# Policy & Services Committee
# Staff Report

**From: Chantal Gaines, Deputy City Manager**

**Meeting Date: August 8, 2023**

**TITLE**

Receive and Discuss Seismic Risk Assessment Study and Seismic Hazards Identification Ordinance Update

**RECOMMENDATION**

Staff recommend the Policy and Services Committee receive a report from staff on the 2016 Seismic Risk Assessment Study and discuss the Council-directed update to the Seismic Hazards Identification Ordinance. No action is recommended at this time.

**OVERVIEW**

This report updates the Policy and Services Committee on progress on the Seismic Hazards Ordinance update project; no Policy and Services Committee action is required or requested at this time. Staff recommends that the Policy and Services Committee review the Seismic Risk Assessment Study prepared by Rutherford + Chekene (R+C) (Attachment A), structural engineers. During the discussion, staff requests Committee members' input regarding the proposed next steps.

The Council identified the update of the seismic ordinance as a part of the Community Health and Safety Priority in January 2023. This item is further nested under "Invest in reliable safety infrastructure and systems."[1]

**EXECUTIVE SUMMARY**

As the Planning and Development Services Department (PDS) prepares to draft amendments and updates to the Palo Alto Municipal Code for the Regulation of Seismically Vulnerable Buildings, staff seeks to familiarize the Policy and Services Committee with the topic, resources needed, and gain high level input on the proposed action plan.

The Seismic Risk Assessment was prepared in 2016 and made available to the City Council in 2017. Since that time, the composition of nearly the entire Council has changed significantly. Therefore, staff desired to reintroduce the topic and report contents to the Policy and Services Committee before undertaking outreach, pursuing consultants, and other work associated with prior Council direction.

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[1] https://medium.com/paloaltoconnect/council-adopts-extensive-objectives-building-upon-selection-of-2023-priorities-13413012919e

This report begins with the background section, giving a brief history of the project. That is followed by the policy implications, then a discussion of resources and draft work plan, and environmental review.

That is followed by a summary of the Seismic Risk Assessment Study. This summary largely mirrors an informational report submitted to Council in April 2017. Lastly, the full study is provided as an attachment. Additional information can be found in additional prior reports linked throughout the report.

Staff wishes to note that the City's contract with the consultant team that prepared the studies has long since concluded. Staff regret that the consultant team is not available for preparation of this staff report or nor during the Committee's discussion.

## BACKGROUND

### *Concise Project History*

The effort to update the City's seismic ordinance began with City Council direction in 2014. At that time, following the 6.0 magnitude earthquake in August 2014 in the Napa Valley and the Office of Emergency Service's Threats and Hazard Identification and Risk Assessment Report, the Council directed staff to identify and prioritize buildings that pose a potential seismic hazard in Palo Alto; review 'best practices' used by other communities for addressing retrofit of seismically vulnerable buildings; and review current and pending State legislation addressing these building types.

A competitive bidding process was conducted and Rutherford + Chekene was selected to perform a comprehensive assessment of the expected performance of the City's building stock in potential earthquakes, including a community engagement effort to help identify resiliency goals and associated mitigation policies and programs. The study was prepared and provided to Council as an informational report on April 16, 2017.

On November 13, 2017, via a consent item, the Council directed staff to "Return to Policy and Services Committee With Amendments to the Municipal Code for the Regulation of Seismic Vulnerable Buildings." To accomplish this directive, staff will engage a consultant to assist with designing an updates seismic hazards identification and mitigation program. Staff will then bring forward proposed legislative changes (draft ordinance) to Council for consideration and ultimately adoption. Finally, once adopted staff will implement the policy (adopted ordinance) and associated seismic hazards identification program. Follow-up to this direction was subsequently hampered by limited resources, staff turnover, and other priorities.

In fiscal years 2022-2023 and 2023-2024, the Council appropriated funding to the Planning and Development Services Department to carry out the update of the Palo Alto Municipal Code. The funds are designated to hire a consultant to aid in the development of the updated ordinance. Appropriated in fiscal years 2022-2023 and 2023-2024, the amount available totals $225,000. Staff will carry out a

competitive procurement process, expecting to have a consultant team on board and ready to begin work by January 2024.

***Detailed Project History***

On September 15, 2014, the City Council directed staff to work with the Policy and Services Committee to address the following:

A. Identification and prioritization of buildings that pose a potential hazard in an earthquake, including soft-story buildings and other types of construction
B. Review of "best practices" from other cities regarding prioritization of various seismically vulnerable buildings, including retrofit incentives and requirements
C. Review of current or pending State legislation related to soft-story buildings and other structurally deficient buildings

Two events precipitated the Council's direction: (1) the 6.0 magnitude earthquake on August 24, 2014, in Napa Valley and (2) the City Council's review of the Office of Emergency Service's Threats and Hazard Identification and Risk Assessment report on September 15, 2014, which identified over 130 seismically vulnerable buildings.

***Palo Alto Seismic Hazards Identification program***

In 1986, the City Council adopted the Seismic Hazards Identification Program codified at PAMC Section 16.42.[2] This ordinance established a mandatory evaluation and reporting program and created incentives for property owners primarily in the Downtown area to voluntarily upgrade their structurally deficient buildings. Three categories of buildings were identified, including:

1. Category I Buildings: Buildings constructed of unreinforced masonry (except for those smaller than 1,900 square feet with six (6) or fewer occupants). These buildings are located in the Downtown Commercial area.
2. Category II Buildings: Buildings constructed prior to January 1, 1935, containing one hundred (100) or more occupants.
3. Category III Buildings: Buildings constructed prior to August 1, 1976, containing three hundred (300) or more occupants.

The categories used in 1986 were developed by a citizens' committee, reviewed by staff and the Policy and Services Committee, and adopted by the City Council. These categories were created to record known URM buildings and other potentially structurally deficient buildings with relatively high numbers of occupants.

This program identified 89 buildings and was successful in two significant ways. One hundred percent

[2] This section of the Palo Alto Municipal Code is available here: https://codelibrary.amlegal.com/codes/paloalto/latest/paloalto_ca/0-0-0-74168

(100%) of the property owners complied with the ordinance and submitted engineering reports detailing structural deficiencies and recommendations to strengthen structures to alleviate the threat of collapse.

Further, as of 2017, approximately 74 percent (74%), or 66 buildings, were strengthened, demolished, or proposed to be demolished. An updated status of these buildings is being prepared in anticipation of releasing a request for proposals (RFP) for the consultant team for this phase of the project.

Part of this success may be attributed to incentives that allowed upfront engineering report costs be applied toward permit fees and the ability for property owners in the Downtown Commercial (CD) district to add up to 2,500 square feet of new floor area, or twenty-five percent (25%) of the existing building area, whichever is greater, to the site without having to provide additional parking. This floor area bonus could be used onsite or transferred to another owner or property in the Downtown Commercial district. Approximately 21 property owners took advantage of this incentive.

More recently, the City Council adopted an ordinance updating PAMC 18.18 modifying the seismic incentive so that parking must now be provided if an owner seeks to add 2,500 square feet or 25% of the total building area in the CD District.

Despite its successes, some buildings identified from that original inventory remain vulnerable. Further, there are other building types in the City that were not surveyed prior to adoption of the 1986 ordinance. For example, problems with soft-story wood-frame construction were documented following the 1994 Northridge Earthquake, which resulted in changes to construction industry standards a few years later.

In 2003, the Collaborative for Disaster Mitigation at San Jose State University completed an "Inventory of Soft-First Story Multi-Family Dwellings in Santa Clara County." According to the report, the City of Palo Alto had 130 soft story multi-family buildings including 1,263 residential units housing 3,158 occupants.

Other construction types of concern that were not surveyed in 1986 include non-ductile concrete buildings, older steel moment frame buildings, and older concrete tilt-up buildings, in addition to soft story wood-frame construction.

The City's existing ordinance requires annual reporting to the City Council on the status of the program. This reporting appears to have ended in 2004 for unknown reasons. The draft ordinance may consider reviving or adjusting the reporting requirement.

***Seismic Risk Assessment Study***

On December 9, 2014, the Policy and Services Committee of the Palo Alto City Council recommended the City Council authorize an RFP to develop information for use in updating the City's Seismic Hazards Identification Program (Ordinance 3666). The City Council approved the recommendation, and staff prepared an RFP.

A consulting team led by Rutherford + Chekene was selected to:

A. Summarize relevant state and local seismic mitigation legislation
B. Obtain detailed information on Palo Alto's existing building stock
C. Develop conceptual retrofits for vulnerable building types
D. Make loss estimates of expected damage to current and retrofitted building
E. Work with a City advisory group to develop policy recommendations for consideration by the Council.

A stakeholder Advisory Group was convened and was an essential element in discussing earthquake risks in Palo Alto's existing building stock prepared by the consultant team and in reviewing policy alternatives. Members included people with a range of relevant expertise and interests, including interested citizens, earthquake risk and engineering experts, local developers and owners, and representatives of various community groups. City departments also participated in the Advisory Group, including Building, Planning, Fire, Office of Emergency Services, and Public Works. See Attachment C for a list of Advisory Group members.

A summary of the R+C report is provided after the "Environmental Review" section of this report.

**ANALYSIS**

Overall, an updated seismic ordinance aims to enhance the resilience of Palo Alto when seismic activity occurs. Decreasing the number of buildings that sustain significant damage from an earthquake and limiting the loss of life or injury that may occur are two ways the city can be more resilient. With more structures suitable for occupancy after an earthquake, the City and its residents can more quickly recover from the event. Further, with more multifamily structures habitable, fewer residents will be displaced after an earthquake.

The desire to increase resilience, speed recovery, and limit the loss of life and limit property damage must be weighed against the risk earthquakes pose and balanced with the cost of retrofitting buildings. The R+C recommendations aim to balance resilience and recovery with risk and cost.

