

OVERCOMING PUBLIC AND POLITICAL CHALLENGES  
FOR NATURAL HAZARD RISK INVESTMENT DECISIONS

by

HOLLY BONSTROM

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written by Holly Bonstrom  
has been approved for the Department of Civil and Environmental Engineering

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Professor Ross Corotis, Ph.D., P.E.

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Professor Keith Porter, Ph.D., P.E.

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Professor Abbie Liel, Ph.D., P.E.

Date\_\_\_\_\_

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Bonstrom, Holly (M.S. Civil and Environmental Engineering)

Overcoming Public and Political Challenges for Natural Hazard Risk Investment Decisions

Thesis directed by Professor Ross Corotis and Associate Research Professor Keith Porter

The cost of natural disasters continues to rise around the world, in part due to the direct and indirect effects of population growth, urbanization, and the pressures they place on land use. To reduce the vulnerability of infrastructure, especially existing infrastructure, will require that engineers bring more than technical capabilities to bear. Engineers also need to know *which* measures of risk are most meaningful or relevant to decision makers, and then be able to communicate those risks, and the costs and benefits of mitigation, in concise, credible, meaningful terms. A major challenge in developing a plan to retrofit under-designed structures is demonstrating a need to the public and their political leaders, who may have difficulty extrapolating un-experienced low-probability, high-consequence events. Many issues must be addressed which all play a role in the tension between short-term rewards to decisions and long-term sustainable actions. Review of current knowledge along with a reassessment offering new understanding and communication tools will be presented focusing on the issues of: (1) public risk perception, (2) public participation in hazard mitigation planning, (3) incorporation of community values, (4) incompatibility of political motivation and long-term planning, and (5) finances of risk and return. A case study reviewing the work done by the San Francisco Community Action Plan for Seismic Safety (CAPSS) team will be presented as an example that effectively implements methods presented in this thesis.

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# Chapter 1

## Introduction

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### *1.1 Background*

Humanity is becoming more vulnerable to natural disasters, largely as a consequence of population growth and urbanization. According to the EM-DAT International Disaster Database (2005), the number of weather-related disasters has increased over nine-fold and geological disasters such as earthquakes have quadrupled since the 1950's. In 2005, the United States ranked third among countries most often hit by natural disasters, and it led the world in the cost of these events (EM-DAT, 2005). One of the primary factors contributing to the rise in US disaster losses is the steady increase in the population of high-hazard areas, such as the US hurricane-prone Gulf and Atlantic coasts, and the earthquake-prone west coast. For example, between 1980 and 2009, the US population increased by 35%, but the populations of California and Florida increased by 56% and 90%, respectively (US Census Bureau).

Within these areas, the largest population growth has been in developed urban regions, where construction has increased already high densities and led to building on more vulnerable lands. While the US population has been growing by an average of 12% each decade since 1950, 89% of the population growth has been in urban areas (Olshansky, 1999). Unfortunately, rapid urban growth can outpace prudent planning and the realistic assessment and management of hazards. This can be attributed to a fundamental principle illuminated by Kathleen Tierney, Director of the Natural Hazards Research and Applications Information Center at the University of Colorado, who explains “Human settlements are based on the principles of short-term growth and profits for privileged segments of the population instead of safety and sustainability for the society as a whole” (quoted in Corotis, 2010).



Addressing this incompatibility between short-term growth and long-term sustainability may facilitate the implementation of essential hazard mitigation actions in current and future planning. Adding to this conflict is the difficulty in demonstrating a need to the public and public decision makers for reducing hazard risk. Since the occurrence of most high-consequence hazards is characterized by uncertainty and low probability, many people have difficulty understanding the need to take action. Furthermore, this gap between long-term, low probability natural hazards and short-term decision making is exacerbated by the political rationale of getting re-elected. As a result of recognition from his or her constituents, the motivation behind political actions is often driven by low risk decisions that offer immediate, recognizable benefits to society. Often, actions that offer immediate benefits may not align with optimal long-term policies for a community (Tversky and Bar-Hillel 1983).

To reverse the vulnerability of infrastructure, changes must be made in hazard mitigation and land use planning that overcomes these fundamental incompatibilities. The consequences of previous natural disasters have shown that it is important to focus on anticipated needs and preparedness for future hazards instead of responding to yesterday's events. In the future, natural hazards may no longer be viewed as uncertain events that society responds to after the disaster hits, but rather, must be incorporated into a community's future long-term planning as if they will occur.

## *1.2 Scope of Thesis*

Many of the tools necessary to mitigate natural hazard risk are known, but their implementation is met with political and public challenges. These challenges include but are not limited to psychological biases in natural hazard risk perception, difficulties with public participation mechanisms, the frequent disconnect between political rationale and long-term

sustainability, as well as difficulties in using financial based methods to quantify risk and risk mitigation actions. To overcome these challenges, it has become essential for engineers to increase their accountability for the security of society, and to integrate engineering solutions within the social challenges of the risk decision making process. New understanding and communication tools that will be presented in this thesis focus on the issues of: (1) public risk perception, (2) public participation in hazard mitigation planning, (3) incorporation of community values, (4) incompatibility of political motivation and long-term planning, and (5) finances of risk and return. It is hoped that developing effective risk communication strategies based on an understanding of the framework of these issues will promote optimal long-term sustainable policy with recognizable benefits to society.

Chapter 2 of this thesis will present the current state of the knowledge with respect to the above mentioned five important issues in communicating and implementing retrofit. Chapter 3 will present analysis, suggested approaches and model case studies that are hoped to add additional insight to the literature review presented. In Chapter 4, a case study will be presented on a project developed for the City of San Francisco called the Community Action Plan for Seismic Safety and analyzed on the framework of the five previously mentioned issues. Finally, Chapter 5 presents conclusions, limitations, and recommendations for future research.

## Chapter 2

### Literature Review

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#### *2.1 Public Risk Perception*

While California cities have recently incorporated seismic safety into development plans, there has been limited success in convincing communities to integrate natural hazards issues into their planning for future growth (Burby, 1998). Reluctance to plan ahead can be attributed at least in part to the lack of effective risk communication on natural hazard risk. If engineering professionals are to be effective in communicating risk, they will need to understand the basis by which the public at large and elected officials in particular, make decisions with respect to risk management (Corotis, 2003). Effectively educating the public must address the inherent conflict between short-term needs and optimizing long-term sustainability. This conflict is related to the inability for individuals and society as a whole to fully understand the risk of low-probability, high-consequence events of which many have not personally experienced (Kahneman and Tversky, 2000). There are specific psychological barriers and biases related to this issue that may cause both decision makers and the public to ignore or underestimate the likelihood and potential consequences associated with a natural disaster. In the domain of earthquake risks, participants often underestimate the risks with which they are faced (Viscusi & Zeckhauser, 2006). Underestimating and ignoring the risk creates issues in not only public safety, but also in allocating optimal financial support towards public safety measures. Therefore, raising risk awareness and support for mitigation is a goal in risk communication (Keller et al., 2006).

According to Keller et al. (2006), a first step in risk communication is to gain people's attention on natural hazard risk by increasing their risk perception, or in other words, increasing the perceived likelihood that an individual will experience the effect of a danger. Some of the

decisions made by the public are due to a lack of understanding and often underestimation of the true probabilities of occurrence (Kahneman and Tversky, 2000). Current research proposes that the affect heuristic, where subjective impressions or emotions influence perceived judgments, can be used as a framework for risk perception (Slovic et al. 2004). In the affect heuristic, two modes of thinking are distinguished, the experiential system and the analytical system (Slovic et al., 2004). The analytical system is based on probabilities, logical reasoning, and evidence. The experiential system relies on images, metaphors and narratives. It is thought that people use the affect and feelings related to a hazard as a cue for estimating the probability of a hazard (Keller et al., 2006). Slovic et al. (2004) suggest that strong emotional experiences with hazards (the affect) may be important for increasing the perception of risks.

Kahneman and Tversky (2000) propose the availability heuristic as an explanation for the biases associated with probability judgments. According to the availability heuristic, people use the ease with which examples of a hazard can be brought to mind as a measure of estimating the probability of a hazard (Keller et al., 2006). However, Slovic (2004) suggests that the ease of imaginability associated with an event may be influenced by the affect and feelings related to those images. Therefore, it is possible that both the affect and availability heuristic are closely related when influencing perceived risk.

Past experience is an important factor in people's perception of natural hazard risk (Keller et al., 2006). More specifically, Jackson (1981) concluded that past experience with earthquakes influenced the adoption of seismic hazard policies. Kunreuther (2010) explains that this delayed perception of risk has become a general problem in disaster mitigation, since "Decision makers often regard catastrophic events as below their threshold of concern until they occur." Therefore, the affect and impressions that arise from experiencing a natural hazard play

a large role in increased risk perception of an event. The availability of these emotions when confronted with a similar event, provide a bias when making judgments. For example, the affect and availability heuristic can be related to the purchasing of flood insurance. Many property owners decide to buy flood insurance only after their houses are under water (Kunreuther and Michel-Kerjen, 2010). As a result of the emotions and affect from the flood, homeowners who experienced the flood perceived a higher flood risk than homeowners who did not. However, the affect from past experiences may fade as time passes, which also implies the availability of these emotions decrease (Kunreuther and Michel-Kerjan, 2010). Kunreuther and Michel-Kerjan (2010) suggest that there is a tendency to reduce the impact of past, unpleasant experiences over time. Emotions run high when one experiences a natural disaster, but as time passes the initial affect may fade and it may be difficult to recall such concerns for the catastrophe. This explains why years after a flood, many people end up canceling their flood insurance if they have not experienced any further flood damage (Kunreuther and Michel-Kerjan, 2010). While the probability that the flood will occur may be the same when homeowners buy the insurance as it is years later when they cancel, the high emotions associated with a current catastrophic event increase the mental availability and hence the assessed risk of the flood event.

In communicating risk effectively, another challenge arises due to the fact that the public has difficulty thinking in probabilistic terms (Patt and Schrag, 2003). According to Kahneman and Tversky (2000), small probabilities (which are frequently associated with natural hazard events) are often underestimated. For events with probabilities of occurrence of less than a few percent, many people classify them as equally unlikely, and often even consider that they have no chance of occurring (Kahneman and Tversky, 2000). This issue is increasingly noticeable in the political arena, where a politician's career may be measured over a period of just a few years.

Since the event's small probability is viewed as almost impossible, measures taken to prevent it may go unrewarded.

There have been various proposed approaches for communicating low-probability risks to maximize risk perception. Most methods rely on the biases of imaginability and past experiences associated with the affect and availability heuristics. Past research by Keller and colleagues (2006) has shown that when problems are formulated in terms of frequencies rather than probabilities, the perceived threat of the risk is increased. In a study by Slovic et al. (2000), clinicians who received risk information about a person's violence in a frequency format judged the patient to be more dangerous than did the clinicians who received the identical information in a probability format. In the arena of natural hazards, frequency formats can be used to quantify risk. For example, if there is a 1% probability of a flood each year, this may also be expressed as "on average, there is one flood every 100 years." While this may open the door to some confusion (i.e., some may think *only* one flood can occur every 100 years), Keller et al. (2006) believe the frequency format may evoke frightening or emotional images which probabilities are unable to stimulate.

