Measuring Hospital Capacity: Assessing the Emergency Capacity of Bay Area Hospitals in Times of Disaster

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Abstract As centers for emergency care, hospitals must be well-prepared in order to provide proper care for individuals in times of disaster. This is especially important during large-scale disasters where emergency cases are so numerous as to overwhelm a region's capability to handle emergencies. This study examines whether or not hospitals possess the capacity to provide care for such an influx of patients. Also, this study examines the distribution of hospitals in the study area to determine if hospitals adequately serve their communities. A simulation model looks at the capacity of hospitals in Alameda and San Francisco Counties in relation to the different populations that each hospital serves. This model also examines the relationship of age and socioeconomic factors with hospital capacity. Results show that hospitals have the capacity to provide care for critical levels of injury in times of emergency. Furthermore, age and socioeconomic factors have only a minor correlation with hospital capacity distribution.

Introduction

Disasters, both natural and unnatural, can strike without notice in all parts of the world. California is at risk for a number of natural disasters such as landslides, earthquakes, wildfires and flooding (Office of Emergency Preparedness 2006). In the past twenty years, several natural disasters have struck California. The Loma Prieta earthquake of 1989 struck the San Francisco Bay Area causing 63 deaths, leaving more than 3,700 injured, and causing almost $6 billion dollars in property damage. The 7.1-magnitude earthquake was the largest earthquake to strike along on the San Andreas Fault since the 1906 earthquake (Stover 1993). A 6.9-magnitude earthquake centered in Northridge in the San Fernando Valley struck in 1994 causing 57 deaths and $20-40 billion in property damages (Wald 2000). Severe storms have struck throughout California with flooding and landslides causing hundreds of millions of dollars in damage. The most recent event occurred in April of 2005 when floods struck the area between Kern and San Diego Counties causing tens of millions of dollars in damage (FEMA 2006).

Wildfires are prevalent in California and history has shown they can be as destructive, or even more so, as other disasters. In 1991, the Oakland/Berkeley Hills fire killed 25 people, injured 150 others, burned over 1,600 acres, destroyed several thousand homes, and caused nearly $1.5 billion in damage (Oakland/Berkeley Hills Fire 2005). In 2003, ten major fires struck Southern California causing 22 deaths, burning over 800,000 acres, destroying over 3,000 homes, and causing an estimated $12 billion in damage (FEMA 2006).

Although the threat of natural disasters is considerable in California, the threat of unnatural disasters is also significant. The events of 9/11 have heightened the perception of the threat of terrorism in the U.S. Following identification of several potential terrorist targets in the SF Bay Area, there have been recent efforts to increase the safety in these areas through increasing the security on bridges, ports, public-transit systems and other public areas highlighting their potential for attacks (SF Chronicle Editorial 2006). Also, the threat of disease outbreaks is a cause for major concern. The recent threat of avian influenza, which has been lethal in several cases, has caused panic throughout the world (Bradsher 2006). Efforts have taken place to prevent an outbreak from occurring in the United States as pharmaceutical companies are rushing to produce vaccines and anti-viral drugs and hospitals and other health organizations are preparing plans to administer care for the potentially large number of patients (Russell 2006).

Preparation for disasters such as earthquakes and disease outbreaks has become a priority, as most organizations possess some sort of emergency plan in case of disaster. Organizations can minimize the impact of disasters through preparation. The Federal Emergency Management Agency, or FEMA, has made it mandatory for organizations and local governments to develop an emergency disaster plan in order to receive federal grant money. Furthermore, programs such as the National Bioterrorism Hospital Preparedness Program have been established to fund preparedness (HRSA 2006). Likewise, hospitals and other health facilities will typically have emergency disaster plans.

One of the most important elements of hospital disaster preparedness is capacity. Hospital capacity is the maximum number of patients that a hospital can provide health services. My research assesses hospital capacity in terms of nursing staff size and numbers of beds available for treating patients. These figures are then compared to the populations that each hospital serves. Through this comparison, I hope to answer questions concerning the general preparedness of hospitals and the distribution of hospitals in my study area. The objective of this project is to determine whether hospitals are equipped to care for a large increase in emergency cases during a major disaster. By simulating different levels of injury rates, I will determine whether or not care can be administered by the hospitals with regards to their respective hospital capacities.

Methods

To determine the emergency preparedness of hospitals, I have looked at several of the hospitals in the Bay Area. My study sites are Alameda and San Francisco Counties, which have 25 hospitals/trauma centers in total. San Francisco is an area composed of urban areas, whereas, Alameda County is composed of both urban and rural areas (U.S. Census 2000). Urban areas are defined as areas with population densities above 1000 people per square mile (U.S. Census 2000 Urban and Rural Classification). Densely populated areas have more emergency needs during disaster. There are 10 San Francisco County hospitals in this study:

(1) Laguna Honda Hospital and Rehabilitation Center

(2) St. Luke's Hospital

(3) St. Francis Memorial Hospital

(4) Chinese Hospital

(5) UCSF Medical Center

(6) California Pacific Medical Center

(7) Kaiser Foundation Hospital (San Francisco)

