SPUR SAN FRANCISCO PLANNING + URBAN RESEARCH ASSOCIATION

BUILDING IT RIGHT THE FIRST TIME:
IMPROVING THE SEISMIC PERFORMANCE OF NEW BUILDINGS

SPUR REPORT

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INTRODUCTION

The year is 2029 and a major earthquake, of an intensity not seen since 1906, hits the Bay Area. Like any earthquake it comes without warning, striking suddenly while the people of San Francisco go about their daily routines in the city's offices, homes, shops, and other community buildings. Although the earthquake comes as a shock and surprise, it is not really unexpected. In fact, we had been warned by seismologists and engineers that, sooner or later, such an event was inevitable.

What happens when the quake strikes depends on how well the city has prepared in the previous twenty years. In one scenario, little special preparation has been done: a few existing buildings were retrofitted by owners voluntarily and a few others through attrition were replaced by newer structures. The newer structures have better seismic performance than the older buildings and very few of these buildings collapse and kill occupants. But many new structures are rendered unusable by the quake, some will not be back in service for months, and several are not economically repairable and must be demolished. The damage has cascading consequences for San Francisco. People are displaced from their homes, companies and residents are forced to move out of the area, small businesses fail, and reconstruction demands overwhelm the city's damaged infrastructure.

An alternative scenario, promoted by SPUR, relies on San Francisco taking action now to prepare for earthquakes and improve the seismic performance of buildings and infrastructure. SPUR defines this improved post-earthquake scenario for San Francisco using a timetable of targets for when the city will recover its functions and services.[1] Achieving such targets will create a city that remains vibrant and resilient in the face of the inevitable earthquake.

SPUR Recommendations for New Buildings:

- Establish seismic performance targets (and incentives) for new buildings that allow the city to recover quickly from the inevitable strong earthquake.
- Make near-term improvements to the San Francisco Building Code to provide cost-effective improvements in seismic performance.
- Declare the expected performance that will be achieved by the current building code, and develop options for quantifiably improved seismic performance.
- Develop strong incentives and a clear communication of seismic performance expectations that encourage building to higher seismic standards.

WHY NEW BUILDINGS?

Improving the seismic performance of new buildings (that is, projects not yet built) is an important part of improved earthquake resilience for San Francisco, and is the subject of this paper. While older buildings are more likely to be damaged than new structures, the cost to retrofit older buildings is relatively high. In contrast, improving the seismic safety of new structures costs relatively little and thus has a relatively good benefit-cost ratio. Equally important, improving the safety of new structures helps arrest the growth

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[1] SPUR, *The Resilient City*, Overarching Paper, 2008

of earthquake threats in San Francisco. We should be building new buildings that will not need costly repairs or subsequent seismic improvements.

The most effective strategy for achieving SPUR's overall targets for building performance is to set a target for new buildings higher than the overall target, and to accept a target for existing buildings somewhat lower than the overall target.

This idea is shown in Table 1[2]. The overall seismic performance targets for buildings result from the combination of performance targets for new and existing buildings. In all cases, SPUR's overall performance targets require a substantial improvement in seismic performance compared to the current situation.

TABLE 1: TARGET STATES OF POST-EARTHQUAKE RECOVERY FOR NEW AND EXISTING BUILDINGS, COMPARED TO THE CURRENT SITUATION

SERVICE	WHEN RESTORED								
	4 hrs	12 hrs	24 hrs	72 hrs	30 days	60 days	4 mos	36 mos	36+ mos
85% of residents back in their homes	N		E					X	
95% of residents back in their homes		N	O		E			X	
100% of residents back in their homes					N		O E		X
Medical provider offices		N			O	E		X	
Schools back in operation		N			O E		X		
90% of neighborhood retail services		N			O	E			X
50% of offices and workplaces back in operation	N						O	E	X
95% of neighborhood retail services		N					O E	X	
All businesses open						N		O E	X

Source: SPUR analysis

Targets and estimates of recovery are for the "expected" level of earthquake ground motion.

- O: Overall goal
- N: Goal for new buildings
- E: Goal for existing buildings
- X: Current situation

BUILDING CODES FOR STRUCTURAL AND SEISMIC DESIGN

The seismic performance of a building depends on the building code requirements to which it is designed, built, and inspected. The building code provisions for earthquake design are updated approximately every

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[2] The table is based on a similar table in SPUR's *The Resilient City* overarching paper. The table here shows the city functions and services related to buildings, with expanded detail.

five years, and with each revision important new requirements are added. The local jurisdiction—in this case the City and County of San Francisco—has the responsibility to enact and enforce a building code, typically using national and state codes with local amendments permitted.

For seismic design, the overall trend is for requirements to become more restrictive with each revision to the building code. The changes are made as new knowledge about the performance of structures in earthquakes becomes accepted by the profession. Often this acceptance is slow; seismic performance issues identified by engineers and researchers can take years or decades to be fully incorporated into construction practice. The occurrence of a damaging earthquake tends to increase the impetus for change. Many improvements to the earthquake requirements in the building codes come after damaging earthquakes. The quakes that have spurred the most changes occurred in Long Beach in 1933, Anchorage Alaska in 1964, San Fernando in 1971, Loma Prieta in 1989, and Northridge in 1994. But ideally, such improvements to the building codes would not have to wait for an earthquake to occur, but would instead be implemented *before* a damaging earthquake.