As the report further elaborates, different communities have balanced these objectives in a variety of ways. Ranging from developing completely voluntary retrofitting programs to mandatory retrofitting programs where the retrofits must occur within a fixed timeline.

Likewise, other California communities have created a range of incentives and/or financing options to help property owners retrofit more cost effectively. These range from local development standards or incentives (such as permit fee reduction, additional development rights, etc.) to tailored financing programs.

As Council seeks to create safer buildings, especially dwelling units, this goal must be balanced with the real costs property owners will incur to retrofit their buildings. Without appropriate incentives, available financing, or other policy mechanisms, the costs of retrofits may be passed on to tenants in the form of increased rents. Even if these financing tools are available additional policies may be considered to limit the impact retrofitting may have on tenant rents.

***Proposed Action Steps***

This section describes actions staff anticipate, pending Committee discussion and further Council direction. In addition, this section notes decision points when Council direction will be needed to advance the project. The following list outlines a high-level action plan, with associated sequencing of steps. Of note, there is some overlap between action steps. Staff look forward to the Policy and Services Committee's suggestions on the proposed action steps.

- ***Develop and release a Request for Proposals for a consultant/consultant team (consultant):*** During the study period of this effort, R+C provided significant technical expertise and additional project management skills and resources that led to a very thorough report. In addition to the study, the consultant assisted with preparing for and facilitating the Advisory Group. Based on this experience, staff requested additional resources for a new contractor that will be identified through a competitive bidding process.

  Based on the volume of procurements from PDS and other departments that require Purchasing assistance, staff hope to release the RFP and receive initial responses back by the end of 2023. This would allow proposal review and any interviews to be conducted in late 2023/early 2024. Following selection of the consultant, staff will bring a contract forward to City Council for consideration and approval.

- ***Refresh aspects of the Seismic Risk Assessment study as needed.*** The study remains very relevant and, due to its thorough nature, comprehensive. There may be limited need for the selected consultant to refresh certain aspects of the report.

  These updates may include assessing if the building code updates in the past two code update cycles have any bearing on this project. In addition, we want to assess if enhanced seismic knowledge from the past several years (often gained after an earthquake) indicates a need to expand or otherwise adjust the building categories considered for inclusion in the seismic program.

  Lastly, given the rapid and steep increase in construction costs due to materials and labor cost increases, refreshing the cost estimates for 2023 dollars may be prudent. The differences in actual costs shape the incentives and/or financing options considered by the Council.

- ***Refresh the review of other cities policies, programs, and progress since 2017***. The report reviewed the seismic programs undertaken by several California jurisdictions. Programs were at various stages of implementation at the time the report was written. The consultant team may be asked to review the progress and/or changes to the programs that have occurred in the intervening years. In addition, if a notable new program or policy has been adopted and implemented by a California jurisdiction, the consultant will review and summarize that program.

Lastly, if any changes to California state law have occurred that impact the City of Palo Alto's ordinance, the consultant will be asked to summarize the law(s) and their impact on this project.

- ***Establish and execute a community engagement strategy***. The consultants, along with City staff, will re-establish the Advisory Group to assist in discussing the project and providing feedback on the ordinance as it is drafted for Council consideration. The Advisory Group will continue to include a wide range of stakeholders throughout Palo Alto and including partner City departments. With clear tasks, scope, and meeting schedule along with skilled facilitation, this group can once again provide valuable insight to staff and policy makers to shape a policy that can be successfully implemented.

- ***Return to Council and/or Policy and Services Committee for policy direction based on preliminary recommendations and policy framework.*** As the framework for a policy is proposed by staff and the consultant, with assistance from the Advisory Group, staff will return to Council for direction. This milestone will allow the Council to digest the policy options, consider consequences of each option, and consider staff's recommended policy path. This recommendation will include potential incentives and/or financing tools as well as a draft implementation plan.

  Staff, with the consultant team, plan to present a framework for the policy with preliminary recommendations. The framework and recommendations will build on the options presented in the 2016 R+C Risk Assessment. The recommendations will have greater detail and resolution to questions raised in the study.

- ***Draft ordinance in accordance with Council direction.*** Once Council provides clear direction based on the policy framework (described immediately above), staff and the consultant team will draft the ordinance and return to Council for adoption. Depending on the nature of the ordinance and overall program, a recommendation from the Planning and Transportation Commission may be needed. This would occur prior to Council consideration of the draft ordinance.

- ***Council adoption of the ordinance and appropriation of implementation funds as needed.*** Council will consider, potentially amend, and ultimately adopt the ordinance. At the same time, staff would bring forward an implementation plan and a request for additional resources for the plan.

  Additional resources might include specific expertise in the plan review team of PDS, need for outreach and promotion of the new policy, new or augmented technology, or additional needs to successfully implement the program. Resources needs will also vary greatly depending on the overall design of the program. For example, a mandatory retrofit program with a fixed timeline may need greater resources than a voluntary retrofit program.

**RESOURCE IMPACT**

In fiscal years 2022-2023 and 2023-2024, the Council appropriated funding to the Planning and Development Services Department to carry out the update of the Palo Alto Municipal Code. The funds are designated to hire a consultant to aid in the development of the updated ordinance. Appropriated in fiscal years 2022-2023 and 2023-2024, the amount available totals $225,000. Staff will carry out a competitive procurement process, expecting to have a consultant team on board and ready to begin work in January 2024.

In addition, managers and leaders within PDS will need to dedicate significant time to the project. This includes the Chief Building Official, the Assistant Chief Building Official, and a Management Specialist. Further, partner departments, such as the Office of Emergency Services, the Fire Department, and others may be requested to participate in the Advisory Group, review the draft ordinance, and assist with implementation to the extent the adopted program requires deployment of their skills and is within the department's purview.

**ENVIRONMENTAL REVIEW**

The preparation of the Seismic Risk Assessment Study is exempt from environmental review under the California Environmental Quality Act (CEQA) Guidelines Section 15306 (Information collection leading to an action which a public agency has not yet approved, adopted, or funded).

**SEISMIC RISK ASSESSMENT STUDY**

**This section summarizes the Seismic Risk Assessment Study. The full study is provided as an Attachment to this report. This summary provides a high-level overview. Readers seeking deeper knowledge and understanding may review the accompanying section of the full study.**

**This section repeats, nearly verbatim, the staff report published on April 16, 2017 and again in November 2017. The information is repeated here for the benefit of Council members and Committee members as a refresher or introduction to the study and report's original publication. In addition, the information is repeated here to help inform the public to aid their participation in the Committee discussion and/or the project overall.**

The risk assessment carried out by R+C included a series of task reports. They have been combined into one composite report as Attachment A and include surveys of state and local seismic policies and practices, an inventory of buildings in Palo Alto, a summary of vulnerable building categories, conceptual seismic retrofitting of representative vulnerable buildings, loss estimates for the current condition of the building stock and if buildings are retrofit, a review of past seismic retrofits in Palo Alto from selected City records, and a discussion of additional recommended program features for an improved seismic risk mitigation program.

Table 1 summarizes the outcome of the seismic risk assessment and includes the Advisory Group discussions. The table is organized around eight vulnerable building categories or building types. Categories I, II and III encompass the identified vulnerable buildings for the 1986 ordinance and are primarily located in the downtown commercial district. Categories IV through VIII include additional

buildings at risk, as identified in the Seismic Risk Assessment Study; these buildings are located throughout the City.

***Survey of State and Local Seismic Policies***

The risk assessment study includes two reports that address (1) a detailed review of the seismic risk management policy context within the State of California including relevant State legislation, and (2) the status of local seismic safety and mitigation programs. Development of the reports included searches of legislative data bases, search and review of published and online reports and materials, phone interviews with community leaders as well as local and State government staff, and development of insights from the consulting team based on their experiences in this arena. The two reports were discussed at Advisory Group meetings and helped inform the development of potential seismic risk management policies relevant to Palo Alto.

***State Level Policy Review***

The report on State level risk mitigation policies provides review of relevant historic and pending (in 2017) State legislation related to seismic risk mitigation of vulnerable buildings. High level legislative findings from the report include the following:

A. Palo Alto is affected by numerous relevant California existing laws and regulations dating from the 1930s through the present. These laws regulate many aspects of Palo Alto's built environment, including certain classes of building uses such as hospitals, public schools, and essential facilities; setting code minimums for new construction; and mandating land use planning and real estate disclosure measures for natural hazards including earthquakes. Unreinforced masonry (URM) is at present the only structural system type for which the State requires local jurisdictions to have a program.
B. If it so chooses, Palo Alto has wide authority to expand or strengthen its approaches to seismic mitigation. The power to do more about earthquake vulnerabilities is primarily in the hands of the local jurisdictions that have significant discretion in the kinds of policies they can adopt.
C. Palo Alto has many additional actions it can take to make sure it is complying and taking greatest possible advantage of State level regulations and opportunities.