(8) San Francisco General Hospital Medical Center

(9) Veterans Affairs Medical Center

(10) St. Mary's Medical Center

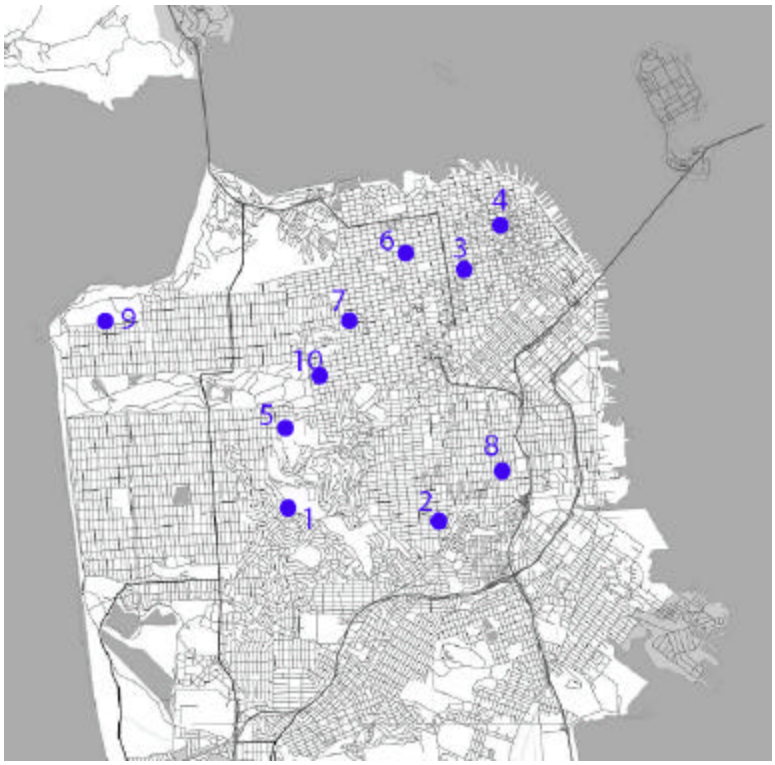

Figure 1: San Francisco County with hospitals (see above)

And 15 Alameda County hospitals:

(11) Alta Bates Medical Center (Berkeley)

(12) Kaiser Foundation Hospital (Oakland)

(13) Children's Hospital and Research Center (Oakland)

(14) Alameda County Medical Center (Oakland)

(15) Alta Bates Medical Center – Summit Campus (Oakland)

(16) Alameda Hospital (Alameda)

(17) Eden Medical Center (Castro Valley)

(18) Kindred Hospital – San Francisco Bay Area (San Leandro)

(19) San Leandro Hospital (San Leandro)

(20) Alameda County Medical Center – Fairmont Campus (San Leandro)

(21) St. Rose Hospital (Hayward)

(22) Kaiser Foundation Hospital (Hayward)

(23) Washington Hospital Healthcare System (Fremont)

(24) Fremont Hospital (Fremont)

(25) ValleyCare Medical Center (Pleasanton)

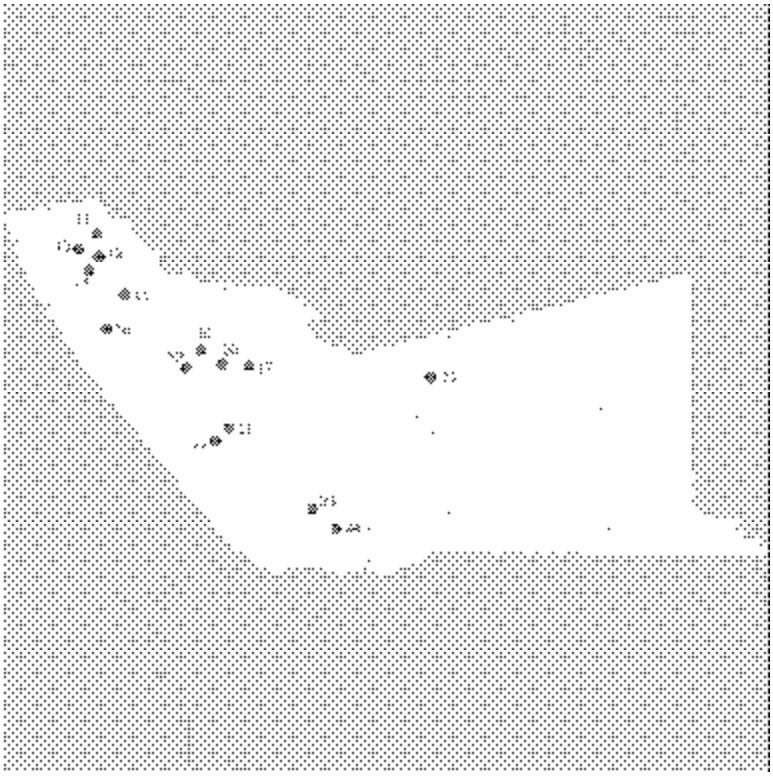

Figure 2: Map of Alameda County with hospitals (see above)

For each hospital, I have collected information on the nursing staff size and the number of beds. I have compared this value to the populations surrounding the hospital. Using data maps from the 2000 US Census, I have assigned certain census tracts to each hospital. Each census tract was assigned to the closest hospital, based in part on the hospital's baseline capacity (original size of hospital). That is, a census tract that in North Oakland may be closer to Kaiser Hospital in Oakland, but it is assigned to Alta Bates Summit Campus in Oakland because the latter has a capacity better suited to handle this census tract. (See Appendix A for all census tracts)