The time periods for which a risk is given also have an influence on how a particular risk is perceived (Keller et al., 2006). For example, Keller et al. (2006) showed that presenting the risk of flooding over a time period of 80 years increased the homeowners' perceived risk, as opposed to presenting the corresponding probability of risk over a time period of one year. This result of time period manipulation also falls within the influence of the affect and availability heuristic. Small probabilities of natural hazards associated with shorter time periods may not induce large emotions or negative images while higher probabilities over longer time periods may evoke a more vivid, fearful response.

On the other hand, eliminating the probability and frequency of an event altogether when communicating risk may increase risk perception (Taleb, 2010). According to Taleb (2010), instead of forcing the understanding of the probabilities associated with a rare event which may be beyond people's mental capacity, it is advantageous to focus on the payoff and benefits of an event if it were to take place. According to Taleb, "We can have a clear idea of the consequences of an event, even if we do not know how likely it is to occur." For example, individuals may not know the exact probability that an earthquake will occur in San Diego, but they do know that it could cause extensive damage if it did occur. Taleb (2010) proposes that focusing on the consequences of an event to make a decision rather than the probability can influence the perceived risk associated with a natural hazard as well as the decision making to reduce such a risk.

Many studies and reports have been based on the concept of focusing on the tragic outcome of an event as opposed to the low probability. In the CAPSS case study presented later in this thesis, probabilities of scenario earthquakes are presented, but ignored in the analysis. Instead, the study focuses on the consequences of various scenarios of earthquakes, presenting the potential disaster as if the earthquake occurred today. According to Samant (2011), "By eliminating probability, which is a confusing concept for a lot of people, the [risk] becomes way more impactful for the average person. You can imagine: if this happens, this is the result." Many authors believe the scenario approach may also impact the emotions associated with an event. Kerjan and Slovic (2010) explain that when low-probability risks give rise to dread, they are likely to trigger a larger behavioral response than statistically identical comparisons involving less feared possibilities. As discussed earlier, when a situation provokes emotion, probabilities may get neglected or skewed and as a result, people often exaggerate the benefits of

risk mitigation (Kerjan and Slovic, 2010). Therefore, it is not surprising that public leaders and other communicators describe risk in terms of its tragic outcome rather than the probability of occurrence.

By describing risk in terms of a tragic outcome, fear and dread for the event produce an enhanced emotion. This produces a heightened imaginability and availability of the event in one's mind which is similar to that associated with negative past experiences. According to Slovic et al. (2004), availability may work because concrete and imagined images come tagged with affect. Keller et al. (2006) hypothesizes that the manipulations of such images should evoke emotions which result in a greater perceived risk. Keller and colleagues believe that this can be done by presenting participants with negative images associated with an event prior to gauging the participant's perceived risk. While participants may not have the availability of past experience with a specific event to draw a negative affect from, the presentation of negative images may induce such an affect.

The research described above proposes that the manner in which risks are presented can influence the level of perceived risk. However, all approaches suggest that evoking a negative affect associated with an event results in greater perceived risk. In addition to past experience, the negative affect associated with natural hazards may also be aroused through experimental manipulation. A study will be presented later in this thesis which tests the hypothesis that manipulating the time period associated with an event probability as well as manipulating a negative affect with images will influence the level of perceived risk. A second study will be discussed which evaluates the relationship between past experience and knowledge of a hazard event with risk perception for a future, similar natural hazard.



## *2.2 Public Involvement*

Public involvement of various forms has been a fundamental feature of politics in the United States since before independence. While it has been popular in many political arenas, it has recently become very important in environmental decision-making processes as a means of increasing public accountability for long-term decisions (NRC, 2010, McDaniels, 1999 and Beierle, 1999), improving decision-making processes (Beierle, 1999 and Gamper and Turcanu, 2009), and avoiding opposition to such risk mitigation decisions (Beierle, 1999).

According to Beierle (1999), the national environmental focus has been shifting from immediate large point sources of environmental catastrophe, to more distributed long-term disaster issues. Such issues may not be suitable for hierarchal political decision making but instead may require the commitment, knowledge, and involvement of the government and general public over time (Beierle, 1999). McDaniels et al. (1999) consider that the objective of public involvement should be, “To provide insight that will foster widely supported policy choices reflecting public values, and to build lasting support for those choices.” With a political focus on long-term environmental issues, public involvement requires building collaboration between community organizations, special interest groups, and other public groups which are all affected by such issues. The authors of a report by the National Research Council (2010) believe it is important for those engaged in collaboration to share a commitment to the greater goal of the continuity of the community, as opposed to pursuing only parochial interests. It is important not only to identify common issues related to natural hazard risk reduction, but also identify how risk reduction is a part of a broader community building effort. According to Ron Carlee, a previous County Manager for Arlington County, New York, “A community most likely to survive disaster

is one that actively commits to social equity and inclusion and creates a vision to which all its residents and institutions can relate” (National Research Council, 2010).

Another reason public involvement is becoming more popular in environmental decision making is due to the fact that experts and the general public bring very different and unique perspectives to the risk decision-making process (Beierle, 1999). While experts may have a narrow specialized view on a topic, the general public may present varying insight since they are affected differently by a decision. Given the uncertainty and variability of risk reduction decisions, even the most technical analytical methods for making decisions are met with large subjectivity. According to Gamper and Turcanu (2009), participation is essential in public issues, particularly highly conflicting situations with a significant degree of uncertainty. Direct representation of public preference in risk reduction decision making can complement views of experts, and develop support for a decision maker’s final choices (Gamper and Turcanu, 2008). Risk perception and communication literature contains numerous examples of the differences between public and expert opinions on environmental issues. For example, in a 1987 study by the U.S. Environmental Protection Agency (EPA), various environmental issues were ranked and assigned a priority based on the risk to the public. The order the EPA authors ranked the issues was found to be entirely opposite to the ranking the public reported in the opinion polls (Davies and Masurek, 1998). According to the National Research Council (1996), even the most technical aspects of environmental policy analysis including risk assessment and cost-benefit analysis, often require “unacknowledged value judgments.”

Finally, if public opinion is left out of a decision-making process, it is possible that the effectiveness of a project or policy may be affected. According to James and Blamey (1999), the quality of a project design and stakeholder support for the project will be reduced if effective

participation has not occurred. Beierle (1999) believes that public opposition is often an indicator of the public's mistrust of the willingness and ability of government to manage risks appropriately. According to Slovic (1993), active public involvement may be one of the few ways to start resolving issues of mistrust. When the public is involved in decision making, people are more likely to understand the issue at hand, and develop a sense of accountability for the issue. Without public involvement, people may develop opposition to risk-related issues as a result of lacking education and accountability for the issue.

For these and many other reasons, the National Research Council argued in its 1996 book "Understanding Risk" that it is imperative to incorporate "...the perspectives and knowledge of the spectrum of interested and affected parties from the earliest phases of the effort to understand the risks." According to the NRC (1996), "If it is desired to communicate risk as credible and relevant to the interested parties, it must address what these parties believe may be at risk in the particular situation, and it must incorporate their specialized knowledge. Often, the best way to do this is by the active involvement or representation of the parties affected."

As a result, public participation in local plan making is increasingly a requirement by federal, state, and local laws. While public involvement in local policy decisions theoretically sounds ideal, there is an underlying reality that people are not always interested in participating. This may be due to pure disinterest or poor planning efforts aimed to gain public attention (Godschalk et al., 2003). According to Burby (2003), despite substantial evidence of risks associated with flood, hurricane, and earthquake catastrophes, it has been particularly difficult to generate participation in decision making to reduce natural hazard risks. The question is, if people know they are at risk to natural hazards, why would they lack a desire to participate in the decision making to reduce such risk?

In a 2002 study, Godschalk et al. (2003) examined evidence from case studies in Florida and Washington to suggest the causes of disinterest in public participation in natural hazard decision making. The authors studied five different jurisdictions, all with differences in planning approaches and types of natural hazards. While each jurisdiction had comprehensive planning mandates with participation requirements, each lacked interest from the public in issues relating to natural hazard decision making. Godschalk and colleagues identified common factors in each case study which led to a decrease in public interest in natural hazard reductions. To begin with, the authors observed that communities and government parties perceived hazard mitigation planning to involve technical issues most effectively addressed by trained experts. They explain, “Citizens generally felt that they lacked the ability to provide input on issues related to engineering and building codes” (Godschalk et al., 2003). Citizens were also most interested in concerns with neighborhood issues and did not feel as compelled to focus on city or county wide natural hazard issues. In areas of Florida where relative newcomers lacked experience with natural hazards, Godschalk and colleagues also noted there was little interest in natural hazard risk reduction since they did not feel it to be a direct concern. Since people did not believe that natural hazard reduction would impact their daily lives and what was important to them, they did not feel it to be necessary to focus on such issues.

While research has shown that public involvement in risk decision making is both vital and beneficial to achieving support for risk mitigation policy, effective methods must overcome the disconnect between public involvement and natural hazards. The observed separation between natural hazard mitigation and community concerns is of great importance in overcoming such challenge. It should be noted that there are also drawbacks to the use of public participation in risk investment policy making. Due to the time and resources necessary to achieve public

understanding and a general consensus on a project, delay of project deliveries and higher costs may be expected. Also, unless properly educated on options and alternatives, the public may be concerned with different issues and want to allocate funds and focus in many different directions. This is why a clear understanding of what must be done and what can be done is essential to achieve a public participatory program where everyone is working towards the same goal.

### *2.3 Focus on Community Values*

As explained by the National Research Council (1996), risk communication must address what affected parties believe may be at risk in the particular situation. In other words, people want to know how they will be directly affected. In research involving various case studies in natural hazard risk reduction, Olshansky (2003) has shown that it is important to personalize a particular issue to each party affected.

Most communities share general physical, environmental, and social assets, including safety, land value, education, etc. In addition to this, each community also has specific assets which they value more than others. For example, San Francisco, California may be more concerned about rent control and neighborhood character while Orlando, Florida may focus more on tourism and landscape. In their research on public participation in various Florida and Washington jurisdictions, Godschalk et al. (2003) concluded that people were more concerned with neighborhood issues as opposed to wide natural hazard risk reduction policies. According to Godschalk and colleagues (2003), “Stepping down from the general community scale to the local neighborhood scale creates opportunities to involve citizens directly in land use policy and decision making.” By personalizing the benefits of a larger-scale risk mitigation issue to a neighborhood level, a community will see how they are directly affected based on their specific values.