Based on what state laws allow and, in some cases, recommend, policy directions Palo Alto could pursue going forward include the following:

**Table 1:** Summary of Recommended Policy Directions from the Seismic Risk Management Program Advisory Group

| Category | Approx. Number | Building Type | Date of Construction | Occupants | Evaluation Report | Voluntary, Triggered, or Mandatory Retrofit[1] | Deadlines for Evaluation Report and Retrofit Construction (years)[2] | Disclosure | Potential Incentives |
|---|---|---|---|---|---|---|---|---|---|
| **Current Program (Potential Revision in *Italics*)** | | | | | | | | | |
| I | 10 | Un-reinforced masonry | N/A | Over 6 (and over 1,900 sf) | Required | *Mandatory* | Report: Expired<br>Construction: *2-4* | *Website listing and tenant notification* | *Fee waiver, expedited permitting, FAR bonus/ transfer of development rights (TDR)* |
| II | 4 | Any | Before 1/1/35 | Over 100 | Required | Voluntary *or Triggered* | Report: Expired<br>Construction<br>• Voluntary: Not required<br>• *Triggered: At sale or renovation* | | |
| III | 9 | Any | Before 8/1/76 | Over 300 | Required | Voluntary *or Triggered* | | | |
| **Expanded Program** | | | | | | | | | |
| IV | 294 | Soft-story wood frame | Before 1977 | Any | Required | Triggered or Mandatory | Report: 2-4<br>Construction<br>• Triggered: At sale or renovation • Mandatory: 4-6 | Same as above | Fee waiver, expedited permitting, TDR, parking exemptions, permission to add units |
| V | 99 | Tilt-up | Before 1998 | Any | Required | Triggered or Mandatory | Report: 2-4<br>Construction<br>• Triggered: At sale or renovation • Mandatory: 4-6 | Same as above | Same as Categories I, II and III |
| VI | 37 | Soft-story concrete | Before 1977 | Any | Required | Voluntary, Triggered or Mandatory | Report: 2-4<br>Construction<br>• Voluntary: Not required<br>• Triggered: At sale or renovation • Mandatory: 6-8 | Same as above | Same as Categories I, II and III |
| VII | 35 | Steel moment frame | Before 1998 | Any | Required | Voluntary, Triggered or Mandatory | | | |
| VIII | TBD | Other older non-ductile concrete | Before 1977 | Any | Not rec. at this time | Not recommended at this time | Report: N/A<br>Construction: NA | N/A | N/A |

[1]Voluntary: Retrofit is voluntary.
Triggered: Retrofit is triggered when the building is sold or undergoes substantial renovation.
Mandatory: Retrofit is required per a fixed timeline.

[2]Deadlines provide a potential range. Timelines would vary depending on tiers or priority groupings of different subcategories.

**Figure 1:** Category IV, Wood-frame Soft Story Building built before 1977 Earthquake Damage


**Figure 2:** Category I, Unreinforced Masonry Building Earthquake Damage

**Figure 3:** Category I, Unreinforced Masonry Building Earthquake Damage

A. Implement measures to increase the effectiveness of its current program, for instance by offering additional or larger incentives or devoting more resources to program visibility and implementation
B. Expand the City's current voluntary seismic mitigation programs to address additional building types, uses, or sizes
C. Add mandatory screening or evaluation measures for one or more vulnerable building types such as soft-story wood frame or concrete buildings
D. Upgrade the City's current voluntary URM program to make retrofitting mandatory
E. Create a program that mandates seismic retrofits for one or more additional (non-URM) vulnerable building types
F. Craft a program that combines any or all of the above measures. Local precedents for all of these types of approaches exist
G. Continue the status quo current program

***Local Program Best Practice Assessment***

The local program best practices assessment report reviews current practices among local jurisdictions and agencies that require seismic retrofitting. The report summarizes what has been done legislatively and programmatically to increase awareness, assess, and motivate mitigation of seismically vulnerable buildings.

Palo Alto is currently laying a solid foundation for future program development through this study. Through this study, the City has invested in new inventory and risk information as well as community outreach and internal staff discussions. In doing so, it is joining a group of leading California coastal jurisdictions such as Berkeley, Oakland, San Francisco and Los Angeles that have recently stepped up their earthquake risk reduction efforts. San Leandro and Fremont have also had policies in place for over a decade. While there is much learning and information sharing going on, each jurisdiction has developed their own customized policy package. There is no single best model that Palo Alto can straightforwardly adopt. Existing local approaches differ widely in the following ways:

A. Policy mechanisms used to achieve progress
B. Scope of targeted building types or uses addressed
C. Prioritization for retrofit among vulnerable structures and compliance timeframes
D. Types of incentives offered to property owners
E. Disclosure measures used to increase public awareness

*Policy Mechanisms*

The policy mechanisms being used by other jurisdictions range from inventory only with no subsequent requirements to mandatory retrofit completion in under five years. In between are more gradual approaches such as voluntary retrofit advocacy, incentives, provisions that make building deficiencies more visible to the public (disclosure measures), and mandatory screening and evaluation requirements. An important policy decision is whether any mandated actions are implemented on a fixed timeline or triggered at sale or at some renovation cost threshold.

*Scope of targeted building types and characteristics*

The most commonly addressed building type is unreinforced masonry (URM) construction due to state law SB 547, passed in 1986. Over half of URM building programs in the state require mandatory retrofit, often but not always, with a time frame on the order of ten to twenty years. By 2006, seventy percent of all identified URM buildings statewide were either demolished or retrofitted. Retrofit rates on average were three times higher in jurisdictions with mandatory retrofit compared to voluntary programs. Jurisdictions used a wide variety of both financial and policy incentives to assist URM building owners. Some voluntary URM building programs coupled with incentives, including Palo Alto's, have achieved similar rates of success to mandatory programs.

More recent programs have focused on soft-story wood frame multi-family residential buildings, including ten Bay Area jurisdictions and, most recently, Los Angeles as of 2015. Soft-story wood frame building programs range in requirements from notification only to mandatory retrofit. Several jurisdictions have innovatively used intermediate mandatory screening and evaluation phases to further assess risk exposure and determine the final set of buildings that will be affected by retrofit requirements. Soft-story wood frame programs have largely been supported in the local community. Compliance timeframes in soft-story wood frame programs tend to be short, on the order of two to seven years.

A comparatively small number of Southern California jurisdictions have acted to address older concrete buildings, including Los Angeles, Burbank, Santa Monica, and Long Beach. Non-ductile concrete frame and tilt-up concrete structures, in particular, are known to pose serious risks. Programs aimed at older concrete buildings range from voluntary guidelines to mandatory evaluation and full retrofit requirements. Timeframes on mandatory retrofit of older concrete buildings vary greatly, from years to decades. Information about the implementation and outcomes of these few programs is very limited.

*Incentives*

To complement program compliance requirements, jurisdictions can offer either financial or policy oriented incentives. Financial incentives in increasing order of cost and implementation difficulty include: waivers or reductions of building department fees, pass through of retrofit costs to tenants (in jurisdictions with rent control), property-assessed financing loads, subsidized or special term loans, real estate transfer tax rebates, special district or historic designation tax reductions, tax credits, grants, and general obligation bonds.

Program incentives, in order of increasing difficulty, include: exemption from future retrofit requirements, expedited reviews, exemption or relief from standards or non-conforming conditions, condominium conversion assistance, technical assistance for retrofitting, zoning incentives, transfer of development rights, and density or intensity bonus such as a floor area or floor area ratio bonus. Jurisdictions vary widely in the extent and type of incentives offered, and many offer a number of different types of incentives.

*Disclosure Measures*

Public disclosure provides a powerful mechanism for influencing the opinions and actions of owners, renters, and buyers, particularly in programs without mandatory retrofitting requirements. Officially publicizing a city's concerns about deficiencies of a specific building type could, for instance, change public opinion about the resale or rental value of listed properties, an owner's eligibility for refinancing or future loan terms, or the cost of purchasing property and earthquake insurance.

Jurisdictions have used a variety of techniques to motivate attention to seismic risk concerns.

Disclosure measures include the following:

A. Mandatory disclosure at time of sale: Sellers of property are required to disclose features that could relate to earthquake performance.
B. Recorded notice on deed: Jurisdictions can record on the property title or deed, the fact that the building is subject to additional requirements related to its seismic vulnerability status.
C. Public listing of affected properties: Jurisdictions that operate web sites to describe their programs can feature a full list of property addresses and the compliance status of the property. Generally, owner names are not listed.
D. External signage: California law requires signage on all URM buildings. Similar signage has been required since 2007 on soft-story wood frame buildings in the City of Berkeley and non-complying soft-story wood frame buildings in San Francisco.
E. Tenant notification: Owners are required to present straightforward, standardized information about the listed status of the property.
F. Earthquake performance rating systems: Owners can be either encouraged or required to have their building rated on a standardized scale that classifies expected performance in an earthquake. In 2015, the City of Los Angeles launched a voluntary effort to encourage owners to rate the properties using the US Resiliency Council's rating system and pledged to rate its own public buildings. For more information about the US Resiliency Council, see their website at <http://www.usrc.org/>.

***Palo Alto Options***

Based on the review of state and other jurisdiction policies, alternative program options for Palo Alto were identified:

1. Status Quo: In this option, the existing ordinance with its mandatory evaluation, voluntary retrofit approach remains in place without changes. Floor area ratio bonuses are (were) available and could continue to be offered.
2. Increase Number of Building Types Regulated, but Retrofit Remains Voluntary: Additional categories of structures are added to the mandatory evaluation requirements beyond those of the current ordinance. These could include any or all of the building types discussed above, potentially also using additional location, use, or occupancy criteria.
3. Increase Number of Building Types Regulated with Additional Disclosure Measures Incorporated: This option would be similar to Option 2, but with increased use of disclosure

measures such as prominently posting the building list on the City website, notifying tenants, requiring signage, and/or recording notice on the property title.

4. Increase Number of Building Types Regulated, Some Building Types Have Voluntary Retrofit and a Few Building Types Have Mandatory Retrofit, with Enforcement by a *Trigger Threshold*: This option builds on Option 3, but retrofitting would be required for some building types at whenever future time a building is sold or undergoes substantial renovation above a set threshold.
5. Increase Number of Building Types Regulated, Retrofits for Some Categories are Voluntary and a Few Categories are Mandatory, with Enforcement by a *Fixed Timeline*: This option would be similar to Option 4, but retrofitting is required according to a fixed timeline. Timelines and enforcement emphasis could vary depending on tiers or priority groupings to motivate prompt action for the most vulnerable or socially important structures.
6. Increase Number of Building Types Regulated, but More Categories are Required to Have Mandatory Retrofits: This alternative is similar to Option 5, but retrofitting would be required for additional categories on a fixed timeline.