It takes time for the profession to absorb, accept, and implement the new knowledge about structures in earthquakes. Once the new concepts are accepted and developed into specific technical requirements, there is still a time lag in implementation. The time lag between when the earthquake building requirements are essentially complete and when they become legally adopted is about five years. For example, the major requirements for the current building code were essentially completed in 2003, they were adopted into a standard published in 2005, which was adopted into a national code in 2006, adopted by California in 2007, and adopted by San Francisco in 2008[3].

One result of the development over time of more robust seismic requirements is a likelihood that a building designed to today's codes will at some point be judged deficient according to future standards for earthquake design. In the Bay Area, steel braced frame buildings constructed as recently as the late 1980s, and steel moment frame buildings constructed as recently as 1995, are now considered to have structural deficiencies that will limit their ability to perform reliably in earthquakes.

One strategy to avoid the pitfall of new buildings quickly becoming "obsolete" in terms of seismic performance is for the City to encourage (and provide incentives to) building developers to incorporate into the seismic-structural design state-of-the-art knowledge and approaches, even though such design practices are not yet required in building codes.

SEISMIC PERFORMANCE CURRENTLY PROVIDED BY THE BUILDING CODE

The level of seismic performance provided by the current building code is not explicitly defined. In general language, the Structural Engineers Association of California[4] states that the intention of the building code with respect to seismic performance is that a building designed to the code should be able to

- "Resist a minor level of earthquake ground motion without damage."
- "Resist a moderate level of earthquake ground motion without structural damage, but possibly experience some nonstructural damage."
- "Resist a major level of earthquake ground motion … without collapse, but possibly with some structural as well as nonstructural damage."

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[3] In 2003, requirements were essentially completed by the Building Seismic Safety Council (BSSC) for the National Earthquake Hazards Reduction Program. They were approved by BSSC in 2004, and adopted with modifications as a standard by the American Society of Civil Engineers in 2005. A more expeditious process can be used in the rare case of urgent "emergency code changes".

[4] SEAOC 1999 Blue Book

The Structural Engineers Association is intentionally vague in its description of expected performance - buildings are expected to "possibly" experience "some" nonstructural damage in a moderate level of earthquake ground motion, and "some" structural as well as nonstructural damage in a major level of earthquake ground motion. This qualified language recognizes the variability in the observed performance of buildings in earthquakes. The variability in performance comes from the inherent randomness of earthquake and material phenomena, and from the limitations in our knowledge of the best methods and assumptions to use in all the steps of predicting seismic performance.

Although the descriptions of the seismic performance intentions of the Building Code are vague, they undoubtedly define an expectation that is less ambitious than the targets proposed by SPUR in Table 1. If the SPUR targets are to be met, new buildings in San Francisco should be designed for enhanced seismic performance rather than meeting the default of the building code.

CLEAR COMMUNICATION OF SEISMIC PERFORMANCE EXPECTATIONS

In parallel with improving seismic performance, SPUR advocates a clearer communication of what seismic performance is expected from each building in our community. We propose five categories of seismic performance:

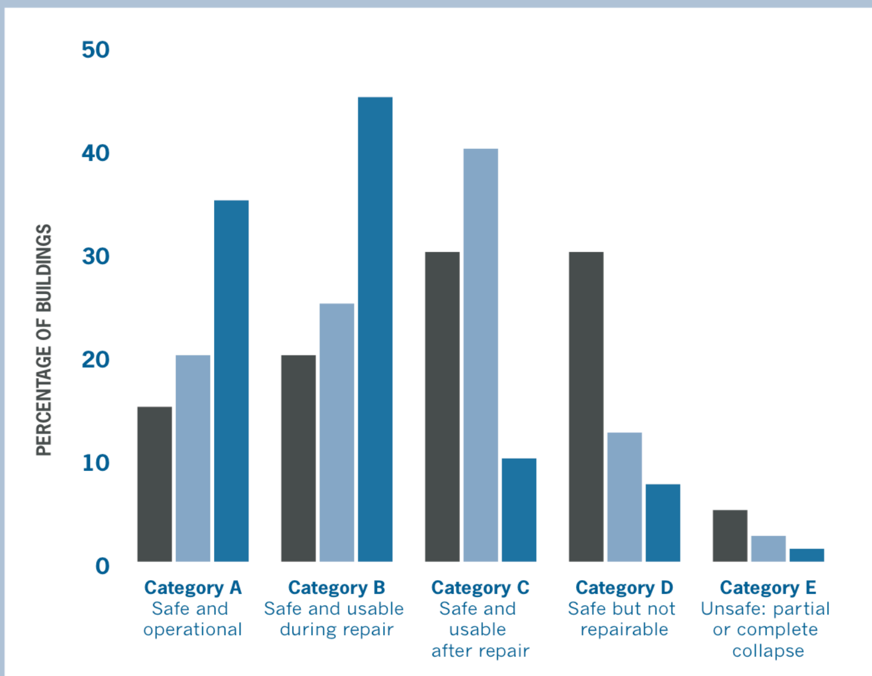
TABLE 2: SEISMIC PERFORMANCE MEASURES FOR BUILDINGS

Declaring in simple, concise and understandable terms the expected seismic performance of structures and systems, given a specific earthquake size, requires first the adoption of terms that are recognizable, consistent with other performance rating systems and useful is establishing policy.