According to Tobin (2011), who served ten years as Executive Director of the California Seismic Safety Commission, “It is important to identify what a community values, and speak to those values”. Focusing on assets specific to communities will elevate the understanding of risk to a direct and personal level, and create the ambiance of immediacy for the taking of action. A prime example of specific community assets can be found in San Francisco which is one of the most vulnerable American cities to natural disasters (Paxton, 2004). As a result, effective communication to mitigate a potential disaster is crucial. Instead of communicating the potential seismic risk through probabilities and other technical terms which the average person may not relate to, Tobin (2011) notes that it is beneficial to personalize an issue in relation to the specific community values. For example, the older housing stock of San Francisco is held in high regard, and according to Paxton (2004), “Exudes the quintessential charm and character of the city.” Without retrofitting these structures to current seismic codes, these historic buildings are among the most vulnerable to damage. An earthquake could easily threaten a large percentage of this housing stock, and the valued essence of the city could be in jeopardy.

Personalizing an issue to the intended audience may also mean focusing on the social and physical make-up of a community. For example, San Francisco often has relatively low residential vacancy rates. An earthquake could conceivably render so many buildings unsafe that more people are made homeless than there is space for them in the vacant residential buildings that remain. If those people work in the City, but cannot live there, they may be forced to leave the area. This could adversely affect the city’s economy, as happened in New Orleans after Hurricane Katrina in 2005 caused widespread damage to the city’s housing stock, resulting in a diaspora of city residents. Concerning the physical framework of San Francisco, most of the housing stock is constructed of wood. As a result, fire may create greater damage than the initial

earthquake. While this claim is up for dispute due to much uncertainty, Paxton (2004) notes that ninety percent of the building loss in the 1906 San Francisco Earthquake was caused by fire.

Effective risk communication may also focus on the future value of assets to a community (Tobin, 2011). Since major earthquakes have a relatively low occurrence probability, it is possible that the benefits of mitigating now may be seen 50 years later. These benefits from risk mitigation may not be assessed accurately in light of current community values, but instead may need to be compared to the future value of assets. For example, another significant attribute of San Francisco communities is their effort toward “green living.” As part of the City’s “Zero Waste Plan”, San Francisco is working to achieve a recycling rate of 100% by 2020, which will also dramatically reduce carbon emissions (SFO, 2010). All of the debris and destruction which accompany seismic activity would not only set back the community value of “green living” today, but would also set back a large community goal of becoming 100% recyclable in the future.

In addition to communicating the consequences of natural hazards in light of specific community assets, hazard mitigation can be piggy-backed on other pertinent issues at hand such as transportation, zoning, and development (Godschalk et al., 2003). For example, natural hazards often affect large numbers of low income housing. Hazard mitigation may be intertwined into disadvantaged neighborhood upgrading programs. Additional examples of incorporating hazard mitigation into issues involving community values will be presented later in this thesis. Incorporating hazard mitigation into additional prominent issues at an early stage can set a precedent for building mitigation into policy making.

## *2.4 Overcoming Incompatibility of Lifetimes*

Over the years, views of natural hazards have been increasingly transformed from emergency response to risk mitigation. While pre-disaster measures are necessary to protect against natural hazard destruction, local governments are sometimes reluctant in adopting risk reduction policies (Corotis, 2010).

Prater and Lindell (2003) offer three explanations for this reluctance in developing risk mitigation plans. To begin with, they believe residents and local governments tend to discount the risks associated with developing hazardous areas unless a disaster has recently been experienced. This theory complements the concept of affect and availability bias, as well as Kunruether's (2010) claim, mentioned, earlier that decision makers often regard hazardous events as below their threshold of concern until they occur. Secondly, Prater and Lindell believe that the pressure associated with moving to highly hazardous areas, including the scenic beauty and therefore prime real estate, makes hazard mitigation difficult and costly. The authors also explain that more short-term local government issues such as crime and education usually absorb more attention, time, and money rather than future risk reduction issues (Prater and Lindell, 2000).

Corotis (2009) claims that focus on short-term decision making as opposed to long-term sustainability may be due to not effectively showing a need for hazard risk reduction to the public and their political leaders. The motivating rationale of decision makers is dictated by low-risk decisions with direct and recognizable benefits to the public. Pennsylvania Governor Ed Rendell explains "It [was] easy, especially in tough economic times, to push aside infrastructure initiatives, including basic maintenance and repair, in favor of issues that seem more pressing or more appealing" (Herbert, 2010).



There are basic pressures and often incompatibility between the motivating rationale of an elected decision maker and optimal policies for long-term sustainability (Corotis, 2009). The political system is based on lifetime cycles of approximately 4-8 years, whereas the lifetime of infrastructure, and similarly, the return period of a low-probability, high-consequence natural-hazard events may be 100 years or more. Therefore, the probability of a major disaster occurring during a specific elected official's term in office is low. As a result, a political leader may rightfully conclude that spending resources on definite decisions with immediate effects instead of investments in long-term sustainability is the best way to satisfy his or her constituents. While such justification may work for a particular decision maker, Tversky and Bar-Hillel (1983) note that consecutive short-term decision making may not result in what is best for the long term. For example, five consecutive, four-year terms held by different elected public leaders may not equal 20 years of efficient decision making. If each politician holds the same rationale that short-term, immediate benefit decisions will promote re-election, the necessary decisions for the long-term sustainability of a community may be overlooked. Without an increase in public accountability in risk mitigation, it is unreasonable to expect elected public leaders to sacrifice immediate benefits for their constituencies in order to develop long-term sustainability.

In a study using data on natural disasters, election returns, and government spending, Healy and Malhotra (2010) examine how the public responds to political decisions on natural hazards. Their studies show that the public often reward politicians for delegating disaster relief spending only after the disaster occurred, but not for investing in disaster preparedness. By not providing any acknowledgment or reward to government entities for preparing for disasters before they occur, politicians lack accountability for such issues, and community sustainability is

in jeopardy. Politicians are instead incentivized to respond post-disaster, after most damage has occurred and lives have been lost.

So how does one incorporate long-term sustainability into the political agenda while ensuring recognition and support for making such long-term decisions? Birkland and Waterman (1998) argue that an effective way of getting hazard mitigation on the public agenda is using a focusing event such as a disaster that gets public attention. He believes that people's concerns when their household is recovering from a disaster are different from the issues directing their attention when no such extraordinary event has occurred. The aftermath of a focusing event creates a "window of opportunity" for hazard-mitigation policy. There have been many hazard-mitigation policy acts enacted as a result and soon after major disasters, including building code prohibition of unreinforced masonry buildings after the 1933 Long Beach earthquake (Hess, 2008), passing of The URM Law after the 1971 San Fernando earthquake (RMS, 2004), advances in seismic code provisions after the 1989 Loma Prieta earthquake and 1994 Northridge earthquake, and many more.

However, as Kunreuther and Michel-Kerjan (2010) point out, the public's attention span on the disaster issue will be reduced over time and may soon switch to other issues. Also, with the ability to mitigate and predict the outcome of future earthquakes from extensive past research, is it necessary to wait for a disaster to occur in order to put hazard mitigation on the political agenda? In *Practical Lessons from the Loma Prieta Earthquake*, Tobin (1994) explains, "I think we are all generally aware that we possess the knowledge to reduce earthquake risk across the nation." When addressing the destruction from the 1989 Loma Prieta earthquake, he adds, "I was ashamed that we had not fully used what we knew. We are all culpable for failing to

use our knowledge to effect change. We spend too little time using what we know to change public policy.”

Therefore, much literature has offered more immediate ways of overcoming the incompatibilities of long-term sustainability policy with the short-term political office tenure. Corotis (2009) believes that in order to get hazard mitigation on the political agenda, it is necessary to design policies and reward systems which encourage long-term sustainability. Kerjan and Slovic (2010) provide an example of encouraging long-term decision making in the financial markets in their book *The Irrational Economist*. They explain, “As a way of encouraging bankers to consider the long-term implications of their actions, the executive compensation system could be redesigned so that it promotes a risk-adjusted reward mechanism where bonuses are a function not only of short-term market performance but also of sound risk profiles” (Kerjan and Slovic, 2010). Similar incentives can be used to bridge the chasm between long-term hazard planning and optimal political decision-making.

By creating strategies which promote a sense of accountability for long-term decision making, the public as well as their political leaders are incentivized to focus on long-term sustainability. The city of Palo Alto, California, developed an incentive-based ordinance which is often used as a model for jurisdictions seeking success with voluntary retrofitting (FEMA, 1994). The city requires owners of hazardous buildings to submit detailed engineering reports describing the potential for damage in the event of an earthquake. The building owner is then required to notify tenants of any potential risk, and post the report so that it attracts the attention of residents and future tenants and buyers. Palo Alto’s approach has resulted in the voluntary retrofit of 22 of the 91 buildings originally identified as hazardous (FEMA, 1994). By publicizing the potential deficiencies of hazardous buildings, which may in turn impact the value

the building offers to a customer, tenant or prospective buyer, the building owner is held accountable for the seismic risk. Many cities have implemented various incentive programs that increase public accountability for seismic safety, but at the same time reduce the need for political decision-makers to set mandatory retrofit ordinances which may be met with hostility.

Kerjan and Slovic (2010) suggest a method to increase the political accountability for long-term risk mitigation decisions based on increased public involvement and observation in the decision-making process. They explain, “If a decision maker knows he or she is being observed while making a decision, this will have predictable effects on the process and outcomes of decision making.” For example, if the public is involved and educated concerning issues of natural hazard risk, a political leader may be more likely to put additional efforts in decision making to retrofit structures. This logic of accountability will be seen in the CAPSS case study presented later.

### *2.5 Cost Presentation Methods*

Financial tools are often used as a method of allowing the public and their political leaders to understand the balance between risk and return. For example, two presidential executive orders (Clinton 1993, 1994) required federal agencies to assess the cost-effectiveness of regulatory alternatives and of infrastructure investments. The public uses multiple standards to assess future benefits and risks, and these must be incorporated into financial methods used to gauge the future benefit to the public for undertaking risk mitigation actions. Fischhoff et al. (1979) have identified several comparison methods used in comparing risk and rewards, including the cost-benefit method. To be effective, this method requires accounting of all short and long-term costs and benefits, as well as the incorporation of an appropriate discount rate.

A limitation to cost-benefit analysis is the sensitivity to discounting in rare events, such as natural hazards, where the timeframe of reference may be many decades. The transition of the concept of discounting, used typically in relatively short-term projects with tangible outputs, to long-term environmental issues has become quite a controversial issue (Percoco, 2002). As a result, there are intense debates about the discount rate that should be used for environmental long-term issues (Percoco, 2002). While discounting is largely based on economic theory, there are also many psychological issues which must be taken into consideration when developing an appropriate discount rate (Corotis and Gransberg, 2006). Discounting reflects the generally accepted idea that resources available in the future are worth less than the same resources available today. In addition to this, psychological studies have also prompted an additional type of discounting based on the observed behavior that people prefer to consume resources now rather than in the future.