***Other Program Features and Implementation Factors***

By updating its current ordinance, Palo Alto has a variety of opportunities to expand and better link its earthquake mitigation program efforts to other City efforts in support of community resilience goals. For instance, Palo Alto could encourage a building occupancy and resumption program like San Francisco, encourage or fund installation of strong motion instruments, or pursue special programs or requirements for cell phone towers, facades, private schools, and/or post-earthquake shelter facilities.

***Building Inventory***

***Summary of Survey Methodology***

One of the first steps in the Seismic Risk Assessment Study was to develop a digital inventory of buildings in Palo Alto that includes all the information necessary to build the exposure model for the loss estimate. Information sources used to develop the inventory included county tax assessor files, City GIS files, a survey done by the Palo Alto Fire Department and San Jose State University of soft-story wood frame buildings, field notes from the building department files of selected buildings when the 1986 ordinance was being developed, Google Earth and Street View visual reviews, and an extensive visual sidewalk survey.

After the sidewalk surveys and additional quality assurance refinements, the study identified a total of 2,632 buildings in the study group for Palo Alto. This included 66 buildings subject to Palo Alto's current seismic mitigation ordinance, because 23 of the original 89 buildings subject to the ordinance have been demolished.

Not all buildings were field surveyed and not all key attributes needed for loss estimation were available for all buildings. For buildings that were not surveyed and were missing information, the missing attributes were developed using statistical comparisons with buildings that were surveyed on a sector- by- sector basis. A multi-step procedure was developed to fill in other

missing attributes based on the best available comparative information. As a result, while the information for buildings that were not surveyed may not be fully accurate at the individual building level, the overall data set is seen as sufficiently representative for the type of loss estimates used in the project and relative comparisons made between different building types that are discussed ahead.

***Replacement Cost Values for Palo Alto***

In addition to the information discussed above, a locally-customized replacement cost had to be established for each building. Standard 2014 *RS Means* Replacement Cost values included in the project loss estimation software (Hazus) used were reviewed as a starting point, but not considered representative for Palo Alto. R+C and Vanir Construction Management prepared adjustments to RS Means values to capture 2016 data and local factors unique to Palo Alto. These were reviewed by a task group of the City's project Advisory Group that included local design professionals and developers familiar with the local cost climate.

The group recommended an increase of the values in general and identified target values for selected common occupancies. Based on these recommendations, R+C updated the values and Vanir reviewed them and revised the non-targeted occupancies for estimating consistency. The resulting replacement costs are shown in Table 2, and were used in the loss calculations. It is noted that resulting costs are 1.7-2.6 times the RS Means-based Hazus default values (2014 cost data), and that costs are intended to be representative of averages across the town.

**Table 2:** Average $/SF replacement building cost by Hazus occupancy class.

| Occupancy Class | RS Means 2014 Average Palo Alto Cost[1] [$/SF] | Market Factor for Palo Alto | Escalation Factor from 2014 costs to 2016 costs | Demo & Minimal Sitework (5' around building) [$/SF] | Soft Cost Premium[2] | Average 2016 Palo Alto Cost w/ Soft Costs [$/SF] | Multiplier (Replaced with Soft Costs / RS Means) |
|---|---|---|---|---|---|---|---|
| Multi Family, duplex | $130.75 | 40% | 10% | $17.50 | 20% | $263 | 2.01 |
| Multi Family, triplex/quad | $114.94 | 40% | 10% | $17.50 | 20% | $233 | 2.03 |
| Multi Family, 5-9 units | $206.41 | 40% | 10% | $17.50 | 20% | $402 | 1.95 |
| Multi Family, 10-19 units | $194.12 | 40% | 10% | $17.50 | 20% | $380 | 1.96 |
| Multi Family, 20-49 units | $212.26 | 40% | 10% | $17.50 | 20% | $413 | 1.95 |
| Multi Family, 50+ units | $199.90 | 40% | 10% | $17.50 | 20% | $390 | 1.95 |
| Temporary Lodging | $217.83 | 40% | 10% | $17.50 | 20% | $424 | 1.94 |
| Institutional Dormitory | $234.44 | 50% | 14% | $25.00 | 20% | $511 | 2.18 |
| Nursing Homes | $238.07 | 50% | 12% | $25.00 | 20% | $510 | 2.14 |
| Retail Trade | $121.66 | 80% | 10% | $17.50 | 20% | $310 | 2.55 |
| Wholesale Trade | $118.13 | 60% | 10% | $17.50 | 20% | $$270 | 2.29 |
| Personal & Repair Services | $143.47 | 60% | 10% | $17.50 | 20% | $324 | 2.26 |
| Professional/Technical/ Business Services | $194.52 | 65% | 12% | $17.50 | 20% | $452 | 2.33 |
| Banks | $281.88 | 40% | 12% | $25.00 | 20% | $560 | 1.99 |
| Hospitals | $372.59 | 50% | 14% | $35.00 | 20% | $807 | 2.16 |
| Medical Office/Clinics | $267.85 | 20% | 10% | $17.50 | 20% | $445 | 1.66 |
| Entertainment/Recreation | $248.61 | 25% | 12% | $25.00 | 20% | $448 | 1.80 |
| Theaters | $186.45 | 35% | 12% | $25.00 | 20% | $368 | 1.98 |
| Parking | $84.59 | 20% | 10% | $17.50 | 20% | $155 | 1.83 |
| Heavy | $144.71 | 25% | 10% | $17.50 | 20% | $260 | 1.80 |
| Light | $118.13 | 25% | 10% | $17.50 | 20% | $216 | 1.83 |
| Food/Drugs/Chemicals | $229.48 | 30% | 12% | $17.50 | 20% | $422 | 1.84 |
| Metal/Minerals Processing | $229.48 | 30% | 12% | $17.50 | 20% | $422 | 1.84 |
| High Technology | $229.48 | 40% | 14% | $17.50 | 20% | $461 | 2.01 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Construction | $118.13 | 30% | 10% | $17.50 | 20% | $224 | 1.89 |
| Church | $118.13 | 50% | 12% | $25.00 | 20% | $268 | 2.27 |
| Agriculture | $199.08 | 10% | 12% | $17.50 | 20% | $315 | 1.58 |
| General Services | $152.63 | 40% | 10% | $17.50 | 35% | $341 | 2.23 |
| Emergency Response | $259.52 | 40% | 14% | $25.00 | 35% | $593 | 2.28 |
| Schools/Libraries | $193.00 | 40% | 12% | $25.00 | 35% | $442 | 2.29 |
| Colleges/Universities | $214.91 | 60% | 12% | $25.00 | 35% | $554 | 2.58 |

Notes:

1. RS Means average cost includes RS Means default location factors to adjust national average to Palo Alto of 15% for residential and 11% for commercial.
2. Soft costs include architect and engineer design fees, testing and inspection, utility connection fee, permits, and an allowance for owner change order contingency.
3. Costs are intended to be representative of average in Palo Alto across the town, including downtown areas together with other areas in the city.
4. Costs were previously prepared following a 3/7/2016 discussion with the Palo Alto Seismic Risk Program Advisory Group Technical Advisory Committee. Table includes minor updates based on internal review between Rutherford + Chekene and Vanir Construction Management to achieve improved relative ratios between different occupancy types.

### *Number and Distribution of Vulnerable Buildings by Aggregate Size and Value*

Table 3 shows how the number and aggregate value of Palo Alto's buildings is distributed by type of structure, using the FEMA Model Building Type classification system for structural system. The table is sorted by aggregate building value. Wood frame buildings make up about 60% of the number of buildings and represent 35% of the total value. About 20% of the buildings are concrete, and they represent over 40% of the total value. Of the remaining 20%, about two-thirds are masonry buildings, and one-third steel. However, the steel buildings represent about twice the value of the masonry buildings.

**Table 3:** Distribution of number of buildings, building area, and building value by Model Building Type.

| Model Building Type | Number of Buildings | Aggregate Square Feet (1,000) | Aggregate Building Value ($M) |
|---|---|---|---|
| Concrete shear wall (C2) | 318 | 9,699 | 4,082 |
| Concrete tilt-up (PC1) | 242 | 8,054 | 3,368 |
| Wood frame larger residential (W1A) | 331 | 8,403 | 3,232 |
| Wood frame commercial/industrial (W2) | 307 | 6,209 | 2,369 |
| Steel braced frame (S2) | 50 | 3,116 | 1,391 |
| Wood frame smaller residential (W1) | 898 | 3,821 | 1,278 |
| Steel moment frame (S1) | 75 | 3,005 | 1,242 |
| Reinforced masonry, wood floor (RM1) | 285 | 2,806 | 1,209 |
| Reinforced masonry, concrete floor (RM2) | 30 | 574 | 211 |
| Steel light metal frame (S3) | 41 | 533 | 177 |
| Precast concrete frame (PC2) | 5 | 334 | 125 |
| Concrete moment frame (C1) | 18 | 325 | 117 |
| Steel frame with concrete shear walls (S4) | 13 | 162 | 72 |
| Unreinforced masonry bearing wall (URM) | 9 | 274 | 15 |
| Concrete with masonry infill (C3) | 8 | 26 | 8 |
| Steel frame with masonry infill (S5) | 2 | 6 | 3 |
| **Totals** | **2,632** | **47,346** | **18,899** |

The study group of buildings can be further divided into age groups separated by significant milestones in building code implementation. The following age groups were selected: pre-1927, 1927-1961, 1962-1976, 1977-1997, and 1998 to present. The milestones reflected include the first earthquake code in Palo Alto in 1926, adoption of the 1961 Uniform Building Code (UBC) and associated more stringent design requirements, code changes in the 1976 UBC following the 1971 San Fernando Earthquake, and code changes in the 1998 UBC following the 1994 Northridge Earthquake. Figure 1 shows a histogram of the year built of the buildings in the study group.