CATEGORY	BUILDINGS
A	**Safe and Operational.** This describes the performance now expected of new essential facilities such as hospitals and emergency operations centers. Buildings will experience only very minor damage and have energy, water, wastewater and telecommunications systems to back up any disruption to the normal utility services.
B	**Safe and usable during repair.** This describes the performance needed for buildings that will be used to shelter in place and for some emergency operations. Buildings will experience damage and disruption to their utility services, but no significant damage to the structural system. They may be occupied without restriction and are expected to receive a green tag after the "expected" earthquake.
C	**Safe and usable after repair.** This describes the current expectation for new, non-essential buildings. Buildings may experience significant structural damage that will require repairs prior to resuming unrestricted occupancy, and therefore are expected to receive a yellow tag after the "expected" earthquake. Time required for repair will likely vary from four months to three years or more.
D	**Safe but not repairable.** This level of performance represents the low end of acceptability for new, non-essential buildings, and is often used as a performance goal for existing buildings undergoing rehabilitation. Buildings may experience extensive structural damage and may be near collapse. Even if repair is technically feasible, it might not be financially justifiable. Many buildings performing at this level are expected to receive a red tag after the "expected" earthquake.
E	**Unsafe.** Partial or complete collapse. Damage that will likely lead to significant casualties in the event of an "expected" earthquake. These are the "killer" buildings that need to be addressed most urgently by new mitigation policies.

Source: SPUR analysis

FIGURE A: HOW WOULD "SEISMIC GOLD" AND "SEISMIC SILVER" BUILDINGS FARE AFTER AN EARTHQUAKE?



Source: SPUR analysis; Note: Example effect on seismic performance of improved "silver" or "gold" seismic structural design provisions. The vertical axis on the chart can be interpreted either as the percentage of buildings in each performance category after the expected earthquake or as the probability of a particular building being in that category. (The two interpretations are equally correct. The former interpretation is useful in considering the resilience of a group of buildings or citywide resilience. The latter is relevant to the owner or tenant of a single building, who is only interested in the likely performance of that building.)

The seismic performance reflected in the above categories depends not only on the performance of the building structure – its beams, columns, walls, floors, roofs, and foundations – but also on the equipment and systems that are required to keep a building usable and in operation. Such systems include water and sewer systems, gas, electricity, fire sprinklers and alarms, elevators, emergency lighting, heating, ventilation, air conditioning, weather-tightness, telephone, and internet.

For ordinary buildings, current building codes promise no better than Category D performance in the expected earthquake. There will be, however variability in the resulting performance, and while some buildings designed to the code will only provide Category D performance, a large number of buildings will happen to perform much better. Thus, even though all buildings are designed to the same overall building code seismic criteria, when the expected earthquake ground motion strikes, there will be a distribution of resulting performance. This is illustrated in the bar chart of Figure A.

Enhancements to seismic design and inspection provisions can be developed to improve the seismic performance of new buildings. As discussed later, targeted building code enhancements could be grouped into voluntary provisions that can be certified by labels such as *Seismic Silver* or *Seismic Gold*. Such provisions would provide an overall improvement to the seismic performance of a stock of buildings, as shown in Figure A.

REASONS TO REQUIRE IMPROVED SEISMIC PERFORMANCE FOR NEW BUILDINGS

A number of factors support the idea that new buildings in San Francisco should be built for better seismic performance than the default level provided by the current building code, which is based on nationally applicable codes. Among U.S cities in areas of very high seismic hazard, San Francisco is unique because of its geography, urban density, reliance on public transportation, and susceptibility to post-earthquake fires.

Damage to new buildings and developments can have magnified impacts that affect adjacent structures and the city's transportation and utility networks, and can cause cascading economic disruption if workplaces or businesses are closed, if exterior cladding has fallen off buildings, or if people cannot occupy their homes. (See Figure 2)

Interviews with Bay Area building owners, occupants, and other stakeholders, conducted for the Peer Tall Buildings Initiative, indicate a clear desire for improved seismic performance in new buildings (whether tall or not)[5]. The interviews did not indicate expected costs of seismic improvement. As discussed in the section on the cost of improvements, such improvement is expected to increase building costs by 3% to 7% if targeted improvements are made to seismic provisions.

DESIGN AVAILIBLE RESOURCES AND PRECEDENTS FOR MAKING A CHANGE

Local governments are permitted to impose more restrictive standards than those in the national and state codes when this can be justified by local conditions such as seismicity, topography (for example hilly terrain), or climate. San Francisco adopts the California Building Code with modifications for the resistance to ground-shaking and hillside construction, as well as some long-standing local provisions for new construction. The San Francisco Building Code is adopted by the Board of Supervisors and implemented by the Department of Building Inspection (DBI), which reviews building plans and inspects buildings under construction to ensure that the approved plans and codes are followed.