Unlike pure economic discounting, which often has a constant discount rate, the discount rate associated with social or psychological factors tends to decrease with time (Percoco, 2002). This time-variant, hyperbolic curve suggests that people want immediate gratification for the decisions they make versus delayed benefits. There have been many studies of time-varying discounting models including that of Robert Strotz (1956) who was one of the first to study time inconsistency in discounting. According to Strotz, “Special attention should be given ... to a discount function which differs from a logarithmically linear one in that it ‘over values’ the more proximate satisfaction relative to the more distant ones” (Strotz, 1965 quoted in Thaler, 1981).

The main justification for the use of psychological discounting based on a time-varying function is based on evidence in psychology studies which contradict economic functions with fixed discount rates. Thaler (1981) performed many psychological experiments leading to the

theoretical conclusion that some people prefer “one apple today” to “two apples tomorrow”. In one experiment, Thaler asked subjects to imagine they had won a large sum of money in a lottery and that they could either take the money now or wait for an increased amount later. Given variations of the amount of money given at a future time, with money given immediately, Thaler notes that the average discount rate decreases with time. For decisions involving infrastructure risk, this concept of a discount rate with psychologically influences must be addressed (Corotis and Gransberg, 2006).

Corotis (2010) models the psychological discount rate which varies over time with the following equation

$$r_i = a^{i-1}r_1 \quad (1)$$

where  $r_1$  designates the rate of discounting for the first year,  $a$  is a psychological parameter factor, and  $r_i$  is the modified rate in year  $i$ . A present discounted value,  $P$ , assuming continuous compounding, can be related to a future value,  $F$ , in the following equation

$$P = Fe^{-rn} \quad (2)$$

where  $r$  is the effective discount rate and  $n$  is the number of years where the future value,  $F$ , is discounted into a present value,  $P$ . By substituting the psychological discount rate,  $r_i$ , from equation (1) into equation (2), the present value equation becomes

$$P = Fe^{-r_1 a^{i-1} n} \quad (3)$$

Corotis (2010) provides a graph of equation (3) shown in figure 1, plotting the present value as a function of the number of years in the future when the benefit will accrue, assuming the first-year discount rate is 5% and the psychological factor,  $a$ , varies from 1.0 to 0.5.

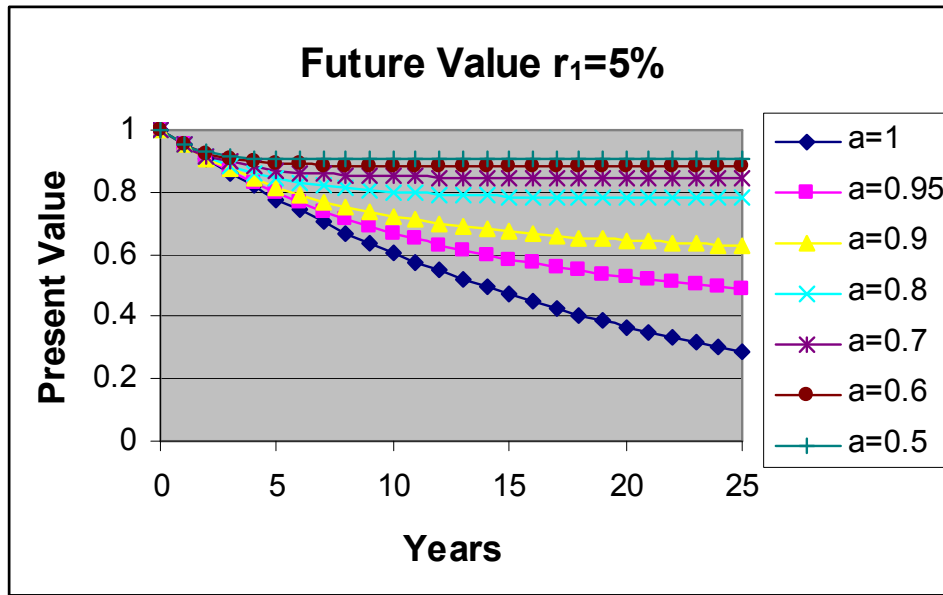


Figure 2.1 – Present discounted value for a future unit value benefit utilizing the psychological adjustment to annual discount rate. (Corotis, 2010)

It can be seen in this graph that the modified effect of psychological discounting is significant for the longer time periods associated with infrastructure lifetimes. Traditional economic discounting, which is represented by the curve with  $a=1$ , continues to decrease dramatically with time, whereas adding a psychological adjustment decreases the rate of discounting over time. Since a discount rate tells us the amount of future benefits which will justify spending a dollar today, it can be seen why there is considerable debate regarding the appropriate discount rate to apply to a cost-benefit analysis conducted over longer lifetimes. It should be noted that the parameter ‘ $a$ ’ in equation (1) provides for a reduction in discount rate with distance in the future.

An appropriate subject for future study would be the pursuit of a societal normative value for ‘a’ and an investigation as to whether it changes for different rewards and across different societies.

Newell and Pizer (2001) performed research examining the implications of using a conventional discount rate versus one that is discounted at lower rates over time with respect to the cost benefit ratio of climate change mitigation. Currently in climate mitigation economics, a single rate is chosen, typically between 2 and 7 percent, and is held constant over the lifetime of the model. Newell and Pizer argue that future rates are uncertain and demonstrate that acknowledging uncertainty will lead to a higher value of future benefits regardless of the initial rate one chooses. Their studies show that by including the effects of discount rate uncertainty, the future value of risk mitigation decisions could be raised by as much as 95 percent relative to conventional discounting (Newell and Pizer, 2001). The applications to this approach of discounting may be utilized in infrastructure decision making to significantly increase projected benefits for addressing natural hazard risk.

In addition to discount rate, an assumption must also be made with regard to the time period associated with the costs and benefits when presenting a benefit-cost analysis for long-term risk mitigation decisions. A widely shared public rationale during the course of decision making is “what does it cost me now?” Solely focusing on the initial cost of risk mitigation does not align properly with the objective of long-term sustainability. The large initial cost makes it easy for some to ignore the probability of risk over the lifetime of a structure, and overlook the need to reduce such risk. As discussed earlier, this is often the case in the political arena, where politicians tend to be persuaded against long-term sustainability decisions due to the higher initial costs. When presenting financial-based methods it is beneficial to focus on the total cost of



a hazard mitigation investment over the lifetime of infrastructure, and view it as investing money now so that it can pay off in the long run.

There are many different presentation methods that can be used when presenting a cost-benefit analysis. One option is using the present discounted value through an infrastructure risk evaluation. The present discounted value includes the initial cost, along with all of the annual costs of a structure including maintenance discounted to a present value. Unfortunately, using the present discounted value is not easily comparable across different types of structures. Since communities do not set aside funds to pay for future maintenance, the present discounted value of infrastructure building or repair is not a realistic cost to society. Since the present discounted value incorporates long-term repair and maintenance, it is much higher than the initial cost of a structure, which may not be an effective way of presenting and justifying costs for public spending.

A more effective option of presenting costs may be converting all costs to an equivalent annual cost. Converting costs to an equivalent annual basis may help alleviate the issue of incompatibility of lifetimes as discussed earlier. For example, it is much easier for a politician to justify spending four to eight years of the annual cost of a structure than a large present discounted value. An important issue in computing the annual cost associated with a project is the selection of the appropriate design lifetime. When considering a traditional present discounted value, a shorter design lifetime will minimize the present value of future maintenance and future risk-related costs. On the other hand, when converting costs to an equivalent annual cost, the amortization, or the “pay back” of initial costs favors a longer lifetime. For example, if the initial cost of a structure along with the annual maintenance cost were equally divided over “n” years with discounting, the annual equivalent cost would be much lower for a structure with

a 100-year lifetime than a similar structure with a 50-year lifetime. Corotis (2009) explains that longer design lifetimes provide a political reward that is consistent with long-term sustainable design. The use of infinite design lifetimes, or very long time periods which would seem infinite in terms of a benefit-cost analysis, may be even more beneficial for a politician, because not only does this decrease the annual equivalent cost, but also, building a structure with an infinite lifetime provides a “permanent” reward to a community.

Assumptions of discount rate and time period associated with a cost-benefit analysis as well as the presentation format of costs to a society will greatly affect the perceived benefit of risk mitigation. With the ongoing debates over such issues, it is obvious that there are disagreements over the set of values to be used for specific long-term risk mitigation activities. Opinions on these controversial topics from current experts in the field of natural hazard risk mitigation will be summarized and analyzed later in this thesis.

## Chapter 3

### Reassessment of the Issues

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The intent of this chapter is to present a reassessment of the current knowledge presented in the previous chapter. Further analysis, questionnaires, discussions, and case studies will be utilized to provide additional insight to the literature review and develop conclusions with respect to the five outlined issues in communicating risk and implementing retrofit.

#### *3.1 Public Risk Perception*

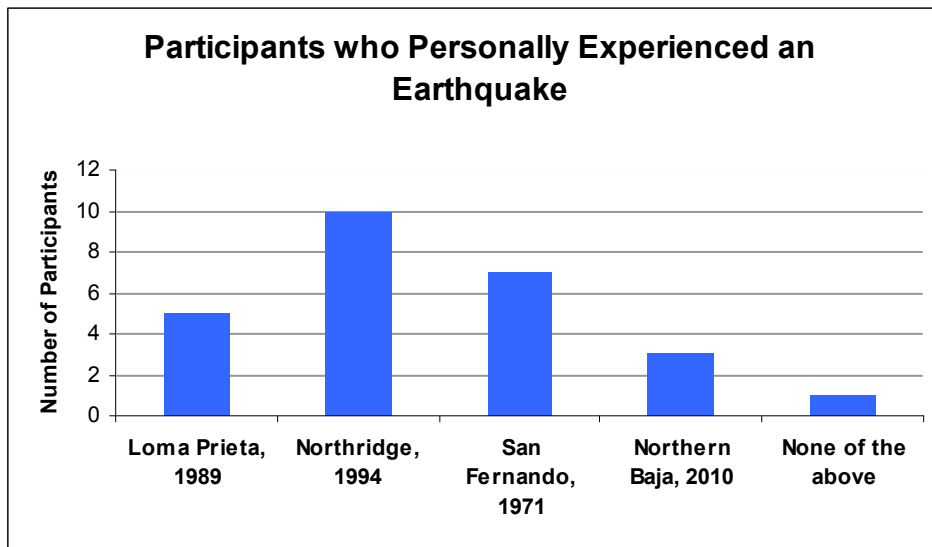
As discussed earlier, the way in which information about natural hazard risk is presented influences the level of perceived risk. When promoting hazard mitigation, public and political risk perception can drive the acceptance of long-term policies. Therefore, the details and parameters of presenting risk can provide a challenge to gaining people's attention and promoting accurate risk perception. Many studies presented earlier have suggested that the affect bias which is linked to the strong emotional feelings about a hazard may play an important role in risk perception. Since negative images and emotions increase the availability of an event, the availability bias suggested by many authors also influences risk perception. As discussed earlier, the negative emotions and prevalent availability associated with an event can be largely influenced by past experiences (Keller et al., 2006, Kunreuther and Michel-Kerjen, 2010). For example, if an individual contracted food poisoning from a restaurant, they may be more cautious about where they eat. If someone was in a serious car accident, they may become a more cautious driver. The negative feelings associated with past experiences may impact an individual's perceived risk opposed to someone who did not have any related past experiences.