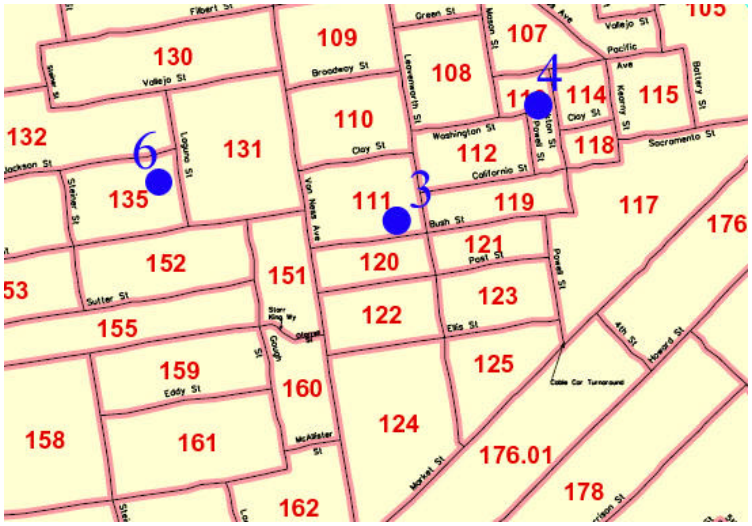

Figure 3: Sample Census tract of San Francisco with hospitals (U.S. Census)

The Census Bureau provides a variety of information about the population in each census tract. This study uses the following information from each census tract: total population, total minority population, total population of people age 14 and under, total population of those age 65 and over, and total population of people considered living below the poverty line. My project utilizes poverty guidelines established by the U.S. Census Bureau, which looks at income and household size among other factors (Poverty 2005). Aside from looking at the total populations of each census tract, this study looks at whether minority population in a given area affects hospital capacity distribution. According to *Beach et al*, the U.S. healthcare system does not provide minority populations the same level of care that it does for white populations (Beach et al, 2004). Also, youth and senior populations tend to have high injury rates in time of disaster. Emergency care for youths and seniors takes up more hospital resources because they are more susceptible to sickness or injury caused by various agents and they can quickly deteriorate if not monitored carefully (Krug 2006). Lastly, density of populations living in poverty will be studied as a possible cause of different hospital capacity distribution.

Statistical data for each census tract are summed together to obtain total populations served by each hospital. These populations are then used to determine the maximum capacity that each hospital can serve, otherwise known as its Surge Capacity. The Surge Capacity of each hospital for my model is determined by the number of beds in each hospital (1 bed: 1 patient) as well as the number of nurses staffed in each hospital (1 nurse: 5 patients). The 1:5 nurse-to-patient ratio

is the number mandated by the California Department of Health Services (Klutz 2005). I used the following equations to determine surge capacity:

Surge Capacity (Beds) = (Total beds in Hospital)/(Total Population Served by Hospital)

Surge Capacity (Nurses) = 5*(Total nurses in Hospital)/(Total Population Served by Hospital)

Next, these surge capacities are compared to the youth and senior populations, populations of those living under the poverty line, and minority populations that each hospital serves.

According to the Red Cross, the threshold injury rate of 0.05% is considered serious and a 0.1% injury rate is considered to be critical (Burkle 2002). In this study a 0.1% surge capacity is considered the threshold level needed to manage a "critical event" such as a severe earthquake with widespread injury and destruction or a disease outbreak affecting large sums of people for example. The surge capacity data will determine if the hospitals in this study can provide care for the influx of emergency cases and also will determine whether the hospital distribution serves all ages and socio-economic groups effectively. For the purposes of this study, a hospital population with a youth (13 and under) population of over 20% is used in comparison to surge capacity. Hospital areas with senior (65 and over) population of over 13% are compared to surge capacity. Hospital populations with minority population of over 50% are compared to its respective surge capacities. Lastly, areas with poverty rate of over 12% are compared to surge capacities.

Results

The following results show that all the hospitals in San Francisco and Alameda Counties were able to meet the critical injury rate threshold of 0.1% surge capacity looking both at the number of beds:

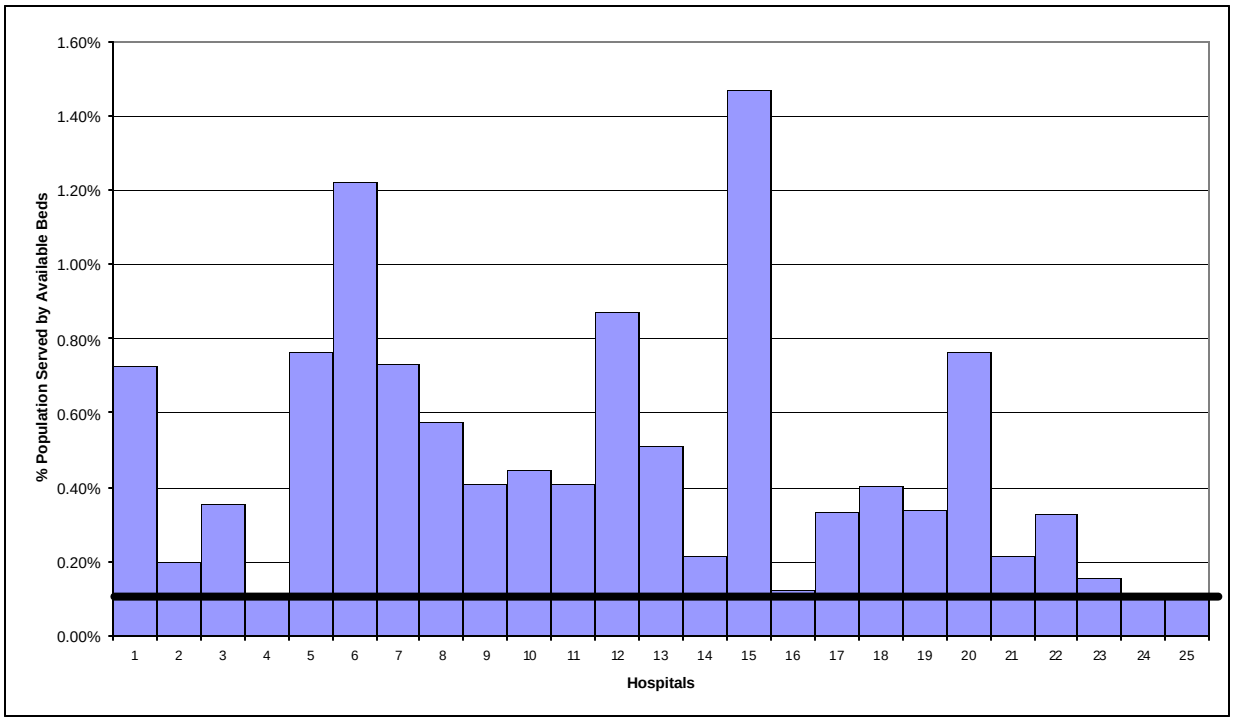

Figure 4: Surge Capacity of hospitals (Based on Available Beds). See methods section for listing of hospitals. Bold line represents 0.1% Surge Capacity threshold.