While jurisdictions like San Francisco typically adopt some changes to the state codes, other jurisdictions, notably Los Angeles, have previously imposed substantially stricter seismic requirements in their city building code. Such requirements typically are developed by the local community of earthquake and structural engineering professionals.

[5] PEER 2007

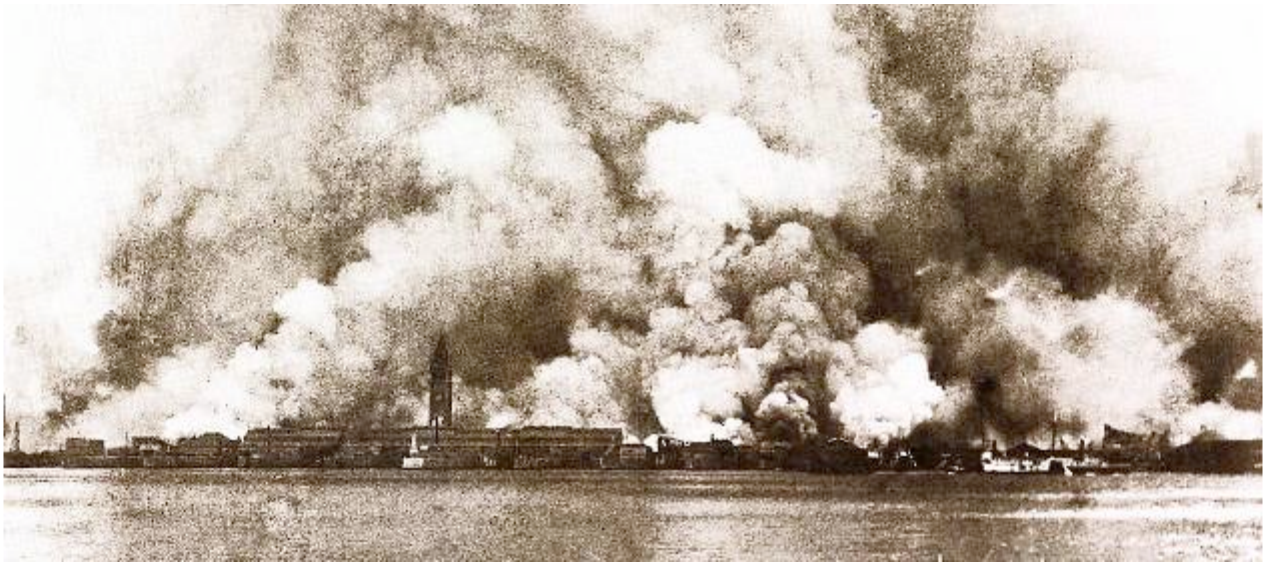


Figure 1. San Francisco burns following the 1906 earthquake. Because initial fire ignitions are typically caused by building damage or collapse, reducing the amount of damage in the entire building stock would reduce the likelihood of fire, which in turn would reduce damage to infrastructure, utilities, and buildings, and the demands on emergency response. These types of interrelationships in the city's earthquake resilience components support the argument for improving the seismic performance of new and existing buildings.

San Francisco is fortunate that many of the world's experts in earthquake and structural engineering are located in the Bay Area. In addition to individual experts, a number of their important professional and research organizations are located here. The Structural Engineers Association of California has an active section based in San Francisco. The Pacific Earthquake Engineering Research Center promotes and coordinates research at the leading West Coast universities, including Berkeley and Stanford, and is headquartered in Berkeley. (The center studies the specific problem of designing for earthquakes with targeted performance objectives.) The Earthquake Engineering Research Institute is an international organization headquartered in Oakland. The Applied Technology Council manages applied research in earthquake engineering and is based in Redwood City. The earthquake groups of the United States Geological Survey and California Geological Survey are based in Menlo Park. California has an Office of Emergency Services focused on earthquake response that is located in Oakland.

Having these experts and organizations at our doorstep is a valuable resource in carrying out the recommendations described in this paper.

RECOMMENDATIONS

To help create a city that remains resilient in the face of the inevitable earthquake crisis, SPUR has developed one long-term and three near-term recommendations.

RECOMMENDATION #1

(Long Term): Establish seismic performance targets for new buildings that allow the City to recover quickly from the inevitable strong earthquake.

SPUR has defined seismic performance goals according to an intended timetable for the city's recovery. Table 1 details the performance targets applicable to new buildings. The targets are ambitious and will take proactive efforts and incentives to achieve. The targets are long-term goals, to be achieved over the next two or three decades. Among the efforts necessary to achieve these earthquake resilience targets, SPUR recommends beginning with the following three near-term actions outlined below.

RECOMMENDATION #2

(Near Term): Make near-term improvements to the San Francisco Building Code to provide cost-effective improvements in seismic performance.

Improvements can be made to the San Francisco Building Code that should have little cost impact on construction, but should lead to improved seismic performance for new buildings. (See sidebar for example improvements.) The San Francisco Department of Building Inspection should support this effort, with the goal that the City should adopt new requirements within two years. The city should engage a group of experts in seismic/structural engineering, construction, and inspection to determine how, through specific changes to the building code, particular building systems can be designed to achieve better seismic performance. In this effort, DBI and the city will need to commit to doing more than the default standards of national building codes.

