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SB1953 and the Challenge of Hospital Seismic Safety in California

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Executive Summary

For 33 years, there has been a continuing public policy effort in California to reduce the seismic vulnerability of the state's hospital infrastructure. Driven by historical experience and public concern regarding the availability of health care following a natural disaster, the state of California has enacted laws to ensure continued hospital operations following a large earthquake. On one hand, the laws have addressed a straightforward public health concern, and they have been repeatedly endorsed by legislation and state policy actions. However, they are also controversial. Because of the age and engineering of the California hospital infrastructure, it is projected that the seismic safety goals will require reconstruction of about 50 percent of the current hospital floor space.

In this report, funded by the California HealthCare Foundation, RAND updates its previous analysis of the costs, construction activities, and policy issues stimulated by SB1953, California's hospital seismic safety legislation. The intended audience for this report includes California policymakers, hospital and health care leaders, and residents of California. Inspired by large increases in the costs for hospital construction and by rapidly approaching deadlines to comply with seismic safety goals, this report employs new data and analysis on the following issues:

- Updated and detailed information on hospital infrastructure and construction costs;
- Hospital decision making for large construction projects;
- Historical and current records of hospital construction in California; and
- Quantitative seismic hazard information for California hospitals.

With this information, the authors assess the overall progress toward SB1953 compliance, identify plausible deadlines for meeting SB1953's requirements, and quantify total construction cost scenarios that may occur as hospitals rebuild their facilities. Much of this analysis is focused on the "collapse-hazard" buildings classified as SPC-1, which are the largest fraction of the California hospital infrastructure.

This analysis identifies factors that have created significant challenges for SB1953 implementation. Specifically:

The pace of SB1953 compliance has been slow. Based on historical rates of construction and permit filings with the California Office of Statewide Health Planning and Development (OSHPD), about half of the SPC-1 hospital infrastructure will not comply with the 2008/2013 deadlines for SB1953, and many may not be able to comply with the final 2030 deadline.

Because of the size of the infrastructure that needs to be constructed (40 million to 70 million square feet) and the maximum pace for the design, regulatory, and construction processes (1.5

million to 2 million square feet per year), it could take more than 30 years to complete the implementation of SB1953.

The costs of achieving compliance will be high. The total cost to replace all of the SPC-1 structures is likely to be large compared to historical hospital construction spending in California. The ultimate size of the construction program, and hence the cost, will depend on decision making by hospital leaders regarding the size of new facilities. Over this period, inflationary forces could also have a large impact on the total cost.

Considering these factors, cost scenarios were developed to examine a range of potential costs, accounting for trade-offs in inflation rates, construction rates, and the sizing of new facilities. With plausible parameters for these factors, the scenarios indicate that total construction could cost $45 billion to $110 billion, in 2006 dollars. This estimate does not account for the cost of financing, which could increase the total by as much as a factor of two.

At these levels, construction for SB1953 compliance could translate to significant increases in health care costs. There are, however, these large uncertainties in the absolute magnitudes and the ultimate bearer of these costs:

Special skills are required to plan and execute projects for SB1953 compliance. Planning and executing large hospital construction projects requires complex skills and competencies in strategic planning, financial management, and health care facility design. Notably, these skills differ significantly from the traditional expertise for seismic safety (e.g., earthquake engineering), and they may not be present in hospital organizations simply because they are not required to support general ongoing health care operations. Without these capabilities, it is not feasible for a hospital to plan and execute large construction projects for SB1953 compliance.

Change in hospital design is an important factor in increased construction costs. Compared to hospital buildings from the 1950s, '60s, and '70s, new hospital buildings in California are substantially larger for a given level of medical functionality. Recent design data for an SB1953 replacement facility show the gross square footage for each department is 20 percent to 150 percent larger than the previous hospital *assuming the same medical driver* (e.g., number of beds, number of patients). Generalizing this result indicates that hospitals will build substantially larger facilities, requiring larger construction expenditures, simply because of modern design standards (35 percent to 60 percent larger). And it does not include the costs of reconstructing SPC-2 buildings by 2030, which would probably increase the overall cost estimate by an additional 20 percent.

In practice, the SB1953 deadlines have been moved ahead by 17 to 22 years. According to the original SB1953 deadlines, hospital owners must retrofit or rebuild the SPC-1 structures by January 1 2008/20013**.** If the structures are retrofitted, they must be rebuilt by 2030, but if they are rebuilt, no further deadlines apply. It appears that these deadlines were developed as a phased strategy to meet seismic safety goals: The most vulnerable structures (those with a "potential risk of collapse") were to be partially mitigated in the near term with seismic retrofits and then totally replaced 22 years later. In this way, SB1953 implementation was anticipated over a 35-year period (from 1995 to 2030), addressing the collapse risk by 2008/2013 and the goal for continued hospital operations by 2030. However, in practice the compliance schedule seems to differ significantly from the original plans. As reported by earthquake engineers, state officials, and hospital owners, only a few organizations are implementing retrofits because they are expensive and disruptive to health care operations. Because reconstruction without retrofits appears to be the preferred compliance strategy, it effectively moves the 2030 deadline up to 2008/2013 for all SPC-1 structures.

Based on these results, the authors conclude that hospital seismic safety is an extremely challenging policy goal for California. After 33 years, there has been only limited progress on this issue. RAND’s analysis suggests that there are special challenges to implement disaster mitigation policy for hospitals because of the costs, planning, and policy requirements of hospital reconstruction. In this environment, the key questions for the SB1953 policy debate will focus on the appropriate time scales to achieve California’s seismic safety goals and the relationship between seismic safety and broader public health goals where hospitals play a critical role.

I. Introduction

In 2002, RAND carried out a study to quantify the expected construction costs driven by California SB1953, the state law governing seismic safety for all acute-care hospitals.[1] Under the law's requirements, about 50 percent of California hospital buildings must be replaced or substantially strengthened. Given the magnitude of the anticipated construction activities, the RAND study was motivated by concerns in the California hospital industry regarding the affordability of SB1953.

When the study was performed, there had been few major hospital construction projects in California, even though the deadlines were approaching and a large infrastructure needed to be addressed. In this environment, RAND estimated that the total construction costs stimulated by SB1953 could be as large as $41 billion, though there were two important caveats for this conclusion. First, the RAND study emphasized that most buildings targeted by SB1953 would be more than 50 years old at the time of replacement, raising questions of whether construction might be viewed as normal business modernization rather than compliance with seismic safety standards. Second, the study noted that "replacement" hospital buildings were significantly different from the original structures in design and function, indicating that SB1953 compliance activities involved far more than simple seismic strengthening of hospital buildings. However, the study also noted that construction trends and hospital financial data indicated that a large-scale modernization program, suitable to meet SB1953's requirements, was highly unlikely as part of normal business operations in California. Even if such an effort could be funded, the study emphasized, there would be severe logistical challenges to meeting the current SB1953 deadlines because it would require unprecedented hospital construction rates in the state. Thus, the authors concluded that SB1953 compliance would be closely tied to the policy debate surrounding implementation of seismic requirements.

Five years later, RAND has re-examined the costs and construction activities stimulated by SB1953's requirements. Compared to the policy- and decision-making environment at the time of the first report, some issues have become significantly more challenging, motivating this new and updated analysis. In the past few years, hospital construction costs have increased dramatically, just as the number of construction projects for SB1953 has started to increase. Today, the California hospital design and construction industry is working at capacity. The initial deadlines for SB1953 are now less than two years away, though many hospitals have received a small extension of five years. Together, these factors have triggered a large policy debate on the possibility of legislative and regulatory changes to the original SB1953 requirements. In this environment, hospital owners face extreme uncertainty in a number of dimensions as they approach their compliance decisions for SB1953.

This updated report focuses the analysis on California's oldest hospital buildings, which will generate the largest SB1953 construction expenditures, as detailed in our previous report. Officially classified as SPC-1 structures by the California Office of Statewide Health Planning and Development (OSHPD), these buildings were largely constructed before 1973 using only minimal standards for earthquake engineering. (See Appendix A for OSHPD structural classifications for SB1953 compliance.) Today, these buildings are viewed as "collapse hazards," meaning that they could experience catastrophic failure during a large earthquake. To a degree, it is possible to reduce this seismic vulnerability through structural retrofits on these buildings. However, to meet the full requirements of SB1953 will require complete reconstruction and replacement of these buildings by 2030.

From a policy perspective, the SPC-1 buildings are most important because they represent the largest fraction of the California hospital infrastructure. They are also well characterized because of legislatively mandated survey efforts carried out by the OSHPD. Simply, meeting SB1953's requirements for the SPC-1 buildings will produce large-scale changes in the size and characteristics of California's hospital infrastructure, necessitating a range of other important policy considerations on health care in California.[2]

To update RAND's analysis of SB1953, this report considers the construction costs and decision making that will be required to bring the SPC-1 buildings into compliance with SB1953. For this effort, the authors draw on new data and analysis on the following issues:

- Updated and detailed information on hospital infrastructure and construction costs;
- Hospital decision making for large construction projects;
- Historical and current records of hospital construction in California; and
- Quantitative seismic hazard information for California hospitals.

With this information, the authors assess the overall progress toward SB1953 compliance, identify plausible deadlines for meeting SB1953's requirements, and quantify total construction cost scenarios that may occur as hospitals replace SPC-1 facilities. It is important to emphasize that the authors carry out this analysis *without* consideration of the patient populations that may be affected by SB1953 compliance actions (e.g., by the closing of facilities, continued seismic vulnerability, or increased operational costs). Although these are critical considerations for health care policy issues surrounding SB1953 implementation and will be an important part of any legislative debate to amend SB1953, they are beyond the scope of the basic cost and engineering issues that are the focus of this report. If this study's limited analysis identifies significant costs or challenges for compliance, the authors believe, it will motivate further investigations to identify these factors that shape health care and potential policy solutions.

II. Characterizing the Current California Hospital Infrastructure

For 33 years, there has been a continuing public policy interest in the seismic vulnerability of California's hospital infrastructure. Triggered by the 1971 San Fernando Valley earthquake, which destroyed a number of hospitals, the California legislature passed the original Alfred E. Alquist Hospital Facilities Seismic Safety Act in 1973, requiring all new construction to meet stringent seismic safety requirements. However, by the 1980s there was concern that there had been little new hospital construction and that the state's health care infrastructure was still quite vulnerable to seismic hazards. To assess the problem, the legislature commissioned an anonymous engineering survey, performed by the Applied Technology Council, published in 1991.[3] That study concluded that 83 percent of the hospital beds were in buildings that did not comply with the Alquist Act, a conclusion that was validated by the widespread hospital damage that occurred in the Northridge earthquake three years later.

Following this earthquake, the California legislature passed SB1953, which established new regulations and deadlines for hospitals to comply with the original Alquist Act. The goal for this effort, as stated in this act, was to ensure that hospital facilities would remain operational after a large earthquake so that they could provide urgently needed health care services to the impacted populations. Compared to other building codes in California, which historically have focused on life safety during a natural disaster, the SB1953 requirements were far more demanding and largely untested in a regulatory environment. It was anticipated that hospitals would accomplish this goal in phases. The most vulnerable buildings, subject to collapse during an earthquake (and hence a risk to life safety), were to be mitigated by 2008, with all buildings meeting the operational goals by 2030. (See Appendix C for a discussion of the SB1953 deadlines.)

To facilitate the implementation of SB1953, OSHPD published regulations and required hospitals to survey the vulnerability of their facilities. The results of this effort were published in 2001, and the data were analyzed in RAND's previous report. (See Appendix B for state-level summaries of these data.) Based on the results from the first report, together with updated closure and survey information obtained from OSHPD, this study summarizes the current characteristics of SPC-1 buildings in California hospitals:

- In currently operational hospitals, SPC-1 buildings contain 52.4 million square feet of floor space, which represents 53.9 percent of the total general acute-care hospital building area in California;
- SPC-1 buildings in operational hospitals contain 44,011 licensed beds, which are 47.2 percent of the statewide total;
- SPC-1 buildings are present on 305 operational hospital campuses, out of a total of 456 general acute-care facilities, statewide; and
- According to OSHPD's 2001 survey, there were 975 SPC-1 buildings on hospital campuses at that time, representing 38.9 percent of the statewide inventory.

As documented in the first report, SPC-1 buildings are distributed throughout most of the state. But the largest fraction is disproportionately concentrated in Los Angeles County, which contains 40.9 percent of the SPC-1 floor space with about 28 percent of the state's population.

Since the first report, there have been only minor changes in numbers and characteristics of California's hospitals, re-emphasizing one of the conclusions from that study that California's hospital infrastructure is long-lived and subject to slow change. As documented by OSHPD,[4] 28 general acute-care hospitals have closed in California since January 2001. (See Table 1.) Of these hospitals, 19 included SPC-1 buildings. Through their closure, these hospitals reduced the statewide inventory of SPC-1 floor space by about 4 percent and the beds located in SPC-1 facilities by 4.4 percent. The number of beds in the hospitals that closed with SPC-1 beds totaled 2,006, compared to 1,085 in the hospitals with the no SPC-1 facilities. Other than these closures, the authors are not aware of any other changes to SPC-1 facilities that affect SB1953 (except for ongoing construction projects discussed in the next section).

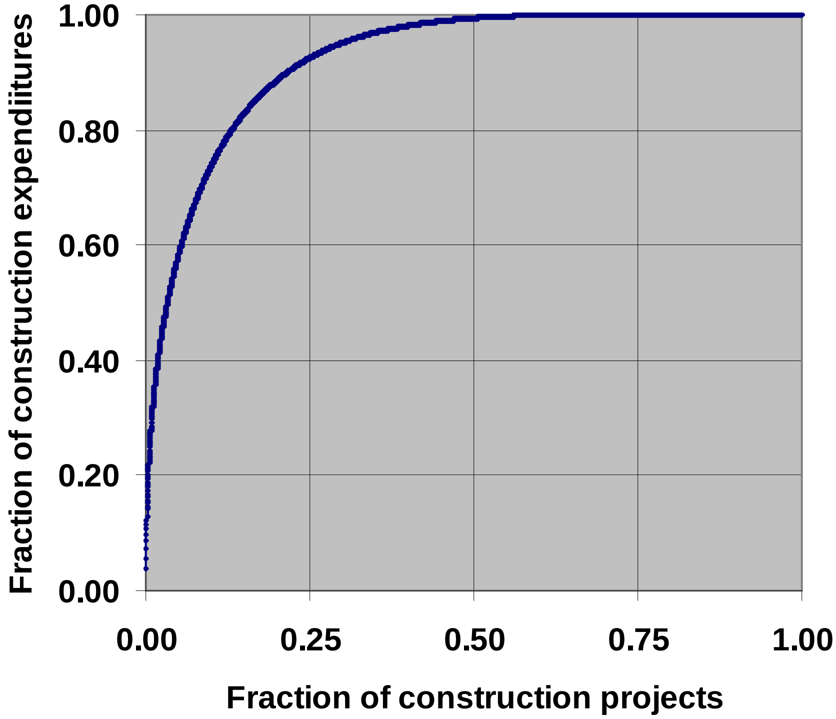
Table 1. Closed and Suspended Acute-Care Hospitals, 2001–Present[5]

Hospital Name	Address	Number of Beds	Date Closed	Square Footage in SPC-1 Buildings
Lassen Community Hospital	560 Hospital Lane Susanville, CA, 96130	59	4/22/03	20,260
Little Company of Mary San Pedro Hospital	1437 W. Lomita Blvd. Harbor City, CA, 90710	130	9/26/02	0
San Luis Obispo General Hospital	2180 Johnson St. San Luis Obispo, CA, 93401	92	6/19/03	70,500
St. Francis Medical Center of Santa Barbara	601 E. Micheltorena St. Santa Barbara, CA, 93103	85	6/18/03	79,750
San Jose Medical Center	675 E. Santa Clara St. San Jose, CA, 95112	328	12/9/04	157,000
Alta Hospital District	500 Adelaide Way Dinuba, CA, 93618	39	10/30/01	50,000
Lindsay District Hospital	740 N. Sequoia Ave. Lindsay, CA, 93247	102	12/3/01	0
Memorial Hospital at Exeter	215 Crespi Ave. Exeter, CA, 93221-1399	80	8/7/02	32,802
Bellwood General Hospital	10250 E. Artesia Blvd. Bellflower, CA, 90706	85	4/6/03	57,576
Granada Hills Community Hospital	10445 Balboa Blvd. Granada Hills, CA, 91344	155	4/20/04	85,000
Robert F. Kennedy Medical Center	4500 116th St. Hawthorne, CA, 90250	229	12/9/04	146,100
Monrovia Community Hospital	323 S. Heliotrope Ave. Monrovia, CA, 91016	49	5/26/04	21,586
Elastar Community Hospital	319 N. Humphreys Ave. Los Angeles, CA, 90022	110	8/19/04	0
Santa Teresita Hospital	819 Buena Vista St. Duarte, CA, 91010-1703	216	6/30/04	149,167

St. Luke Medical Center	2632 E. Washington Blvd. Pasadena, CA, 91107	165	6/1/03	120,288
Northridge Hospital Medical Center	14500 Sherman Circle Van Nuys, CA, 91405	209	11/04	0
Novato Community Hospital	1625 Hill Road Novato, CA, 94947	64	5/01	0
Ukiah Valley Medical Center	1120 S. Dora St. Ukiah, CA, 94582	49	7/01	0
Brea Community Medical Center	380 W. Central Ave. Brea, CA, 92621	162	3/05	69,201
Orange County Community Hospital Buena Park	6850 Lincoln Ave. Buena Park, CA, 90620	53	4/03	24,900
Santa Ana Hospital Medical Center	1901 N. Fairview St. Santa Ana, CA, 92706	69	9/03	42,000
Anaheim Memorial Medical Center West	1830 W. Romneya Drive Anaheim, CA, 92801	144	8/01	87,552
Scripps Hospital East County	1688 E. Main St. El Cajon, CA, 92021	162	7/02	0
Central Valley Orthopedic and Spine Institute	2558 Jensen Ave. Sanger, CA, 93657	31	License in suspense	0
Mercy Westside Hospital	110 E. North St. Taft, CA, 93268	84	License in suspense	0
Orthopedic Hospital	2400 S. Flower St. Los Angeles, CA, 90007	112	License in suspense	168,000
Valley Plaza Doctors Hospital	2224 Medical Center Drive Perris, CA, 92571	34	License in suspense	30,000
Sonora Regional Medical Center-Forest	One S. Forest Road Sonora, CA, 95370	28	License in suspense	75,247

There have been a large number of construction projects in California hospitals since the first report, though the majority of these have been relatively small-scale. Examining OSHPD records of the hospital building permits that were submitted from January 1, 2001, to the present and completed in that period shows a total estimated construction cost of $804 million distributed over 5,793 completed projects.[6] However, only 29 projects accounted for 20 percent of the total. (See Figure 1.) As illustrated in Table 2, all but two of these projects (both at St. Jude Medical Center) appear to be unrelated to SB1953 compliance.