Two studies were performed in this research related to the influence this affect has on risk perception. The first, which is in a form of a survey, focuses on the impact of past experience and knowledge about an event in terms of the perceived risk. As previously discussed, a general cause of people not taking action regarding a natural hazard is that they really don't think the event will occur, given the low probability of occurrence. This may be due to lack of past experience. While mass media is changing this, Harris (2011) explains "One of the big problems with earthquakes is that unless you live in an area where earthquakes are very frequent, you and no one to whom you are related to that is living has ever been in a serious earthquake. Because of this, it is difficult to think that you need to be planning for what might happen." Therefore, the question arises, how many people who live in earthquake prone regions have experienced a severe earthquake? To what extent does this past experience heighten the perceived risk of such an event? If one has not experienced an earthquake, does knowledge from the mass media influence risk perception? To answer these queries, a questionnaire was developed comprised of various questions focusing on whether the knowledge and/or experiences with past earthquakes influences decisions made to mitigate risk against future quakes. The questionnaire was distributed to approximately 11,000 people as an addition to the 2011 ShakeOut Registration Renewal email. The typical participants in the California ShakeOut program live in California and are familiar with hazard risk.

Unfortunately, only 18 responses to this questionnaire were recorded on the survey software. It is not known whether this is due to complications with the questionnaire link, errors in the survey software, or pure disinterest in taking such a questionnaire. The 18 responses, however, represent preliminary results to provide some insight into the influence of past experience and knowledge on perceived risk and risk mitigation action. The complete

questionnaire titled “Earthquake Retrofitting Questionnaire” and results are located in Appendix A.

Participants were asked to check which earthquakes they had either personally experienced at the time of occurrence or about which they considered themselves to be well informed, from a list of four severe California earthquakes. Later in the questionnaire, participants were presented with the scenario where a retrofit program is under consideration for their community to reduce future possible seismic destruction, and they must decide whether or not they support this program. Given a list of the same California earthquakes along with some international past earthquakes, the participants were then asked “To what extent does the knowledge of these earthquakes motivate you to support the retrofit program?” The results from both questions are illustrated in Figures 3.1 through 3.3.



*Figure 3.1 – Study participants who personally experienced a California earthquake*

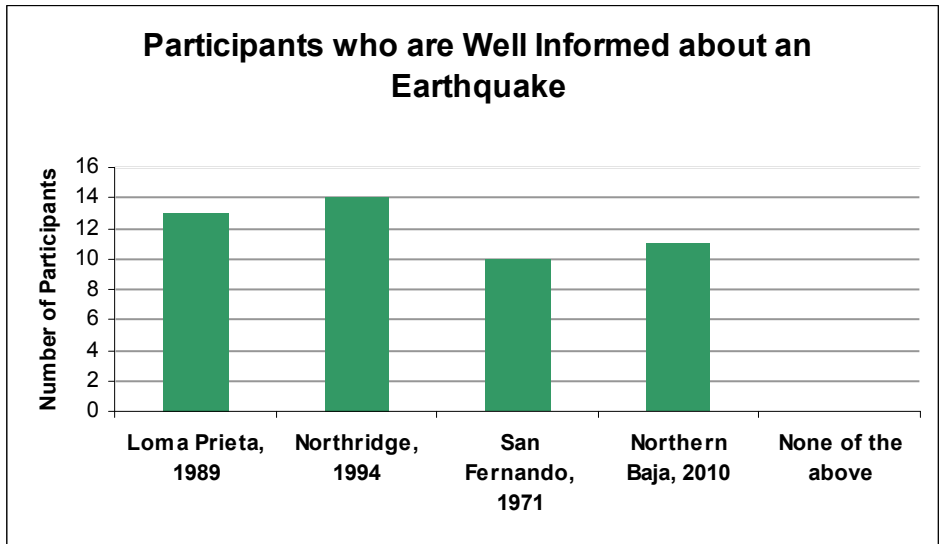


Figure 3.2 – Study participants who are well informed about a California earthquake

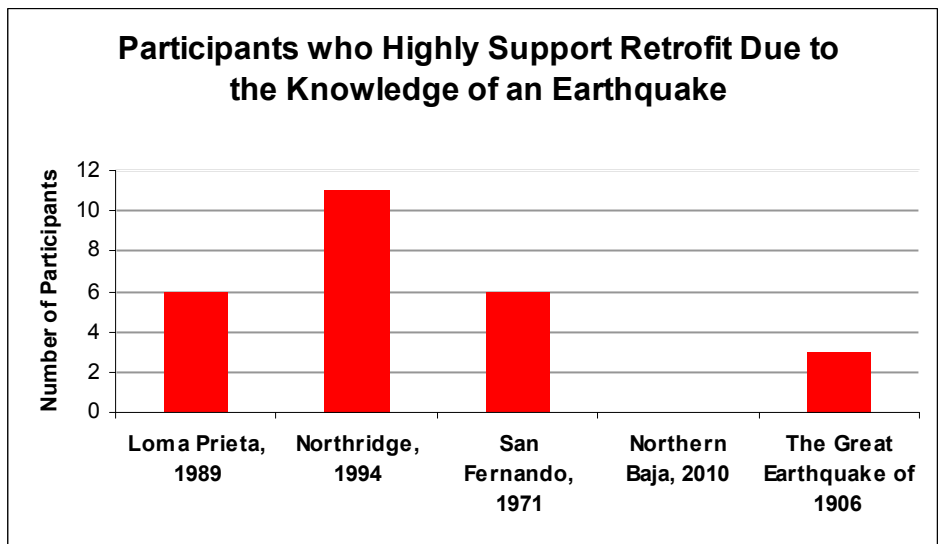


Figure 3.3 – Study participants who highly support retrofit due to the knowledge of a California Earthquake

The analysis revealed that past experience had a significant effect on risk perception. Participants’ motivation to retrofit was clearly influenced by their own experiences in an earthquake. It can be seen in Figure 3.1 that the largest percentage of participants (10 of the 18

respondents) had personally experienced the Northridge earthquake in 1994. Comparatively, the largest percentage of participants who highly support the scenario retrofit program claim to advocate the program as a result of the knowledge obtained from the Northridge earthquake. Furthermore, of the 10 respondents who personally experienced the Northridge earthquake, 8 of 10 claim that they would highly support the scenario retrofit program as a result of this experience, while the other 2 of 10 claim to somewhat support the program.

Based on these initial results, it can be inferred that people who experienced past earthquakes had negative emotions or an availability tagged with a negative affect that may become prevalent when confronted with a similar hazard scenario. These participants who stored this affect were more likely to support the scenario retrofit program versus the participants without such memories. A less conclusive correlation can be seen between the number of participants who are well informed about earthquakes, and those who would highly support the retrofit program. It should be emphasized that these are only preliminary results and the results could vary significantly with a larger number of participants.

In addition to past experience, Keller et al. (2006) hypothesize that risk perception can be influenced by experimental manipulation. Studies presented earlier in this thesis have shown that small probabilities do not evoke as much of an emotional affect as high probabilities. Since probabilities of risk vary depending on the time period with which risk is given, manipulating the time period may affect a person's perceived risk. Keller et al. (2006) believe that presenting probabilities for a longer time period results in higher perceived risks compared with the probability of the same event given over one year.

Keller and colleagues also postulate that the affect associated with natural hazards can be manipulated by using photographs associated with the hazard event. The study's authors found

that negative photographs associated with an event (i.e. building damage from an earthquake) evoke undesirable emotions in participants, which therefore heighten the negative feelings people have for the event.

A questionnaire distributed to undergraduate and graduate students, as part of their coursework, sheds light on Keller's hypothesis that inducing a negative affect through experimental manipulation results in an increased level of perceived risk. The study is intended to gauge the influence of manipulating the time period of probability when communicating the likelihood of a hazardous event as well as the availability of negative images in terms of increases in risk perception. A total of 115 students from the University of Colorado at Boulder participated in this activity. All students are enrolled in the Engineering College, which entails some experience with probability and natural hazard risk perception. Participants include 74 junior and senior level undergraduate students and 41 graduate students within the Engineering College.

This questionnaire focuses on the communication of seismic risk and uses the experimental manipulation of both time period and photographs. Participants were asked to imagine that they were planning to buy a house in the highly seismically active City of San Francisco. It was emphasized that an earthquake would cause severe damage to their house, which is only partly covered by insurance. Half of the participants received the risk information based on one year and the other half received the risk information for a time period of 30 years. Both represented identical probabilities based on a recent assessment of the seismicity of the San Francisco Bay Area (WGCEP, 2008). That study's authors estimated a 63% chance of at least one magnitude 6.7 or greater earthquake in the Bay Area sometime between 2008 and 2038.



The respondents were then divided into an experimental group and a control group. The questionnaire received by the experimental group included two photographs of houses that had been damaged in the 1989 Loma Prieta earthquake. It was indicated that the houses in the photographs were located in San Francisco. The control group did not receive any photographs in their survey but only the scenario described above presented in text. After reading the short scenario, each participant was asked “How risky would you consider living in this house is?” Participants were asked to assess the risks using a number between 1 (not risky at all) to 5 (very risky). The students were randomly assigned one out of the four scenarios. The questionnaire forms are presented in Appendix B.

Study Results: “How Risky Would You Consider Living in this House is?” Ratings 0 (not risky at all) to 5 (very risky)		
	Time Period	
Participant Group	1 Year	30 Years
Experimental Group	2.7	3.6
Control Group	2.5	3.4

Table 3.1 - Study Results for Experimental Manipulation on Risk Perception

The responses are averaged and tabulated in Table 3.1 above. Keller’s hypothesis that a longer time period influences risk perception is supported at the  $\alpha=1\%$  significance level. In both the experimental group and the control group, participants on average felt the house to present more risk when given the probability of seismic risk over 30 years versus the probability of an earthquake expressed for one year. Keller’s hypothesis that risk perception can be enhanced through the use of photographs was not as clearly supported through this study. The

students who were confronted with images of damaged houses and given the probability of seismic risk over a 30 year time period perceived an average level of risk of 3.6, while those who were only presented with text recorded a 3.4 risk level. The averages were also very close for the participants presented with risk expressed over one year. Based on these results, it is difficult to conclude that the images had a large impact on the participants risk perception. However, since the recorded risk levels increased slightly for both probability expressions, it is possible that the images may have had a slight influence.

The results of both studies are consistent with the views of Kahneman and Tversky (2000) and Slovic et al. (2004) presented earlier in this thesis. Based on these studies, it can be concluded that the affect and availability bias increase the perception of risk.