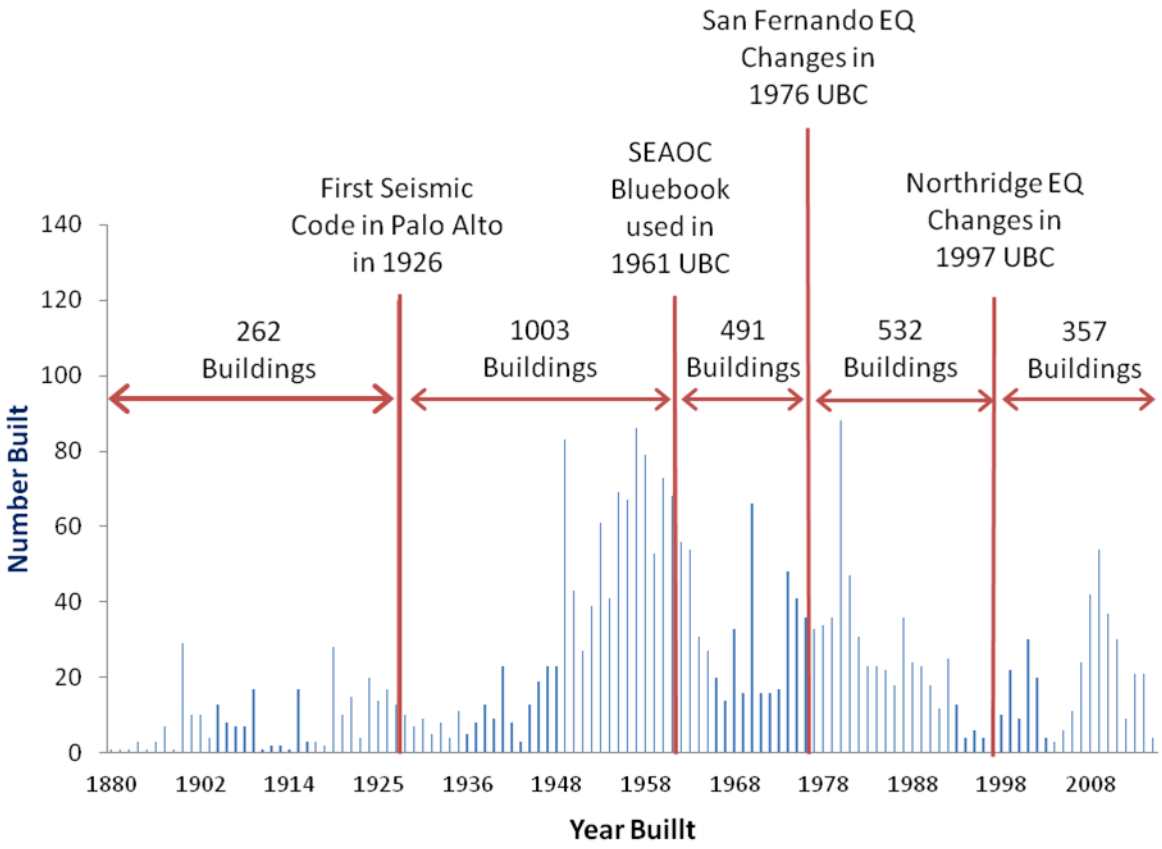


**Figure 1:** Distribution of year built of buildings in study group with significant changes in the building design practice.

***Vulnerable Building Categories***

One of the important tasks in the risk assessment study was to identify potentially vulnerable building categories specific to Palo Alto. Using the building inventory that was developed early in the project, R+C identified potentially vulnerable structural system types based on insights from past earthquake events, milestone improvements in seismic code requirements made in Palo Alto, rankings in prominent seismic risk assessment tools such as the 2015 edition of FEMA P-154 *Rapid Visual Screening of Buildings for Potential Seismic Hazards,* results from past seismic risk assessment studies in California communities, and engineering judgment.

The building categories were then evaluated in analytical loss estimate studies, described ahead, which helped to narrow in on the most important categories for Palo Alto. Key building vulnerability metrics include the risk of deaths and injuries, the cost of damage, and the extent of downtime or loss of use. Buildings in the identified vulnerable building categories tend to perform poorly with respect to all three of these metrics though the relative degree of vulnerability to each factor varies.

***Community Resilience***

Community resilience is improved if residents have homes that remain usable after an earthquake and if businesses can still operate. From a program perspective, the consultant team and advisory group believe that the greatest reduction in losses and the largest benefit to community resilience will come from seismically retrofitting building types known to be both potentially hazardous and present in significant numbers in Palo Alto.

In addition to the three categories already in Palo Alto's seismic hazard identification ordinance (Categories I, II, and III below), five additional categories of vulnerable building types were identified. All five categories meet the criteria of being potentially hazardous and having a significant presence in Palo Alto. The eight categories and the approximate number of buildings included in each category, as of original report publication in 2017, are as follows:

1. Category I: Constructed of unreinforced masonry, except for those small than 1,900 square feet with six or few occupants (10 remaining buildings in Palo Alto)
2. Category II: Constructed prior to January 1, 1935 containing 100 or more occupants (4 remaining buildings)
3. Category III: Constructed prior to August 1, 1976 containing 300 or more occupants (9 remaining buildings)
4. Category IV: Pre-1977 soft-story wood frame (294 buildings)
5. Category V: Pre-1998 tilt-up concrete (99 buildings)
6. Category VI: Pre-1977 concrete soft-story (37 buildings)
7. Category VII: Pre-1998 steel moment frame (35 buildings)
8. Category VIII: Other pre-1977 concrete construction (170 buildings)

The technical assessment confirms that the potential reduction in losses from retrofitting is significant for these categories.

***Conceptual Seismic Retrofitting of Representative Vulnerable Buildings***

Retrofit was considered for all buildings that have not already been retrofitted and were either constructed before 1961 or between 1962 and the "benchmark" year with a soft story. A "benchmark" year is when the code requirements for that building type became similar to those currently in place. Consistent with typical practice, the performance of the retrofitted buildings in an earthquake is assumed to be less than that of newly constructed buildings.

For estimating the cost of retrofit for the improved buildings, R+C developed conceptual designs for Model Building Types that represent a significant number and value of Palo Alto's building stock, as well as a significant loss and loss reduction after retrofit. This process identified wood frame (W1, W1A, W2), steel moment frame (S1), concrete shear wall (C2), concrete tilt-up (PC1), and reinforced masonry (RM1) and unreinforced masonry (URM) as appropriate candidates.

For each Model Building Type, the age, square footage and number of stories were reviewed to identify a "prototype" building. In cases where the prototype building was not representative of more than two-thirds of the total number of buildings, multiple prototypes were considered.

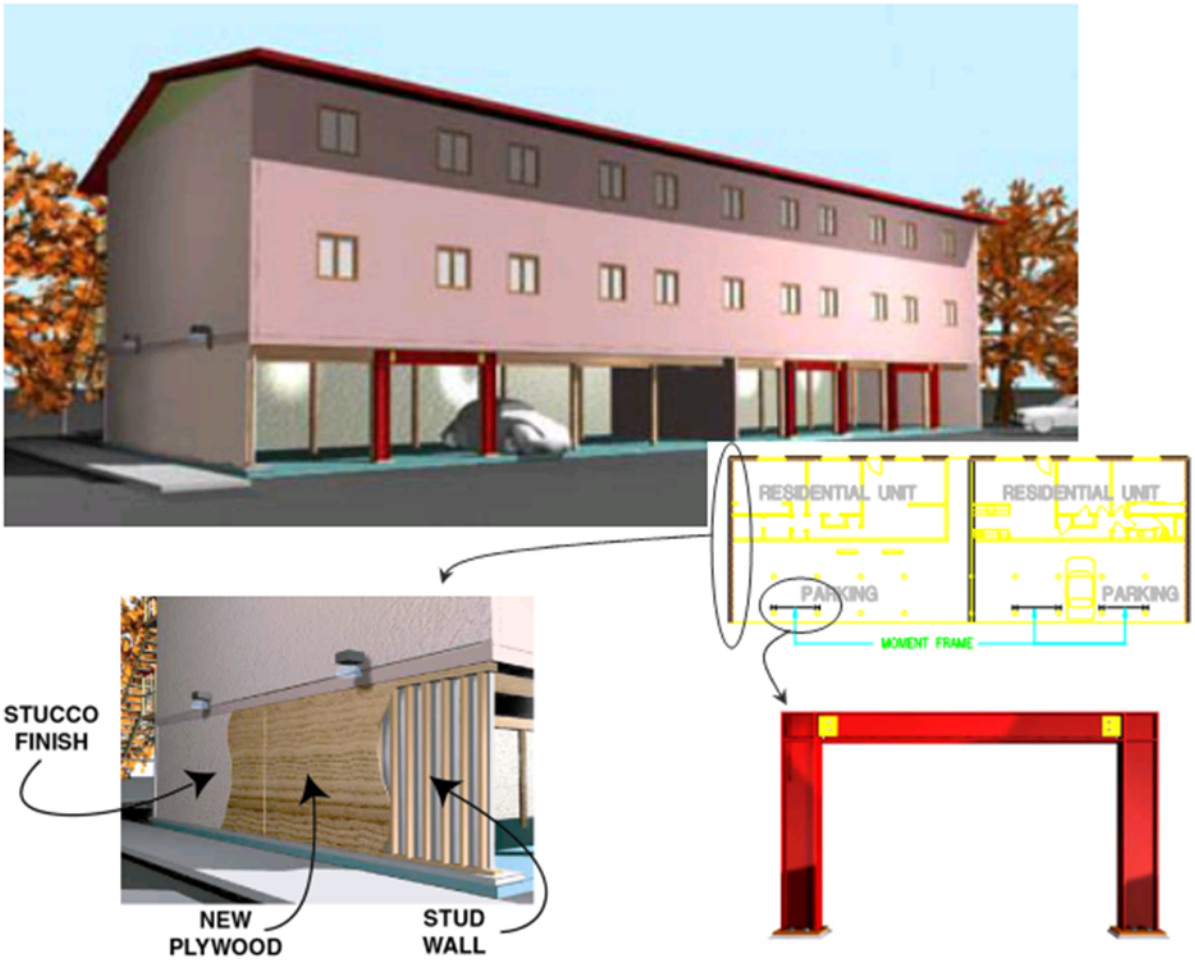


**Figure 2:** Retrofit scheme for Large Multi-family Soft-Story Wood Frame Building.

An example of a conceptual retrofit for the W1A prototype building is shown in Figure 2 from a 2000 brochure by R+C for the City of San Jose entitled "Practical Solutions for Improving the Seismic Performance of Buildings with Tuck-under Parking." The retrofit elements were keyed to representative details in 2006 FEMA 547 *Techniques for the Seismic Rehabilitation of Existing Buildings*, and a written description of collateral impacts was developed as well to provide sufficient detail to allow a rough order of magnitude cost estimate to be prepared.