Figure 1. Distribution of Construction Expenditures*



*Size distribution of the expenditures for California hospital construction projects completed between January 2001 and December 2005, derived from OSHPD records. During this period, 5,793 projects were completed with a total estimated cost of $804 million. The data show that about 10 percent of the projects account for 80 percent of the costs and that most of the projects involve small expenditures.

Table 2. Largest Closed Hospital Construction Projects: 2001-2005

Hospital	Project Description	Estimated Cost
Children's Hospital of Los Angeles	Parking garage Phase 1-Inc. 3	20,520,163
Eisenhower Memorial Hospital	Cogeneration plant-resubmittal for HS-990291-33	17,272,183
Community Hospital Monterey Peninsula	Parking structure	13,635,128
Thousand Oaks Surgical Hospital	New 21-bed hospital	12,661,971
Kaiser Foundation Hospital-Valley Medical Center	48-bed infill and room addition	9,194,285
Kaiser Foundation Hospital-Walnut Creek	1510983/New emergency department	9,000,000
Kaiser Foundation Hospital-West Los Angeles	G0034/24-hour outpatient pharmacy addition/remodel	8,215,366
St. Joseph Hospital-Orange	Site utility preparation	6,612,508
Memorial Hospital Medical Center-Modesto	OB expansion	4,831,521
Riverside Community Hospital	GI observation remodel (non-structural)	4,800,000
Torrance Memorial Medical Center	New labor delivery recovery suites/remodel third-floor east wing	4,507,153
Presbyterian Intercommunity Hospital	Imaging department/Perry Pavilion remodeling	4,216,971
Valleycare Medical Center	New wing third-floor build-out	4,055,455
White Memorial Medical Center	Site infrastructure/utility tunnel	3,570,458
St. Jude Medical Center *	Second floor diaphragm strengthening	3,500,000
St. Jude Medical Center *	Remodel main second floor into a 58-bed acute surgical unit	3,458,356
Good Samaritan Hospital-San Jose	CVOR cardiovascular OR's	3,456,280
Kaiser Foundation Hospital-Fresno	172-914/Inpatient (West) bed/build-out shelled space	3,449,346
Kaiser Foundation Hospital-Riverside	Fire alarm upgrade/K0037	3,200,620
Loma Linda University Medical Center	Pediatric emergency care/CT scanner suite increment 1 and 2 submittal	3,074,824
Kaiser Foundation Hospital-Oakland	111-907-02/Re-internalization fourth floor	3,008,977
Doctors Medical Center	Cardiology relocation program	2,971,793
Barton Memorial Hospital	Dietary remodel	2,881,200
The Covington Care Center	One-story wood construction	2,785,864
University of California Davis Medical Center	Mind Institute tie-in/addition	2,700,000
Kaiser Foundation Hospital-Sacramento	161-351/Angiography suite remodel	2,558,888
Los Alamitos Medical Center	Remodel new imaging center	2,555,468
Woodland Memorial Hospital	Behavioral Health Services expansion	2,402,097
Cedars-Sinai Medical Center	Pneumatic tube system replacement	2,338,968

** SB1953 compliance construction*

Motivated by the rapidly approaching 2008/2013 deadlines for SPC-1 facilities, OSHPD has made a recent effort to refine the assessments of seismic risk for California hospitals with a goal of identifying structures that are not "collapse hazards" and thus not subject to the immediate requirements for retrofits or reconstruction. (See Appendix C.) The rationale for this effort was originally outlined in a California Seismic Safety Commission review of hospital seismic safety in 2001.[7] That report emphasized that California faced a "growing seismic risk from the aging, vulnerable hospital infrastructure," that there had been substantial improvements in the quality of earthquake engineering for new construction, yet there had been little progress in meeting the goals for SB1953, and that hospitals may face severe financial challenges to carry out the needed construction. With this background, the commission made recommendations to facilitate implementation of SB1953, with one focusing on the need to re-evaluate the SPC-1 buildings. Specifically:

> **Refine SPC-1 Building Priorities to be Consistent with Risk Levels:** OSHPD, in consultation with its Hospital Building Safety Board, should be charged with refining earthquake performance sub-categories for hospitals posing risks to life in earthquakes (SPC-1 buildings). The legislature should direct OSHPD to develop and apply the sub-categories by January 1, 2003. These refinements should be based wholly on the level of earthquake hazard and vulnerability of the building, not on the financial conditions of the hospital or the regional need for the facility. The risk represented by the subcategories should be considered in any decision to extend the 2008 deadline.

In general terms, the above recommendation encourages a further refinement of the SPC-1 category to ensure that the buildings facing the greatest risks are mitigated first while those at lower levels can be deferred. Decision making on this issue revolves around three concepts that are not well-understood by the general public and are often misstated in media reporting: seismic hazards, seismic vulnerability, and seismic risk. To elucidate the policy challenges on the SPC-1 buildings, these concepts are briefly discussed below.

Seismic hazards are quantified in terms of the magnitude of the ground shaking that could occur at a specific site. Common measures of seismic hazards, which are useful for engineering efforts, focus on the potential levels of acceleration or velocity as the ground shakes at different frequencies (i.e., the speed of the oscillations in the ground vibrations). The frequency information is important because different types of buildings (e.g., numbers of stories, types of construction material) can be especially sensitive to ground shaking at particular frequencies. In detail, the levels of seismic hazard are usually expressed in terms of the probability of occurrence (e.g., the level of ground shaking that has a 1 percent chance of occurring in a given year).

Seismic vulnerability describes the susceptibility (or potential for damage) in buildings subjected to seismic hazards of different magnitudes. At a fixed level of hazard, the most vulnerable buildings are those that will suffer the greatest damage. A key issue for earthquake engineering is to understand in detail how the vulnerability for different types of structures changes under different levels of seismic hazard.

Seismic risk combines the hazard and vulnerability information to quantify the probability of loss from earthquakes. The seismic risks are highest in regions where buildings are vulnerable to common levels of seismic hazard. With this approach, the regions of highest seismic risk are not necessarily the same as those with the highest seismic hazard because changing levels of building vulnerability have a mitigating impact on the overall levels of risk.

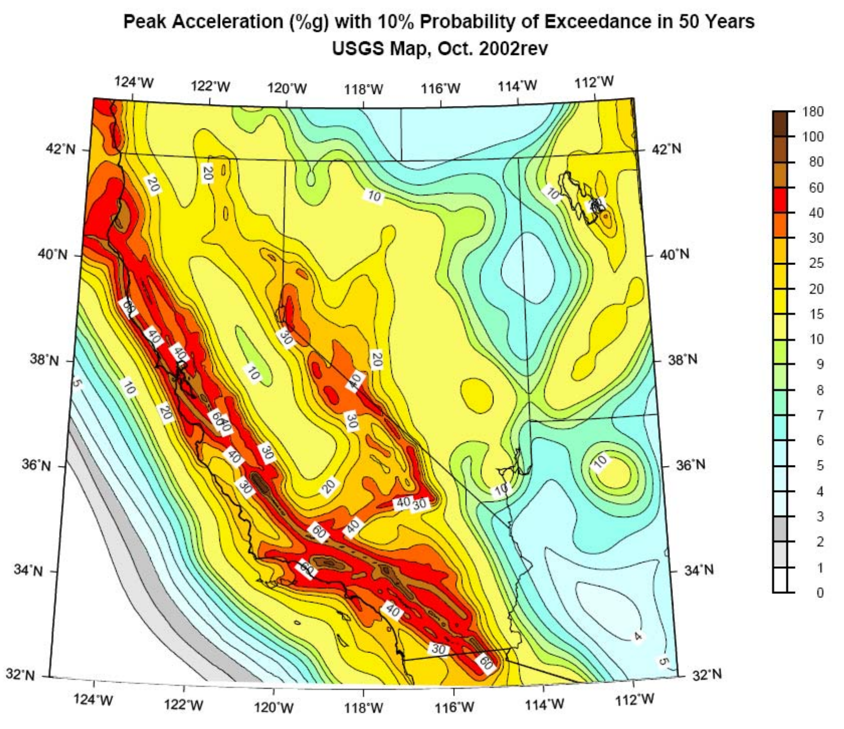
In its original effort to characterize the seismic risks for the California hospital infrastructure, OSHPD embodied these three concepts in its SPC ratings for individual buildings. Using earthquake engineering tools that were current in 1990s together with relatively coarse information on the nature of the seismic hazards,[8] buildings were assigned ranks from 0 to 5. The largest category was the SPC-1 (or "noncompliant"), which contained 39 percent of the total buildings and 45 percent more buildings than the next largest subdivision (SPC-4). At the outset, this might have triggered interest in a refinement given that the largest category of buildings faced the largest and most expensive compliance requirements at the earliest deadline for SB1953.

Much of the problem with the original SPC-1 classification can be traced to the quality of the data and methodologies that were used. As noted by the Seismic Safety Commission, there have been substantial improvements in the tools and analysis for earthquake engineering analysis. And there were significant opportunities to improve the quality of the seismic hazard information that was used in the SPC ratings. To this point, Table 3 shows OSHPD's values of the seismic hazard parameters that were used to calculate the SPC values, expressed as peak ground acceleration as a fraction of gravity. Notably these values vary by only a factor of two across the entire state, which is in marked contrast to the large variation that has been documented in seismic hazard maps compiled by the United States Geological Survey and California Division of Mines and Geology.[9] (See Figure 2.) Using comprehensive information on fault distributions and historical earthquakes, these maps quantify the expected level of shaking at a particular site for a fixed probability. Information from these maps has been widely used in the development of new seismic building codes and in advanced engineering modeling tools.

Table 3. OSHPD Hazard Parameters for SPC-1 Classification

County	Peak Ground Acceleration (Percent of Gravity)
Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, El Dorado, Glenn, Humboldt, Lassen, Madera, Mariposa, Modoc, Nevada, Placer, Plumas, Sacramento, Shasta Sierra, Siskiyou, Sutter, Tehama, Trinity, Tuolumne, Yolo, Yuba	20
Lake, San Joaquin	30
Alameda, Contra Costa, Fresno, Imperial, Inyo, Kern, Kings, Los Angeles, Marin, Mendocino, Merced, Mono, Monterey, Napa, Orange, Riverside, San Benito, San Bernardino, San Diego, San Francisco, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Solano, Sonoma, Stanislaus, Tulare, Ventura	40

Figure 2. 2002 Seismic Hazard Map for California*

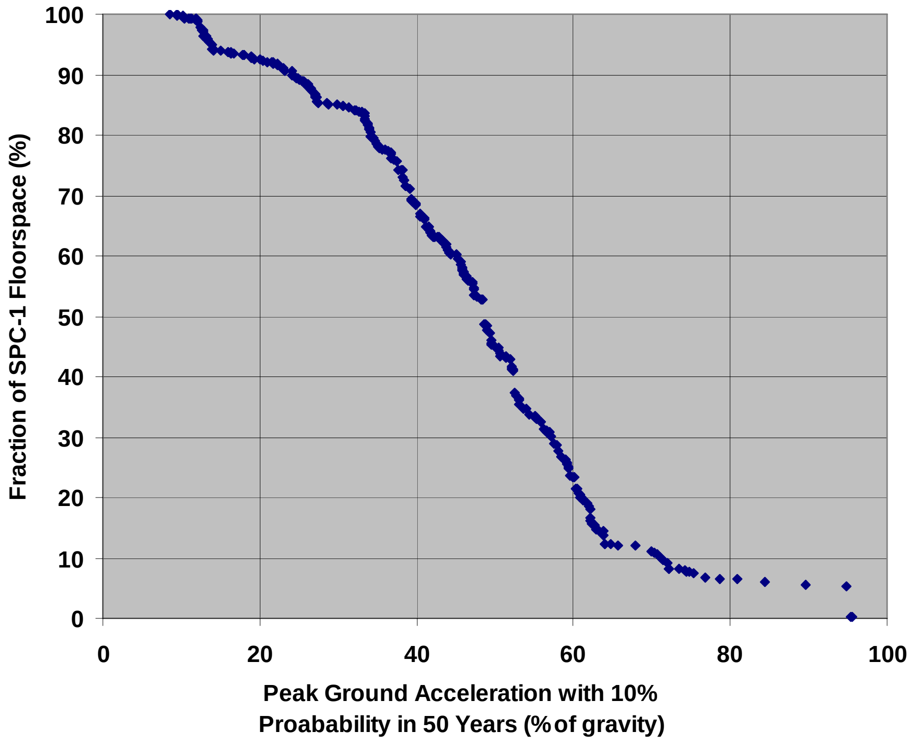


*The map illustrates the peak ground acceleration that could occur with a probability of 10 percent in the next 50 years. Values of ground shaking are quantified as acceleration, expressed as a percent of gravity. Copies of this map can be obtained from http://earthquake.usgs.gov/research/hazmaps/products_data/2002/wus2002.php.

With this background, the Hospital Building Safety Board recently authorized OSHPD to re-evaluate the seismic risks for the SPC-1 buildings using up-to-date engineering and scientific analysis.[10] For this effort, OSHPD will use a publicly available loss estimation model that includes detailed engineering, site, and hazard information for calculating the impact of earthquakes.[11] If the new analysis shows that an SPC-1 building faces a 10 percent or less chance of complete damage, it will be reclassified as an SPC-2 and relieved of the requirement to meet the 2008/2013 deadlines in SB1953. If the analysis shows a probability between 10 percent and 15 percent for complete damage, the building will be placed in a new SPC-1E category, and the 2008/2013 deadlines for mitigation will be moved to 2020. In all cases, the reclassified buildings will still be subject to the final 2030 SB1953 deadline, which will require complete reconstruction to meet the requirements. Although the re-evaluation is still in progress, there is large anticipation in the hospital industry that it might reclassify many of the SPC-1 buildings, thereby removing the requirements of the 2008/2013 deadlines.[12] However, because the results and potential scale of the revisions are unknown, our analysis in the following sections assumes there are no changes to the SPC-1 infrastructure.

To evaluate the above criteria for seismic risk, OSHPD will analyze the performance of SPC-1 buildings subjected to the level of seismic hazard illustrated in Figure 3 (ground shaking with 10 percent probability of occurrence in 50 years). Figure 3 shows the level of this hazard in detail for each of the hospital campuses with SPC-1 buildings. The data for these campuses show hazard levels ranging from 6 percent to 96 percent of gravity (a sixteenfold variation compared to twofold in the original OSHPD classification), with a relatively uniform distribution of hazard levels between 20 percent and 60 percent of gravity for 75 percent of the SPC-1 infrastructure. Viewed from a geographic perspective (see Table 4), the data show that almost 80 percent of the SPC-1 infrastructure is located in high-hazard counties in two regions of California: the Bay Area (San Francisco, Alameda, Contra Costa, Marin, Santa Clara, San Mateo), and Los Angeles/Southern California (Los Angeles, Orange, Riverside, Ventura, and San Bernardino). These data indicate that much of the OSHPD re-evaluation will focus on the engineering details of building performance under high levels of seismic hazard.

Figure 3. Peak Ground Acceleration for SPC-1 Buildings*



*The probability for the ground shaking is a 10 percent chance of occurrence in the next 50 years, derived from the USGS and CDMG seismic hazard map for California for each hospital campus. The horizontal axis shows increasing levels of seismic hazard compared to the corresponding fraction of SPC-1 infrastructure that is susceptible to that level of hazard or greater. Thus, about half of the SPC-1 infrastructure could experience ground shaking with accelerations of 50 percent of gravity or greater.

Table 4. County Averaged Hazard Levels for SPC-1 Facilities, Sorted by Decreasing Levels of Seismic Hazard

County	Average Peak Ground Acceleration (Percent of Gravity)	County SPC-1 Infrastructure (Square Feet)	County	Average Peak Ground Acceleration (Percent of Gravity)	County SPC-1 Infrastructure (Square Feet)
San Bernardino*	82.12	4,509,705	San Diego	25.43	2,254,189
San Benito	76.80	43,000	San Luis Obispo	25.01	171,500
Humboldt	69.59	288,950	Kern	24.89	673,292
Alameda #	68.79	2,782,296	Yolo	21.73	58,100
Imperial	66.87	115,695	Plumas	21.72	90,530
San Mateo #	64.28	1,647,879	Merced	20.94	175,200
Contra Costa #	62.19	266,410	San Joaquin	20.69	464,479
Ventura*	61.59	640,953	Stanislaus	18.22	308,500
Sonoma	59.19	259,958	Shasta	18.11	73,765
Riverside*	55.88	896,407	Trinity	17.84	75,320
San Francisco #	54.28	3,589,185	El Dorado	17.55	189,750
Santa Clara #	51.97	1,885,962	Glenn	15.88	48,444
Los Angeles*	48.89	20,934,525	Nevada	14.38	166,150
Marin #	47.91	131,400	Modoc	13.89	11,293
Kings	45.69	111,680	Tulare	13.42	139,871
Mendocino	45.24	56,220	Sacramento	12.98	1,427,150
Solano	43.93	436,800	Butte	12.83	196,112
Napa	41.55	142,700	Madera	12.63	90,702
Santa Barbara	39.62	758,220	Fresno	12.31	945,255
Lake	38.06	41,000	Sutter	12.06	36,900
Orange*	34.82	4,129,215	Yuba	11.84	51,600
Monterey	33.21	341,900	Mariposa	11.21	27,000
Santa Cruz	29.63	259,000	Placer	10.17	150,000
Inyo	29.59	73,316	Tuolumne	9.55	54,765
Sierra	25.67	21,336			

* Los Angeles Area county

Bay Area county

III. The Progress of SB1953 Compliance

It has long been recognized that achieving compliance with SB1953 will be extremely challenging because of the size and distribution of the SPC-1 infrastructure, discussed in the previous section. As emphasized in RAND's first report, the required construction and investment to replace all of these buildings would be unprecedented in the history of the California hospital industry (and presumably the United States).