### *3.2 Public Involvement*

Policy makers and stakeholders widely accept that members of the public should be involved in environmental planning (National Research Council, 1996). Not only is public involvement the foundation for democratic ideals, but it is a growing strategy used by decision makers to expedite the conformance and effectiveness of environmental decision making (Beierle, 1999). Involving the public in environmental issues not only reduces public opposition and obstruction to decision making but also acquires public resources and knowledge in implementing such decisions. Regardless of the benefit of public involvement, an effective method of how to involve the public remains controversial (Webler and Tuler, 2001).

Public participation and involvement has evolved over the years. In the past, public participation meant having the ability to provide comments at public hearings, vote in public polls, or participate in a social movement (Webler and Tuler, 2001). As pressures to increase

public participation in environmental policies grow, public involvement has transformed into giving the public a voice and influence in such decision making. Various methods have been developed that enable to public to be active participants in policy option deliberations and often in policy decision making. Many of these efforts including focus groups, town-hall meetings, open houses, advisory committees, and various surveys have been proven useful (Gregory, 2000). However, decision makers often show the intent of seeking and considering the views of the public, but instead make decisions based on their own interpretation of the issue (Gregory, 2000). Therefore, it is not surprising that there is often public dissatisfaction with the quality and credibility of stakeholder input in environmental risk-management decisions (Stave, 2002).

This thesis presents three case studies evaluated on the framework of three goals to evaluate the success of public involvement extracted from the literature review presented previously in this paper. These goals include:

1. Educating the public
2. Incorporating public values, and
3. Increasing the importance and credibility of public influence in decision-making.

The case studies involve varying levels of effectiveness in public involvement used in decision making regarding environmental issues. The first case study involves successful public participation in decision making to build hazardous waste facilities in Alberta, Canada. The second presents a case where public involvement was initially ineffective, but subsequently improved to ultimately be successful on a study of the cleanup and protection for the Tillamook Bay in northwestern Oregon. The third case study illustrates ineffective community participation in Papillion Creek watershed planning.

### *Case Study: Hazardous Waste Facilities in Canada*

This case study involves proposals for siting hazardous waste facilities in Alberta, Canada. Typically, any proposal to create hazardous waste facilities is met with community opposition. According to Gray (1989), “One of the most difficult but potentially most promising areas for the use of collaborative approaches is in the siting of hazardous waste facilities.” While efforts to resolve siting of such facilities are often met with limited success (Gray 1989), this first case study is evidence of successful waste facility placements in Alberta, Canada accredited to the collaborative use of public involvement and education. The following summary of events is taken from Barbara Gray’s 1989 book, “Collaborating: Finding Common Ground for Multiparty Problems.”

To overcome the challenge of community opposition to the placement of hazard waste facilities, the Canadian province of Alberta developed a unique approach to involving local communities in the siting process. In 1980, Alberta’s provincial government launched a Province-wide public siting and education process. The education portion was composed of a series of public forums that informed the public of the waste handling procedures along with their own responsibility in preventing waste dumping. The siting portion involved multi-level mapping which was opened to public comment via public meetings. The public was encouraged to participate in further progress and improvement of the mapping process and volunteers were requested to participate in government negotiations.

The Province elicited volunteer communities for the placement of a waste facility and negotiated incentives in return focusing on important values to the community. The negotiated incentives included “tax benefits, economic spin-offs, roadway improvements, employee

housing, and employment priority for local township residents” (Gray, 1989). By 1985, the hazardous waste facilities were approved and constructed.

Gray (1989) believes that the siting process was successful due to the extensive public education and site selection program. It was publicized from the beginning that facility siting would not take place unless communities were in agreement with the location. Therefore, community stakeholders may have felt their views and involvement held more credibility, since the siting location was ultimately left at their discretion. The fact that the provincial government negotiated incentives for the community which volunteered to host the facility siting may have also aided the success of public involvement. By focusing on specific community values and assets, the Province was able to tailor incentives to promote community acceptance of the siting. As a result of this unique and successful approach to voluntary public involvement, the Canadian cabinet created a standard mechanism for establishing voluntary site selection processes in 1988 (Gray, 1989).

#### *Case Study: Tillamook Bay Watershed*

In 1998, a small team was funded by the U.S. Environmental Protection Agency (EPA) and the National Estuary Program (NEP), to examine the use of a public participation process to assess the cleanup and protection options for the Tillamook Bay watershed in northwestern Oregon. The Bay supports fish and birds, and is an integral component to local economies based on timber, agriculture, tourism, competitive fishing, and local dairy farming (Gregory, 2000). The study, titled Tillamook Bay National Estuary Project (TBNEP), was given the task to develop a science-based, community-supported management plan for the watershed. The following project description is summarized from the research of Gregory (2000).

Leading up to the project, there were many limited public-involvement programs used for managing the watershed. Open meetings were held prior to the start of TBNEP to seek citizen ideas and concerns on the watershed. Since the TBNEP project had not officially begun, there was no way to process or derive remedial actions for any public concerns. Without response and communication with stakeholders on matters discussed in public meetings, the community lost interest in the project issues. The TBNEP team believes that this took away any credibility to public participation or public interest in the bay project (Gregory, 2000).

Therefore, the official TBNEP project began by holding a series of meetings with community leaders to establish an appropriate project focus. The team decided a primary project focus was to "...find a way to meaningfully involve local residents at a detailed, action-specific level and to attempt to ensure that participants' judgments recognized the benefits, costs, and risks of the program initiatives under consideration" (Gregory, 2000). The project sought to develop a strategy where the community could learn more about the issues of the Tillamook Bay as well as the tradeoffs of proposed actions, and then use this knowledge to contribute to the decision making of these issues.

The team began with performing individual and group interviews with members of the community, asking participants what they cared about in terms of possible actions taken in managing the Tillamook Bay. The team elicited various community values regarding the bay including water quality, jobs, flooding, and social impacts. The distinction among these values led to informative discussions among participants about the relationships and tradeoffs of various actions in light of what was important to the community members. While there were many disagreements between participants in ranking the importance of such community values, the input provided from all stakeholder groups was useful in reflecting the connections between

possible program actions and their own values. This dynamic strategy to public involvement not only stimulated brainstorming and creative thinking but also energized public interest on the topic.

When identifying various program objectives and tradeoffs, public participants were met with the challenge of gauging the alternative actions for the bay since it seemed as if each presumed benefit would be offset by a resulting lifecycle cost. For example, Gregory (2000) explains, “What helped coastal anglers would hurt regional dairy farmers, and what helped the tourist industry would result in higher costs to forest operators.” To cope with these incompatibilities, the TBNEP project developed a process to educate community participants on such tradeoffs to promote public understanding competing objectives and aid in decision making. With the knowledge of technical information through historical data bases, impact studies, and computer models, public stakeholders were able to more thoroughly assess the impact of proposed actions in managing the bay.

By educating the public on various alternative actions, as well as focusing on specific community values in regards to these alternatives, the TBNEP project incorporated effective public involvement in the sense that each participant was willing to work toward the final objective of this project. Given that the objectives of the project were primarily based on the concerns of the community, the public was incentivized for their participation.

#### *Case Study: Papillion Creek*

The final case study involves decision making methodology evaluated by authors Irvin and Stansbury (2004) regarding new management alternatives for the Papillion Creek Watershed located in Omaha, Nebraska. With support from the U.S. Environmental Protection Agency, the authors incorporate multi-criteria decision-making methodologies from various literature sources

into a public-participation process that involves affected the stakeholders in the Omaha region. The following study objectives and results are taken from Irvin and Stansbury's 2004 publication, "Citizen Participation in Decision Making: Is it Worth the Effort?"

The Papillion Creek system gathers pollutants from agriculture and urban runoff and covers over three counties with a combined population of 605,000. As a result of flooding damage and mismanagement, the creek system does not provide much flood protection, offers poor water quality, has become very expensive to maintain, and is aesthetically unpleasing. An advisory group of municipal and county agencies charged with environmental planning and regulation, evaluated many management alternatives aimed at improving the creeks environmental impact, regional development, recreational use, and flood protection. According to Irvin and Stansbury (2004), it was hoped that "...making the decisions together with area citizens would have several beneficial effects."

Through newspaper articles, brochures, direct contact with landowners, phone calls, and free pizza at meetings, the advisory committee attempted to develop a participatory working group composed of rural and urban residents, recreational users, and developers. These efforts were unsuccessful. Only 15 citizen representatives promised to attend the first forum, and of the 15, only one attended. The project team deemed the public participatory element of the study unsuccessful and decided to eliminate any future public forums from the study.

Irvin and Stansbury credited the lack of effective public involvement to various inefficiencies in the project. To begin with, the authors believe the project failed to ignite public interest because it failed to define the problem with the bay and the alternatives. Without proper public education on the remedial alternatives for improvement to the creek's condition, the public was unable to see any incentive to participate in the project's public advisory group. The



authors also noticed widespread public complacency with the creek's management issues. According to Irvin and Stansbury (2004), the residents were relatively satisfied with local government decisions and also did not feel strongly about environmental issues. The complacency toward environmental issues may be indicative of a general disinterest in public involvement (Irvin and Stansbury, 2004), but it should be noted, as shown in the study by Godschalk et al. (2003) presented earlier, there are general causes for such a lack of interest. According to Godschalk et al., citizens were more interested in concerns with neighborhood issues, as opposed to regional, natural-hazard issues. If the Omaha residents did not believe the improvements to the Papillion Creek would affect their daily lives and what was essentially important to them, they did not feel it to be necessary to focus on such an issue.

Irvin and Stansbury found there was also a history of opposing community values and interests. Previous to their studies, the authors explained that the incorporation of public involvement in management actions resulted in rural citizens residing upstream opposing projects that could benefit urban Omaha located downstream. The current Papillion Creek project may have benefitted by focusing on specific community values, which are shown to vary per location on the creek. As discussed previously in this thesis, people want to know how they will individually be affected by a decision (Olshansky, 2003).

Finally, the project announced from the beginning that the stakeholder's decision would only be advisory, which ultimately discounts any authority or credibility of the stakeholders views on the issues. The public might have been better motivated if their participation had been directly incorporated into a decision-making process. Otherwise, there is little incentive for the public to participate.

### *Case Study Comparison*

While implementation of a successful public-participation approach in environmental decision making can be challenging, the ultimate goals are to provide policy makers with improved insight about the decision at hand and promote support from stakeholders. Through these three case studies, it has been shown that educating the public on the issue and alternatives is beneficial for drawing interest to the issue. Focusing an issue on the framework of community values also promotes public interest, but more importantly, allows the public to see how they are affected by an issue with the objective of promoting support for risk mitigation. Finally, these case studies have shown that public involvement benefits from a clear acknowledgement of stakeholder views and concerns. Without credibility and concern for public viewpoints, the public lacks incentive to participate. Using the knowledge of stakeholder input, policy makers are then able to advocate a specific project or decision with a complete understanding of possible concerns as well as the ability to satisfy the views of constituents.