and the number of nurses of each hospital.

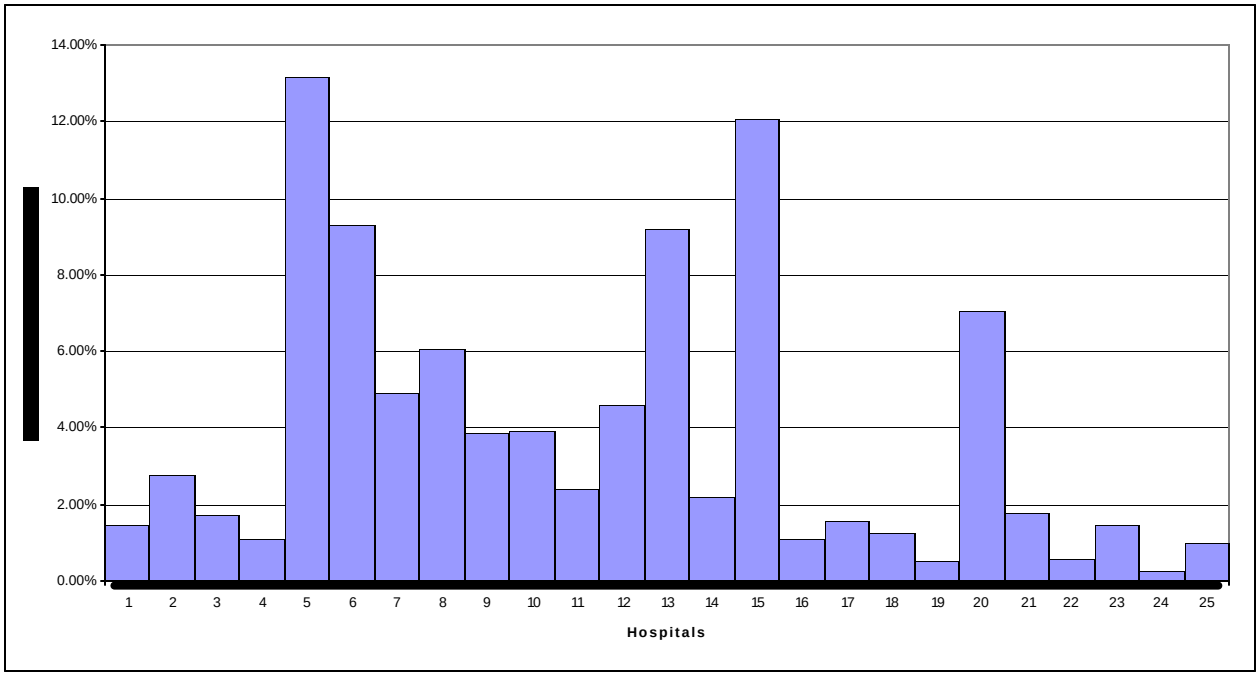

Figure 5: Surge Capacity of hospitals (Based on Available Nurses); See Methods section for listing of hospitals. Bold line represents 0.1% surge capacity threshold.

From the graphs above, all hospitals have surge capacities well above the critical rate of 0.1% with the exception of ValleyCare Medical Center in Figure 4, which has a surge capacity of exactly 0.1% and Fremont Hospital in Figure 5, which has a surge capacity of 0.28%.

In the following two graphs, the top eight hospital areas with the highest youth populations are shown along with their respective hospital surge capacities:

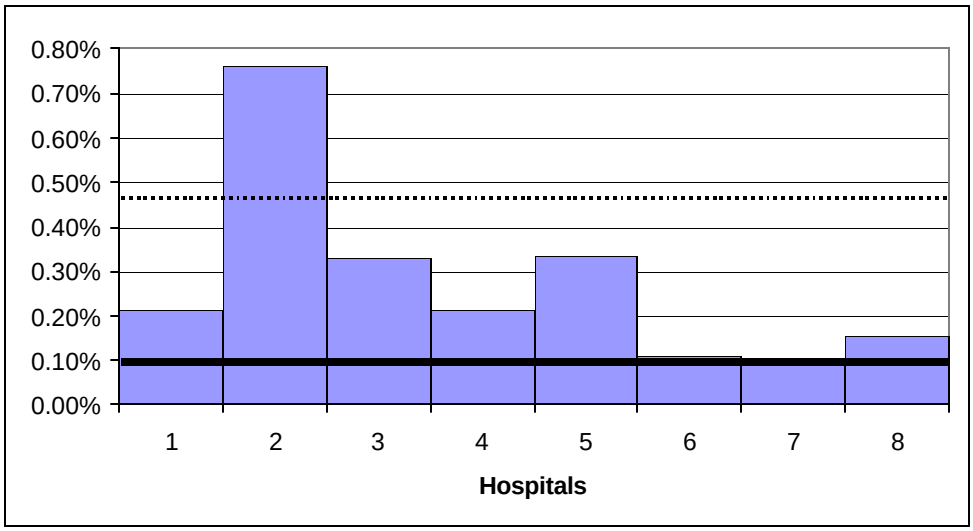

Figure 6: Surge capacities of hospitals with **youth populations** above 20% (Based on beds available); Bold line represents the 0.1% threshold. The dotted line represents the total average of 0.47% available beds surge capacity for hospitals in study

