research (SPUR) in its position paper of February 2009, "*The Resilient City: Defining What San Francisco Needs from Its Seismic Mitigation Policies*."

A. Safe and Operational
This is a high performance objective that requires robust buildings and back-up utility systems. Buildings would experience only minor damage, and all functions could continue immediately after an earthquake. Few existing buildings would meet a standard that results in this level of performance, and bringing most buildings to this level would be costly.

B. Safe and Useable Until Repair
This is a performance objective that would allow residents to remain in their homes after a major earthquake. Buildings retrofitted to a standard that results in this level of performance could have some damage after a major earthquake but would be expected to withstand strong aftershocks. There may be significant damage to nonstructural building elements, utility services may not function, and some areas of the building may be off limits. The use of these damaged buildings will depend in part on the City's post-earthquake inspection and posting policies.

C. Safe and Useable After Repair
This performance objective would allow significant damage to buildings and means that many San Franciscans would be displaced from their homes after a major earthquake. The time required to conduct repairs would range from months to years depending on factors such as the extent of damage, the availability of qualified engineers and contractors, financing, and permits. Only a few buildings meeting the standard adopted to achieve this objective would be demolished; thus, this standard would maintain repaired rental units under rent control restrictions. It would also maintain neighborhood character as defined by style of construction, building scale, and mix of uses.

D. Safe but Not Repairable
This is a minimal performance objective intended to reduce harm to those who live and work in or frequent these buildings. Collapse would be prevented, and most people would be able to escape the building safely, but some might require rescue, and fire would remain a threat. The City could permanently lose significant amounts of rent-controlled housing, as well as buildings that contribute to the architectural character of the City. While no explicit performance objective was set, this is the presumed objective achieved by the required standards for retrofit of San Francisco's approximately 2,000 unreinforced masonry buildings.

E. **Unsafe, Collapse Risk**
   This performance objective recognizes that buildings in their current condition could be unsafe in earthquakes. Without retrofit, this is the default performance expectation of many multi-unit, wood-frame soft-story buildings.

SPUR believes that San Francisco must strive to become “resilient,” that is, preparations should be made and the building stock improved, so that 95-percent of San Franciscans could safely remain in their homes or apartments following an earthquake. This goal would leave 40,000 San Franciscans seeking shelter after an earthquake. Currently, SPUR estimates it would take approximately three years for 95-percent of residents to be back in their homes after a large earthquake. This goal implies that the overall performance objective for residential buildings in San Francisco should be Performance Objective B (Safe and Useable Until Repair). Some buildings might have a higher performance than this, and others might have a lower performance, so that on average the City’s housing stock performs to this level.

In reality, no retrofit can guarantee specific performance for an individual building. Retrofitting makes it more likely that a building will be safe, repairable and fit for occupancy after earthquakes. After an earthquake, the performance of each building will vary based on the strength, duration and direction of shaking experienced at its location, the local soil on which it sits, the unique characteristics of its construction, and other factors.

CAPSS Recommended Performance Objective

The CAPSS project recommends that the City and County of San Francisco adopt Performance Objective B, Safe and Useable Until Repair, to apply to multi-unit, wood-frame buildings with three or more stories with residential uses or mixed residential and commercial uses. The City should consider requiring any critical uses to relocate, or for those buildings’ retrofits to meet performance Objective A, Safe and Operational.

The CAPSS project believes that it is important to keep San Franciscans in San Francisco after an earthquake. Performance Objective B is necessary to let people remain in their homes, resume their normal lives, reopen local businesses, and contribute to the rebuilding of San Francisco. Greater levels of damage and disruption could cause the City to reach a tipping point, at which recovery would become prolonged, and many of the people who would leave the City would never return. Performance Objective B would keep people out of emergency shelters, preserve rent-controlled housing in the City and retain the architectural feel of San Francisco’s neighborhoods.

The CAPSS project recommends that the Board of Supervisors enact minimum retrofit standards applicable to three story and taller wood-frame buildings with five or more residential units that would result in most retrofitted buildings meeting the adopted performance objective. This standard should be based on an existing retrofit code but may need to adapt an existing code to control building deformation. This standard would replace the standard in the San Francisco Building Code chapter 3400 provisions (often referred to as 104(f)) that applies to wood-frame, soft-story buildings with three or more stories undergoing expansion or change of use.