The cost estimators of Vanir Construction Management used the conceptual designs to estimate a range of probable cost to implement the retrofits. The retrofit costs for each prototype building are shown in Table 4. These costs include hard costs, which are the costs the owner pays the contractor, plus a design contingency since these are conceptual retrofits. The estimate further includes soft costs, representing architect and engineer design fees, testing and inspection costs, permit fees, and an owner change order contingency.

Considered costs do not include hazardous material abatement, costs associated with performing the work while occupants are using the building, triggered accessibility upgrades, cost premiums associated with retrofit of a historic building, tenant relocation or business interruption during construction, project management, renovation, financing, repair of existing conditions, and legal fees. These costs are more variable and project and site specific, and are typically not included in loss estimates for this type of study.

The retrofit costs were extrapolated to Model Building Types not represented by a prototype retrofit as shown in the fifth column of Table 4.

**Table 4:** Conceptual retrofit cost.

| Retrofit Prototype | Model Building Type | Stories | Square Feet | Used for Model Building Types | Used for Square Feet | Average Retrofit Cost ($/SF) |
|---|---|---|---|---|---|---|
| 1 | Wood frame smaller residential (W1) | 2 | 5,320 | W1 | All | 12 |
| 2 | Wood frame larger residential (W1A) | 2 | 9,500 | W1A | < 15,000 | 11 |
| 3 | Wood frame larger residential (W1A) | 3 | 30,000 | W1A | ≥ 15,000 | 6 |
| 4 | Wood frame commercial/industrial (W2) | 2 | 10,000 | W2 | All | 14 |
| 5 | Steel moment frame (S1) | 2 | 43,900 | S1, S2, S3 | All | 10 |
| 6 | Concrete shear wall (C2) | 1 | 5,000 | C1, C2, S4, PC2 | < 10,000 | 50 |
| 7 | Concrete shear wall (C2) | 2 | 17,280 | C1, C2, S4, PC2 | ≥ 10,000 | 40 |
| 8 | Concrete tilt-up (PC1) | 1 | 18,435 | PC1 | < 25,000 | 29 |
| 9 | Concrete tilt-up (PC1) | 2 | 38,400 | PC1 | ≥ 25,000 | 21 |
| 10 | Reinforced masonry, wood floor (RM1) | 1 | 2,750 | RM1, RM2 | < 5,000 | 74 |
| 11 | Reinforced masonry, wood floor (RM1) | 2 | 8,150 | RM1, RM2 | ≥ 5,000 | 46 |
| 12 | Unreinforced masonry bearing wall (URM) | 1 | 5,000 | URM, S5, C3 | All | 110 |

***Loss Estimate Findings for Current Condition***

Hazus is a geographic information system (GIS) based, standardized, nationally applicable multi-hazard loss estimation methodology and software tool. It is used by local, state, and federal government officials for preparedness, emergency response, and mitigation planning. The Advanced Engineering Building Module from the latest Hazus version 3.1 was used to conduct the loss estimates in the study so that individual buildings could be analyzed using the specific inventory data collected for Palo Alto.

Analyses were conducted for two specific earthquake scenarios developed by the United States Geological Survey (USGS): a major M7.9 San Andreas Fault event, and a strong M6.7 San Andreas Fault event.

Contour plots for the short period spectral acceleration for the two M6.7 and M7.9 scenarios are shown in Figure 3. Spectral acceleration is a measure of the building response to shaking at the site.

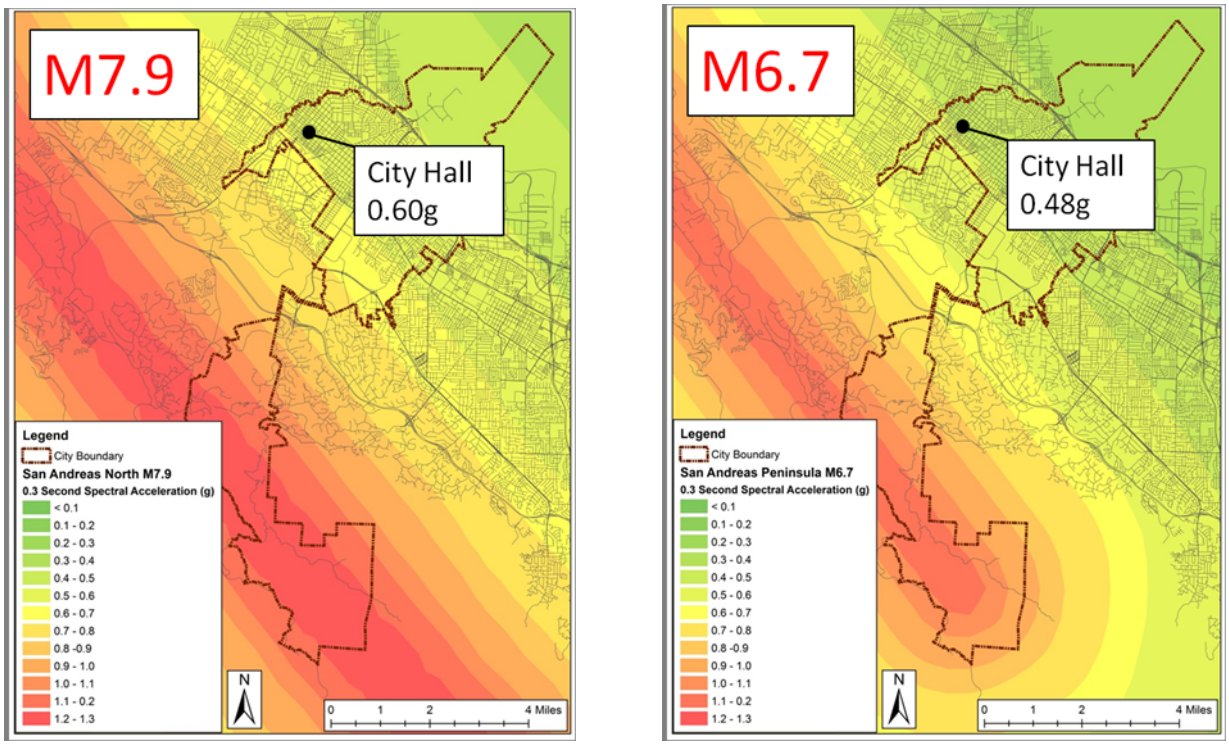


**Figure 2:** Predicted short period spectral acceleration in vicinity of Palo Alto (city boundary shown) for two selected San Andreas Fault scenarios.

***Estimated Losses for Buildings in Their Current Condition***

Table 5 summarizes the total loss calculated by Hazus for the as-is condition for the two earthquake scenarios. The results show that the estimated losses to Palo Alto buildings and contents in a M6.7 scenario will be significant, on the order of $1.2 billion. Though ground shaking in the M7.9 scenario is only about 25% larger than it is in the M6.7 scenario, overall building and content losses double to $2.4 billion. Average building damage and content damage also approximately double with a M7.9 event.

The difference in the number of buildings that are heavily damaged with the larger earthquake is more pronounced with a 12-fold increase from the M6.7 to the M7.9 scenarios. This is shown in the fourth column of Table 5 as the number of buildings with a damage ratio exceeding 20%.

**Table 5:** Total losses for study group in as-is condition.

| Earthquake Scenario | Building Value[1] ($B) | Content Value[2] ($B) | Number of Bldgs. with Damage Ratio ≥ 20%[3] | Estimated Building Damage[4] ($B) | Estimated Content Damage[4] ($B) | Total Building and Content Damage ($B) |
|---|---|---|---|---|---|---|
| M7.9 | 18.9 | 17.3 | 224 | 1.7 | 0.7 | 2.4 |
| M6.7 | 18.9 | 17.3 | 19 | 0.8 | 0.4 | 1.2 |
| Ratio of M7.9/M6.7 | | | | 2 | 2 | 2 |

Notes:

1. Building value is the complete replacement cost for the building, and includes the structure, architectural, mechanical, electrical, and plumbing components (e.g., ceilings and lighting).
2. Content value includes the complete replacement cost of furniture and equipment that is not integral with the structure (e.g., computers and other supplies). They are estimated as a percent of structure replacement value, dependent on occupancy.
3. Damage ratio is defined as the cost of repairing damage divided by the replacement cost of the building.
4. Estimated building and content damage cost is the cost associated with repair and replacement of the building and its content.

To put the loss from building damage in context, the average annual valuation of Palo Alto construction permits was $400M between 2013 and 2016 (which represents a boom period). The total loss of $1.7B in a major M7.9 earthquake represents more than four years' worth of construction, and the total loss of $0.8B in a strong M6.7 earthquake represents more than two years' worth of construction.

It should be noted that these losses do not include the effects of lives lost and business disruption, or the ripple effects in the local economy or real estate market. Much of this loss will

not be insured.