### *3.3 Focus on Community Values*

At a Christmas function this past year, the author of this thesis was discussing the subject of hazard mitigation with a friend's mother who lives in San Francisco. When asked what her thoughts were on a bill for mandatory retrofit of under-designed public and private buildings in San Francisco, she responded "I would like to know what this means to me." She explained that beyond announcing such an action is mandatory and will make the City a safer place, she would be interested in the specific benefits of mandatory retrofit to her family. For example, would her children be safer at their school? How much safer would her family be in their house? Would she see benefits with her job specific to the local economy? She explained that many of her peers in San Francisco would not spend money and time on hazard mitigation and preparedness

without more understanding of how it would personally affect them. She believes people would be more interested in hazard mitigation if the City's seismic risk was assessed in light of the values and actions that comprise a resident's daily life (Rough, 2011).

Obviously it is neither expected nor reasonable for engineers or hazard mitigation policy proponents to explain to each resident how retrofit would affect their individual lives. Nonetheless, as the National Research Council (1996) explains risk communication must address what interested and affected parties believe may be at risk. A high-level evaluation of the possible financial loss or fatalities due to a natural hazard may not incorporate many values important to a community. While some of the direct and indirect costs of natural hazard damage are measurable, some are nonfinancial and/or difficult to quantify in dollars. As presented previously in this thesis, these values may include community character, architecture, local economy, rental property vacancy, etc.

This thesis presents two examples that illustrate successful hazard mitigation through the retrofit or removal of public infrastructure. Both successes can be accredited to assessing the benefits of risk reduction on the framework of specific community assets. A third example will be presented where successful seismic safety was piggy-backed on more pertinent issues to society involving regional values.

### *Case Study: Bay Bridge*

After a 250-ton section of the Bay Bridge upper deck collapsed during the Loma Prieta Earthquake of 1989, it was obvious that the peoples of the San Francisco Bay area had to increase the seismic safety of the bridge. Even though the bridge opened within a month after the collapse, San Francisco got a taste of what life was like without such a vital regional lifeline structure. As one of the longest spans in the world, the Bay Bridge accommodates over 280,000

vehicles per day, linking the cities of San Francisco and Oakland (TBPOC, 2010). In addition to providing a direct route between cities, the bridge is viewed as the linkage between businesses, cultures, and communities. It essentially represents a variety of community assets to the California cities.

Caltrans engineers determined that in order to make the bridge seismically safe, several sections of the bridge and the approach structures needed strengthening. The West Approach seismic safety retrofit work, which was completed in early 2009, involved removing and



*Figure 3.4 – Bay Bridge East Span Construction (TBPOC, 2010)*

replacing a one-mile stretch of I-280 viaduct in San Francisco as well as various on and off ramps to the highway. Seismic retrofit of the West Span (the 4-span suspension bridge between San Francisco and Yerba Buena Island) included adding steel reinforcement, new seismic viscous dampers, and bracing (TBPOC, 2010). The East Span, which a portion of experienced the 50-foot span collapse in the Loma Prieta earthquake, had to be completely replaced (see Figure 3.4). The seismic retrofit design team added many features to the bridge that not only enhanced its seismic safety, but

also community character. The eastbound and westbound lanes of the East Span no longer include upper and lower decks but instead are constructed as parallel lanes. A portion of the new east span also includes a monumental self-anchored suspension bridge that gives the portion of

the bridge between Yerba Buena Island and Oakland new character and architectural appeal generally felt to be lacking in the heavy truss structure it replaces. The new bridge also provides motorists with more expansive views of the Bay (TBPOC, 2010). Reconstruction plans also include a new pedestrian and bike path, which adds another community asset for the surrounding cities (TBPOC, 2010).

The values that accompany linking the two cities together gives much more value to the Bay Bridge than simply a transportation route. By incorporated new aesthetic and functionality features into the bridge reconstruction, the retrofit projects are also increasing the bridge's value to the neighboring communities.

#### *Case Study: San Francisco City Hall*

Built in the late 1800's, the San Francisco City Hall is considered one of the finest examples of classical architecture in the country (Malloy). The City Hall was rebuilt between 1913 and 1915, after being destroyed by the 1906 San Francisco earthquake. While the structure remained standing after the 1989 Loma Prieta Earthquake, cracks in the structure's walls and slabs rendered it seismically unsafe. In June 1990, San Francisco voters passed a \$332.4 million general-obligation bond for repair and seismic retrofitting of 191 city buildings damaged in the Loma Prieta Earthquake, including City Hall (SEAONC). In November 1995, San Francisco voters approved a \$63.5 million general obligation bond issue for funding for additional improvements to City Hall (SEAONC).

Retrofits included the installation of 530 lead-rubber base isolators, making the San Francisco City Hall the world's largest base-isolated building at the time (Malloy). The strengthening also included a new ground floor constructed above the isolators, additional concrete shear walls with steel collectors to transfer seismic forces to the walls, additional

reinforcement to the tower walls, and installation of steel braces and shotcrete walls at various levels of the dome (SEAONC). While seismic safety was a main objective of the City Hall's reconstruction, restoring the building and its dome to its original architectural beauty was held at high importance to the City. The structural engineers worked from copies of the original blueprints to restore the beauty and ornate design of the post-1906 City Hall.

By incorporating both seismic safety and the community asset of architectural beauty and historic preservation as reasons for reconstruction, voters were likely more willing to spend the money to repair the public structure. After reconstruction, the San Francisco City Hall continues to stand as one of the finest examples of Beaux Arts architecture as well as one of the most seismically safe municipal buildings in the country (SEAONC).

### *3.3.3 Case Study: Embarcadero Freeway*

According to Godschalk et al. (2003), hazard mitigation can be piggy-backed on other issues at hand that may draw more interest or provide more immediacy to take action from the public. This strategy is illustrated in the events surrounding the removal of the Embarcadero Freeway in San Francisco. While it was originally constructed to connect the Bay Bridge and Golden Gate Bridge, political turmoil over the City's freeway system left the freeway as a one-mile stretch connecting the Bay Bridge to Chinatown and North Beach. In addition to a transportation route, the Embarcadero Freeway more noticeably acted as a visual barrier between San Francisco and its waterfront, and it was widely considered an eyesore (Seattle Urban Mobility Plan, 2008).

Demolition of the freeway was put to a citywide vote in 1987 but was rejected. Shortly thereafter, the freeway became damaged during the Loma Prieta Earthquake in 1989. According to the Seattle Urban Mobility Plan (2008), "Once the freeway was damaged and San Franciscans

began to live without it, the barrier it created on the waterfront made it a stronger candidate for demolition.” When the freeway was demolished in 1991, not only was the city asset of an aesthetic waterfront view enhanced, but also seismic risk associated with motorists using the bridge was reduced.

Reclamation of the waterfront view was likely a contributing factor to local industries flourishing. San Francisco’s tourism industry grew following the freeway removal. Between 1995 and 2000, visitor spending citywide increased 39% (Seattle Urban Mobility Plan, 2008). In 2006, visitors to San Francisco spent \$7.76 billion, the highest total in the city’s history (Seattle Urban Mobility Plan, 2008). The double-deck freeway was soon replaced with a boulevard that raised property values in the surrounding neighborhoods by 300 percent and stimulated development dramatically (Boyd, 2010). Neighborhoods, retail centers, and recreational facilities were rebuilt. The City’s main ferry terminal called the Ferry Building, which was vacant for years preceding the Embarcadero Freeway removal, was redeveloped as a center for gourmet and natural food (Boyd, 2010). The Embarcadero Center, a five-block commercial district located between San Francisco's Financial and Waterfront Districts, explains on their website that “The Embarcadero Roadway Project has led to an entire renewal of the Downtown Waterfront District that is ensuring a bright future for the Embarcadero Center” (Embarcadero Center).

The overwhelming dislike for the visual barrier that came along with the Embarcadero Freeway left little need for promoting the removal of this bridge for seismic safety. However, this example does illustrate that seismic safety can be achieved by focusing attention on other community values. By incorporated hazard mitigation into more noticeable issues, communities may be able to achieve seismic safety through future planning more easily.

### *3.4 Overcoming Incompatibility of Lifetimes*

As discussed early, a major challenge with implementing a plan to retrofit inadequate structures is the prevalent incompatibility between policies for long-term sustainability and the political motivation for re-election. With a political term of around two to six years, the inherent rationale of a decision maker is dictated by low risk decisions with immediate returns and recognition from society. Without proper understanding of seismic risk, the public is less likely to reward long-term risk reduction decisions that provide mitigation against future damages from low-probability natural-hazard events. To bridge the gap between the future well-being of a community and political decision making, it is necessary to develop communication tools which allow a politician to make decisions that may sacrifice immediate benefits for their constituencies but promote long-term sustainability.

With the goal of getting re-elected, the political rationale is primarily based on the public response to his or her decisions. While public response is often dictated on perceived benefits, it is necessary to develop tools which allow the public to see and gauge the benefits of both immediate decisions but also decisions of a larger time scale. For example, while the public is able to immediately see the benefits in investing in a spring carnival or other community events, the benefits of retrofitting against an earthquake may go unnoticed for years or decades until an earthquake occurs. Therefore, the challenge is to bring public recognition and accountability to the election process in regard to long-term sustainability. By implementing strategies that promote a sense of accountability for risk mitigation decisions of a larger time scale, the public as well as their political leaders are incentivized to focus on long-term planning.

There have been many methods both implemented and suggested that promote public and political accountability through quantifying various risks to society. One option is the use of a



public report of the seismic risk to infrastructure in a community. This report helps enables the public to perceive the benefits associated with risk mitigation decision making and therefore reward such political action. In this section, two different risk-reporting methods are presented and compared. The first method consists of various infrastructure report cards and status updates issued by the American Society of Civil Engineers (ASCE) since 1998. This rating system presents the current state of infrastructure and provides potential solutions for improvement that can be used as a guide for policy decisions. The second reporting technique is proposed by Ross Corotis, a Professor at the University of Colorado at Boulder. This method incorporates a similar strategy of quantifying current risk levels of existing infrastructure, but also quantifies the risks, costs, and benefits associated with new or proposed structures or retrofit activity. In contrast to the ASCE report card, Corotis' proposed reporting would be published prior to local jurisdiction elections, and is intended to rate infrastructure risk at a more local community level (Corotis, 2010).

The concept of the ASCE report card to grade the nation's infrastructure originated in 1988 as a reporting tool used by the commission titled the National Council on Public Works Improvement. The commission released a report titled *Fragile Foundations: A Report on America's Public Works* where the council issued recommendations on how to improve the nation's infrastructure. As a method to guide the authors when evaluating the infrastructure, a rating in the form of a report card was established that assigned letter grades based on infrastructure performance and capacity.