Approach

Approaches that the City could use to reduce damage in multi-unit, wood-frame soft-story buildings can be summarized in three distinctly different intervention approaches. The details of each of these options could vary in numerous ways, and different approaches could be applied to buildings with different characteristics.

- **Option 1: Provide information and encouragement**

  The City would give an official notice to owners of buildings suspected to be seismically deficient, informing them that they are on a City list of potentially seismically deficient buildings. Owners would be encouraged to do the "right thing" and would be offered incentives to evaluate their buildings and retrofit, if necessary. The City would continue to enforce Building Code Chapter 3400, which requires retrofitting of buildings when certain changes of use or additions are undertaken. The Department would be required to report to the Mayor and Board of Supervisors after four years on the accomplishments of this program.

- **Option 2: Require analysis**

  The City would require owners to undertake an engineering evaluation of their buildings and to compare the results to a designated minimum seismic retrofit standard. Owners would submit a report to the City with their engineering evaluation and a letter describing what action they intend to take in response to the report's findings. Deadlines would be established for submitting reports and owner statements. Owners of buildings that do not meet the City's standard would be required to inform tenants, prospective buyers, insurers and lenders, and to post signs at the entrances regarding their building's vulnerability. The City would continue to enforce San Francisco Building Code Chapter 3400, which requires retrofitting of buildings when certain changes of use or additions are undertaken. The Department would be required to report to the Mayor and Board of Supervisors after four years on the accomplishments of this program.

- **Option 3: Require retrofit**

  The City would require owners to retrofit seismically deficient buildings. Owners with buildings that do not meet the City's standard would be required to inform tenants, prospective buyers, insurers and lenders, and retrofit according to a schedule and established priorities. This approach is similar to the City's unreinforced masonry building program.

There are endless ways in which the three approaches described here could be varied. Currently, the City requires buildings to conduct seismic upgrades when specific changes in use or additions are undertaken. There are a variety of other occasions that the City could use to trigger requirements for evaluations, retrofits, tenant notification, or other actions, including the sale of a building, transfer of a building title, submission of an application for condominium conversion, or vacancy of ground floor tenants.

Lessons from Other Communities

Decades of experience show that building owners rarely retrofit unless required by law to do so. In 1986, the State of California passed a law requiring communities to develop a program to reduce risk in unreinforced masonry buildings (UMBs). Local governments were required to inventory all unreinforced masonry buildings within their jurisdiction, to notify the owners that their building is of a type that performs poorly in earthquakes, and to adopt a risk reduction program. Many communities, including San Francisco, elected to require owners of unreinforced masonry buildings to retrofit them. Other communities left seismic retrofits as voluntary. Communities with voluntary programs have had little success in achieving safer buildings, as shown in Table 6. Despite incontrovertible evidence that unreinforced masonry buildings collapse and kill their occupants and nearby persons in moderate and large earthquakes, the majority of owners have not chosen to pay for seismic retrofits when given the choice.

Table 6 Rates of Retrofit or Demolition of Unreinforced Masonry Buildings in Communities with Voluntary and Mandatory Programs[26].

	Mandatory Programs	Voluntary Programs*	Notification Only**	Other Programs†
Percent of UMB's retrofitted or demolished	87%	24%	13%	26%
Number of cities or counties with this type of program	134	39	46	41

* Voluntary programs: communities set a retrofit standard, require owners to evaluate buildings and write letter stating intentions.

** Notification only programs: communities send a letter to owners stating their building type is known to perform poorly in earthquakes.

† Other programs are variations of the other program types with unique requirements and ranges of effectiveness.

There are a few cases in which voluntary building retrofits have been somewhat effective. Two of these examples come from the City of Berkeley. In Berkeley, a transfer tax is charged when residential properties are sold, and the new owner can choose to use a portion of those funds for seismic upgrades on the property, in lieu of paying the tax. A large number of homes, from 40 to 60 percent in the City, have been improved with some retrofit measures because of this program.