To gain further insights on these challenges, the authors discussed compliance strategies, activities, and plans with California hospital representatives who are involved in the reconstruction of SPC-1 facilities.[13] Of particular interest was how they were approaching the decision making and planning in response to SB1953's requirements. What factors influenced their decision making? What level of effort is required in hospital organizations to comply with SB1953? How did they approach problem, and what was the importance of seismic safety in their planning efforts?

From these discussions the authors discovered that although the standards for SB1953 compliance are relatively straightforward, the law has triggered large and complex decision making processes within hospitals as administrators strive to optimize their plans to construct new facilities to replace SPC-1 buildings. In large part, this effort is influenced by the fact that the new buildings will not simply be replacements. Instead, they will embody significantly new designs and capabilities, reflecting the large changes in health care and medical technology during the past 30 years.

Throughout the planning process, competing objectives have emerged. On the one hand, hospitals have a strong desire to build updated facilities that will maximize their strategic and marketing goals. However, there is also a great need to manage the costs, and quite often a hospital's ability to pay for construction limits the access to larger or more elaborate facilities. In this environment, the authors observed large planning teams addressing a broad range of financial, technical, medical, and strategic issues arising from large hospital construction projects. Because of the importance of these efforts, these teams typically reported to the senior management and the governing boards for their hospital.

To illustrate the complexity of the planning process for SB1953, Figure 4 shows the planning framework cited in a board-level briefing from one of the hospitals involved in SPC-1 reconstruction planning. Although the process is clearly motivated by a need to "comply with law," the requirements of SB1953 are immediately overshadowed by strategic, financial, and health care considerations. Once a hospital makes a decision to build a large new facility, it motivates a range of new decision making regarding the specifics of the design, sizing, financing, and management. In general, the scale and sophistication of the observed efforts are consistent with the hospital facility planning process described by the Healthcare Financial Management Association (HFMA) in its recent report series, *How Are Hospitals Financing the Future?*[14] As emphasized in these reports, developing a large facility requires three key tasks, which are performed in a complex and interdependent framework: strategic planning, managing the balance sheet, and hiring capital advisers.

Figure 4. Planning Framework for New Hospital Facilities*

Key Planning Assumptions

- Represents Our Best Thinking
- Maintains Presence In Market
- Remain Competitive In Market
- Attempt To Minimize Service/Revenue Interruption During Construction
- Do Not Compromise The Long-Term Site Development
- Comply With Law
- Provide Maximum Flexibility
- Minimize Capital Expenditures During The Initial Phases

Project Goals

- Develop Flexible Planning Solutions For The Future
- Meet Workload Projections
- Identify Opportunities To Increase Productivity
- Maximize Capital Assets While Minimizing Investments In Antiquated Buildings
- Coordinate Project Schedules With Available Cashflow
- Enhance "Healing" Environments
- Continue The Long-term Commitment To The Communities We Serve
- Comply With SB 1953 - Ensure That After A Major Earthquake "Essential" Medical Services Are Available To The Community
- Analyze Service Integration Potential

*Slides from a board-level briefing, describing planning approach for a hospital involved in reconstruction of SPC-1 facilities.

Based on this result and discussions with California hospital personnel, the authors make two observations regarding challenges for SB1953 compliance, viewed simply from a planning and organizational perspective.

- Planning and executing hospital construction projects requires a broad range of complex skills and competencies that differ significantly from the traditional expertise for seismic safety (e.g., earthquake engineering). In many cases, these skills may not be present in a hospital organization simply because they are not required to support general ongoing health care operations. If they are not present, it is simply not feasible to plan and execute large construction projects for SB1953 compliance.
- Planning and executing hospital construction projects require decision making and large organizational efforts over long periods of time. Hospitals report that the in-house planning process for a new facility can last four to five years because of the complexity of the considerations discussed above. Including the time for OSHPD review, contractor selection, and construction activities, the organizational time scales required to build a new facility can exceed ten years. Considering that this planning process needs to occur on 305 hospital campuses, it would not be surprising if SB1953 compliance activities occur over a long period of time in California.

Together, these observations raise further concerns regarding the progress that California hospitals are making toward SB1953 compliance. Specifically, the observations, described above, coupled with the analysis in our first report, suggest that only a fraction of California hospitals will be able to marshal the financial, organizational, and logistical resources to carry out large-scale construction programs to meet the law's deadlines. This observation further emphasizes the need to assess the progress of SB1953 compliance. Specifically, is the challenge of achieving SB1953's goals reflected in the progress toward compliance?

The details of the SB1953 compliance schedule are presented in Appendix C. In the original bill, there were two basic deadlines for SPC-1 structures. At a minimum, by 2008, these structures had to be seismically retrofitted, and by 2030 they had to be in full compliance with the act. The final step would require full reconstruction, though hospitals could exercise this option to meet the 2008 deadline. Since the original act was passed, there have been two important revisions to the 2008 deadline. In 2000, SB1801 provided an opportunity for a five-year extension to the 2008 deadline (to 2013), which would be accessible for most California hospitals. Then in 2006, SB1661 provided an opportunity for another two-year extension (to 2015) for hospitals that had made substantial progress on large construction projects for compliance. Other than these general requirements, the steps to SB1953 compliance are largely unspecified. Although it is recognized that construction and seismic retrofits are the only strategies for compliance other than facility closure, planning and accomplishing these tasks are dependent on hospital decision making, as described above. In this setting, there are no predefined milestones leading up to the SB1953 deadlines, making it difficult to assess the progress toward compliance before the required dates. Indeed, for this reason there have been no official efforts by the state of California to assess SB1953 compliance, there has been no reporting by hospitals, and no government databases are currently maintained for this purpose. However, in coming years, there will be important changes on this issue because of the recent approval of SB1661. Under the law's provisions, hospitals must provide detailed schedules describing their plans for construction activities to meet SB1953's requirements. Depending on the compliance status for individual hospitals, these plans are due either in 2007, 2009, or 2011. OSHPD is required to publish the collected data on its Web site within 90 days of the submittal deadlines.

Considering the current data availability, RAND has developed analytic techniques to assess the status of SB1953 compliance across the California hospital industry by focusing on hospital construction activities, which are highly regulated and thus documented. For this task, the authors have focused on publicly available building permit data as a proxy measure of the progress to compliance. These data, which are compiled by OSHPD, are initiated when a hospital communicates its intent to carry out a construction project. The date of the initial communication is recorded, and OSHPD begins a process of reviewing plans for the effort. Once the plans are approved, a building permit is issued, and the file is updated to record the progress of construction. An estimate of the total cost is also included because fees are paid to OSHPD based on this amount. Examples of these records are illustrated for different types of projects in Table 5.

Table 5. Example Hospital Building Permit Data from OSHPD

County	Hospital	Address	Project Description	Submittal Date	Estimated Cost	Completion (percent)
County: 41-San Mateo	Facility: 10804-Peninsula Medical Center	1783 El Camino Real, Burlingame 94010	Hospital replacement project	4/22/2005	$210,800,000	0
County: 19B-Los Angeles	Facility: 17207-Kaiser Foundation Hospital-Baldwin Park	1011 Baldwin Park Blvd., Baldwin Park 91706	OR sterilizer replacement	7/12/2005	$60,000	94

These data provide valuable insights to SB1953 compliance because they represent a comprehensive record of past, present, and planned hospital construction activities in California. However, some important shortcomings must be considered in the analysis. First, the summary data file contains only limited information about the nature of the construction. In particular, the total square footage for the construction activities is not included. Also the permit files contain no direct information on the contribution to SB1953 compliance. Although some cases are apparent (e.g., “SB1953 replacement hospital”) others are vague (e.g. “new patient tower”), and in all cases, the scale is unknown. That is, it is unclear whether the construction meets a portion or all of the SB1953 requirements. To address this uncertainty, this report conservatively assumed that a permit file for a large construction project signaled a hospital’s intent to address all its SB1953 compliance requirements on a particular campus.

Second, there is no guarantee that currently planned projects under OSHPD review will ever be completed. It is possible that the plans may not be approved. If a building permit is granted, it is possible that a hospital may not start construction (e.g., funds may not be available). To address this uncertainty, this report conservatively assumed that all of the currently pending building permits will eventually be completed. Considering these uncertainties, and the conservative assumptions in response to these factors, the authors conclude that the OSHPD permit data provide an upper bound on the pace of SB1953 compliance, and that the real rate of compliance may be substantially lower.

With this background this analysis reviewed the entire OSHPD database of construction activities for California hospitals (past, present, and planned), looking for records of seismic work, replacement buildings, new buildings, and SB1953 work. Focusing on the hospitals with SPC-1 facilities, the authors separated the facilities into five groups:

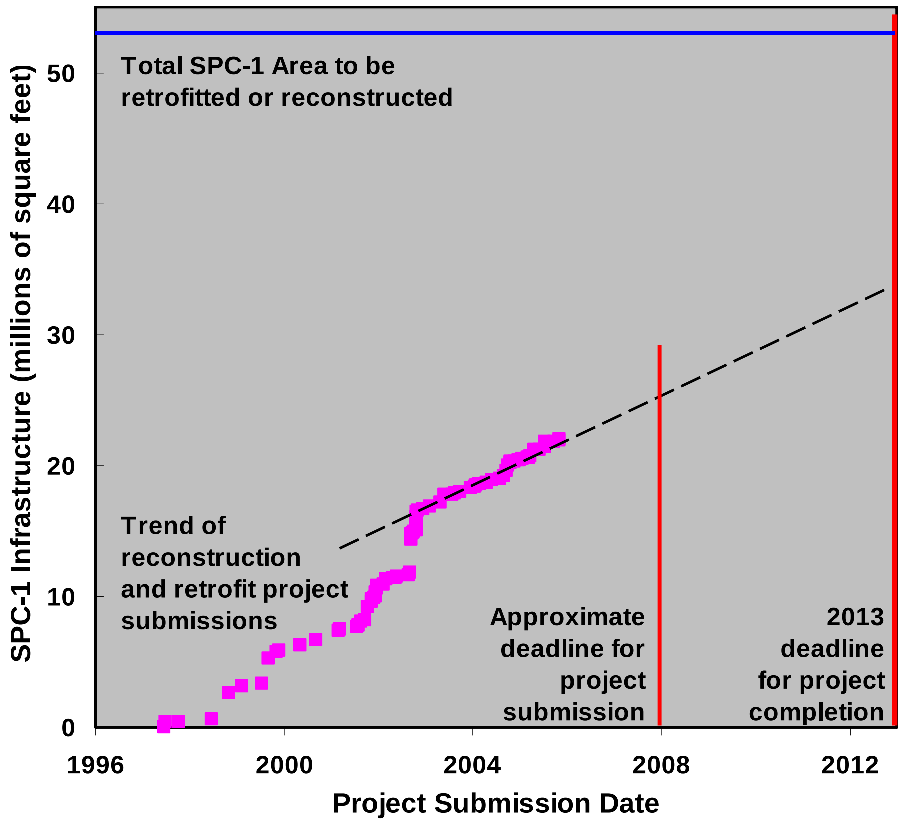
- No building permits currently on file with OSHPD;
- Building permits currently on file with OSHPD but for non-seismic work;
- Permits for seismic related construction on file (e.g., retrofits), not including construction of new buildings;
- Permits on file for the construction of new buildings, which appear to replace SPC-1 facilities; and
- Permits on file for other large construction projects.

The results of this analysis are presented in Table 6. Clearly, large numbers of hospitals have not initiated permit activity for SB1953 construction. To illustrate the results in the context of impending SB1953 deadlines, figures 5A and 5B plot the results according to the time of submission and the magnitude of the SPC-1 square footage on a particular campus for the two principal SB1953 deadlines: 2008 and 2013. With this approach, it is clear that large construction projects have been submitted at a fairly consistent pace since 1998, when measured in terms of existing SPC-1 square footage. The rate appears to be about 1.5 million SPC-1 square feet per year for submitted projects.

Table 6. Summary Analysis of OSHPD Building Permits

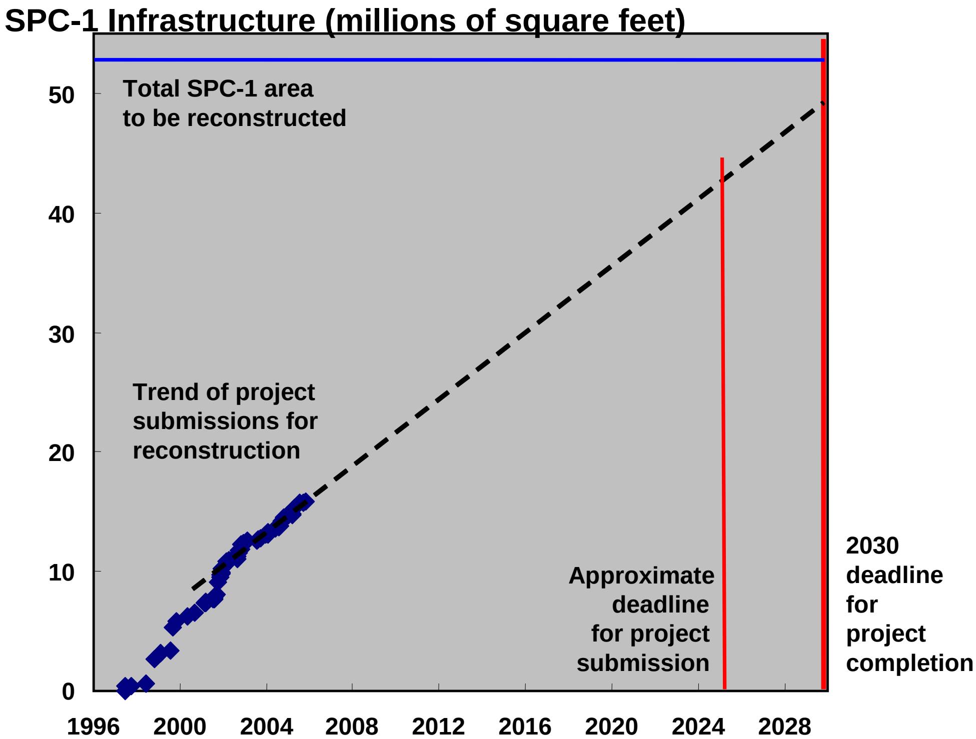
Total general acute-care hospitals	456
Total number of hospitals with SPC-1 buildings	305
Hospitals without permits or seismically related permits	203
Large construction projects	61
Seismic-related permits (not construction)	32
Large permits, seismic component unclear	9
Application extension received (8/7/06)	299

Figure 5 A. Building Permit Submittal Trends (2013 Deadline)*



***Trends of permit submittals to OSHPD for large seismic retrofits and reconstruction projects pertaining to SB1953 compliance. The data points show the cumulative progress of mitigating the seismic vulnerability for the entire SPC-1 infrastructure. Each data point records the contribution from individual hospitals, assuming that the submitted projects will address all of the SPC-1 infrastructure improvements on the campus. For most hospitals, the initial deadline for project completion is January 1, 2013. To assess the feasibility of compliance by this date, the authors extrapolate the trend of project submissions. Given that about five years is required for OSHPD review, project planning, and execution, large retrofit and reconstruction projects should be submitted by January 1, 2008, to ensure completion by 2013. On this basis, the authors conclude that as much as 50 percent of the SPC-1 infrastructure may be non-compliant by the time of the first SB1953 deadline.

Figure 5 B. Building Permit Submittal Trends (2030 Deadline)*



*Trends of permit submittals to OSHPD for large reconstruction projects pertaining to SB1953 compliance. The data points show the cumulative progress of mitigating the seismic vulnerability for the entire SPC-1 infrastructure. Each data point records the contribution from individual hospitals, assuming that the submitted projects will address all of the SPC-1 infrastructure improvements on the campus. For all hospitals, the deadline for project completion is January 1, 2030. To assess the feasibility of compliance by this date, the authors extrapolate the trend of project submissions. Given that about five years is required for OSHPD review, project planning, and execution, large reconstruction projects should be submitted by January 1, 2025, to ensure completion by 2030. On this basis, the authors conclude that as much as 20 percent of the SPC-1 infrastructure may be non-compliant by the time of the final SB1953 deadline.

Viewed from this perspective, the results have important implications for SB1953 compliance. Based on an analysis of project data through December 2006, the analysis finds that about 30 percent of the SPC-1 floor space has been addressed by large construction projects submitted to OSHPD. This includes approved projects and those currently under review. If large seismic retrofits are included, the magnitude of the floor space increases to about 40 percent. The rate of project submissions indicates that a significant fraction of the SPC-1 floor space will not meet a 2013 deadline, assuming the current rates continue. In extrapolating the trends in Figures 5A and 5B, it should be emphasized that the data record the submission date for the project and not the time of completion and that the data represent an upper bound on compliance trends because of the conservative assumptions in this analysis. Discussions with industry experts indicate that about five years is required between the time of OSHPD submittal and completion for large construction projects. And as discussed above, the date of OSHPD submittal is often preceded by as much as five years of internal planning at a hospital. With this perspective, all hospital construction projects would need to be submitted by January 1, 2008, (about a year away) to be sure of meeting the 2013 deadline. And by today, projects should be almost complete considering internal planning and design efforts.