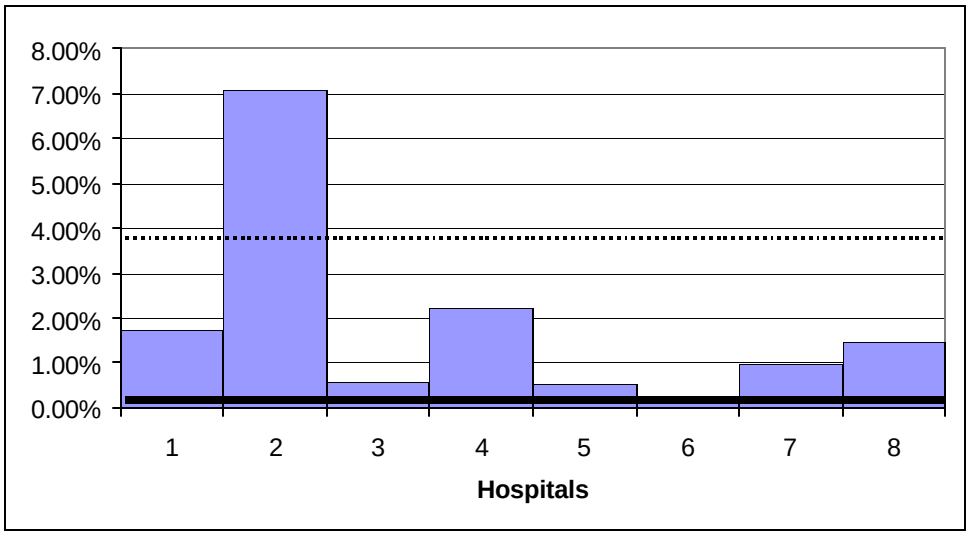

Figure 7: Surge capacities of hospitals with **youth populations** above 20% (Based on nurses available). Bold line represents the 0.1% threshold. Dotted line represents total average of 3.81% nurse surge capacity for hospitals in study.

Table 1: Listing of hospitals for Figures 6 & 7 with **youth population** percentage.

1	St Rose Hospital (Hayward)	24.56%
2	Alameda County Medical Center-Fairmont Campus (San Leandro)	23.75%
3	Kaiser Foundation Hospital (Oakland)	23.33%
4	Alameda County Medical Center (Oakland)	23.08%
5	San Leandro Hospital (San Leandro)	22.86%
6	Fremont Hospital (Fremont)	22.85%
7	ValleyCare Medical Center (Pleasanton)	22.79%
8	Washington Township Health Care Dist (Fremont)	21.71%

The following two graphs show the ten hospitals with senior (age 65 and older) populations of 13% or more with their respective surge capacities.

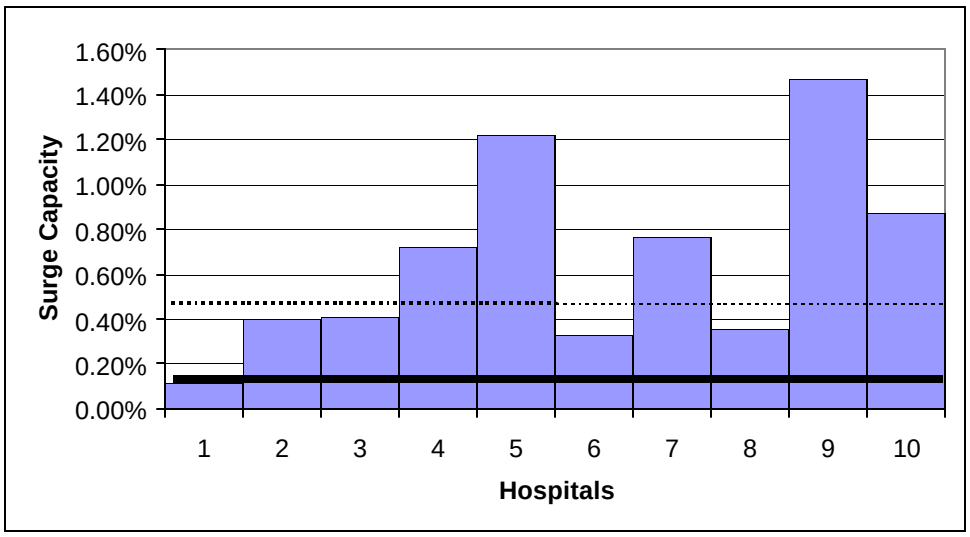

Figure 8: Surge capacities of hospitals with **Age 65+ populations** above 13% (Based on beds available); Bold line represents the 0.1% threshold. The dotted line represents the total average of 0.47% available beds surge capacity for hospitals in study