The City of Berkeley also requires owners of multi-unit, wood-frame soft-story buildings to submit an engineering report evaluating the seismic performance of their building. Buildings with seismic weaknesses are required to post this information at entrances and to notify tenants. Berkeley began this program in October 2005. In response to this mandate, 33 buildings (about 10 percent of their inventory) had elected to voluntarily seismically retrofit their buildings as of October 2008, either instead of or in addition to producing an engineering report and notifying tenants. Berkeley might seek to make retrofit mandatory for multi-unit wood-frame soft-story buildings in the near future.

CAPSS Recommended Approach

The CAPSS project recommends that the City require owners to retrofit wood-frame buildings with three or more stories and five or more units that have a soft-story.

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[26] California Seismic Safety Commission, 2006, p7.

Under this approach, building owners would be required to hire an engineer or architect to conduct a simple analysis of their building’s seismic safety. Buildings shown to have adequate seismic capacity would be required to take no further action. Owners of buildings that have a soft-story condition would be required to inform tenants, prospective buyers, insurers and lenders, and to retrofit according to a timeline and standards set by the City. The City would offer incentives to ease the burden of retrofits on building owners and would impose meaningful sanctions on owners that did not comply with the ordinance. This approach is similar to the City’s Unreinforced Masonry Building program.

Scope and Priorities

San Francisco needs to decide which multi-unit, wood-frame buildings should be covered by a city program to reduce soft-story risk. Further, it needs to decide if the program should have phases, with some buildings addressed first and others addressed later.

There are approximately 4,400 three-story wood-frame buildings with five or more residential units in San Francisco that were built before May 1973, when building codes were improved. There are approximately 2,600 more three-story buildings with four units and 3,400 more with three units. All of these buildings could potentially have soft-story weaknesses. Realistically, the City cannot effectively administer a program to address the risk in all of these buildings at once. It makes sense for the City to prioritize these buildings and to address those of greatest concern first.

Specific features of buildings indicate higher risks of damage in earthquakes (see Chapter 1). These include the following:

- Having larger openings in perimeter walls and few interior walls at the ground level;
- Being located on a corner;
- Being located mid-block with a gap between one or both adjacent buildings;
- Having wood deterioration due to rot or pest damage;
- Being located on soft soils; and
- Having three or more stories.

Other characteristics that affect how damage to a particular building would impact the broader community include the following:

- The number of residential units in the building;
- Uses of the ground floor of the building; and
- The building’s historic and architectural distinction.

CAPSS Recommended Scope and Priorities

CAPSS recommends that the City’s initial program focus on wood-frame buildings with three or more stories and five or more residential units built before May 1973. While some three-story buildings with three and four residential units may face risk similar to five unit buildings, buildings with five or more units are generally larger and each contain more residential units. The City established a reasonable precedent of focusing on buildings with five or more units in its unreinforced masonry building program. Using the five-unit cutoff restricts the City's program to a scope that will be manageable to administer. However, the vulnerability of buildings not meeting these criteria can be substantial and should be addressed in a different program.

The CAPSS project recommends that the program not be limited to those buildings with significant ground floor openings in external walls, because buildings with smaller openings in the ground floor perimeter walls could also have significant structural weaknesses due to lack of interior partitions or deteriorated materials. Instead, the City should create a simple screening protocol that an engineer or architect will follow to determine whether a building is likely to have a soft-story weakness. All owners of wood-frame buildings built after May 1973 with three or more stories and five or more units should be required to hire an engineer or architect to complete the screening protocol.

Buildings covered by the program should be addressed in order of greatest concern, based on the consequences of damage to the neighborhood, City and occupants. A Working Group should be convened by the City to develop details of how a City program will be implemented, including how to prioritize which types of buildings (e.g., corner buildings, those located on soft soils, historic buildings) should comply with a City program first.

Implementation Period

Any time line adopted by the City must balance hardships associated with deadlines with the potential for earthquakes striking San Francisco: this is a race for safety. The timeline that the City puts in place for a program must consider many factors, including the following:

- How long the City is willing to wait for the building stock to be strengthened;
- How many buildings can be processed by the program administrators within the City during a given interval; and
- How much time building owners can reasonably be given to comply with any requirements.