The permit data also illustrate the large unanticipated challenges associated with the 2008/2013 deadlines for SPC-1 structures. As discussed in detail in the first report, hospital owners can meet these deadlines by retrofitting or rebuilding SPC-1 structures by January 1 2008/2013. If the structures were retrofitted, they would need to be rebuilt by 2030. In its design, SB1953 reflected previous legislative proposals (from the 1990s and 1980s) for a phased solution to seismic safety goals. With this approach, the most vulnerable structures (those with a "potential risk of collapse") were to be partially mitigated in the near term with seismic retrofit, and then totally replaced 22 years later. Implicit assumptions to rationalize this approach were that retrofits could be performed relatively quickly and cheaply, compared to large construction projects.

The problem, as demonstrated by the recent experience in California, is that these assumptions turned out to be largely incorrect. As reported by earthquake engineers, state officials, and hospital owners, the costs of retrofits are often comparable to new construction projects, and they are highly disruptive to hospital operations. Most important, at the end of the project, they do not change the health care capabilities for individual buildings. For these reasons, relatively few hospitals are implementing retrofit solutions for the 2008/2013 deadlines. Given that reconstruction appears to be the predominant compliance strategy for SPC-1 buildings, this has effectively moved the 2030 deadline ahead by about 20 years, which is not feasible, given the scale of SPC-1 infrastructure and the pace of hospital construction.

Setting aside the feasibility of the 2008/2013 deadlines, the historical data also indicate that it is unlikely that all hospitals will be able to meet the 2030 deadline for SPC-1 replacement. Based on these data, and decision making discussed in the next section, we estimate that it will take at least 25 years to bring the remaining SPC-1 facilities fully into compliance with SB1953's requirements, assuming the California hospital regulatory, design, and construction industry continues to work at its current historically high pace over the entire period.

In addition to the above challenges, there will be a need to reconstruct the original SPC-2 buildings by 2030. Although the details of this infrastructure have not been quantified, these buildings represented 8.3 percent of the statewide building inventory, according to the 2001 OSHPD survey. On this basis, the authors estimate that the SPC-2 building may contain as much as 10 million square feet of floor space that will need to be reconstructed by 2030. At these levels, it would increase the reconstruction target by about 20 percent in Figure 5B, which would significantly increase the compliance shortfall by the 2030 deadline.

Using the OSHPD permit data, this analysis estimates the amount of the remaining SPC-1 infrastructure that needs to be addressed by construction. For this task, the authors have identified the SPC-1 hospitals with construction projects currently underway. (See Table 7.) Adding the amount of the SPC-1 floor space at these facilities (10.8 million square feet) and subtracting the value from the SPC-1 total at all operational acute-care hospitals (52.4 million square feet) suggests that 41.5 million square feet of SPC-1 floor space has yet to be addressed by active construction projects. This is the value to be used in the subsequent cost analysis.

Table 7. Ongoing and Completed Large Construction Projects for New Facilities at Hospitals with SPC-1 Buildings*

Hospital	Project Description	SPC-1 Area (Square Feet)
Alameda County Medical Center- Highland Campus	New critical care/parking structure	344,784
City of Hope National Medical Center	Replacement hospital	198,723
Community Hospital Monterey Peninsula	South pavilion	152,700
Community Medical Center-Fresno	Trauma/critical care building	499,600
Grossmont Hospital	ED/CCU/3 shell-A five-story addition	52,128
Hoag Memorial Hospital Presbyterian	East addition building	512,030
Kaiser Foundation Hospital-Harbor City	Maternal child/perioperative services building	82,400
Kaiser Foundation Hospital-Sunset	A8525/Rebuild LAMC Sunset	433,400
Kaiser Foundation Hospital-West Los Angeles	Hospital tower replacement	471,000
Kaiser Foundation Hospital-Rehabilitation Center Vallejo	Replacement tower	268,800
Kaiser Santa Clara Medical Center	Phase 1-hospital	400,000
Kaiser Santa Clara Medical Center	Phase 2-hospital	
Laguna Honda Hospital & Rehabilitation Center	East residence	978,670
Los Angeles County USC Medical Center	Inpatient tower and common systems/Package 5	1,897,950
Los Robles Regional Medical Center	Hospital expansion	80,000
Memorial Hospital Medical Center-Modesto	North tower addition	69,500
Presbyterian Intercommunity Hospital	Foundation tower for advanced medicine	262,251
Redlands Community Hospital	Phase 2 building addition	127,955
San Joaquin Community Hospital	New addition and alterations	132,900
Santa Monica-UCLA Medical Center	SM-OHRP-replacement hospital	255,580
Santa Monica-UCLA Medical Center	SM-OHRP-replacement hospital	255,580
Simi Valley Hospital & Health Care Services-Sycamore	Patient bed tower	128,735
St. Johns Hospital and Health Center	Steps 1 and 2: Inpatient, diagnostic, and treatment buildings	45,000
St. Joseph Hospital-Orange	Patient care center/Plaza tower project	215,800
St. Jude Medical Center	Southwest tower and central plant	216,000
UCLA Medical Center	UCLA-Westwood replacement hospital	2,016,561
University of California Davis Medical Center	9550900 Surgery and emergency services pavilion	367,500
White Memorial Medical Center	New main hospital building	356,080

*Data obtained from OSHPD

IV. Estimating SB1953 Construction Costs

This section examines the total construction expenditures that may be required as hospitals rebuild SPC-1 facilities to meet SB1953 compliance requirements. The analysis draws on a wide range of information, including:

- Detailed project cost information from hospital construction firms;
- Briefings on hospital decision making regarding large construction projects;
- Design trends for new hospital buildings;
- Financial reporting from California hospitals;
- Detailed infrastructure surveys of California hospitals; and
- Recent surveys of hospital construction cost inflation.

By comparison, the analysis in RAND's previous study focused on the *compliance* costs associated with SB1953 construction. That effort involved two tasks: estimating the total costs associated with SB1953 construction as of 2002 and identifying the costs associated with compliance (which were presumably less than the total).

The estimate of total construction costs in the first study focused on the number of inpatient beds in SPC-1 buildings (41,100 according to 2002 OSHPD data). Given the relatively low occupancy rate for these beds (54 percent in 2001), the authors considered the possibility that hospitals might choose to build new buildings with fewer beds as a way to minimize the cost of SB1953 compliance. Using a construction cost factor of $1 million per bed for a new, fully equipped hospital, the analysis devised a number of construction cost scenarios for SB1953. The maximum level was 100 percent replacement for all existing beds, giving a total construction cost of $41.1 billion for new buildings.The possibility of a 30 percent reduction in the inpatient beds resulted in a construction cost scenario of $28.8 billion.

The estimate of compliance costs in that study involved subtracting some items that might not be viewed as a requirement for SB1953 compliance (e.g., new medical equipment and parking facilities). Although these items were included in new construction projects, they did not address the seismic safety goals for health care in California. The subtractions were arranged in a number of cost scenarios with increasingly stringent views on the required elements for SB1953 compliance. Viewed from this perspective, the estimated compliance costs were significantly less than the total construction costs, ranging from a low of $0.08 billion to a maximum of $8.8 billion.

The current study focuses on the total construction costs for SPC-1 replacements rather than the compliance costs, which were emphasized previously. There are two motivations for this approach. First, although the seismic component of new construction may be small, it is widely recognized that full-scale reconstruction is the only viable compliance strategy for SB1953. Because there are no partial compliance solutions, it may be valid to equate the compliance and total construction costs in the current policy debate. Second, there has been large inflation in the costs for California hospital construction in recent years, raising new questions about the overall expenditures for SB1953 and its affordability for California.

With this background, RAND's new construction cost estimate can be viewed as the total cost to implement SB1953, reflecting hospitals' current preference for reconstruction rather retrofitting SPC-1 structures. As such, it is not a maximum estimate because that would include costs for retrofits on all structures together with costs for total reconstruction. Although the estimate reflects the general requirements of the 2030 deadline in SB1953, it would not be accurate to characterize it as the cost of a particular deadline because many hospitals will miss the 2008/2013 deadlines (as documented in the previous section), and reconstruction can be viewed as a strategy to meet both the 2030 and 2008/2013 requirements.

Current Hospital Construction Costs

As documented in the recent Davis Langdon report, *Construction Cost Escalation in California Healthcare Projects*,[15] the basic per-square-foot construction costs have almost doubled since 2001, rising at an annual rate of more than 14 percent above the Consumer Price Index for the past three years. Today, California hospital construction costs are about 40 percent higher than in other states for comparable facilities. As a result of these developments, it has been widely recognized that the total construction costs stimulated by SB1953 are probably substantially larger than the values in RAND's 2002 report.

As documented in interviews with construction and hospitals stakeholders, and described in the Davis Langdon report, several factors have contributed to these trends, including:

- A limited number of contractors for hospital construction projects. Hospital construction in California is highly regulated and supervised. As a result, only a limited number of contractors (general and subcontractors) have the expertise to manage and engage in these projects. As a result, there are few supply and demand mechanisms to correct for prices that may be temporarily inflated.
- A limited labor pool to perform hospital construction projects. The total construction market in California is greater than $150 billion on an annual basis, as estimated by the U.S. Census.[16] At this level, current hospital construction is only about 2 percent of the total market. Because of the small size, and high degree of regulation, it is difficult for hospital construction jobs to compete for construction labor, which is in relatively short supply in the state.
- Considerable uncertainty regarding the pace and execution of work for subcontractors. Because the details of hospital construction are approved by state representatives on the job site, there can be large variations in the pace of work, depending on the review process. If tasks are not performed according to standards, subcontractors have been required to repeat the job with new materials and labor. Because there are large cost implications associated with these reviews, they have prompted subcontractors to include substantial risk premiums in their bids for hospital construction work. As a result, it is widely viewed that the bids for hospital construction work are significantly higher than bids for comparable work on non-hospital jobs.
- Inflation in the cost of labor and materials. According to Davis Langdon, labor and material costs for construction have increased by about 8 percent per year in the past three years. Because materials represent about half of the construction costs for a

hospital, this trend would lead to a 4 percent annual increase in overall construction costs.

- A large increase in demand for hospital construction projects. As the deadlines for SB1953 have approached, the pace of hospital construction activity in California has increased substantially. To quantify this trend, Figure 11 shows the historical monetary value of “construction-in-progress” for general acute-care hospitals as reported to OSHPD. Currently, the California hospital construction industry is working at capacity to complete the current (and planned) jobs. In the current state of “congestion,” jobs are often delayed, which adds costs at the level of 1 percent to 2 percent of the total contract per month of schedule delay.

Considering the data from construction and hospital corporations, together with the assessment from Davis Langdon, the authors estimate the following cost factors for California hospital construction in 2006: For a fully furnished and equipped facility, the nominal costs are $1,000 per square foot. For an unfurnished and unequipped building, the costs are about $560 per square foot.

Comparing detailed costs for a California hospital construction project to those of a standard office building (also in California) provides context for these values. (See tables 8 and 9.) These data illustrate the origins for some of the elevated costs for hospitals compared to other structures. Most important, the hospital data illustrate the increased costs requirements for basic building services, which reflect the enhanced design and function of a hospital compared to other types of buildings. Whereas plumbing accounts for only $3.82 per square foot in an office building, the costs are more than $42 in an hospital, reflecting the substantial difference in the size and sophistication of plumbing facilities between these types of buildings (e.g, bathrooms and plumbing facilities in each patient room in hospitals compared to a few bathrooms per floor in an office building). There are similar large differences for some items, include heating, ventilation, and air conditioning (HVAC); fire protection; elevators; electrical; and drywall. In fact, the cost for a hospital exceeds an office building if one only includes the following items: HVAC, electrical, plumbing, glass and glazing, drywall, concrete, and structural steel. On a qualitative level, the increased detail of the hospital construction budget reflects the increased complexity of these jobs, which contributes further to the costs. Thus, a portion of the elevated costs for new hospital construction simply reflects the costs requirements of building modern health care facilities.

Table 8. Example of Costs for California Hospital Construction (February 2006)[17]

Cost Element	Cost ($/Square Foot)	Cost Element	Cost ($/Square Foot)
General requirements	8.81	Glass and glazing	31.14
Site demo and soil remediation	4.77	Drywall/plaster	64.88
Retaining wall and miscellaneous concrete	1.25	Ceramic tile	3.58
Asphalt paving and site concrete	4.88	Resinous flooring	0.19
Underground piping	3.04	Terrazzo	2.82
Traffic signals	1.51	Acoustic ceiling	5.49
Site electrical	2.72	Resilient flooring	8.16
Bus shelter	.26	Painting	2.61
Rework metal fence	0.04	Architectural upgrades	2.82
Landscaping (phase 1)	2.21	Artwork display	1.03
Phase 1 PCOs	0.66	Thematics allowance	3.17
Demolition	4.53	Toilet partition accessories	0.7
Mass excavation and remediation	34.88	Wall protection	3.71
Landscape	4.17	Wood lockers	0.48
Underground piping re-route	4.87	Operable partitions	0.15
Asphalt paving	1.61	Visual display surfaces	0.29
Site concrete allowance	4.79	Signage	0.03
Shoring	10.35	Projection screens	0.03
Reinforcing steel	13.33	Window washing equipment	0.8
Concrete CIP	37.05	OFCI medical equipment	3.47
Unit masonry	3.98	Windows treatment	1.38
Structural steel	38.85	Elevators	12.09
Metal deck	0.53	Chutes	0.37
Miscellaneous metal	13.69	Pneumatic tubes	2.24
Unistrut	0.53	Fire protection	7.42
Ornamental metal	6.34	Plumbing	42.38
Finish carpentry	9.11	Heating, ventilation, air conditioning	46.83
Rough carpentry	0.53	Building controls	10.39
Roofing and waterproofing	6.4	Testing	1.06
Methane membrane barrier	5.21	Commissioning	
Flashing and sheet metal	6.71	Electrical	62.31
Doors and hardware	5.39	Fire alarm system	3.87
Coiling doors	0.39	Telecommunications	4.11
Smoke containment curtains	0.38	Constructability review allowance	2.41
		TOTAL	**573.20**

Table 9. Example of Costs for California Office Construction (February 2006)[18]

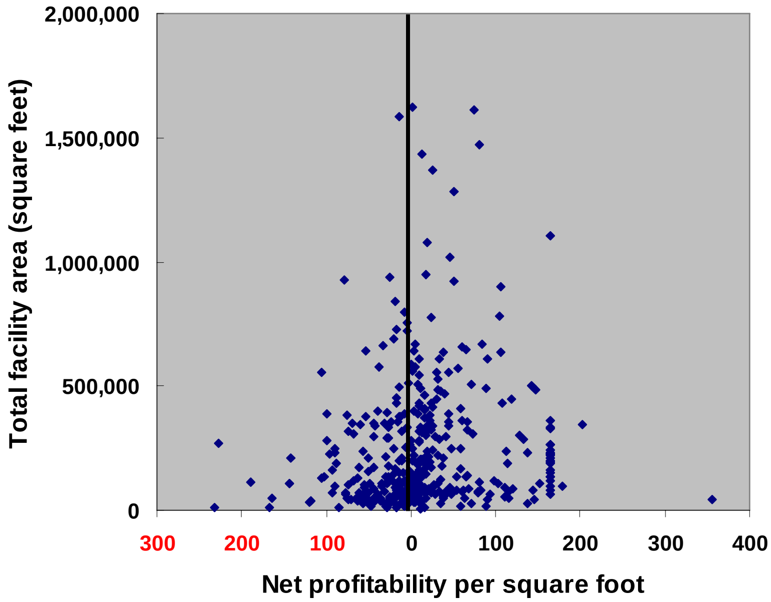
Cost Element	Cost ($/Square Foot)
Excavation and foundation	10.25
Structure	31.13
Roofing	2.09
Exterior walls	26.28
Interior partitions and finishing	7.74
Tenant improvements	60.00
Specialties	0.67
Equipment and furnishings	0
Vertical transport	6.03
Fire protection	3.18
Plumbing	3.82
HVAC	20.89
Electrical	20.53
Site work	17.19
Parking structure	64.04
General conditions, insurance, fee	34.34
Testing and inspection	0.00
Total	**308.21**

Examining the $1,000 per-square-foot requirement from two financial perspectives pertinent to California hospital operations will provide context for current hospital construction costs: First, a comparison of the construction costs and the profitability of the current California hospital infrastructure; second, an examination of the potential effects on the costs of medical services.

Comparison with Hospital Profitability

To assess the first issue, RAND collected data on the gross square footage of all California hospital campuses from OSHPD and compared the values to data in the annual financial reports also filed with OSHPD. (2004 is the latest year available.) To assess the profitability of the current California hospital infrastructure, RAND compared the total building square footage on individual campuses to the financial net from operations, defined as the product of the operating margin and the total operating revenue. Forming a ratio in this way measures the net annual profit per square foot of hospital buildings on a particular campus. As Figure 6 illustrates, the tremendous range in values for this ratio (from more than $300 to less than $200 per square foot) is largely uncorrelated with the size of the current hospital campus. In general, the data indicate a large variability in the financial performance of California hospitals.