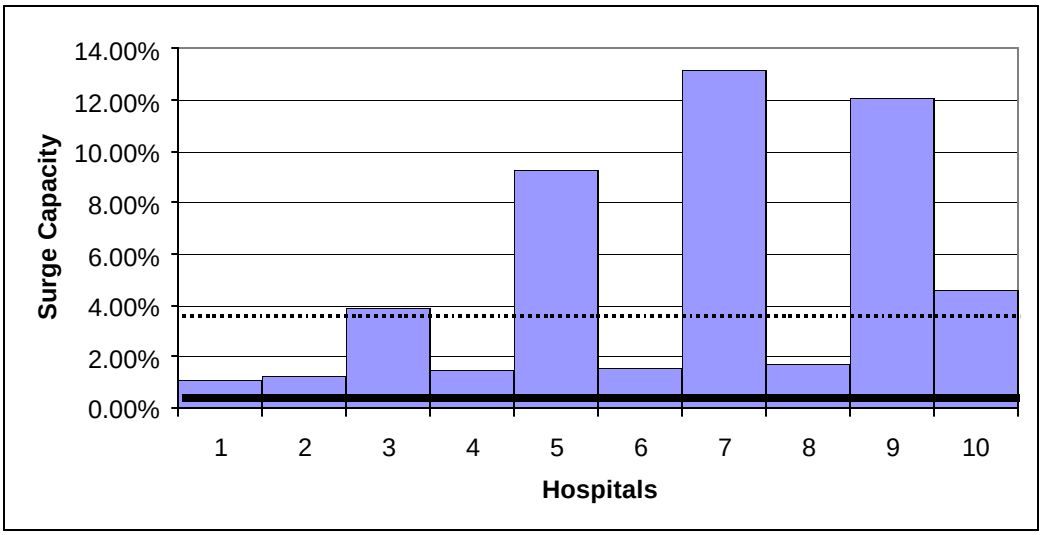

Figure 9: Surge capacities of hospitals with **Age 65+ populations** above 13% (Based on nurses available); Bold line represents the 0.1% threshold. Dotted line represents total average of 3.81% nurse surge capacity for hospitals in study.

Table 2: Listing of hospitals for Figures 8 & 9 with **senior populations** over 13%.

1	Chinese Hospital (San Francisco)	20.72%
2	Kindred Hospital (San Leandro)	16.33%
3	Veterans Affairs Medical Center (San Francisco)	15.94%
4	Laguna Honda Hospital and Rehabilitation Center (San Francisco)	15.68%
5	California Pacific Medical Center (San Francisco)	15.66%
6	Eden Medical Center (Castro Valley)	14.44%
7	UCSF Medical Center (San Francisco)	13.90%
8	Saint Francis Memorial Hospital (San Francisco)	13.90%

9	Alta Bates Summit Medical Center - Summit Campus (Oakland)	13.36%
10	Kaiser Foundation Hospital (Hayward)	13.34%

The following two graphs show the 14 hospitals that have minority populations above 50% with their respective surge capacities.

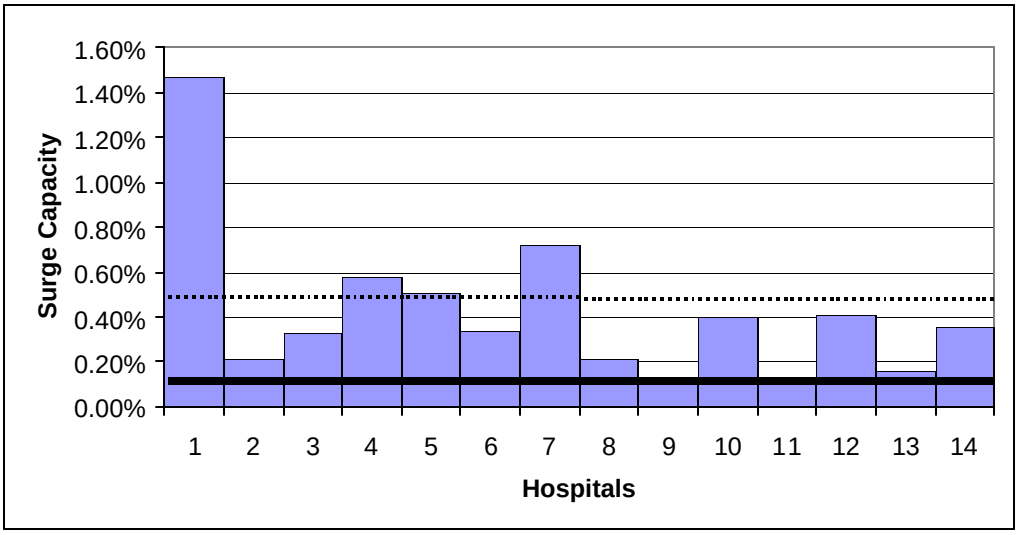

Figure 10: Surge capacities of hospitals with total **minority** (non-Caucasian) populations above 50% (Based on beds available); Bold line represents the 0.1% threshold. The dotted line represents the total average of 0.47% available beds surge capacity for hospitals in study.