The City's program to require owners to retrofit unreinforced masonry buildings covered 2,000 buildings and spanned 14 years, beginning in 1992. Retrofitting wood-frame buildings would involve easier construction, cost less, and be less disruptive to residential tenants than retrofitting unreinforced masonry buildings.

CAPSS Recommended Implementation Period

The CAPSS project recommends that the program allow owners about four years to comply with retrofit requirements, dating from the time when they receive notice that their building is on the Department's list of potentially seismically deficient buildings. Owners need time to make decisions and to arrange for financing, and there are a limited number of qualified engineers and architects available to do this work.

Implementing the entire program will take longer. The first task, initiating the program, requires assigning and training specialized staff members within the Department of Building Inspection, refining the list of building owners, preparing outreach materials, adopting a minimum seismic retrofit standard and creating a screening protocol. These steps could take about one year to complete.

The next task is to notify owners that they must comply with this program and to respond to their questions and to questions raised by design professionals. The CAPSS project recommends that notices be mailed to owners divided into two or more categories, with owners of those buildings most likely to have significant impacts on the community if damaged being noticed first. Assuming that the 4,400 buildings at issue were divided into two categories and that mailing notices would require one year for each category of owners, this pace would require mailing on average 40 to 45 notices a week, and fielding the resulting questions.

This schedule suggests that, assuming the start up tasks take one year, the program could be completed in seven years.

Incentives

It makes sense for the City to encourage compliance with a program, given that there are benefits to retrofitting that accrue to the general public and not just to owners and tenants, and yet owners must bear most of the costs. Incentives for seismic retrofits could be offered to encourage voluntary retrofits or to ease the impact of mandated seismic upgrades.

Building retrofit incentives can be divided into the following categories:

- **Financial incentives:** grants, rebates, credits, loans, loan interest reductions, deferred loans, transfer tax set asides, donated and reduced-rate labor, insurance premium savings, fee waivers;
- **Policy incentives:** zoning incentives, allowing use changes, easing parking requirements, allowing increases in usable floor space, transfer of development rights, expedited processing of permit applications and loan applications, waiving property restrictions;
- **Technical assistance incentives:** advice on retrofitting, standard details, help with garnering incentives, assistance with contracting questions and motivational literature;
- **Information incentives:** Notice to prospective buyers, tenants and visitors.

Options for each of these incentive categories are discussed in depth in the companion volume containing the Documentation Appendices.

Offering multiple incentives is most effective, because no single incentive or combination of incentives would serve the interests of every building owner. Building owners range from a city resident who owns one apartment building that he or she lives in to a corporation, and these owners have different knowledge, resources and motivation. A variety of incentives would allow owners to assemble unique combinations to satisfy their particular needs.

Communities throughout the state have been required to develop programs to address the risk of unreinforced masonry buildings. Incentives have been found to be somewhat effective in encouraging seismic retrofit: eight cities with voluntary programs and economic incentives have an average retrofit rate of 20-percent of unreinforced masonry buildings, compared to a 14-percent rate for the 31 jurisdictions without incentives[27].

[27] California Seismic Safety Commission, 2006, p 8.

CAPSS Recommended Incentives

CAPSS recommends that the City put together a strong package of incentives to help building owners to retrofit and tenants to cope with the hardships presented by increased rents. The City has a vital interest in encouraging owners to retrofit their buildings. Retrofits to these buildings protect affordable housing and maintain the cultural and architectural character of San Francisco neighborhoods. By investing in earthquake mitigation through targeted incentives, the City can help to protect these community values. However, the ability to pay for retrofitting or endure disruption is not universal. Retrofitting costs would cause great hardship for some tenants and owners, especially those with limited income.

Incentives alone will not lead many owners to retrofit, which is why CAPSS recommends that owners be required to do so. However, launching a mandatory retrofit program for multi-unit wood-frame soft-story buildings will take time. Due to the urgent nature of the risk that these buildings pose, CAPSS recommends that the City offer a strong package of incentives immediately, before a mandatory program is established, and that it maintain these incentives once retrofit is mandated.

The City should consider ways to offset the cost of the incentives that it offers; possible offsets include seeking grants from the Federal Emergency Management Agency, using fines assessed on owners who fail to comply with retrofit program requirements, or forming special assessment districts.