Figure 6. Net Profitability per Square Foot, in Dollars*



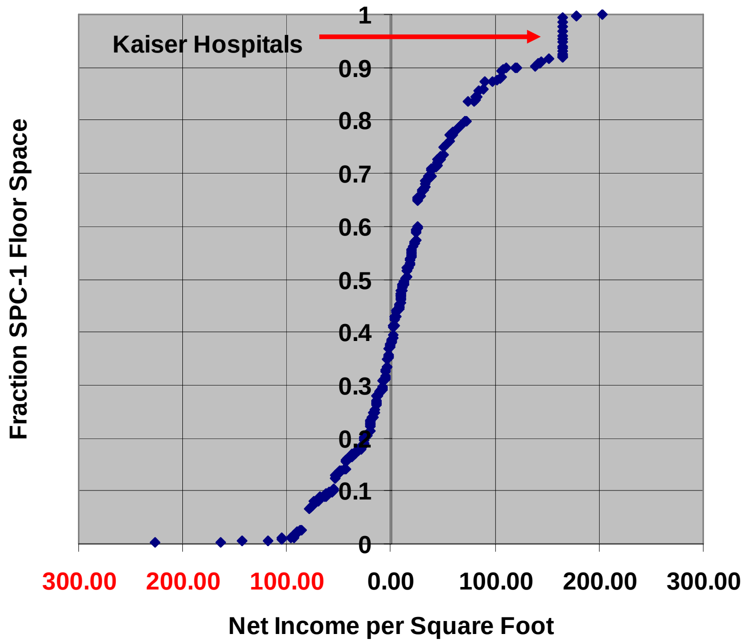
*Data are for all acute-care hospital facilities in California. All data in this figure were obtained from OSHPD.

To examine the implications for SB1953 construction programs, RAND focused only on the ratios for hospitals with SPC-1 buildings and arrayed the data in terms of the profitability per square foot. This perspective (Figure 7) shows that about half of the SPC-1 infrastructure occurs on campuses where the ratio of profit per square foot is only marginally positive or worse, when viewed in absolute terms or on a relative basis compared to the costs of $1,000 per square foot for a new facility. Based on this observation, the authors conclude that financing for much of the SPC-1 replacements will require capital from sources other than ongoing hospital operations.

Impact on Costs for Medical Services

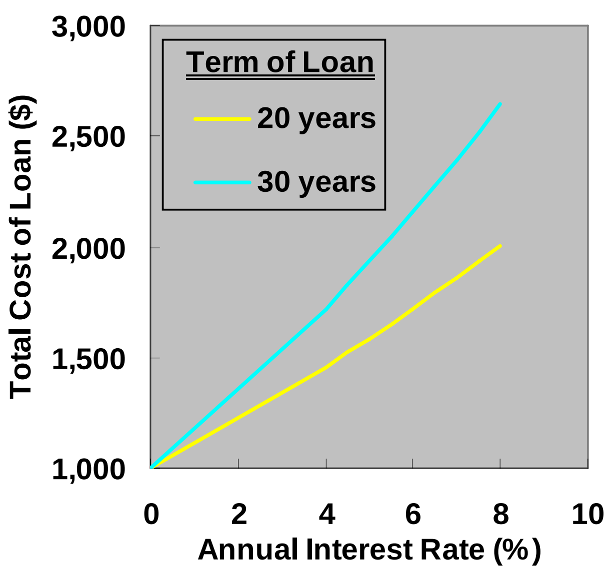
To assess the potential effects on the costs of medical services, RAND considered the magnitude of the increased costs per adjusted patient-day in hospitals that will be needed to balance the construction costs at $1,000 per square foot for a new facility. The first step in this analysis considers the impact of finance charges to assess the total costs of new construction. (See Figure 8.) Because California hospitals include for-profit, non-profit, and publicly owned entities, with wide ranging financial health, the authors expect that a broad spectrum of financing arrangements will be used to obtain capital for new construction (i.e. annual interest rates and terms of loans). With this background, RAND estimates that the total costs for a new hospital facility (construction, equipment, furnishing, and financing) will range from $1,400 to $2,800 per square foot.

Figure 7. Net Income per Square Foot Across SPC-1 Facilities*



*The Kaiser facilities occur as a step in the above curve because they report financial data in aggregate to OSHDP rather than on a facility-by-facility basis. All data in this figure were obtained from OSHPD.

Figure 8. Total Cost of Financing $1,000*



***Values show the nominal cost in 2006 dollars for one square foot of a finished new hospital facility, considering different interest rates and lengths of loans. These calculations use $1,400 as the minimum and $2,800 as the maximum cost that hospitals will have to absorb per square foot of new construction.

The next step in the analysis considers how individual hospitals will amortize these costs over the flow of patients on individual campuses. In detail this assessment requires consideration of the size of the patient flows in relation to the size of the new construction and the period for the amortization. Using OSHPD hospital data, the authors note that the average patient flow for California hospitals can be quantified as 0.26 adjusted patient-days per square foot of infrastructure, based on 2004 data.[19] In general, if a hospital replaces all of its facilities with new construction, maintaining the same gross building area, the impact on costs for medical services would be calculated according to the following relation.

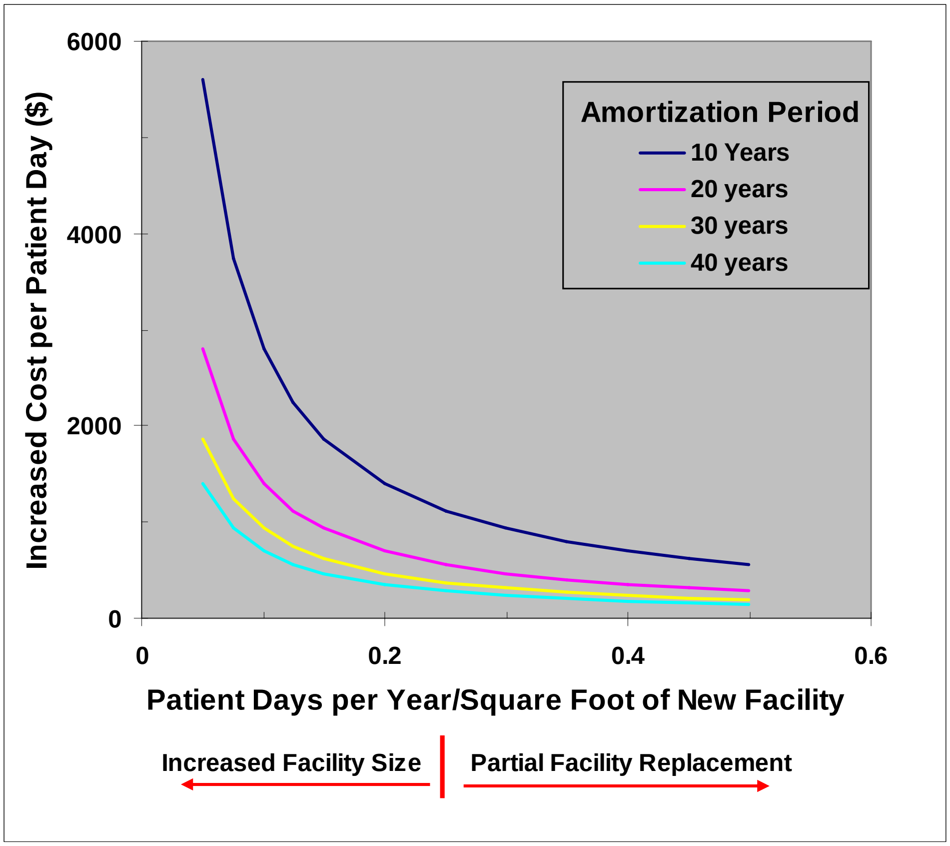
$$\text{Increased cost per adjusted patient-day} = \frac{\text{Total construction costs}}{(\text{Adjusted patient days per square foot per year } X \text{ period of amortization})}$$

On average, considering total construction costs of $2,800 per square foot, and a 20-year amortization period, the costs of new construction would be balanced by an increased cost per adjusted patient-day of $2,800/(0.26 X 20) = $538.

Two factors will alter the above calculation if impacts across the entire SPC-1 infrastructure are considered. Hospitals that replace only a portion of their facilities will be able to amortize the costs over relatively larger patient flows compared to the new facility. This would effectively increase the value of the adjusted patient-days per square foot per year in the above relation and decrease the cost impacts. Alternatively, if hospitals build new facilities that are larger than the original SPC-1 buildings on a per-patient basis (see discussion below), it will cause an effective decrease in the patient flows per square foot to amortize the costs and increase the cost impacts.

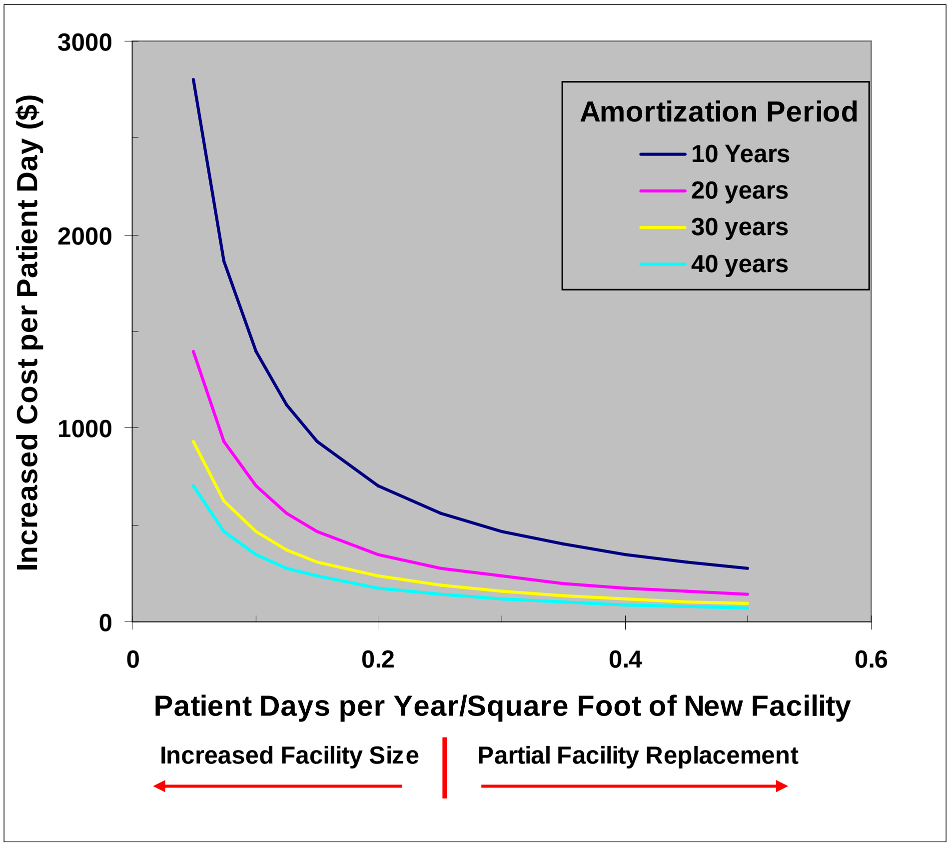
Figures 9A and 9B illustrate these tradeoffs and the cost impacts for all California hospitals. These calculations consider a range of effective patient flows per square foot of new facility, facility costs, and amortization periods. The figures show that for total project costs between $1,400 and $2,800 per square foot, a 20-year amortization period, and a range of patient flows around the statewide average of 0.26 adjusted patient-days per square foot per year, the increased costs per adjusted patient-day could fall between $200 and $950. By comparison, the average cost per adjusted patient-day was about $1,980 for all general acute-care California hospitals in 2004 (defined as total operating revenues/total adjusted patient-days).[20] It should be emphasized that this result only represents the balance of costs from an accounting perspective, and it does not predict the impacts on costs to health care consumers. In some cases, hospitals may identify other sources of capital to balance the construction costs (e.g., donations, decreased profitability). In other cases, it may require increased prices for health care services. And, as indicated in Figure 7, most hospitals will not be able to use income from health care operations to pay for new construction.

Figure 9 A. Estimated Increased Costs per Adjusted Patient-Day: $2,800 per Square Foot Total Construction Cost*



*Curves show increases to accommodate a total cost of $2,800 per square foot for new hospital facilities, considering a range of amortization periods and facility sizes compared to patient loads. As illustrated by the red vertical line, the average number of adjusted patient-days per square foot per year in all California hospitals is currently 0.26. As indicated, the effective number of adjusted patient-days to amortize a new facility will increase when hospitals only replace a portion of their current buildings, but it will decrease if the replacement hospitals are designed to be substantially larger on a per-patient basis. With this background, and considering a 20-year amortization period, the authors estimate that the costs per adjusted patient-day could increase by as much as $950 for individual hospitals to accommodate a total cost of $2,800 per square foot to build new facilities.

Figure 9 B. Estimated Increased Costs per Adjusted Patient-Day: $1,400 per Square Foot Total Construction Cost*



*Curves show increases to accommodate a total cost of $1,400 per square foot for new hospital facilities, considering a range of amortization periods and facility sizes compared to patient loads. As illustrated by the red vertical line, the average number of adjusted patient-days per square foot per year in all California hospitals is currently 0.26. As indicated, the effective number of adjusted patient-days to amortize a new facility will increase when hospitals only replace a portion of their current buildings, but it will decrease if the replacement hospitals are designed to be substantially larger on a per patient basis. With this background, and considering a 20-year amortization period, the authors estimate that the costs per adjusted patient-day could increase by as much as $475 for individual hospitals to accommodate a total cost of $1,400 per square foot to build new facilities.

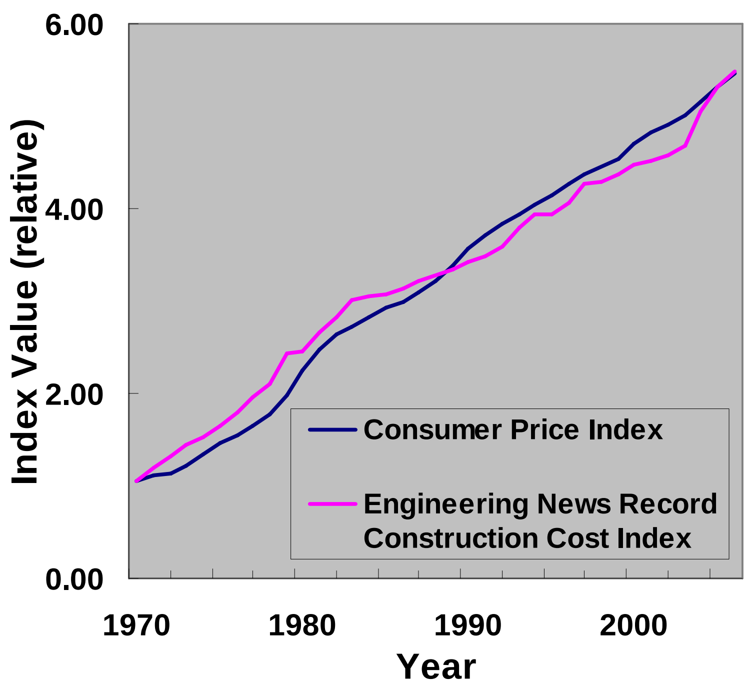
Construction Cost Scenarios

With the above background, the authors estimate the total construction costs that may be required to reconstruct the remaining SPC-1 facilities (41.5 million square feet), using a scenario approach that explicitly models the impact of future trends that are difficult to quantify *a priori* but have a large impact on the total costs. For this effort, the most important considerations involve the magnitude of future construction cost inflation and hospital decision making regarding the size of the their new construction projects. These issues are discussed below.

Inflation

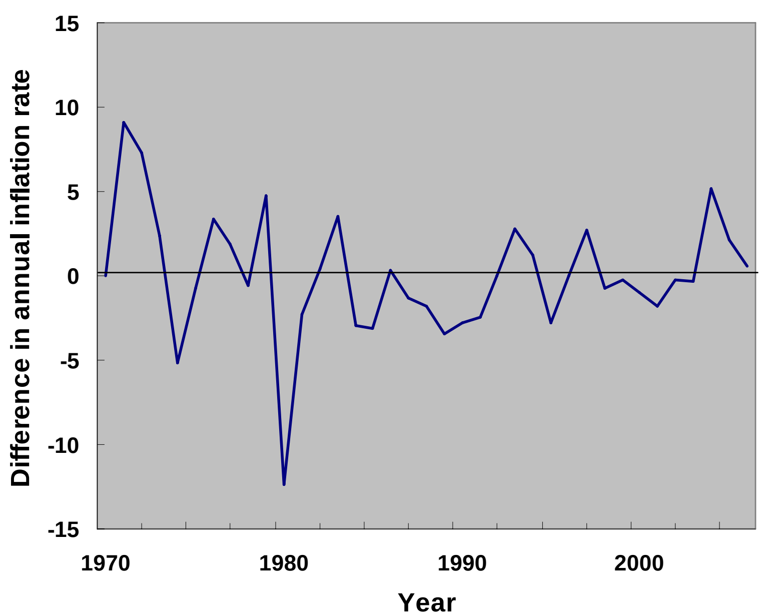
Because the construction effort will occur over a long period of time, the real construction costs can increase significantly with small levels of inflation. On this point, this analysis focuses particularly on the construction inflation rate in excess (or in deficit) of the background consumer price index (CPI) or price deflator. If construction costs increase/decrease at faster rate than these indices, then future construction becomes more/less expensive than today in real terms. Historically, increases in construction costs, averaged across the United States as measured by the Engineering News Record Construction Cost Index, have been comparable to the trends in inflation when measured over a long period of time. (See Figure 10.) However, there can be large differences between the two when viewed over short periods of time. (See Figure 11.) And as illustrated by the recent experience in California, the trends can be further accentuated when focusing on hospital construction. As discussed below, construction cost inflation is a variable parameter when quantifying future cost scenarios.

Figure 10. Historical Inflation Trends*



*Data compare the Consumer Price Index and nationally averaged construction costs.

Figure 11. Difference Between Annual Inflation Rates*



*Comparison between the Consumer Price Index and the Engineering News Record Construction Cost Index.