The types of changes envisioned include things such as better quality and reliability in the inspection of fire sprinkler installation and their seismic bracing, increased seismic design forces for elevator rails, and better column strength requirements in tall moment frame buildings.

RECOMMENDATION #3

(Near Term): Declare the expected seismic performance that will be achieved by the current Building Code, and develop code provisions that give options for quantifiably improved seismic performance.

One way to communicate expected seismic performance and to advocate for improved performance is to use a certification system that defines different levels of seismic resistance measures in terms of how usable or repairable a building will be after an earthquake. Potentially, a certification system could make seismic performance more transparent and allow the marketplace to push for improved seismic performance.

With this understanding, owners may choose to comply with a higher standard of such seismic measures - or "provisions" - because of their own desire for improved seismic performance, and/or because such improved seismic certifications have been shown to appeal to buyers or tenants.

Development and implementation of a seismic performance certification system is challenging because (a) the certification system needs to be fair, consistent, and verifiable, and (b) there is inherent uncertainty in how a given structure will perform under a given level of earthquake ground motion.

A certification system for new buildings (i.e., those not yet built) should be different than one for existing buildings, although both types of rating systems could be keyed into performance levels such as Categories A through E shown above. One reason to have a separate certification system is that existing buildings will generally have a wider range of seismic performance than new buildings, with some existing buildings exhibiting much poorer performance than would be expected of a new building designed to current codes. (This is because new buildings are designed to consistent standards, with a more reliable knowledge of material properties and construction quality.)

A more important reason to have a separate certification system is that for new buildings it is possible to tie the certification to a set of seismic design provisions with which the structural engineer and owner volunteer to comply. This can lead to a more objective certification system than could ever be developed for existing buildings.

The goal is that any claim of improved seismic performance in a new building be a valid and certifiable claim, based on specific and clear improvements in the seismic design, inspection, and/or construction process.

SPUR envisions a certification system for new buildings that is based on developing targeted seismic design provisions, in Building Code language, that give an option for designing for improved performance. The certification system could have two levels, beyond the ordinary Building Code requirements:

- **Seismic Silver** describes a building meeting the minimum seismic/structural requirements of the Building Code plus additional specific provisions, written in building code language, that have been developed to provide improved seismic performance. The target performance for this level might be as shown in Figure A—85 percent of buildings designed to the Silver provisions would achieve Category C or better seismic performance.
- **Seismic Gold** would be similar to *Seismic Silver* except that there would be more stringent provisions, which would provide further improvement to seismic performance. The target performance for this level might be as shown in Figure A—80 percent of buildings designed to the Gold provisions would achieve Category B or better seismic performance. That is, they would need some repairs but could be used safely while those repairs were made.

Some of the targeted provisions for improved seismic performance would depend on the type of structure being built.

Targeted provisions would include inspection and quality control in addtion to design provisions Quality control of building projects is crucial for seismic performance. Countries with poor quality control in construction and structural design typically suffer far more serious damage in earthquakes than they otherwise would.

During construction, quality control incudes inspection of construction activities, and inspection and testing of structural materials, elements, and building systems. Prior to construction, during design, quality control incudes thorough checking of the seismic design process and calculations. Prior to design, quality control should also be applied to the planning process, so that seismic criteria appropriate to building location and site conditions are developed. This is especially important for developments planned on land that has an increased seismic vulnerability, for example because of soil conditions that amplify shaking or cause soil liquefaction.

Simply calling for more inspections will not necessarily improve seismic performance. Any proposed changes should emphasize improving the quality and reliability of inspections.

It may be advantageous to also define a *Seismic Certified* category (below *Seismic Silver*) that can be applied to buildings that meet the 2007 San Francisco Building Code. The reason is that the rating of new building as *Seismic Certified* would raise awareness of the seismic rating system and ultimately could help create a market-based incentive for *Seismic Silver* and *Seismic Gold* buidlings as project sponsors and prospective homebuyers become aware of the new rating system.

IMPLEMENTING A CERTIFICATION SYSTEM

The idea of targeted improvements to the Building Code grouped under categories such as *Seismic Silver* and *Seismic Gold* is a refinement of a concept that already exists in the code.

The national building standard for structures, ASCE 7 [2005], to which nearly all U.S building codes refer, requires more restrictive earthquake designs for certain building types. The more restrictive requirements depend on a categorization of the use that occupies a building and the relative hazards to people if the building fails. Occupancy Category II refers to ordinary buildings, Occupancy Category III includes buildings such as schools, jails, utility stations, chemical facilities, and assembly buildings, and Occupancy Category IV includes critical buildings such as hospitals and fire and police stations. Category I includes buildings that aren't regularly occupied by people or that represent a low degree of hazard if they fail.

Compared to ordinary buildings, Occupancy Category III buildings must be designed for 25% more resistance to earthquake forces and 33% more resistance to earthquake caused deformations. Occupancy Category IV buildings, compared to ordinary buildings, must be designed for 50% more resistance to earthquake forces and double the resistance to earthquake caused deformations.