The City could choose many paths to address the earthquake risk of multi-unit, wood-frame soft-story buildings, but not all choices will be effective in making the City safer. The next chapter describes in detail the program that the CAPSS project recommends.

CHAPTER 5: THE RECOMMENDED PROGRAM

The CAPSS project recommends that the City require owners of wood-frame buildings constructed before May 21, 1973 with three or more stories and five or more residential units with a soft-story condition to seismically retrofit them to a standard that would allow residents in most of the retrofitted buildings to remain in their homes after a large earthquake.

This chapter describes the key elements of the recommended program. Many details of how this program would be implemented would be worked out as the program moves forward, based both on community comments and on considerations of the Department of Building Inspection regarding how the program should best be administered. The CAPSS project recommendations are based on technical analysis and on discussions in public meetings. This work has been guided and reviewed by a dedicated Advisory Committee made up of community members.

It is important to emphasize that many other building types are also vulnerable to earthquake damage. The CAPSS project advises that the City address other building types and will recommend additional programs in the future.

The Mayor and Board of Supervisors should:

- **Adopt a policy statement declaring that the City and County of San Francisco desires that multi-unit, wood-frame soft-story buildings be suitable for occupancy after large earthquakes**[28]. This objective would guide the development of the minimum retrofit standard in the building code. It would allow many residents to stay in their homes and neighborhoods following an earthquake, would improve San Francisco's resilience and would protect its unique attributes. It would reduce casualties and lessen post-earthquake emergency response and shelter demands.
- **Direct the Department of Building Inspection and the Building Inspection Commission to develop code language for a retrofit standard.** This minimum retrofit standard would implement the performance objective policy statement, as it applies to multi-unit wood-frame buildings with three or more stories and five or more residential units. The standard would be used to identify seismically deficient buildings and to set the minimum requirements that must be met through retrofitting. The Department of Building Inspection should convene a panel to assist with this task. This panel should consider developing a standard

[28] This would meet Performance Objective B, described in Chapter 4. Most residents could stay in their homes until repairs are made, even though there may be damage and no working utilities. However, there would be no guarantee that all retrofitted buildings would perform in this manner. This objective represents the desired overall performance for the entire stock of retrofitted multi-unit, wood-frame soft-story buildings in San Francisco.

that accounts for building deformation during earthquakes[29] and reduces fire ignitions. The standard should not require retrofit measures that extend above the ground floor, except in unusual cases in which the Department of Building Inspection decides that this is necessary. Buildings that do not meet the defined standard would be deemed "seismically deficient."

- **Direct the Department of Building Inspection to create and maintain a list of wood-frame buildings considered potentially seismically deficient**. This list initially would include all wood-frame buildings that were constructed before May 21, 1973 that have three or more stories and five or more residential units.
- **Direct the Department of Building Inspection to develop a simple screening protocol that owners would hire an architect or engineer to complete**. This protocol would indicate whether buildings are likely to have a soft-story. It should be designed to be inexpensive to complete and should not require extensive analysis. It could be based on a modified version of the Area Demand Ratio, which is a ratio of square footage of building floors and roof to linear length of solid walls in each direction[30]. The panel convened to develop building code language for a retrofit standard could also assist in developing this screening protocol.
- **Direct the Department of Building Inspection to establish a program that requires owners to retrofit multi-unit, wood-frame soft-story buildings**. A Working Group should be convened to define details of how the program should be implemented.
- **Direct the Department of Building Inspection to notify owners of the potentially seismically deficient buildings on their list that they are required to take the following actions:**
  - Submit a form completed by an architect or engineer. First, this form would indicate whether their building meets the requirements to be included in this program (date of construction, completed retrofit work, number of units, location, etc.). For buildings that are included within the scope of the program, the architect or engineer would complete the screening protocol that identifies whether the building is likely to have a soft-story. Owners of buildings outside the scope of the program or who can demonstrate that their building does not have a soft-story would have no further action required. All others proceed to the next step.
  - Inform current and prospective tenants of the notice from the Department of Building Inspection and of the steps to be taken to comply with program requirements. Owners would update tenants annually in writing on their progress in complying with the program requirements, until they have completed the necessary actions. The Department of Building Inspection should specify the content of these letters. This information also would be

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29 The current San Francisco Building Code requires engineers to design retrofits to resist base shear force but does not require limiting building deformations, yet building deformation, a function of strength and stiffness, is more directly linked to a building's earthquake performance. Code provisions that address or are based on deformation would allow retrofits to provide the desired performance more effectively and efficiently. Deformation-based engineering standards currently exist.