***Estimated Losses by Building Type***

It is important to look at multiple metrics when deciding which buildings are the most vulnerable and significant to the community as a whole. Table 6 breaks out the estimated loss and damage ratio for various model building types, and it can be seen that it depends on the metric used which building type is considered the poorest performer. Looking at the total loss alone, concrete bearing wall buildings and commercial wood frame buildings are responsible for the highest total loss.

This tracks well with the earlier finding that these structural systems are the most prevalent ones. If we look at the highest average building damage ratio instead, buildings with unreinforced masonry bearing walls and unreinforced masonry infills are the most prone to damage. However, not very many of them exist in Palo Alto, and as a result they do not represent much of the aggregate loss.

**Table 6:** Top three vulnerable building types ranked by total loss, average damage ratio, and number of severely damaged buildings.

| Building Type | Number of Buildings | Building Value ($M) | M7.9 EQ Total Building + Content Losses ($M) | M7.9 EQ Average Building Damage Ratio | M7.9 EQ Number of Bldgs. with Damage Ratio ≥ 20% |
|---|---|---|---|---|---|
| Concrete shear wall (C2) | 318 | 4,082 | **477** | 14% | 75 |
| Concrete tilt-up (PC1) | 242 | 3,368 | **365** | 12% | 32 |
| Wood frame commercial/industrial (W2) | 307 | 2,369 | **216** | 9% | 9 |
| | | | | | |
| Steel frame with masonry infill (S5) | 2 | 3 | 1 | **38%** | 1 |
| Unreinforced masonry bearing wall (URM) | 9 | 15 | 4 | **29%** | 9 |
| Concrete frame with masonry infill (C3) | 8 | 8 | 2 | **29%** | 6 |
| | | | | | |
| Concrete shear wall (C2) | 318 | 4,082 | 477 | 14% | **75** |
| Concrete tilt-up (PC1) | 242 | 3,368 | 365 | 12% | **32** |
| Steel moment frame (S1) | 75 | 1,242 | 130 | 18% | **27** |

***Loss Estimate Findings with Buildings Retrofitted***

A second Hazus AEBM run was done assuming a retrofitted building stock. For this model run, it was assumed that a building would be retrofitted if it has not already been retrofitted and was either constructed before 1961 or between 1962 and the benchmark year with a soft story. The Hazus model was rerun with the updated properties simulating retrofit.

Table 7 shows the resulting total losses and damage ratios after buildings have been retrofitted. Though total losses are still significant, comparing the results of Table 7 with Table 5 shows a reduction in total loss of 45% for the M7.9 scenario, and 33% for the M6.7 scenario. In other words, aggregate loss to the community if all considered properties were retrofit could be reduced by one third in a very plausible event and almost halved in a much larger event.

Another important improvement is the reduction of the number of buildings with more than 20% damage. The M7.9 scenario shows a reduction from 224 buildings to 6 buildings. This means that the probability of building collapse and resulting injuries and fatalities has become very low.

Finally, the damage and loss of the M7.9 scenario remain approximately two times the amount of loss sustained in the M6.7 scenario. This suggests that the retrofit has a similar impact for both levels of ground shaking.

**Table 7:** Total losses after retrofitting.

| Earthquake Scenario | Building Value ($B) | Content Value ($B) | Estimated Building Damage ($B) | Number of Bldgs. with Damage Ratio ≥ 20% | Estimated Content Damage ($B) | Total Building & Content Damage ($B) |
|---|---|---|---|---|---|---|
| M7.9 | 18.9 | 17.3 | 0.9 | 6 | 0.5 | 1.3 |
| M6.7 | 18.9 | 17.3 | 0.5 | 0 | 0.3 | 0.8 |
| Ratio of M7.9/M6.7 | | | 2 | - | 2 | 2 |

Table 8 breaks out the reduction in total loss by model building type for the M7.9 scenario, and shows the associated retrofit cost. The average reduction in loss varies by building type. URM buildings showed the highest reduction in loss after retrofit as a percentage of the loss itself. Steel braced framed buildings showed the lowest reduction in losses as a percentage of the loss itself. Wood frame and concrete buildings are responsible for the largest reduction in total loss, with wood frame construction representing over 20% of the loss reduction, and concrete buildings over 50%.

It should be noted that the data in Table 8 also includes buildings that were not retrofitted. As a result, further parsing of the data is needed to better understand which buildings are responsible for the most loss, and those that can be improved more cost-effectively.

**Table 8:** Comparison of retrofit benefits and costs by Model Building Type.

| Model Building Type | M7.9 EQ Average Damage ($/SF) | M7.9 EQ Total Damage Reduction ($1,000) | Average Damage Reduction ($/SF) | Retrofit Cost ($/SF) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Wood frame smaller residential (W1) | 16 | 13,775 | 4 | 12 |
| Wood frame larger residential (W1A) | 25 | 61,317 | 7 | 6-11 |
| Wood frame commercial/industrial (W2) | 50 | 160,155 | 26 | 14 |
| Steel moment frame (S1) | 62 | 76,150 | 25 | 10 |
| Steel braced frame (S2) | 44 | 24,222 | 8 | 10 |
| Steel light metal frame (S3) | 108 | 38,163 | 72 | 10 |
| Steel frame with concrete shear walls (S4) | 101 | 11,118 | 69 | 40-50 |
| Steel frame with masonry infill (S5) | 247 | 695 | 121 | 110 |
| Concrete moment frame (C1) | 55 | 8,045 | 25 | 40-50 |
| Concrete shear wall (C2) | 70 | 336,574 | 35 | 40-50 |
| Concrete frame with masonry infill (C3) | 120 | 865 | 34 | 110 |
| Concrete tilt-up (PC1) | 68 | 218,491 | 27 | 21-29 |
| Precast concrete frame (PC2) | 21 | 0 | 0 | 21-29 |
| Reinforced masonry, wood floor (RM1) | 59 | 87,697 | 31 | 46-74 |
| Reinforced masonry, concrete floor (RM2) | 35 | 3,727 | 6 | 46-74 |
| Unreinforced Masonry Bearing Wall (URM) | 23 | 5,216 | 19 | 110 |
| **Totals** | **51** | **1,046,210** | **22** | |

Table 9 shows those types of buildings that may be considered good candidates for a retrofit program. Although representing only about 15% of the total inventory, these buildings are responsible for over 30% of the total loss. This is reflected in the considerably higher than average loss (fourth column of Table 9). The benefit of retrofit is also considerable for this group of buildings, since they are responsible for over 50% of the reduction in loss. Additionally, the cost to retrofit them is only a fraction of the losses avoided in a major event, ranging from a third for the concrete buildings to a tenth for the steel frames.

Note that these values are based on conceptual retrofits. Actual retrofit costs for individual buildings would vary substantially. The steel moment frame benefit-to-cost ratio is higher than expected by engineering judgment, caused in part by a comparatively low retrofit cost for this Model Building Type.

**Table 9:** Comparison of benefits and costs by selected Model Building Type, date and characteristics.

| Model Building Type | Number of Buildings | Total SF (1,000) | M7.9 EQ Average Loss by Building ($/SF) | M7.9 EQ Average Loss Avoided by Retrofit ($/SF) | Average Cost to Retrofit ($/SF) | (Average Loss Avoided) / (Average Retrofit Cost) |
|---|---|---|---|---|---|---|
| Pre-1977 wood frame soft-story (W1, W1A, W2) | 294 | 3,690 | 66 | 46 | 12 | 4 |
| Pre-1998 tilt-up (PC1) | 99 | 3,078 | 106 | 71 | 23 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Pre-1977 concrete soft-story (C1, C2, C3) | 37 | 842 | 149 | 108 | 42 | 3 |
| Pre-1998 steel moment frame (S1) | 35 | 690 | 152 | 110 | 10 | 11 |

***Review of Past Seismic Retrofits***

To gain a better understanding of the quality of the retrofits and identify relevant issues to updating Palo Alto's seismic risk mitigation program, a sample of the submitted engineering studies and building retrofits drawings for existing buildings was reviewed.

The review identified the following relevant needs for future seismic risk mitigation programs:

A. Clear identification of retrofit design intent, scope, and limitations, also for voluntary retrofits
B. Identification of existing structural systems
C. Decision on requirements for buildings that have had partial seismic retrofits completed; and may have remaining seismic deficiencies

***Additional Recommended Program Features***

In addition to expansion of the building categories included within the City's seismic risk mitigation program and refinement of disclosure measures and incentive options, a number of other program features are recommended.

A. *Use the current inventory, taking note of its limitations* - The inventory developed for the effort to date involved use of digital information and field surveys. A complete field survey of all buildings in Palo Alto was outside the scope of the project. However, the inventory that has been developed is an excellent resource. The first step in any future ordinance will involve notification of building owners that they may be subject to the requirements of the ordinance. Those buildings that were field surveyed and fall within the scope of the ordinance can be notified using the existing inventory. For the remaining buildings, additional field survey is recommended. This would be a rapid visual assessment and could be conducted by City staff or outside consultants.

B. *Use an initial screening form phase* - Typically, as part of the notification process, a screening form of about one page in length is sent. The owner is required to have a design professional, such as a structural engineer or architect, complete the form. This cost to confirm whether or not the building actually is subject to the City's ordinance should be relatively nominal.

C. *Clearly specify seismic evaluation and retrofit scope* - For all buildings subject to regulation, the seismic evaluation (and retrofit) methodology for each building category will need to be defined. Industry consensus standards exist and cover the vulnerable building categories identified for Palo Alto. These include the 2015 *International Existing Building Code (IEBC)* and 2014 ASCE 41-13 *Seismic Evaluation and Retrofit of Existing*

*Buildings*. Both are currently being updated by groups of engineers and building officials. For soft-story wood frame buildings, there is also the 2012 FEMA P-807 *Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings with Weak First Stories.* For steel moment frame buildings, there is also the 2000 FEMA 351 *Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Moment Resisting Steel Structures*. The following table provides recommended evaluation and retrofit standards.