Requirements For New Buildings: How Much Is Too Much?

The components of development cost are threefold: construction costs (or hard costs), indirect costs (or soft costs) and land cost. While the proposals in this paper stand to add significantly to the hard costs of a project, there are also many soft costs that we, as a city, have determined are important to layer on development. These include exactions for public goods such as parks, childcare facilities, libraries and affordable housing.

How much is too much? This is a difficult question to answer. If fees are set too high, we don't get new development, thereby propelling new growth into less costly parts of our region. If fees are set too low, we lose out on public benefits we might otherwise have been able to receive.

Many cities, including San Francisco, have commissioned sophisticated studies that seek to determine how new fees and regulations change the feasibility of development. Typically, these studies look at the impact a new fee or regulation will have on hard costs and soft costs and see how much value is left over to pay for land (known as the "land residual.") If the land residual is too low, a landowner is unlikely to sell his or her land, and new development wont happen.

While there is no "bright line" where all development ceases to occur, it is possible to make some gross judgments about how new fees and regulations will affect the market as a whole. And that is where decisionmakers - such the mayor and the Board of Supervisors - have to start weighing policy options. Can we afford green building requirements and new seismic performance requirements? How strict can those requirements be before the hard costs become too costly to bear? Should we reduce our fee burden for public benefits in favor of increasing our seismic requirements?

These are the sorts of questions that decisionmakers need to grapple with. In a city like San Francisco, where every sort of public benefit has a built-in constituency, it can be challenging for elected officials to find a balance that pleases everyone. Too often, the solution is just to layer more and more requirements on new development. Some argue that we have already made certain types of development impossible through our cumulative set of requirements.

SPUR believes that we cannot achieve the goal of enhanced seismic performance by simply layering on yet one more cost. We believe that resiliency is an important enough goal that the City should make some hard choices to obtain it. This means either rolling back some exactions, changing the timing of the payment of exactions or creating other forms of economic incentives that neutralize the added cost of building more resilient buildings.

Ideally, all Occupancy Category IV buildings will be fully operational after a large earthquake, although currently their expected seismic performance is not explicitly checked to verify that the Building Code requirements will provide the desired performance.

SPUR recommends a two-phased approach to implementing a rating system. Phase I makes use of the Occupancy Category requirements as a starting point for targeted provisions for improved performance. Phase II requires the development of targeted specific optional code provisions for improved seismic performance.

PHASE I: USE OCCUPANCY CATEGORY REQUIREMENTS AS A STARTING POINT FOR TARGETED PROVISIONS FOR IMPROVED PERFORMANCE

Absent the development of more targeted provisions under headings such as *Seismic Silver* and *Seismic Gold*, the existing code requirements for Occupancy Categories III and IV could be used as an objective and verifiable voluntary standard that provides improved seismic performance. Such an option has the following advantages:

- Straightforwardness of simply considering larger seismic forces (and stricter limits on seismic deformation).
- Already established in the building code, thus does not require development (by expert engineers and architects) of targeted provisions.

Advantages of instead developing targeted voluntary provisions under headings such as *Seismic Silver* and *Seismic Gold* include

- Targeted improvements are likely to provide better seismic performance for less cost increase compared to a broad brush approach of increasing seismic forces.
- Targeted improvements can include improvements to inspection and construction quality control, which are not addressed in an approach of only increasing seismic forces.
- Targeted improvements would be evaluated and developed for specific building and structure types, verifying that the improved provisions would be feasible.

PHASE II: DEVELOP TARGETED SPECIFIC OPTIONAL CODE PROVISIONS FOR IMPROVED SEISMIC PERFORMANCE

SPUR recommends that a group of experts develop specific optional code provisions for improved seismic performance. These provisions would define the voluntary *Seismic Silver* and *Seismic Gold* certifications. Requirements similar to those already in the Building Code for Occupancy Category III and Occupancy Category IV buildings can be used as a starting point, although SPUR recommends developing more targeted provisions.

Cost of improved seismic provisions in new buildings

The cost of designing and building for improved seismic performance will depend on a number of variables including the specific design and inspection provisions implemented, material and labor costs, the type of structure, and its use.

A study of the seismic design of equipment and building systems in hospitals compared the unit construction costs of a new hospital in California to that for a new commercial building in California.[6] The additional cost of improved seismic provisions for equipment and systems, not including the main structure, was estimated to be $14 to $17 per square foot in 2004 dollars, about a 5% increase in construction cost according to the report.

[6] Applied Technology Council, 2003, ATC 51-2, Recommended U.S. – Italy collaborative guidelines for bracing and anchoring nonstructural components in Italian hospitals, Redwood City, CA

COMPARISON TO ANALOGOUS CERTIFICATION AND RATING SYSTEMS

In considering a rating system for seismic performance, it is helpful to examine analogous rating systems that have been successfully used in the building industry and other fields.

Comparison to LEED certification

The LEED® certification process for environmentally sustainable buildings provides a useful comparison. For new construction LEED certification is awarded at four levels: Certified, Silver, Gold, and Platinum. The certification level is based on meeting specific requirements to earn points, with some requirements being "prerequisites," which are required for any level of certification. Projects apply for certification using an online system, and fees for certification are based on building area. The Green Building Certification Institute reviews the applications and grants certification points and levels.