This analysis considers the real construction cost inflation rate, on an annual basis, in excess of the CPI over the entire period of construction (i.e., 25 years and greater). Figure 10 illustrates that it is possible for this value to be positive or negative. For example, from 1970 to 1984, the real rate of inflation for the Engineering News Record Index was about 1.5 percent per year while it was negative 1 percent per year from 1984 to 2003. Although the recent inflation trends for California hospital construction have been excessive, most experts believe this trend will not continue. There are two principal reasons for this point of view. First, many of the causes for the recent inflation (noted above) can be viewed as one-time market adjustments rather than a continuing force for increased prices. Second, and perhaps more important, is that hospital construction would be completely unaffordable if prices were to double again in the next five years. With no demand for construction, the prices could easily drop. This background suggests a range of positive and negative inflation values for calculating cost scenarios. Considering the possibility for these trends, real construction hospital construction costs in California may decrease (negative inflation) when viewed over a long period of time.

Hospital Decisionmaking

The second parameter of concern involves hospital decision making on the sizing of new facilities. As discussed above, this analysis considered this issue simply in terms of the demand for inpatient beds. But a more important factor that has become apparent—as increasing numbers of hospitals are proposing designs for new facilities—involves the scaling and sizing of new hospital facilities. In detail, these depend on a complex range of factors, including the age of the population served, their demand for hospital service, the use of new medical technology, and the shift to outpatient care. The net result, as demonstrated by recent California construction projects, is that new facilities are much larger for a given level of medical function compared to hospitals buildings from the 1950s, ‘60s, and ‘70s (the age of SPC-1 buildings). This is measured in ratios of building (or department) square feet per inpatient bed, to the sizes of emergency rooms and imaging departments. (See Table 10.) As illustrated in the design comparison for a recent facility in California, the gross square footage for each department is 20 percent to 150 percent larger than the previous designs from the 1960s and 1970s, *assuming the same medical driver* (e.g., numbers of beds, number of patients). The net result is that if a hospital chooses only to preserve the current function as it builds a new facility (e.g., numbers of inpatient and outpatient flows), modern design standards will dictate a substantially larger facility than the original (35 percent to 60 percent larger). These factors are on top of any increase in size that might be mandated by increasing population and patient flows. This has important implications for calculating cost scenarios on a cost-per-square-foot basis because there may be substantial increases in the construction requirements compared to the original inventory of SPC-1 facilities (i.e., the replacement may be substantially more than 1-to-1 when one considers the current inventory of SPC-1 facilities). Reflecting these trends, this analysis models the construction costs in terms of an SPC-1 “replacement factor,” which is the size of the new facilities compared to the original. Unlike the first report, in which considered the possibility that hospitals will build facilities with fewer beds, this analysis only considers replacement factors greater than 1.0.

Table 10. Change in Departmental Design Factors for an SPC-1 Replacement Facility[21]

Department	Increased Square Footage Requirements (Percent)
Med surg/step down/pediatrics	77
ICU/PICU/high-acuity step down	23
Women/infants/LDRs	43
Postpartum	153
Well baby nursery-not counted as beds	136
NICU	119
Emergency dept/CDU	6
Radiology	24
Nuclear medicine	43
Perioperative services ORs	43
PACU and pre-op	103
ASC (includes ASC pre/post)	165
Total surgical services	64.6
Total bed-driven ancillary support	21
Total logistical support	69
Total admin. support	12
Total departmental gross square footage	83

Figures 12A and 12B explore the tradeoff in the inflation and decision making factors for a wide range of plausible construction scenarios. Assuming a present cost of $1,000 per square foot for a new, equipped hospital facility, the scenarios were constructed at varying levels of inflation assuming a capability to build 1.5 million and 2.0 million square feet of new hospital space per year in California, with a need to replace the 41.5 million square feet of SPC-1 facilities that have not been addressed by current or past construction activities.

Figure 12 A. Construction Cost Scenario: 1.5 Million Square Feet per Year*

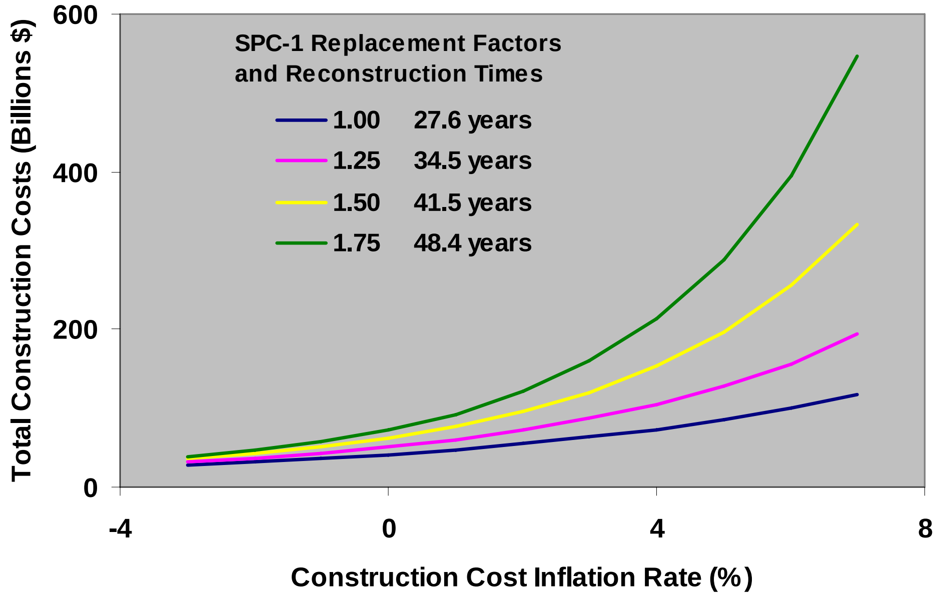
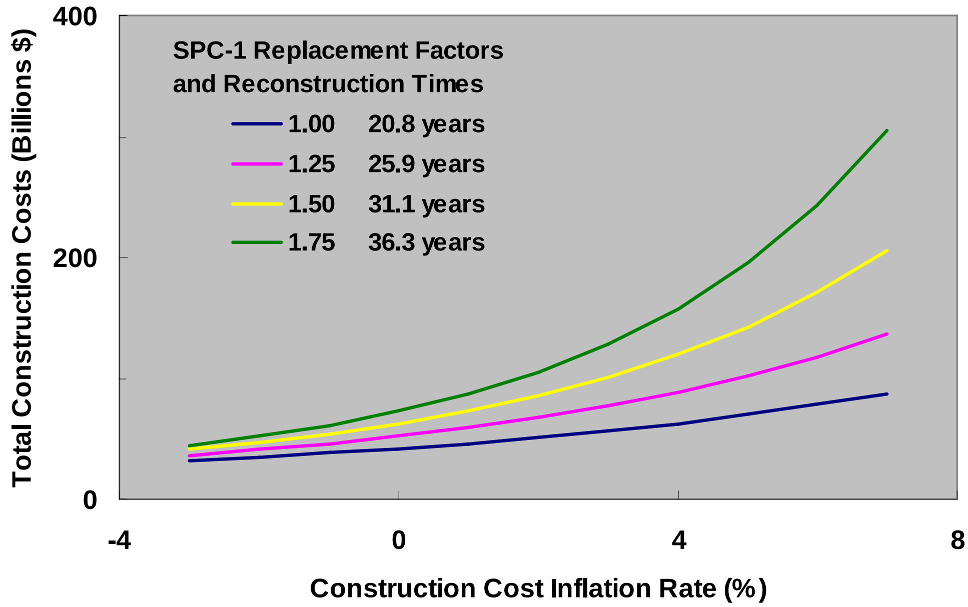


Figure 12 B. Construction Cost Scenario: 2.0 Million Square Feet per Year



*Curves show costs to replace 41.5 million square feet of SPC-1 facilities with new hospitals, considering a range of SPC-1 replacement factors. The scenarios are constructed assuming construction rates of 1.5 million (Table 12A) and 2.0 million (Table 12B) square feet per year. Because of the fixed construction rates, the total time to build the infrastructure increases with higher values of the SPC-1 replacement factor.

These calculations yield important insights. First, it becomes clear that there is very little opportunity to phase the construction, given the size of the infrastructure and the limited time until the 2030 deadline. Indeed it is only possible to meet the deadline with replacement factors of 1.0 and a construction pace greater than 2 million square feet per year. All other scenarios extend beyond the final SB1953 deadline of 2030. Second, it is clear that the total construction costs for the remaining SPC-1 infrastructure, measured in 2006 dollars, will be larger than the values in RAND's first report. Indeed, for inflation rates of –1 percent and +2 percent and replacement factors of 1.35 to 1.6, the total construction costs range from $45 billion to $110 billion to replace the remaining 41.5 million square feet of SPC-1 infrastructure. Note these values do not include the costs of financing, which could as much as double the expenditures, depending on the details of the financing arrangements. At these levels, the average annual construction expenditures range from $1.3 billion to $2.5 billion, measured in 2006 dollars. At higher levels of inflation or replacement factors, the costs become substantially larger. The factors contributing to the increase in costs compared to the first report include the cost inflation for hospital construction, explicit consideration of inflation in the calculations, and considering the possibility that hospitals may build larger (rather than smaller) replacement facilities.

To obtain total construction cost figures to replace the entire 52.4 million square feet of SPC-1 infrastructure, one would add about $7 billion to these totals, reflecting the approximate costs for projects currently in progress (see below). And to obtain an estimate of the total cost for all SB1953 reconstruction activities, one would need to include the contribution from the SPC-2 buildings. As noted above, the details of this infrastructure are uncertain, making it difficult to quantify the cost impact. With this background, the authors estimate that these buildings contain about 10 million square feet of floor space, which could increase the total construction expenditures by another 20 percent to 25 percent.

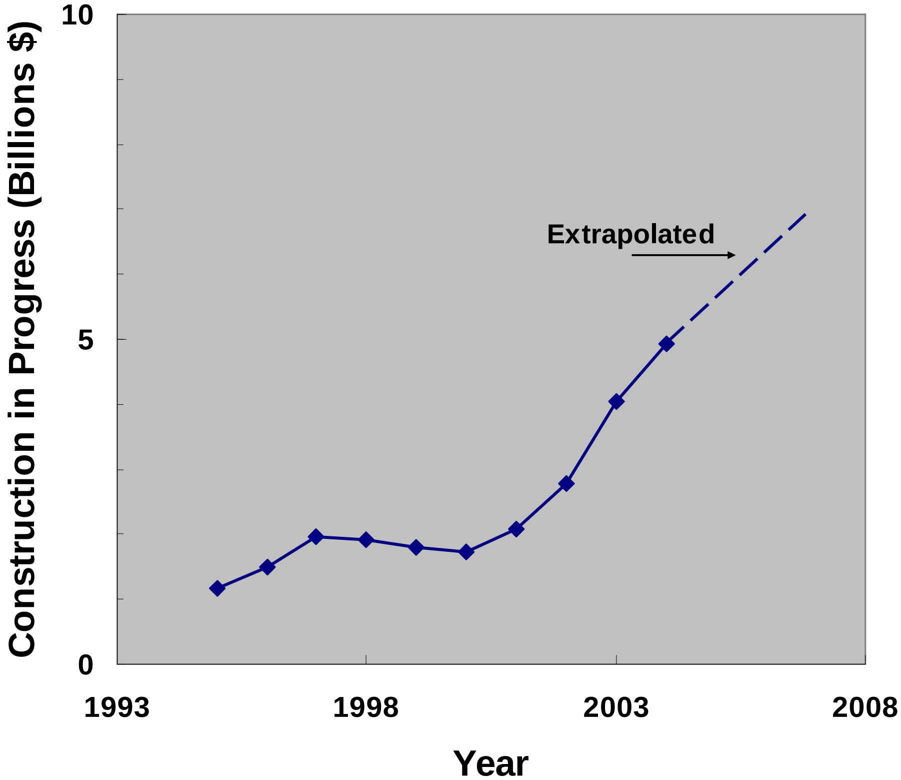
Comparison with Historical Experience

To put these costs in context, this analysis compares them to historical expenditures for hospital-related construction in California and to analyses of national trends in hospital construction expenditures. For the historical perspective, there are two types of data, both available from OSHPD. The first, from the annual financial reports, lists the value of "construction-in-progress" for each hospital campus. The term is defined by OSHPD in the following way:

> The accumulated cost of construction that is in progress and eventually used in hospital operations. Upon completion of the construction project, the asset is reclassified to the appropriate capital asset accounts, such as land and buildings.

If a construction project lasts multiple years, the value of construction-in-progress will grow and be carried over into subsequent years. Thus, these cannot be viewed as annual construction expenditures, but they do give a sense for the magnitude of construction activity. As shown in Figure 13, the value of construction-in-progress for California hospitals was about $2 billion from 1994 to 2001. In real terms, the values actually decreased during this period because the data were reported as then-year expenditures. After 2001, the values more than double because of a large increase in construction activity for SB1953 compliance. Extrapolating the trend to the present suggests the current values of in progress construction may approach $7 billion.

Figure 13. Value of In-Progress Construction*



*Data for acute-care hospitals as reported to OSHPD.

To estimate the annual construction expenditures, the analysis examines the OSHPD building permit data, which include an estimated cost for the project. These data include records of new hospital construction (estimated at hundreds of millions of dollars), together with minor renovations of nursing stations (estimated at thousands of dollars). In terms of frequency, the latter are much more common, and the former contribute to the bulk of the costs.

To estimate historical annualized construction costs, the analysis sums these data according to the closure date on the project. (See Figure 14.) Viewed in this way, the data show a peak for annualized construction expenditures of about $800 million in 1991, with values decreasing in real and absolute terms since that date. The accuracy of the data decreases after 1999 because after that date a number of large construction projects are still open. Thus, RAND expects the values to rise in the subsequent years, reflecting closure for the many large construction projects that were recently initiated. Given that these values reflect basic construction costs, and not the expenditures for a fully finished medical facility, the analysis estimates that the annualized construction expenditures would need to increase about 100 percent from 1999 levels to become comparable to the values in the cost scenarios in figures 12A and 12B. On this basis, the authors conclude that SB1953 compliance will require construction expenditures over a long period of time that are substantially higher that the historical levels for California hospitals.

Figure 14. Annual Value of Closed Construction*

*Compiled from data reported OSHPD for acute-care hospitals.

To view these estimated construction cost scenarios in a national perspective, consider an analysis of hospital "recapitalization" rates. Developed for financial analysis of Department of Defense facilities, the features of recapitalization are defined as follows:

- **Recapitalization:** Major renovation or reconstruction activities (including facility replacements) needed to keep existing facilities modern and relevant in an environment of changing standards and missions. Recapitalization extends the service life of facilities or restores lost service life. It includes the restoration and modernization of existing facilities but not the acquisition of new facilities or the demolition of old ones (unless the demolition is carried out as part of a renovation project or in conjunction with construction of replacement footprint elsewhere).
- **Recapitalization rate:** The number of years required to regenerate a physical plant—either through replacement or major renovation(s)—at a given level of investment.

The Department of Defense formula for determining the recapitalization rate is:

$$\text{Recapitalization Rate (years)} = \frac{\text{Assets (measured in Plant Replacement Value)}}{\text{Annual Investment, Restoration, and Modernization}}$$

In effect, this is a measure of the rate at which hospitals invest in new construction activities, referenced to the value of their original infrastructure. Analysis of data from all hospitals in the United States shows an average value of about 5 percent, with some variation according to location and the type of ownership.[22] That is, the value of annual hospital construction expenditures is comparable to 5 percent of the value of their existing buildings. To be sure, this value can represent an average over a period of time (i.e., it is not a precise annual figure), and it can account for investments in both major and minor projects. In general, the results suggest that hospitals buildings may have a longer service life compared to other infrastructure simply because they are being continuously updated through restoration investments. This analysis scales the recapitalization rate values to California, noting that the current hospital infrastructure is about 100 million square feet. If the "value" of the infrastructure is quantified in terms of the replacement construction costs (about $600 per square foot), the 5 percent level represents annualized construction costs of $3 billion, which is *higher* than the current cash flow levels in the scenarios. That is, the construction costs for SB1953 compliance may be viewed as reasonable, from the perspective of recapitalization activities carried out by hospitals throughout the United States.

V. Conclusions

In this updated study, RAND further analyzes the challenge to implement SB1953 for California's hospitals. At the top level, the most important findings are:

- Based on historical rates of construction and permit filings with the California Office of Statewide Health Planning and Development (OSHPD), about half of the SPC-1 hospital infrastructure will not be compliant with the 2008/2013 deadlines for SB1953, and many may not be able to comply with the final 2030 deadline.
- Because of recent construction cost inflation and changes in the design for modern health care facilities, the authors estimate that total construction costs to rebuild SPC-1 facilities will be significantly higher than the value in RAND's previous report ($41 billion). Depending on future inflation trends and construction planning decisions by individual hospitals, the total reconstruction costs for SPC-1 buildings could range from $45 billion to $110 billion. Notably, this estimate does not include costs associated with financing or reconstructing SPC-2 buildings, which could significantly increase the total costs of SB1953 compliance.
- Construction for SB1953 compliance will require construction expenditures far above historical levels.

The authors' findings on the pace of SB1953 compliance are especially significant in light of the time scales that have been provided to meet hospital seismic safety goals in California. Since the passage of the original Alquist Act in 1973, hospitals will have had 35 to 40 years to meet the requirements by the 2008/2013 deadlines.

Upon first inspection, the slow progress seems surprising, though part of the problem may be attributed to the phased deadlines in SB1953. Specifically, there seems to have been an implicit assumption that it would be relatively straightforward for hospitals to meet the 2008/2013 deadlines through seismic retrofits, with final compliance construction delayed to 2030. In practice, however, retrofits are expensive and extremely disruptive to hospital operations, thus limiting their implementation. Without significant retrofit activity on the SPC-1 structures, the 2030 deadline has effectively been moved to 2008/2013 for many hospitals.

Viewed from the larger perspective of disaster mitigation—and public interest in loss reduction—one would think SB1953 and the Alquist Act would be a priority policy goal for California and that implementation should have been straightforward. The potential for loss and damage from a California earthquake are well-documented and has fueled public concern in the state for many years. As a result California has the most stringent building codes for earthquakes in the nation (and perhaps the world) and, as a result, one of the most aggressive approaches to vulnerability reduction in the nation. In this setting, California's old and vulnerable hospital buildings would seem to be an obvious focus for policy efforts. And one might expect these actions to be motivated by the public interest in maintaining health care services after a large earthquake.