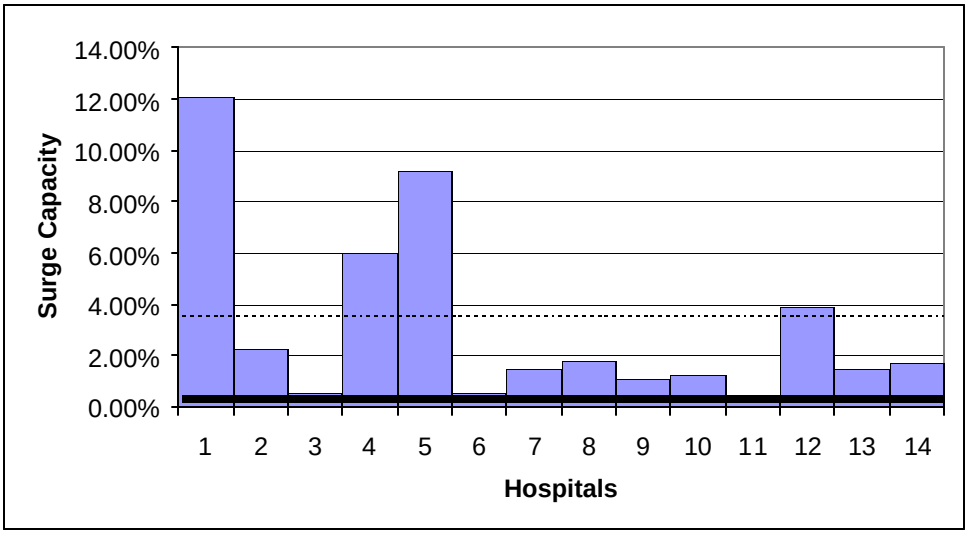

Figure 11: Surge capacities of hospitals with total **minority** (non-Caucasian) populations above 50% (Based on nurses available); Bold line represents the 0.1% threshold. Dotted line represents total average of 3.81% nurse surge capacity for hospitals in study.

Table 3: Listing of hospitals for Figures 10 & 11 with **minority** populations over 50%.

1	Alta Bates Summit Med Center - Summit Campus (Oakland)	76.43%
2	Alameda County Medical Center (Oakland)	71.39%
3	Kaiser Foundation Hospital (Oakland)	67.58%
4	San Francisco General Hospital (San Francisco)	64.53%
5	Children's Hospital and Research Center (Oakland)	64.27%
6	San Leandro Hospital (San Leandro)	61.62%
7	Laguna Honda Hospital & Rehabiliation Center (San Francisco	58.13%
8	St Rose Hospital (Hayward)	57.96%
9	Chinese Hospital (San Francisco)	57.38%
10	Kindred Hosp (San Leandro)	55.08%
11	Fremont Hospital (Fremont)	53.76%
12	Veterans Affairs Medical Center (San Francisco)	52.17%
13	Washington Township Health Care District (Fremont)	51.34%
14	Saint Francis Memorial Hospital (San Francisco)	50.93%

The last two graphs show the hospitals that serve populations with poverty rate of at least 12%, with the corresponding surge capacities.

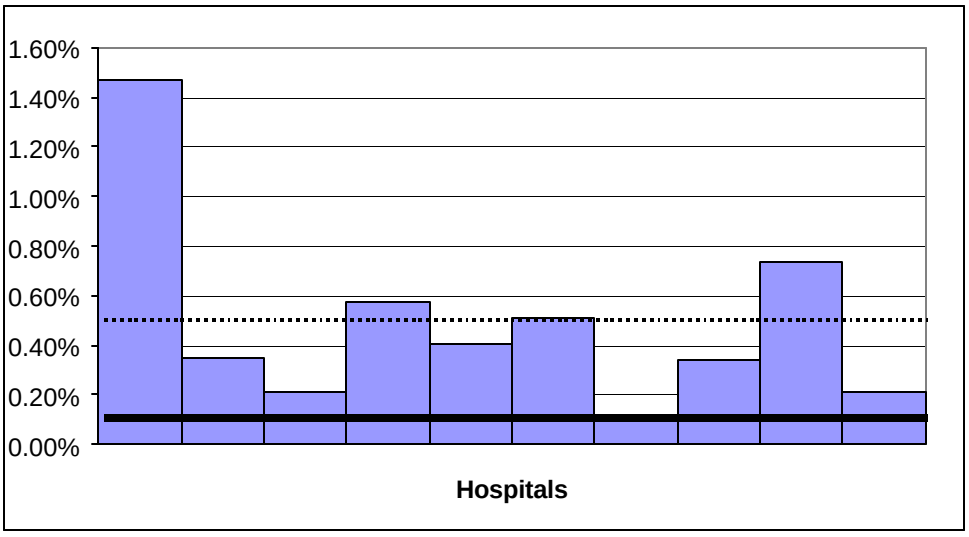

Figure 12: Surge capacities of hospitals with **poverty rate** of area served above 12% (Based on beds available); Bold line represents the 0.1% threshold. The dotted line represents the total average of 0.47% available beds surge capacity for hospitals in study.

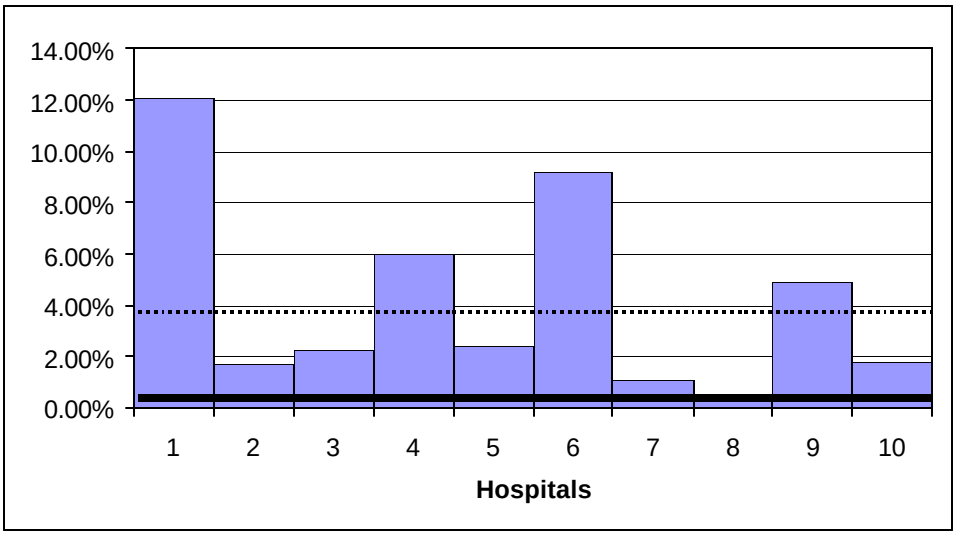

Figure 13: Surge capacities of hospitals with **poverty rate** of area served above 12% (Based on nurses available); Bold line represents the 0.1% threshold. Dotted line represents total average of 3.81% nurse surge capacity for hospitals in study.