The seismic certifications envisioned for new buildings would be simpler to implement than the LEED ratings and would not require the extensive validation process, because the additional requirements for improved performance would be in building-code language. Thus the building authority (DBI) could check that *Seismic Silver* or *Seismic Gold* provisions are met using a process similar to the normal structural plan review process.

Comparison to Probable Maximum Loss ratings

Probable Maximum Loss ratings have been used by the insurance and lending industries and represent the probability that earthquake damage will cause a certain level of loss in a building. The ratings account for the seismic hazard at the location of the building in an objective and accurate way. The ratings typically do not account for local soil conditions, and typically account for structural/seismic vulnerability only based on coarse categorizations of building construction types and number of stories.

Considering seismic/structural vulnerability only based on building type and size would not work for rating the seismic performance of new buildings. Such a scheme would encourage only certain construction types for buildings. In reality all construction types permitted in the building code could be designed for better seismic performance through specific additional provisions applicable to that construction type or to the design deformation or force levels. The design for better seismic performance regardless of construction type is what should be encouraged with a seismic performance rating system for new buildings.

Comparison to vehicle crash test ratings

Vehicle crash test ratings are provided by a number of organizations including the National Highway Traffic Safety Administration, European New Car Assessment Program, and the Insurance Institute for Highway Safety. The ratings, and the testing behind them, have contributed to great improvements in automobile safety over the last five decades. The ratings have led to safety being a verifiable and marketable feature of automobiles.

Potentially, ratings of buildings could lead to a similar improvement in seismic performance and the earthquake resilience of our cities. However, buildings cannot be tested for earthquakes as easily as cars can be crash-tested. Also, buildings are usually unique rather than being a uniform manufactured product like a car, so that safety conclusions will depend on individual building characteristics.

Overall, the examples discussed above demonstrate the potential value, and some of the challenges, of developing a seismic performance rating system for new buildings.

The equipment and systems contributing to this cost increase included ceilings, partitions, fire sprinklers, plumbing, ducts, mechanical equipment, electrical systems, cladding, and miscellaneous metals. The cost increase results from the more rigorous seismic design, inspection, and agency review for these systems, which is required for California hospitals. The increase is estimated on a unit cost basis and does not include the cost of additional equipment or specialized medical equipment in hospitals compared to commercial buildings. Thus the estimate is applicable to potential cost increases in commercial buildings if significantly stricter seismic provisions for equipment and systems are implemented.

An additional, perhaps equal, increase in construction cost may be incurred in designing the main structure of a building for increased seismic forces and stricter deformation limits.

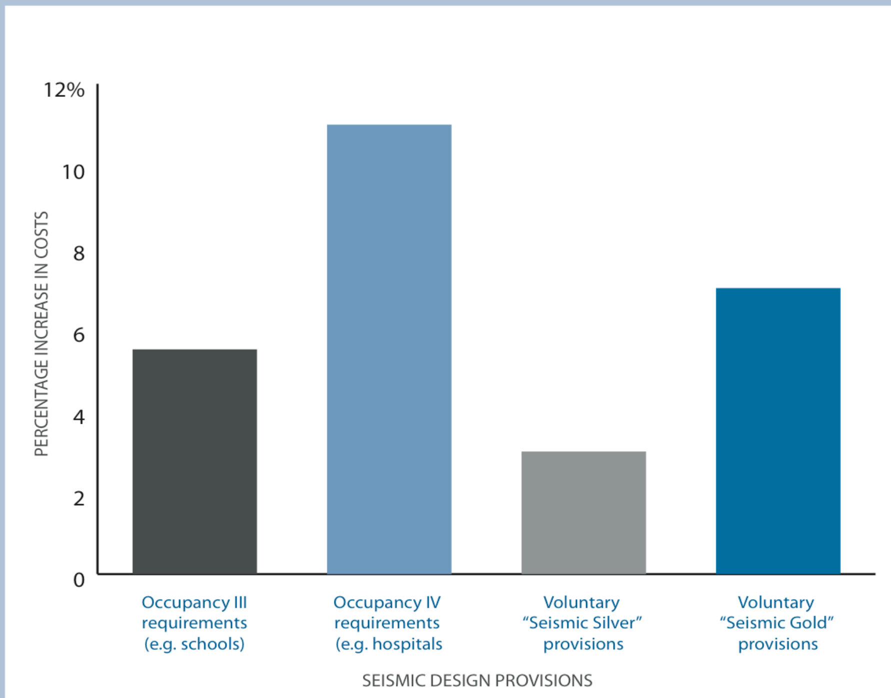
SPUR's own inquiry into potential cost impacts came to similar conclusions. SPUR asked contractors to estimate the percentage increase in construction cost that is likely to occur if a building is to be designed to the requirements for Occupancy Categories III or IV rather than Occupancy Category II. The contractors estimated that hard cost increases were an average of 5.5% for an increase from Occupancy II to Occupancy III and about 11% for an increase from Occupancy II to Occupancy IV[7]. One benchmark that a contractor used to help formulate their estimate was to consider that one way to meet Occupancy IV requirements is to seismically isolate the structure.