The above is supported by the historical record of policy actions following large earthquakes and other natural disasters. One of the first laws in the United States mandating vulnerability reduction for natural disasters was passed in California after the Long Beach earthquake of 1933, which caused the collapse of local school buildings. In response, the Field Act called for new seismic standards in the construction of all school buildings in California. These regulations continue today, though it is notable that it took more than 40 years to achieve full compliance with the pre-existing infrastructure of California schools. Nearly 40 years later, the next destructive earthquake in California (San Fernando Valley, 1971) stimulated the Alquist-Priolo Earthquake Fault Zoning Act, which severely limits construction near active earthquake faults. Similarly, the Alquist Hospital Seismic Safety Act and SB1953 were motivated by earthquakes that damaged local hospitals. Together, these events suggest that future earthquakes in California are likely to prompt new and potentially more restrictive legislation on hospital seismic safety.

Paralleling the California experience with earthquakes, the state of Louisiana recently enacted legislation calling for new standards and retrofits to hospitals and nursing homes to lessen the impact from hurricanes and floods. The bill was directly stimulated by the disastrous experience of devastated nursing homes and flooded hospitals with no power and sewage following Hurricane Katrina. From a disaster policy perspective, the Louisiana efforts are highly significant given the low level of mitigation and building standards that were present in the state before Katrina and the substantially lower levels of income and wealth compared to California (suggesting a lower capability to pay for retrofits and mitigation).

Despite these motivations, our analysis suggests that there may be special challenges to implement disaster mitigation policy for California hospitals. Specifically:

New hospital buildings are extremely expensive. At $1,000 per square foot for a finished facility, new hospitals represent some of the most expensive infrastructure in the built environment. As a result, disaster mitigation for hospitals requires large expenditures, creating a challenge to balance the costs and benefits of new construction, especially if the analysis focuses only on disaster loss-reduction.

It is difficult to replace individual buildings on a hospital campus that may be vulnerable to earthquakes. As noted in RAND's first report, hospital campuses typically contain multiple connected buildings, with the oldest building in the center. From an engineering and construction standpoint, it is often impossible to "replace" the oldest, most vulnerable structure without closing the entire campus. As a result, SB1953 compliance strategies often require larger construction programs than simple replacement of the vulnerable facility.

The California hospital industry has a limited capability to pay for large amounts of new infrastructure. As detailed in the above analysis, there is a large mismatch between the profitability of the current California hospital infrastructure and the costs of new construction. From an accounting perspective, new construction may result in large increases in the costs per adjusted patient-day. Consequently, it may be difficult for many California hospitals to absorb the costs of mitigation as part of their ongoing business expenses.

Special planning and organizational skills are required to build new hospital facilities. New hospital facilities are designed to meet strategic and health care goals for individual health care organizations. Planning and executing the programs for this effort can take as long as ten years for each new building. Thus, the required skills are much larger than straightforward engineering concerns of disaster mitigation, and they may not be present in many hospital organizations.

Enduring regulatory structures are needed given the large numbers of vulnerable hospitals in California and the time scales for mitigation. As detailed above, it will probably require more than 25 years of construction to bring all California hospitals into compliance with SB1953. Policies and regulatory structures need to be developed so they are uniform and consistent over this period.

California hospital operations are influenced by a range of public health policy goals, some of which may conflict with disaster mitigation (e.g., reducing the costs of health care). Ultimately, the costs for new hospital construction will be paid out of the bills for health care or by taxpayers. In some cases, disaster mitigation could limit the access to health care if it forces some hospitals to close. These factors suggest that disaster mitigation for hospitals may need to be integrated into a larger framework for public health.

While the above describes problematic factors for hospital seismic safety in California, the broader implications for disaster mitigation policy are unclear. Today, SB1953 is one of the most aggressive vulnerability-reduction measures for natural disasters in the United States because it includes requirements for private business owners to replace existing and otherwise functioning infrastructure (the SPC-1 buildings).[23] By comparison, most states and municipalities focus regulatory efforts on codes for new construction and appropriate siting for new facilities. And at the federal level, there is very little policy effort to reduce the vulnerability of existing infrastructure to natural disasters.[24] In some states, there are requirements for retrofits on existing buildings to meet various policy goals, but these are usually triggered by other decision making (e.g., a retrofit has to be performed if other large-scale construction projects occur in the building).

Without a record of successful implementation for SB1953-type requirements in other industries or other states, it is difficult to assess whether the challenges in California reflect special circumstances for hospitals or problems with the original policy framework. In this environment, decision making on SB1953 implementation will be difficult, largely because of the lack of precedent, irrespective of the merits of the original policy goals.

These observations suggest that full-scale implementation of SB1953, according to the original schedule, may exceed the current financial and organizational capabilities of government and the private sector. To illustrate the difficult policy choices that lie ahead, the following illustrates a range of possible “solutions” for SB1953, together with the trade-offs that each requires.

Push ahead with SB1953 implementation. The approach would be motivated by a priority to meet the loss-reduction goal in the original legislation. However, it could lead to other substantial problems because the state would be forced to close large numbers of non-compliant hospitals on the deadlines in 2008/2013 and 2030. While the threat of closure would provide a critical incentive to encourage compliance, it could also lead to large-scale negative effects on the availability of health care in California.

Modify or eliminate SB1953's requirements so that most facilities can achieve compliance. While this approach would eliminate the effects on health care availability, noted above, there would be two negative effects. First, there is the question of policy fairness, given that a significant number of California hospitals have already invested large funds to comply with the original law. Second, the seismic vulnerability would be largely unaddressed, which could lead to political backlash after the next large earthquake.

Enact public funding for hospitals that are unable or unwilling to comply with SB1953's requirements. The approach might be rationalized under the view that hospitals serve as critical public facilities, and there is a history of California state funding for seismic strengthening of public infrastructure. However, this approach would also raise fairness questions for those hospitals that have already invested in SB1953 compliance. And it would trigger a large public debate on the best use of taxpayer funds on health care facilities.

While the above suggests considerable challenges in the near term to implement SB1953, it is important to note that California's hospital seismic safety goals will eventually be addressed by the passage of time as hospitals replace their old buildings through normal modernization programs. That is, the key question for SB1953 is not *whether* hospitals will meet seismic goals but *when* will they meet these goals. And on this question, the policy problem is that hospitals clearly favor extended service lives for their buildings in the current financial and business environment. Indeed, without the SB1953 requirements, it could take longer than 50 years to reach full compliance with the Alquist seismic safety goals. And over this period, there is a high probability that California will experience a large and damaging earthquake.

With this background, it appears that it would be appropriate to focus the SB1953 policy debate on the time scales for achieving California's hospital seismic safety goals. While the state has been extremely generous on this issue, providing 57 years for full compliance (between the passage of the original Alquist Act and the final deadline in SB1953), it clearly has become a difficult target for the state's hospital industry, as measured by the pace of compliance toward the current deadlines. Compounding the problem is that it will take more than 20 years to bring the entire hospital infrastructure into compliance even with an aggressive construction program, clearly indicating a need for phased approach to meet the goals. Thus, there will be a need for continuing implementation activity even if the final deadlines are extended to several decades away. As this activity continues, there will be a need to understand the interactions between SB1953 compliance activities and other public policy goals where hospitals play a central role (e.g., public health, cost of health care). And there will be a need for new frameworks to assess these effects in light of the benefits that would occur after a large earthquake disaster.

Appendix A: Structural and Non-Structural Earthquake Performance Standards for SB1953

This appendix summarizes the criteria from the structural and non-structural earthquake performance standards, referenced as “SPC” and “NPC” respectively.

Structural Categories

SPC-0: The hospital evaluated this building but did not provide any rating in its report to the California Office of Statewide Health Planning and Development (OSHPD).

SPC-1: These buildings pose a significant risk of collapse and a danger to the public after a strong earthquake. These buildings must be retrofitted, replaced, or removed from acute-care service by January 1, 2008.

SPC-2: These buildings are in compliance with the pre-1973 California Building Standards Code or other applicable standards but are not in compliance with the structural provisions of the Alquist Hospital Facilities Seismic Safety Act. These buildings do not significantly jeopardize life but may not be repairable or functional following strong ground motion. These buildings must be brought into compliance with the Alquist Act by January 1, 2030, or be removed from acute-care service.

SPC-3: These buildings are in compliance with the structural provisions of the Alquist Hospital Facilities Seismic Safety Act. In a strong earthquake, they may experience structural damage that does not significantly jeopardize life but may not be repairable or functional following strong ground motion. Buildings in this category have been constructed or reconstructed under a building permit obtained through OSHPD. They can be used to 2030 and beyond.

SPC-4: These buildings are in compliance with the structural provisions of the Alquist Hospital Facilities Seismic Safety Act and may experience structural damage that could inhibit the building’s availability following a strong earthquake. Buildings in this category have been constructed or reconstructed under a building permit obtained through OSHPD. They may be used to 2030 and beyond.

SPC-5: These buildings are in compliance with the structural provisions of the Alquist Hospital Facilities Seismic Safety Act and are reasonably capable of providing services to the public following strong ground motion. Buildings in this category have been constructed or reconstructed under a building permit obtained through OSHPD. They may be used without restriction to 2030 and beyond.

Non-Structural Categories

NPC-0: The hospital evaluated the building’s non-structural components but did not report any rating.

NPC-1: In these buildings, the basic systems essential to life safety and patient care are inadequately anchored to resist earthquake forces. Hospitals must brace the communications, emergency power, bulk medical gas, and fire alarm systems in these buildings by January 1, 2002.

NPC-2: In these buildings, essential systems vital to the safe evacuation of the building are adequately braced. The building is expected to suffer significant non-structural damage in a strong earthquake.

NPC-3: In these buildings, non-structural systems are adequately braced in critical areas of the hospital. If the building structure is not badly damaged, the hospital should be able to provide basic emergency medical care following the earthquake.

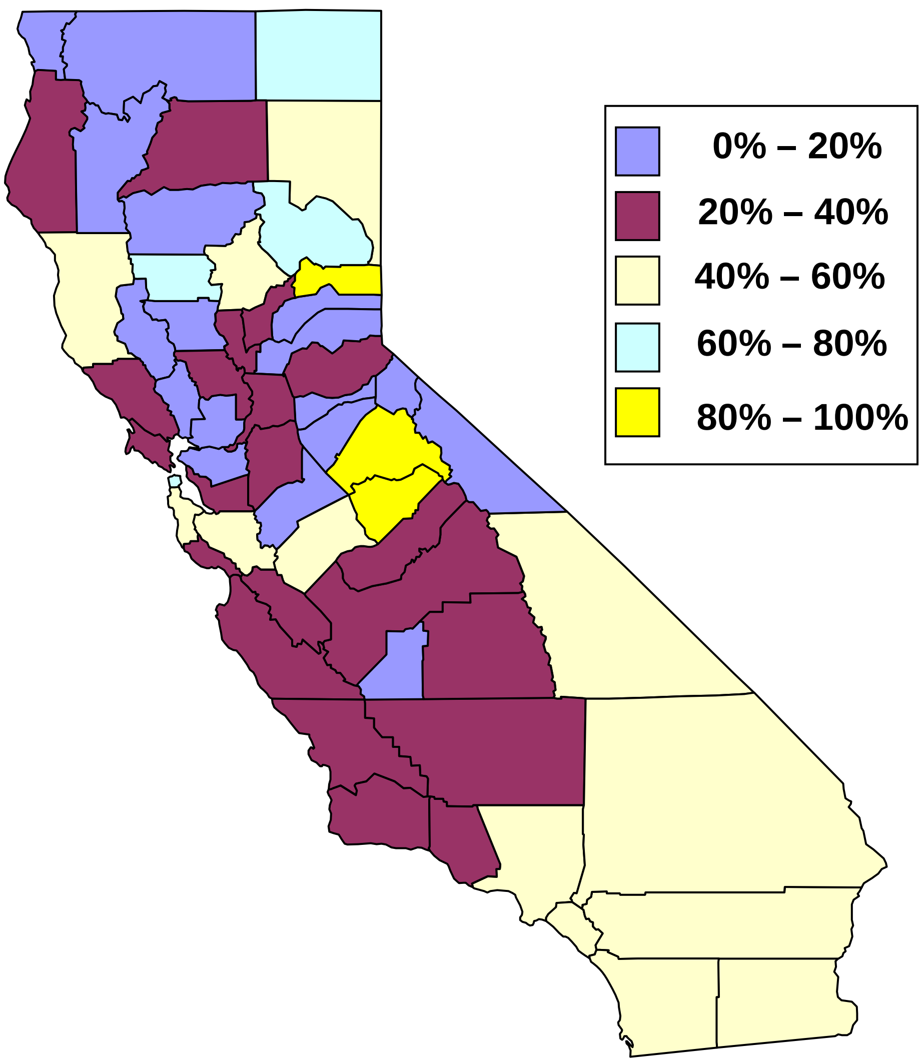
NPC-4: In these buildings, the contents are braced in accordance with current code. If the building structure is not badly damaged, the hospital building should be able to function, although interruption of the municipal water supply or sewer system may impede operations.

NPC-5: These buildings meet all the above criteria and have water and waste-water holding tanks—sufficient for 72 hours of emergency operations—integrated into the plumbing systems. They also contain an onsite emergency system and are able to provide radiological service and an onsite fuel supply for 72 hours of acute-care operation.

Appendix B: Characteristics and Statewide Distribution of SPC-1 Buildings

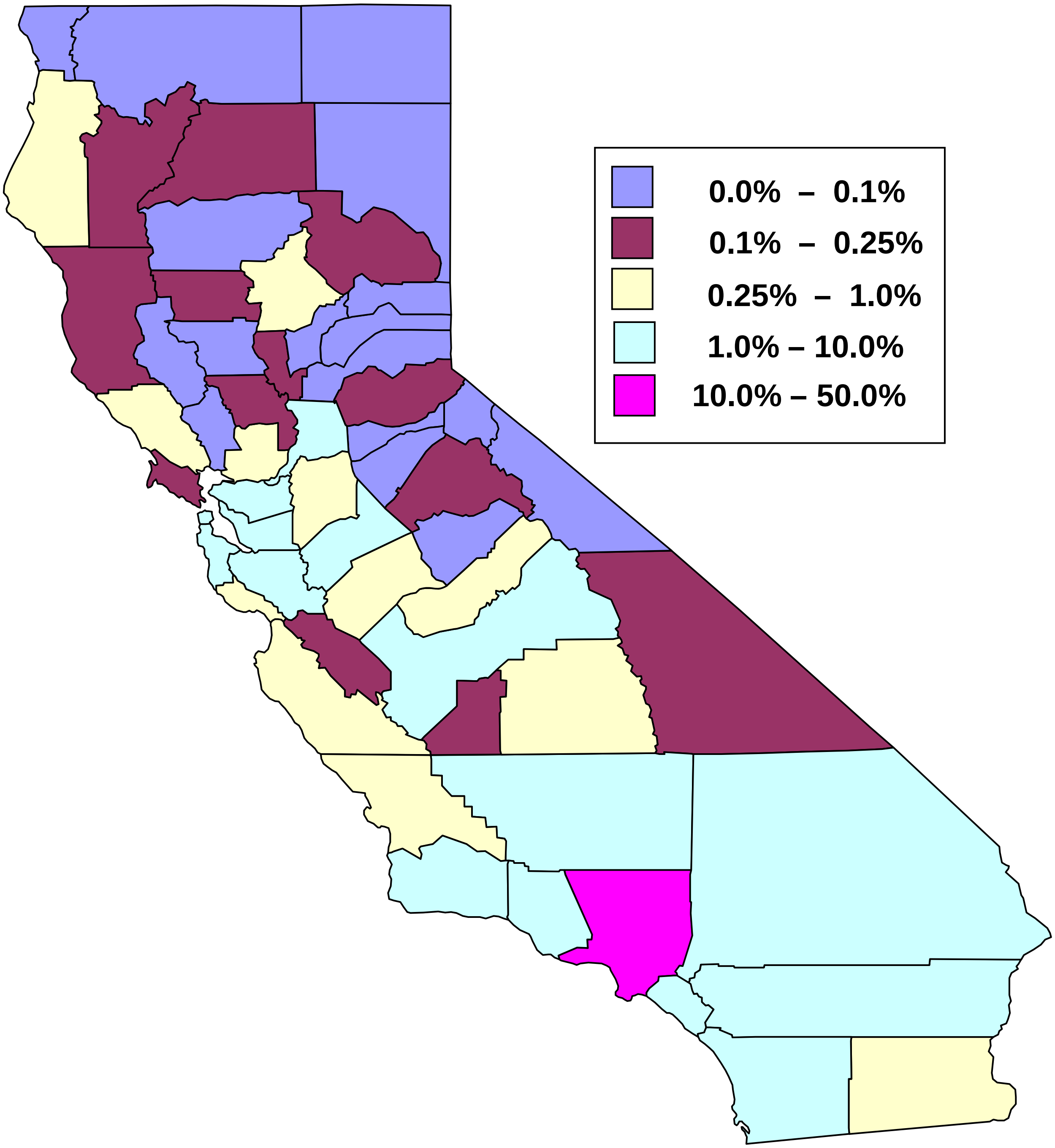
The following figures are reproduced from the previous RAND study on SB1953 compliance costs.[25] They summarize the characteristics of the SPC-1 hospital infrastructure from a statewide perspective.