D. *Provide detailed evaluation report submittal requirements* - Minimum submittal requirements for evaluation reports will need to be defined. The above evaluation and retrofit standards provide some guidance but a short clear set of requirements will be beneficial.

E. *Specify how past partial retrofits will be handled:* In the past, some buildings have had partial seismic retrofits where only selected portions of the seismic force-resisting system have been upgraded; Some seismic deficiencies may still exist in these structures. If mandatory retrofit requirements are implemented that provide for comprehensive retrofitting of the full seismic load path, there may be buildings with previous partial retrofits that do not fully comply and need remaining deficiencies to be addressed. The seismic evaluation reports will help identify these cases.

F. *Update both new and existing building permit submittal requirements:* Review of City records found that basic information such as the building structural system, date of construction, and retrofit standard used (where applicable) are not readily available. It is recommended that submittals for permit for both new buildings and existing building renovations require this information. This will allow the city to have a much better understanding of its total building stock and its expected performance in an earthquake.

G. *Write a new ordinance or set of ordinances to update the program*: After the Council has provided direction and the above issues have been addressed, an updated ordinance will need to be written.

H. *Carefully address program management and interdepartmental coordination needs*: To successfully manage Palo Alto's updated Seismic Risk Mitigation Program, an effective management plan is needed so that progress is monitored by the City and community intent is achieved.

I. *Delineate department and key staff responsibilities:* For Palo Alto's updated Seismic Risk Mitigation Program, City staff will be responsible for several categories of activities. These will include the basic activities such as managing the notification and inventory process, reviewing evaluation reports and plan checking retrofit construction documents, and field inspections of retrofit work. Less obvious activities will include evaluating requested exceptions to the program or alternative means of compliance; managing feedback from design professionals, owners, and the public; tying pre-earthquake retrofitting to post-earthquake safety evaluations records; and managing post-earthquake safety evaluation,

repair, and recovery plans. Depending on the scale of the updated program, it is possible that additional staff members, consultants, and/or an appropriately experienced structural engineer may be needed to provide advice on technical and program management issues, particularly as the program moves to final definition and to initial implementation. Later, as is done in some communities, it may be desirable to create volunteer review boards of local structural engineers who review questions on the evaluation and retrofit criteria and provide the City with technical opinions that staff can use.

**Table 10:** Recommended Evaluation and Retrofit Standards.

| Category | Description | Evaluation and Retrofit Standards |
|---|---|---|
| I | Unreinforced masonry | IEBC Appendix Chapter A1 |
| II | Built before 1/1/35 with 100 or more occupants | ASCE 41 |
| III | Built before 8/1/76 with 300 or more occupants | ASCE 41 |
| IV | Pre-1977 soft-story wood frame | IEBC Appendix Chapter A4, ASCE 41, or FEMA P-807 |
| V | Pre-1998 tilt-up | IEBC Appendix Chapter A2 and ASCE 41 |
| VI | Pre-1977 soft-story concrete | ASCE 41 |
| VII | Pre-1998 steel moment frame | ASCE 41, or FEMA 351 |
| VIII | Other pre-1977 concrete | ASCE 41 |

**ADVISORY GROUP INPUT**

***Summary Report of the Advisory Group***

The purpose of convening an Advisory Group composed of members with local expertise and construction experience was not to create a consensus document or ratify particular recommendations by majority vote. Instead, the goal was to educate, solicit, and explore the range of issues and opinions among interested parties who participated. A summary report, reviewed by all the members of the Group, was prepared to document their input in to the study (Attachment C).

The Advisory Group was a first step in community engagement regarding seismic hazard reduction in Palo Alto. It was intended that the information in the Advisory Group's summary memo would be provided to the City Council as they consider potential revisions to the City of Palo Alto's seismic risk management program and seismic hazard identification ordinance.

***Preferred Policy Directions***

In summary, discussions with the Advisory Group revealed little to no support for maintaining the status quo. Strong support did exist for retrofitting buildings already in the program, particularly URM buildings, and for addressing more building types, particularly soft-story wood frame buildings and older concrete tilt-ups.

For buildings addressed in the current ordinance, the group generally thought a mandatory retrofit requirement would be feasible and fair. Three decades later, market forces alone have clearly not been enough to motivate upgrade of these remaining structures. Because the barriers to retrofit work for these properties are not known, case-by-case management by City staff may be necessary. There was hesitance, however, about extending or increasing incentives for owners that had not voluntarily taken advantage of the FAR bonus available in the past.

More detailed conversations took place about other building category priorities and policy features focused on extending the vulnerable building types they addressed and the requirements for retrofit compliance. These program alternatives are incorporated into Options 3, 4, and 5 (see the "Survey of State and Local Seismic Policies" section). The Advisory Group was briefed on structural types generally known to be vulnerable that are common or significant to Palo Alto and estimated to have reasonable loss reduction to retrofit cost ratios. The Group's goal was to focus on a subset of categories that seemed to have high potential to benefit the owner, occupants, and the broader community. Some participants showed greater concern about residential properties, and debated whether commercial and residential properties should be treated the same or differently.

The Advisory Group showed high interest in addressing multi-family residential earthquake risks, in particular by starting a soft-story wood frame program as many other California cities have done. One soft-story wood frame program approach discussed was to have two phases: 1) owners following notification would be given several years to do a voluntary retrofit, along with more generous incentives; and 2) later a mandatory timeline would kick in and incentives would be phased out. The group noted that exemptions such as parking requirements, permission to

add other unit(s), or the ability to transfer development rights for additional square footage would likely be attractive and useful incentives for the multi-family soft story building type.

Other vulnerable building categories of concern were also reviewed, including pre-1977 tilt-up concrete structures. There are a modest number of these buildings in Palo Alto, but Advisory Group members noted that their uses are changing. Many buildings previously used as warehouses are now being repurposed for office space. The higher occupancies increase the public safety stakes of any seismic deficiencies.

Currently, there is no mandate in the regulations to address earthquake vulnerabilities while other upgrades and build out are being done to these structures. A substantial renovation trigger mandate might make sense, but the percent of the value of the structure used as a trigger might need to be lowered in order to get compliance. Such properties with more than one story should perhaps receive higher priority for retrofit.

***Potential Issues for Future Study and Consideration***

For some issues, based in part on Advisory Group discussions, additional information may be beneficial to help develop a strategy and to better understand potential impacts on key stakeholders and community concerns. Some of these issues are primarily economic and were outside the scope of the current study. The City Council may wish to direct staff and/or outside consultants to investigate some of these items in more detail as the seismic risk management program effort proceeds. These issues include the following:

A. *Occupants and tenants*
    a. How much would a typical retrofit add to the monthly rent of a multifamily soft-story wood frame apartment tenant?
    b. Would some tenants be unable to afford a rent increase and seek housing elsewhere in Palo Alto or move outside the city (and if so, how many might be displaced)?
    c. If soft-story wood frame apartments in Palo Alto are retrofitted in time before the next major earthquake, how much less displacement of residents would occur as a result of the earthquake?
    d. What categories of buildings are most important to address in order to help maintain the commercial viability and vitality of the City's core business districts and tax base?
B. *Property owners, developers, and business owners*
    a. What are the characteristics of property owners that would be affected?
    b. How might small businesses be affected compared to larger ones?
    c. How many property owners are in need of lower cost capital or other substantial financial assistance to fund retrofitting?
C. *Impacts of Seismic Restoration on Retention of Historic Structures in the City*
    a. How can we ensure that the review of initial seismic evaluations identify those structures that are listed in the City's Historic Inventory or potentially significant and flag them for attention during subsequent review?
    b. How can we develop a clear process for reviewing proposed seismic retrofits to historic structures that is coordinated among responsible city departments and is consistent with

current regulations and Community policies?

c. How can we ensure that property owners take advantage of Seek out retrofit alternatives that are consistent with the Historic Building Code, historic characteristics of the structure, and provide the required most risk reduction?

D. *City departmental resources and budgets*
   a. What would be the loss in revenue to the Building Department if fee waivers were offered?
   b. What would be the staffing and budgetary needs over time to administer an expanded program that addresses additional building types?
   c. What kinds of interdepartmental cooperation and staff resources in other departments are necessary to ensure effective implementation and coordination with other city planning and public safety efforts?
   d. What would be the costs to provide and administer any incentives offered to property owners?

E. *Overall community economic health*
   a. What kind of benefits could accrue to Palo Alto in terms of maintaining community function and ability to recover if various building categories are retrofitted in time before the next major earthquake?

F. *Other related issues*
   a. It was brought up in the Advisory Group that the Building Department needs flexibility and authority to take steps to get tough seismic mitigation projects done. One idea was to grant the Building Official the ability to classify certain projects (with well-specified criteria) as warranting a kind of "seismic safety" or "earthquake resilience" fast tracking, with city departments agreeing to coordinate on a specified accelerated project review timeframe.
   b. Although outside the formal scope of this planning effort, several Advisory Group members commented that it would be desirable for the City to do some kind of assessment of any earthquake mitigation needs in public buildings and facilities serving the City.
   c. Advisory group members recommended the community be informed of Palo Alto's overall potential seismic risk by providing a summary of potential impacts on the City's website, including the expected performance of vulnerable buildings.
   d. The group also had a high degree of support for recommending that the City initiate and nest future earthquake mitigation programs within a broader disaster or community resilience initiative, as cities such as Los Angeles, Berkeley, and San Francisco have done. This could be incorporated into the update of the City's Comprehensive Plan Safety Element. There was insufficient time in the project's six advisory group meetings to consider potential initiatives to assess risks for cell phone towers, water supply, facades, private schools, post-earthquake shelter facilities, and/or other assets important to community recovery.

**ATTACHMENTS**

Attachment A: Seismic Risk Assessment Study Final Report

Attachment B: Seismic Risk Management Program Advisory Committee Members

Attachment C: Seismic Risk Management Program Advisory Group Summary Report on Process, Discussions, and Outcomes (November 2016)

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