30 The Area Demand Ration is proposed by Cobeen, Russell and Dolan, 2004.

recorded with the City and County Recorder's office and reported in Reports of Residential Building Records (known as 3R reports). Owners who retrofit their buildings to the minimum retrofit standard or provide evidence that their building is not seismically deficient can have these records changed.

  - Seismically retrofit their buildings. Owners can opt first to conduct a more rigorous engineering analysis of their building, which if it shows their building to have sufficient capacity to meet the retrofit standard, would mean they would not need to retrofit. If it shows their building is seismically deficient, they would then need to retrofit.

- **Direct the Department of Building Inspection to establish a program with the following timeline:**
  - The Department should divide all multi-unit, wood-frame buildings into two or more categories, as defined by the Working Group that develops implementation procedures. The number and characteristics of buildings in each category should be based on the potential consequences of earthquake damage and on the Department's capacity to administer the program.
  - Owners should have about four years from the time when the Department notifies them to complete the retrofit of seismically deficient buildings.
  - The entire program could be completed in seven years after the Department issues its first notices, depending on the Department's pace of notification and time required for start-up activities.
  - Any time extensions would depend on an appeal process that would include an opportunity for a public hearing. The appeal process would consider time extension requests from owners who claim that unique circumstances prevent them from meeting program deadlines. Circumstances might include measures to minimize disruption of ground-floor residential units and/or commercial uses or other conditions that justify according the owner additional time to complete the retrofit.
- **Direct the Department of Building Inspection to expand the current requirements in Chapter 34 of the San Francisco Building code to include the minimum retrofit standard developed for this program and to make it applicable to all wood-frame buildings with three or more stories.** The requirements in Chapter 3400 that are triggered by building expansion and change of use should be consistent with the standard developed for the buildings covered by this program.
- **Require new owners and those who subdivide buildings on the list into condominiums to comply with these requirements as part of the conversion process.** This will apply to owners who receive approval to convert buildings to condominiums after the effective date of the enacting ordinance.
- **Assure that all retrofits of historic buildings preserve the architectural character of the buildings.** Permit applications for retrofitting buildings designated as historic on a local, state or federal list should be reviewed by the City of San Francisco Planning Department and the San Francisco Historic Preservation Commission. The purpose of this review will be to protect the architectural and historic integrity of designated and contributing buildings.

- **Direct the Department of Building Inspection to remove from the list of seismically deficient buildings those buildings that comply with the program.** This includes buildings that are retrofitted or shown by owners to be outside the scope of the program or not seismically deficient. All notices on titles would be removed, and requirements for informing tenants would cease.
- **Direct the relevant City departments to offer incentives to building owners and tenants.** The program described in this report will take time to launch, but the urgent nature of the risk described in this report should be addressed immediately. The following incentives should be offered as soon as possible to encourage voluntary retrofits, and should continue once a mandatory program is established. These incentives will make compliance with the program less burdensome for owners and tenants. These incentives also should be offered to owners of seismically deficient wood-frame soft-story buildings outside the mandatory scope of this program.
    - The Department of Building Inspection should define criteria for "qualified seismic retrofits" that are eligible for the incentives listed below. Qualified retrofits would include retrofit measures directly attributable and necessary to meet the City's minimum retrofit standard, and could include measures to mitigate against earthquake-induced ground failure, achieve higher performance levels, repair and replace deteriorated materials, or reduce earthquake-caused fire ignitions.
    - The Department of Building Inspection, the Planning Department, the Historic Preservation Commission, and all other City departments that review building plans in this program should expedite the review of retrofit permit applications.
    - All City departments should rebate building permit fees upon successful completion of the measures required to meet the minimum retrofit standard.
    - The City should endeavor to establish a City lending program to help owners finance retrofit projects and to cover costs incurred by tenants. This program should use existing bond capacity that is available because of the incomplete use of General Obligation bonds authorized for retrofitting unreinforced masonry buildings. The lending program should be designed to be simple to use and attractive to building owners, and the conditions that made use of these funds unattractive to owners of unreinforced masonry buildings should be amended. These funds should be available for use on all qualified seismic retrofits and not be limited to the types of buildings that are mandated to retrofit by this program. The program could include grants to offset rent increases in cases of hardship. Establishment of this program should be placed before voters at the earliest opportunity.
    - The Department of Planning should provide incentives to encourage and facilitate retrofitting, such as waiving parking requirements, allowing use changes, or allowing increased usable floor space, in return for completing qualified retrofits in accordance with this program.
    - The San Francisco Rent Ordinance Section 37.7 should be amended to allow owners who voluntarily undertake qualified seismic retrofits to pass through to tenants 100-percent of the cost of qualified seismic retrofits over a twenty-year period. The details of how this would be implemented should be