Figure B 1. Percentage of SPC-1 Buildings, by County*



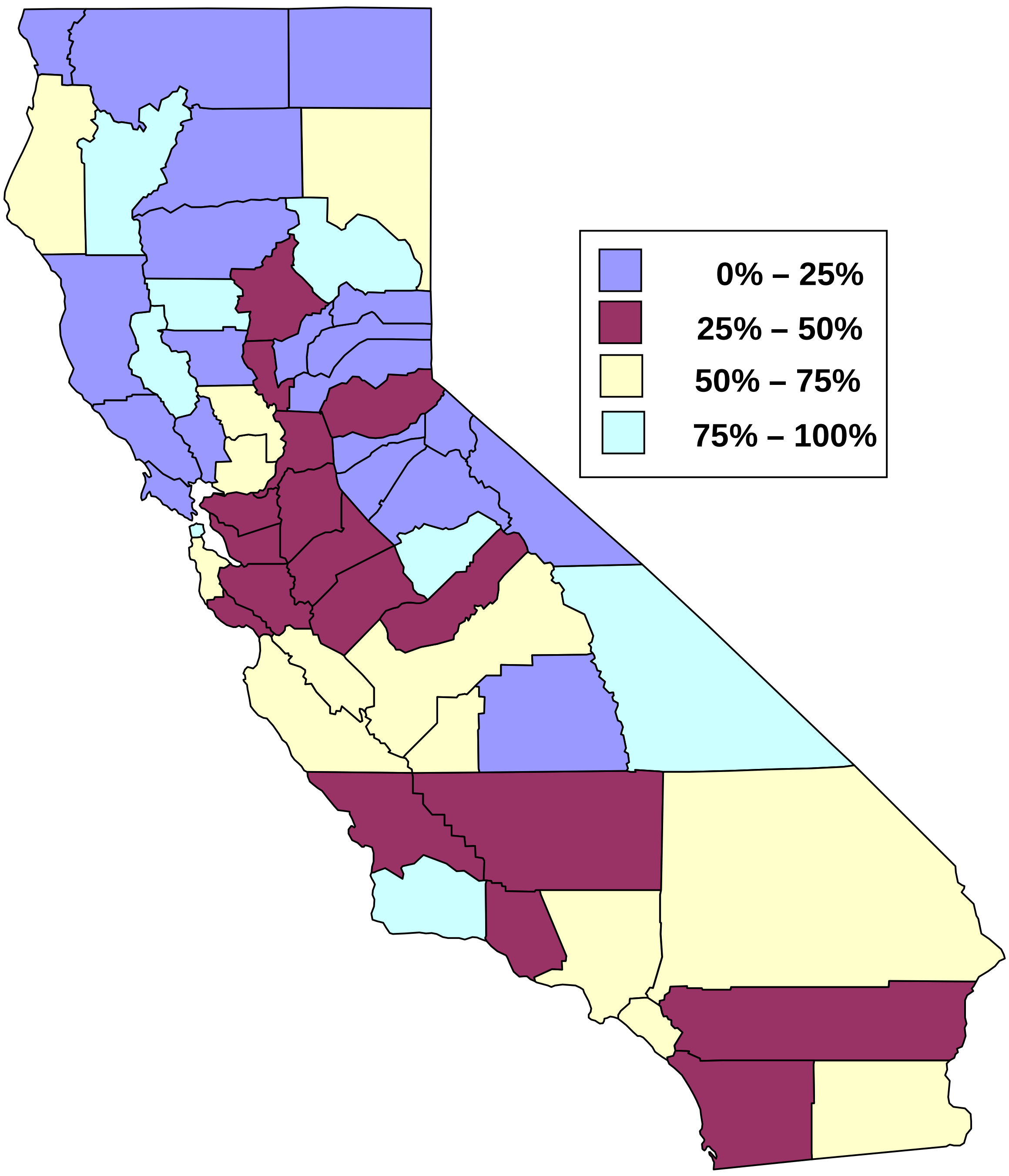
*SPC-1 buildings as a fraction of total hospital buildings for each county in California, derived from the January 2001 reporting to OSHPD. This is a crude measure of the SPC-1 infrastructure because there is considerable variation in the size and contents of hospital buildings.

Figure B 2. Percentage of Statewide SPC-1 Beds, by County*



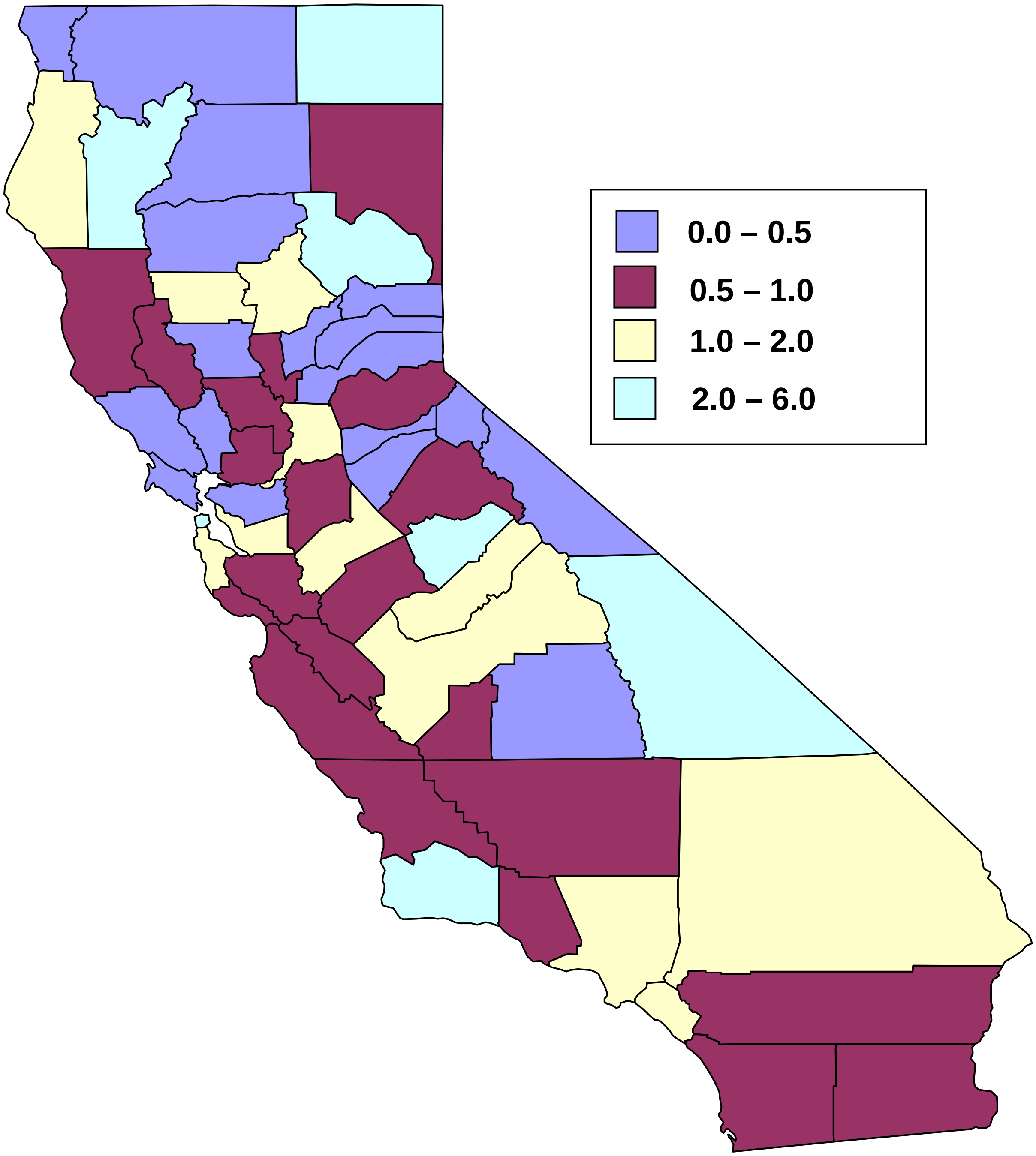
*Statewide share of inpatient hospital beds housed in SPC-1 buildings, for each county in California. Higher values indicate that a county houses a larger share of the SPC-1 hospital beds within California.

Figure B 3. Ratio of SPC-1 Beds to All Available Beds, by County*



*Countywide fraction of inpatient hospital beds housed in SPC-1 buildings, for each county in California. Higher values indicate that larger fractions of the hospital infrastructure are composed of collapse-hazard buildings.

Figure B 4. SPC-1 Beds per Thousand Population, by County*



*Number of inpatient hospital beds housed in SPC-1 buildings, per thousand population for each county in California. Higher values indicate that a larger fraction of the population is served by hospital beds in collapse-hazard buildings.

Appendix C: SB1953 Deadlines and Compliance Standards

The deadlines and compliance standards for hospital seismic safety are detailed in the California State Code. The first deadline, involving major construction activities, was originally targeted for 2008 in SB153. Specifically:

> After January 1, 2008, any general acute-care hospital building that is determined to be a potential risk of collapse or pose significant loss of life shall only be used for non-acute-care hospital purposes.

The key compliance standard for buildings in the above is the phrase “potential risk of collapse.” Although subsequent OSHPD regulations equated the standard with the structural classification “SPC-1,” the legislative intent is clear: The potential hazard of building collapse must be mitigated before 2008. As specified throughout the law, and subsequent amendments, the penalty for non-compliance with this and all other deadlines is closure of the building for acute-care hospital services.

Subsequently SB1801, approved by the governor in September 2000, provided a five-year extension for many hospitals to the 2008 deadline. Specifically:

> (3) To receive the five-year extension, a single building containing all of the basic services or at least one building within the contiguous grouping of hospital buildings shall have obtained a building permit prior to 1973 and this building shall be evaluated and classified as a non-conforming Structural Performance Category 1 (SPC-1) building. The classification shall be submitted to and accepted by the Office of Statewide Health Planning and Development. The identified hospital building shall be exempt from the requirement in subdivision (a) until January 1, 2013, if the hospital agrees that the basic service or services that were provided in that building shall be provided, on or before January 1, 2013, as follows:
>
> > (A) Moved into an existing conforming Structural Performance Category 3 (SPC-3), Structural Performance Category 4 (SPC-4), or Structural Performance Category 5 (SPC-5) and Non-Structural Performance Category 4 (NPC-4) or Non-Structural Performance Category 5 (NPC-5) building.
> >
> > (B) Relocated to a newly built compliant SPC-5 and NPC-4 or NPC-5 building.
> >
> > (C) Continued in the building if the building is retrofitted to a SPC-5 and NPC-4 or NPC-5 building.
>
> (4) A five-year extension is also provided to a post-1973 building if the hospital owner informs the Office of Statewide Health Planning and Development that the building is classified as a SPC-1, SPC-3, or SPC-4 and will be closed to general acute-care inpatient service use by January 1, 2013. The basic services in the building shall be relocated into an SPC-5 and NPC-4 or NPC-5 building by January 1, 2013.

> (5) Any SPC-1 buildings, other than the building identified in paragraph (3) or (4), in the contiguous grouping of hospital buildings shall also be exempt from the requirement in subdivision (a) until January 1, 2013. However, on or before January 1, 2013, at a minimum, each of these buildings shall be retrofitted to a SPC-2 and NPC-3 building or no longer be used for general acute-care hospital inpatient services.

To receive the above exemption, most hospitals have submitted applications to OSHPD.

In September 2006, the governor signed another amendment to SB1953 (SB1661), which provides an opportunity for an additional two-year extension to the 2008 deadline (effectively moving it to 2015). Specifically:

> (1) A hospital that has received an extension of the January 1, 2008, deadline … may request an additional extension of up to two years for a hospital building that it owns or operates.
>
> (2) The office may grant the additional extension if the hospital building subject to the extension meets all of the following criteria:
>
> > (A) The hospital building is under construction at the time of the request for extension under this subdivision and the purpose of the construction is to meet the requirements of subdivision (a) to allow the use of the building as a general acute-care hospital building after the extension deadline granted by the office pursuant to subdivision (a) or (b).
> >
> > (B) The hospital building plans were submitted to the office and were deemed ready for review by the office at least four years prior to the applicable deadline for the building. The hospital shall indicate, upon submission of its plans, the SPC-1 building or buildings that will be retrofitted or replaced to meet the requirements of this section as a result of the project.
> >
> > (C) The hospital received a building permit for the construction described in subparagraph (A) at least two years prior to the applicable deadline for the building.
> >
> > (D) The hospital submitted a construction timeline at least two years prior to the applicable deadline for the building demonstrating the hospital's intent to meet the applicable deadline. The timeline shall include all of the following:
> >
> > > (i) The projected construction start date;
> > > (ii) The projected construction completion date; and
> > > (iii) Identification of the contractor.
> >
> > (E) The hospital is making reasonable progress toward meeting the timeline set forth in subparagraph (D), but factors beyond the hospital's control make it impossible for the hospital to meet the deadline.

The final deadline for hospital seismic safety is 2030, as specified below.

> …no later than January 1, 2030, owners of all acute-care inpatient hospitals shall either:
>
> (a) Demolish, replace, or change to non-acute-care use all hospital buildings not in substantial compliance with the regulations and standards developed by the office pursuant to the Alfred E. Alquist Hospital Facilities Seismic Safety Act and this act.
>
> (b) Seismically retrofit all acute-care inpatient hospital buildings so that they are in substantial compliance with the regulations and standards developed by the office pursuant to the Alfred E. Alquist Hospital Facilities Seismic Safety Act and this act.

To accomplish the above standard, all SPC-1 buildings must be completely replaced with new structures, even if they were seismically retrofitted to meet the 2008/2013 deadlines.

Endnotes

1. See *Estimating the Compliance Costs for California SB1953*, Charles Meade, Jonathan Kulick, and Richard Hillestad, 89 pages. Published by the California HealthCare Foundation, April 2002. Available at http://www.chcf.org/topics/hospitals/index.cfm?itemID=19753.

2. Reconstruction of the SPC-2 buildings for SB1953 compliance will drive a smaller but still significant level of hospital construction before 2030. Because this portion of the California hospital infrastructure is not well characterized, this study does not analyze the costs or requirements for these construction activities in detail.

3. *General Acute Care Hospital Earthquake Survivability Inventory for California*, Applied Technology Council, Report 23, 1991.

4. For this study, the authors analyzed a large amount of data compiled by the California Office of Statewide Health Planning and Development (OSHPD). All of these data are publicly available, either on the OSHPD Web site (http://www.oshpd.ca.gov) or by email requests.

5. Hospital addresses are provided because in some cases the closed facility has the same name as a currently operational hospital in the same community.

6. Data on open and closed hospital construction projects can be accessed at http://www.oshpd.ca.gov/oshpdKEY/ProjStatus.htm. For this study, the authors received a data file from OSHPD that was updated through December 2005.

7. *California Seismic Safety Commission, Findings and Recommendations on Hospital Seismic Safety*, November 2001, 9 pages.

8. The original regulations for the SPC classifications can be accessed at http://www.oshpd.ca.gov/FDD/SB1953/index.htm. For a description of the evaluation methodology, see *NEHRP Handbook for the Seismic Evaluation of Existing Buildings*, 1992, Federal Emergency Management Agency Report 178.

9. See *Documentation for the 2002 Update of the National Seismic Hazard Maps*, Arthur D. Frankel, Mark D. Petersen, Charles S. Mueller, Kathleen M. Haller, Russell L. Wheeler, E.V. Leyendecker, Robert L. Wesson, Stephen C. Harmsen, Chris H. Cramer, David M. Perkins, and Kenneth S. Rukstales, USGS Open File Report 02-420, 33 pages; *The Revised 2002 California Probabilistic Seismic Hazard Map, June 2003*, Tianqing Cao, William A. Bryant, Badie Rowshandel, David Branum, and Christopher J. Wills, California Geological Survey.

10. The board authorized the review on May 2, 2006.

11. HAZUS is open-source, publicly available software for modeling the losses from natural hazards such as earthquakes, hurricanes, and floods. It was developed with funding from the Federal Emergency Management Agency (FEMA), in collaboration with the National Institute for Building Sciences (NIBS). Details on HAZUS can be obtained from the FEMA (http://www.fema.gov/plan/prevent/hazus/index.shtm) and NIBS (http://nibs.org/hazusweb/) Web sites.

12. See “All shook up over seismic deadlines: Hospitals hope new plan based on local quake risk will ease the pressure,” Gilbert Chan, Sacramento Bee, May 23, 2006.

13. Because of confidentiality agreements that protect proprietary data, the authors are limited in the detail they can provide regarding the discussions and data received from stakeholders in the California hospital industry.

14. See *How Are Hospitals Financing the Future? Core Competencies in Capital Planning*, Healthcare Financial Management Association, 31 pages, 2004. Accessible at http://www.hfma.org/library/accounting/capitalfinance/FinancingtheFuture.htm.

15. *Construction Cost Escalation in California Healthcare Projects*, prepared for the California Health Care Association, Davis Langdon, 10 pages, January 2006.

16. See *California: 2002 Economic Census,* U.S. Census Bureau, 54 pages, August 2005.

17. Representative cost data provided to RAND by a California hospital construction contractor.

18. Representative cost data provided to RAND by a California office construction contractor.

19. Adjusted patient-days are defined as the sum of inpatient days and outpatient visits multiplied by the ratio of outpatient revenue per outpatient visit to inpatient revenue per inpatient-day for the year.

20. This value was assessed from the 2004 annual financial data reported to OSHPD.

21. Representative design data for an SPC-1 replacement facility provided to RAND by a California hospital corporation.

22. See *Facilities Recapitalization: Determining the Rate of Facilities Investment in the Private Healthcare Sector*, Wendy Weitzner, Mitretek Systems, 23 pages, July 2003; *The Cost of Staying Young*, Wendy M Weitzner and Thom Kurmel, Healthcare Financial Management; May 2004, 92-96.

23. See *Planning the Safety of Healthcare Structure,* Charles Meade, RAND WR-309, 9 pages, 2005.

24. See *Assessing Federal Research and Development for Hazard Loss Reduction*, Charles Meade and Megan Abbott, RAND MR-1734, 2003, 65 pages.

25. *Estimating the Compliance Costs for California SB1953,* Charles Meade, Jonathan Kulick, and Richard Hillestad, 89 pages. Published by the California HealthCare Foundation, April 2002.