Table 4: Listing of hospitals for Figures 12 & 13 with **poverty rates** over 12%.

1	Alta Bates Summit Med Center - Summit Campus (Oakland)	27.74%
2	Saint Francis Memorial Hospital (San Francisco)	20.99%
3	Alameda County Medical Center (Oakland)	19.03%
4	San Francisco General Hospital (San Francisco)	18.44%
5	Alta Bates Medical Center (Berkeley)	17.84%
6	Children's Hospital & Research Center (Oakland)	15.39%
7	Chinese Hospital (San Francisco)	14.78%
8	San Leandro Hospital (San Leandro)	12.80%
9	Kaiser Foundation Hospital (Hayward)	12.68%
10	St Rose Hospital (Hayward)	12.14%

Discussion

The results assure that at a critical level of a large-scale emergency, hospitals are able to care for those injured in the surrounding area. However, there are great discrepancies between the surge capacities of certain hospitals. Hospitals such as Alta Bates Summit Campus Medical Center in Oakland and California Pacific Medical Center in San Francisco had the largest bed surge capacities while hospitals such as ValleyCare Medical Center, Fremont Hospital, and Alameda Hospital have bed surge capacities near the Red Cross critical injury rate of 0.1% (Burkle 51, 2002). Surge capacities based on nursing staff available showed similar results. UCSF Medical Center and Alta Bates Summit Campus had the highest surge capacities while Fremont Hospital, Kaiser Foundation Hospital in Hayward, and San Leandro Hospital had the

lowest surge capacities. This is a good sign for hospitals that coordinate with one another – hospitals with smaller surge capacities can readily send patients to other nearby hospitals if they are no longer able to take in patients.

There was a correlation between hospital surge capacities and youth populations. The surge capacities of each of the hospitals with high youth populations are mostly below the total average (mean) surge capacity of 0.47% for available beds and 3.81% for available nurses. These hospital areas are underserved in relation to the other hospitals in the region, but they are still adequate if a large-scale disaster were to strike the area because all the hospitals have surge capacities over the 0.1% threshold. The other factors (older age population, minority population, poverty population) of the hospital populations, however, showed no definite correlation with the corresponding surge capacities.

Nevertheless, there are a number of factors of emergency care that were not taken into account in this simplified model. The ability of a hospital to expand its capacity was not taken into account. The true, more broad definition of Surge Capacity is a hospital's "ability to expand quickly beyond normal services to meet an increased demand" in light of a large-scale health emergency (Agency for Health Research and Quality 2004). Most hospitals are able to expand their emergency capcity in a number of ways. Increasing the staff size is another technique used in increasing capacity. Volunteer and non-active nurses are trained and on-call in case of emergency (Agency for Health Research and Quality 2004). Another way is to set up patient areas in lobbies, meeting areas, or other areas with enough space for patients to lie. Yet another technique is to set up tented care units in parking lots surrounding hospitals (Voelker 1499, 2006). However, this technique depends on weather conditions and is not commonly used by the hospitals that I interviewed in this study.

Nevertheless, the model did not account for the possibility of hospital infrastructure to be damaged by natural disaster, terrorist act, etc. There is a significant chance that some or all of these hospitals will be damaged in some way during a disaster whether it is with the hospital equipment being damaged or the buildings themselves being damaged. Some hospitals are well over 50 years old, such as Alameda County Medical Center, and could experience structural damage during an earthquake. Also, hospitals that are currently receiving structural retrofits like San Francisco General Hospital may not be completed before a disaster may occur.

Structural damage is not limited to hospitals themselves, but could happen in areas surrounding hospitals. This would limit the ability for ambulances and other emergency vehicles to transport patients to certain hospitals. This, however, would be difficult to model because of the numerous scenarios that could occur. Also, the strain produced by traffic after a disaster event would certainly affect where emergency vehicles would be able to travel.

One important aspect of the population that needs to be considered is the difference of nighttime and daytime populations. The populations provided by the 2000 Census only account for the nighttime household populations in each census tract. In a daytime population, you can expect to see higher populations in downtown areas of Oakland (Alameda County) and San Francisco and lower populations in suburban or rural areas. The surge capacities of the hospitals in these downtown areas would then decrease.

In the most devastating of disasters when most or all of the above has occurred, hospitals may be unable to care for the overwhelming number of patients. In this scenario, health organizations can turn to temporary Surge Hospitals These Surge Hospitals are temporary health facilities that are setup in places such as retail stores, sporting arenas, and even veterinary hospitals. (Joint Commission on Accreditation on Healthcare Organizations 2006) Facilities can even be mobile facilities which can be setup conveniently adjacent to affected areas (Voelker 2006) These are ideal when permanent health facilities have been damaged. In the case of Hurricane Katrina, the local hospitals in New Orleans were almost completely devastated and people were reliant upon the surge hospitals for emergency care (Romano 2005).

The simplified model for this project shows that the current hospital capacity in place for the hospitals in San Francisco and Alameda Counties are sufficient for providing care for large-scale emergencies. These estimated hospital capacities also are not correlated with socio-economic backgrounds or senior populations. However, there is great uncertainty with the hospitals themselves in whether they will be able to provide emergency care. Perhaps the Red Cross estimate of 0.1% critical Surge Capacity underestimates the true impact of a large-scale disaster. Nevertheless, there are various techniques that can be employed in order to maximize surge capacity to provide necessary emergency care.

Acknowledgments

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