Contractors involved in this study noted that it is critical that improved seismic provisions not lengthen the duration of construction, as this would cause further cost impacts. One contractor also noted that some structural systems (for example post-tensioned concrete walls) can potentially offer improved seismic performance with no cost increase.

Phase II of implementing a seismic certification system requires the development of targeted standards for Seismic Silver and Seismic Gold. SPUR assumes that Seismic Silver provisions will be somewhat less strict (and less costly) than code requirements for Occupancy III buildings (a 3% cost increase as compared to a 5% increase). We also assume that Seismic Gold provisions will be more strict than code requirements for Occupancy III buildings, but less strict than those for Occupancy IV buildings (a 7% cost increase as compared to a 12% cost increase). This is illustrated in figure 3 (below)

[7] Some contractors estimated construction cost increases for Occ II to Occ IV as high as 20%.

FIGURE 3: ESTIMATED INCREASE IN CONSTRUCTION COSTS FOR IMPROVED SEISMIC PROVISIONS



Source: SPUR analysis

RECOMMENDATION #4 (NEAR TERM): DEVELOP STRONG INCENTIVES THAT ENCOURAGE BUILDING TO HIGHER SEISMIC STANDARDS.

To balance negative impact on project feasibility arising from improved seismic provisions, incentives must be provided, other fees and requirements must be reduced and/or the marketplace must be willing to pay more for improved seismic performance.

SPUR recommends that San Francisco should develop strong incentives to encourage developers to implement higher performance standards for buildings. This should be done in parallel with the development of building code options for improved seismic performance,

As part of San Francisco's Community Action Plan for Seismic Safety,[8] currently under development, a range of possible seismic incentives have been identified. These include property tax reduction or deferment, transfer tax rebates, fee waivers, zoning incentives, expediting of permits and reviews, and permitting the transfer of development rights.

A. Density Bonuses

Of the potential incentives, planning incentives may be the most effective option that does not incur additional cost to the city. A relatively straightforward incentive would be to allow additional gross area in the zoning approvals by the Planning Department.

[8] Community Action Plan for Seismic Safety, Incentives to Encourage Seismic Retrofits: Options for San Francisco, 5 September 2008.

Other cities enact legislation that includes development incentives to progress issues that are important to the community. In Sydney Australia, a floor space incentive was enacted as a part of their "Living City" planning controls enacted in the mid-1990's. The objective for Sydney was to increase the number and density of housing units in the city. The floor space incentive was available to developers for an intentionally limited period. Project sponsors had approximately five years in which to have their projects become entitled and commence construction. After this period, the prior floor space controls were re-instated and the incentives were no longer offered. The incentives worked. The number of housing units rose significantly and the city became a more exciting and livable place to be. .[9]

Figure 4 Sydney, Australia. Between 1993 and 2000, as part of the "Living City" planning initiative, development incentives including increased floor area allowances succeeded in encouraging downtown residential density.

While modification of zoning height and bulk controls in San Francisco are frequently a subject of debate, there appears to be a way to use the existing height bonuses that are in the current zoning controls with a slight modification. In some locations in San Francisco, there is a 10% height bonus for more slender buildings. This has all but never been used and, as such, may be considered ineffective. A more successful scenario may be that a 10% height bonus with the same bulk allowance on lower levels be allowed on developments that build to a higher seismic performance.

SPUR recommends that density bonuses be used as an incentive to encourage developers to build to seismic silver and seismic gold standards to enable San Francisco to become more resilient.

B. Tax Abatement

Seismic Silver and Seismic Gold projects should be eligible to receive some type of tax abatement. This could include property tax abatement, transfer tax abatement or tax abatement for other types of taxes, such a payroll taxes for commercial structures.

C. Reduction in Insurance Costs

The cost of earthquake insurance is extremely high. The City of San Francisco should work with the California Earthquake Authority to ensure that Seismic Silver and Seismic Gold projects are able to obtain discounted insurance that reflect their reduced risk based on increased seismic performance. Even if earthquake insurance (and thus monthly HOA dues) could be reduced, it is unclear whether prospective buyers would pay more upfront in exchange for future operating savings.

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[9] Sydney: Planning for the "Living City" October 2000. http://unpan1.un.org/intradoc/groups/public-/documents/APCITY/UNPAN007491.pdf. Retrieved 12 November 2008.

D. Deferred Payment of Public Benefit Fees

Seismic Silver and Seismic Gold projects should be eligible to defer payment of public benefit fees until a Certificate of Occupancy is obtained.

CONCLUSION

It is crucial that San Francisco start preparing now for the inevitable earthquake. SPUR has defined overall goals for San Francisco's buildings and infrastructure to remain resilient in such a disaster. The effort requires a view of longer-term goals as defined by SPUR, as well as specific actions that should be started now. These actions include declaring and clearly communicating expected seismic performance, giving options for quantifiably improved seismic performance, making near-term improvements to the building code, and developing strong incentives, such as increased height limits, for buildings that meet higher seismic standards.