developed through discussions between owners and tenants to ensure that an evenhanded process is established.

- The San Francisco Residential Rent Stabilization and Arbitration Board should expedite action on applications from owners to pass through the cost of qualified seismic retrofits. The Board should also assist tenants and owners in resolving temporary relocation issues caused by the need to carry out construction in areas used for parking, storage and residential occupancy.
- The Assessor should advertise and facilitate owners' use of the provisions to avoid increased assessments due to expenditures on qualified seismic retrofits, as provided by Article 13A, Section 2(c)(4) of the California Constitution.
- The City should promote the recently-authorized use of one-third of the real estate transfer tax for seismic retrofitting purposes.
- The Department of Building Inspection should create the position of Earthquake Programs Facilitator. The Facilitator would advise and assist building owners and others in understanding the program, its requirements and its procedures. This office would support permit applicants and retrofit projects by preparing literature and offering training to owners, tenants, engineers, contractors and realtors about the program, compliance procedures and requirements. The facilitator would work with other City departments to facilitate retrofit projects.
- The Board of Supervisors should adopt language that prevents the City from imposing additional retrofit requirements on buildings for 15 years following the notice of completion of the measures to comply with this program.
- The Department of Building Inspection should endeavor to conduct demonstration projects with owners of representative buildings to publicize the program and build the capacity of owners, engineers and architects to carry out the program.
- The Department of Emergency Management should seek Federal Emergency Management Agency funds for the Department of Building Inspection to cover the cost of waiving fees, creating the position of Earthquake Programs Facilitator, conducting demonstration projects, and providing services such as training programs for owners and design professionals, as well as to facilitate building retrofit.
- The Mayor should contact members of the California Legislature and the United States Congress to request that economic stimulus funds be spent in San Francisco on the retrofit of seismically deficient residential buildings and that the tax codes be revised to offer an income tax credit for and accelerated depreciation of the cost of qualified seismic retrofit projects.

- **Direct the City Planning Code to be changed to prevent owners from benefitting from policies guiding the replacement of earthquake-damaged buildings if they do not comply with this program.** The City Planning Code should be changed to prohibit the replacement of a damaged apartment building with condominiums, or rebuilding non-conforming conditions, if the owner has been notified by the Department of Building Inspection that his/her building is on the list of buildings considered to be potentially seismically deficient and if the owner has failed to comply with the program schedule.

- **Request the San Francisco Chapter of the American Institute of Architects to draft retrofit guidelines.** These guidelines should be designed to help owners of multi-unit, wood-frame soft-story buildings to protect their architectural character when undergoing retrofit.
- **Require the Department of Building Inspection to monitor the program, collect data on all retrofitting, and recommend program changes.** The Department of Building Inspection should document progress, collect data, publicize lessons learned, and report annually to the Mayor and Board of Supervisors on progress, problems and policy changes needed to improve effectiveness and reduce the cost of compliance. It should also track seismic retrofits for all building types in its records system.
- **Grant the Department of Building Inspection powers to enforce this program.** These powers should include imposing graduated fines on owners who do not comply with program requirements according to the specified timeline and requiring the posting of placards describing the building's potentially hazardous condition at all entrances. The Department should be encouraged to use its receivership authority under existing law to complete the necessary work when owners do not comply.
- **Direct the Department of Building Inspection to clarify and publicize its procedures for enforcing compliance with this program.**

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APPLIED TECHNOLOGY COUNCIL: AN OVERVIEW

The Applied Technology Council (ATC) is a nonprofit corporation founded to protect life and property through the advancement of science and engineering technology. With a focus on seismic engineering, and a growing involvement in wind and coastal engineering, ATC's mission is to develop state-of-the-art, user-friendly resources and engineering applications to mitigate the effects of natural and other hazards on the built environment.

ATC fulfills a unique role in funded information transfer by developing nonproprietary consensus opinions on structural engineering issues. ATC also identifies and encourages needed research and disseminates its technological developments through guidelines and manuals, seminars, workshops, forums, and electronic media, including its web site (www.ATCouncil.org) and other emerging technologies.

Key Publications

Since its inception in the early 1970s, the Applied Technology Council has developed numerous, highly respected, award-winning, technical reports that have dramatically influenced structural engineering practice. Of the more than 100 major publications offered by ATC and its Joint Venture partners, the following have had exceptional influence on earthquake engineering practice:

ATC-3-06, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, funded by the National Science Foundation (NSF) and the National Bureau of Standards and completed in 1978, provides the technical basis for seismic provisions in the current *International Building Code* and other model U. S. seismic codes.

ATC-14, *Evaluating the Seismic Resistance of Existing Buildings*, funded by NSF and completed in 1987, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 31, *Seismic Evaluation of Existing Buildings* (the national standard for seismic evaluation of buildings).

ATC-20, *Procedures for Postearthquake Safety Evaluation of Buildings*, funded by the California Office of Emergency Services and the California Office of Statewide Health Planning and Development, is the *de facto* national standard for determining if buildings can be safely occupied after damaging earthquakes. The document has been used to evaluate tens of thousands of buildings since its introduction two weeks before the 1989 Loma Prieta earthquake in Northern California.

ATC-40, *Seismic Evaluation and Retrofit of Concrete Buildings,* funded by the California Seismic Safety Commission and completed in 1996, won the Western States Seismic Policy Council' s "Overall Excellence and New Technology Award" in 1997.

FEMA 273, *NEHRP Guidelines for the Seismic Rehabilitation of Existing Buildings,* funded by the Federal Emergency Management Agency (FEMA) and completed in 1997 under the ATC-33 Project, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 41, *Seismic Rehabilitation of Existing Buildings* (the national standard for seismic rehabilitation of buildings).

FEMA 306, *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual*, **FEMA 307,** *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources*, and **FEMA 308**, *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings*, funded by FEMA and completed in 1998 under the ATC-43 Project, provide nationally applicable consensus guidelines for the evaluation and repair of concrete and masonry wall buildings damaged by earthquakes.

FEMA 352, *Recommended Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings,* funded by FEMA and developed by the SAC Joint Venture, a partnership of the Structural Engineers Association of California, the Applied Technology Council, and California Universities for Research in Earthquake Engineering, provides nationally applicable consensus guidelines for the evaluation and repair of welded steel moment frame buildings damaged by earthquakes.

FEMA P646, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*, funded by FEMA and completed in 2008 under the ATC-64 Project, provides state-of-the-art guidance for designing, locating and sizing structures to resist the effects of tsunamis and thereby provide safe evacuation refuge in affected coastal areas.

Organization

With offices in California, Delaware, and Virginia, ATC's corporate personnel include an executive director, senior-level project managers and administrators, and technical and administrative support staff. The organization is guided by a distinguished Board of Directors comprised of representatives appointed by the American Society of Civil Engineers, the National Council of Structural Engineers Associations, the Structural Engineers Association of California, the Structural Engineers Association of New York, the Western Council of Structural Engineers Associations, and four at-large representatives.

Projects are performed by a wide range of highly qualified consulting specialists from professional practice, academia, and research—a unique approach that enables ATC to assemble the nation's leading specialists to solve technical problems in structural engineering.

Funding for ATC projects is obtained through government agencies and from the private sector in the form of tax-deductible contributions.