Nearly a decade later, ASCE issued the first infrastructure rating titled the Report Card for America's Infrastructure. Unlike the 1988 report, the new reporting rates the current state of infrastructure, and also provides solutions for improvement. To establish the grading system,

ASCE formed an advisory panel of the nation’s prominent civil engineers. The advisory panel analyzes hundreds of studies, reports, and surveys thousands of engineers to determine the state of infrastructure per region (ASCE). The national report card evaluates 14 categories of infrastructure including the following (ASCE):

- Aviation
- Bridges
- Dams
- Drinking Water
- Energy
- Hazardous Waste
- Inland Waterways
- Levees
- Public Parks and Recreation
- Rail
- Schools
- Solid Waste
- Transit
- Wastewater

Each state can focus on specific infrastructure categories that are of most importance, and develop individual goals and objectives. While relevant for most states, the California Infrastructure Report Card Committee states a short-term goal is to “Educate the public and political leadership so that they will be supportive of developing, enacting and implementing the practices and funding mechanisms needed to realize our long term vision” (ASCE California). In addition to developing ways to improve the state’s infrastructure, the California Infrastructure Report Card Committee explains that it is used to raise the public awareness of the risks and challenges policy makers face in maintaining public infrastructure. By educating the public on infrastructure risk, the desired outcome is to essentially raise public accountability for such risks and increase support of infrastructure funding initiatives and fees (ASCE California).

When the *Fragile Foundations* report was released in 1988, the nation's infrastructure earned an overall grade of a C. Two decades later, the latest 2009 Report Card assigned an overall D grade and estimated that it would take a \$2.2 trillion investment from all levels of government over the next five years to bring it into a state of good repair. Though some infrastructure categories have achieved a higher grade over the past two decades, it is noteworthy that the nation's infrastructure has essentially deteriorated over the years. With the goal of raising public risk perception, and guiding decision making to improve the nation's infrastructure, the reduction in infrastructure rating shows that there may be areas for improvement in the overall implementation of the Report Card. The method proposed by Corotis may provide insight into modifications to the ASCE reporting system.

Corotis (2010) suggests a similar reporting system in the form of a financial-based report card for accounting infrastructure risk to society. On a regular basis, the proposed report would include a present value analysis of public infrastructure within a region. This would include not only the current risk levels and implied future costs of all existing infrastructure but also the costs, risks, and benefits associated with new or proposed structures. Previous risk levels can be compared with current levels of risks, as well as risk associated with proposed structures or retrofit. According to Corotis (2010), "If nothing had been done to improve the efficiency and lifetime safety of existing infrastructure, this would be reflected in the report." Titled Infrastructure Risk and Accountability Trust Evaluation card (Infrastructure RATE card), the report would include the total risk and expected future maintenance and operation cost imposed on the public.

While many aspects of the Infrastructure RATE card would need further examination, a draft version of the reporting method is illustrated in the Table 3.2. The report system is set up

in a way where credits and debits associated with existing and new infrastructure would be the basis for the current value of a community’s infrastructure reflecting discounted future benefits and costs. The basic concept of such financial risk report card could eventually be used as a public trust report card and used as a framework to influence political decision making.

Infrastructure Risk and Accountability Trust Evaluation (RATE) Card: Credits and Debits in Present Discounted Value							
	Prior Campaign Status			Current Campaign Status			Δ
Category	Value	Operations	Risk	Value	Operations	Risk	
Cash Assets							
Bonding Liens							
Taxing Changes							
Outside Funding							
Existing Infrastructure							
New Infrastructure							
Etc.							

Table 3.2 Sample Infrastructure RATE Card Required at Time of Elections (Corotis, 2010)

Unlike the ASCE report card which is published approximately every 3 years (ASCE), the Infrastructure RATE card would be published at least each time there is any election within a particular community or state (Corotis 2010). With access to the updated Infrastructure RATE card close to the time of election, the public is able to assess the political contributions to

infrastructure improvement. The reporting would also show if nothing has been done to reduce infrastructure risk and therefore could serve as a guide to elect a more beneficial policy maker for the sustainability of a community.

Another difference between the ASCE Report Card and the Infrastructure RATE card is the community scale with which the risk is reported. The ASCE Report Card rates the condition and capacity of infrastructure at a national and state level with only a handful of county ratings. The Infrastructure RATE card is designed to quantify risk at larger scales but also at the community level. It has been noted throughout this thesis that some communities may focus their concerns on local policy issues to a greater degree than high level matters of a larger scale. With a more personalized approach, the Infrastructure RATE card may increase a community's risk perception as they may feel more directly affected and accountable for infrastructure risk. Perhaps if the ASCE Report Card identified infrastructure condition and capacity in more local jurisdictions, public interest and awareness would increase, encouraging support for risk mitigation policy making.

While the ASCE Report Card and Infrastructure RATE card differ in methods of risk measurement, time period, and community scale of risk evaluation, both methods share the objective of raising public awareness and improving the nation's public infrastructure. These reporting techniques provide a method of bringing public recognition and political accountability to long-term policy decision making.

### *3.5 Cost Presentation Methods*

A benefit-cost analysis (BCA) is a financial comparison method presented earlier in this thesis for allowing the public and political leaders to understand the balance between risk and return. Comparing the costs and benefits of a proposed action allows investors and stakeholders

to determine the economic return to potential risk mitigation interventions and to support comparison between available alternatives. It should be noted that economic criteria are not the only parameter by which projects are judged, however the ProVention Consortium states, "...in the face of tight budgetary constraints and many competing demands for public resources, there is widespread pressure to demonstrate that government funding and international aid resources are well spent."

As discussed earlier, the public uses multiple criteria and often varying measures to assess the future benefits and risks associated with risk reduction (Corotis and Gransberg, 2006). This provides many limitations to the cost-benefit analysis, including the increased sensitivity to discounting in natural hazard events analyzed often over a timeframe of many decades. The discount rate to be used for environmental long-term issues has become a controversial issue in the engineering world, along with the incorporation of psychological time-variant influence into an otherwise constant economic discount rate. Other key topics discussed which influence the effectiveness of using financial based methods when communicating risk include present vs. annual cost presentation methods and assumptions regarding time period.

Throughout this research, it has become apparent that these cost presentation topics have been met with varying viewpoints. The controversy itself can reflect the psychological nature behind these topics and the fact that people see these issues from different perspectives. In order to explore these concepts more, discussions were held with four professional who are very knowledgeable and highly educated on the concepts of natural hazard risk and risk mitigation. The professionals who participated in this study were engineers Keith Porter, Research Professor at the University of Colorado at Boulder, Jim Harris, Principal of J.R. Harris and Company, Laura Samant, Associate Project Manager of the CAPSS project, and social scientist Kathleen

Tierney, Director of the Natural Hazards Research and Applications Information Center, Institute of Behavioral Science. It is hoped that these discussions will provide insight into the differing attitudes of engineering risk professionals and socialists alike on discounting and cost presentation methods. The discussion questions and complete responses are located in Appendix C.

As discussed previously in this paper, the use of a constant discount rate for environmental consequences is controversial since over a longer time horizon, future monetary and life safety benefits become trivial. The first question of the discussion elicits the participants' viewpoints on whether they believe using a constant discount rate to discount all future benefits is appropriate for a benefit-cost analysis for natural hazard mitigation. Porter and Harris agree with using a constant discount rate to discount monetary benefits. According to Harris, "In controlling economic loss, one must pick a discount rate, but the discount rate used could vary by the circumstances." Harris explains that one may adopt different discount rates for different kinds of physical elements. For instance, in Memphis where there are only a few significant bridges, losing one bridge may severely impact the overall economy. For such important public infrastructure, a lower tolerance for future loss must be taken into account in a cost-benefit analysis. He explains a higher tolerance for loss may be incorporated in the analysis of a bridge over a little creek that has four alternate routes within 2 miles where the significance of the bridge not collapsing is much lower. Tierney's response agreed with Harris in regard to a varying discount rate per event, but also expanded on the fact that each individual may have his or her own discount rate. She explains, "Perhaps the choice of weighting is individual. For example, if the property in question is an historic family farm and the owner wants to give it to his children, a much different discount rate may be used in a cost benefit analysis versus a typical

house.” Tierney adds that she has a difficult time with discount rates given there are multiple costs and benefits that are both comparable and not comparable. According to Tierney, “In light of the fact that there is a commensurability problem around benefits and costs, discount rates should be used with caution.”

Professor Porter discusses the use of a constant discount rate further in respect to discounting the benefits of life-safety. According to Porter, “Economists can offer rationale for and against discounting human life, but the rationale only matters if I (or others like me) find it compelling and integrate it into the value that we individually assign to avoiding a statistical fatality 100 years from now.” He explains that there is a difference between the price of something and the perceived value. Since the value of a statistical fatality is a personal judgment, it is difficult to assign a value, and even more an intergenerational value. Porter believes the rationale offered by economists for intergenerational discounting of human life is unconvincing, inconsistent, and fatally flawed, adding, “...if one accepts any positive discount rate that applies perpetually, then at some point in the future, avoiding the fatalities of 1 million people would be worth less to me now than the café mocha on my table.”

Previous discussion in this thesis introduced the incorporation of a psychological time variant influence to a constant discount rate. Many authors believe that when discounting the consequences of natural hazards, the discount rate should change with the time horizon (Percoco, 2002, Thaler, 1981, Corotis, 2010). When asked for her views on this topic, Tierney replied that the topic of a time-variant discount rate is subject to much debate. She explains, “We must agree what we are talking about as far as a time horizon goes. Often, a cost-benefit analysis is based on a life expectancy that is shorter than the actual lifetime of a structure.”



Harris related a time varying discount rate to the factors of life safety built into safety measures. For wind and snow loads, the importance factors that are applied to the loads have the effect of reducing the probability of failure on some constant time basis. Harris adds, “This is not accurate but it is a very rough approximation to think of risk categories for structure use.” The building categories in ASCE range from Category 1 which is used for buildings which present very little risk to human lives to Category 4 which is for buildings that pose the most risk including facilities which contain hazardous materials. The time declining risk approximation takes place in terms of people put at risk if the structure failed. Category 1 affects  $10^0$  people, Category 2 affects  $10^1$  and  $10^2$ , Category 3 affects  $10^3$  and Category 4 affects  $10^4$  people. According to Harris, “If the potential life loss is a larger number, we’re going to design for a higher level of safety, making failure a more rare event. That is like saying we are taking a time discount on life safety.”

The next topic in the discussion dealt with the concept of presenting costs as a present discounted value versus an equivalent annual value. As discussed previously, converting costs to an equivalent annual cost versus a large present discounted value may provide justification for political spending for long-term events (Corotis 2010). The participants in this study were presented with a scenario of owning a commercial building with a 1% risk of significant damage due to an earthquake each year. It was explained that it would cost \$750,000 to retrofit the building to dramatically increase its strength in an earthquake and the cost of damage without retrofitting would be \$4 million dollars. The participants were then presented with the cost and benefits of retrofit using a present discounted value and an equivalent annual discounted value and asked which they found to be most meaningful. Porter and Samant agreed that the method of presentation depends on the user and the purpose of the cost benefit analysis. Porter explains,

“If I am responsible for institutional property, I would make my choice based on the presentation I think will be most compelling or meaningful to ... whoever I report to on capital investments.”

Porter believes the annual discounted value presentation to be more meaningful, particularly with a loan involved, but would offer the present discounted value as another way to look at the investment.

Tierney replied that she would likely not have a tendency to retrofit given either of the cost presentation formats since her focus would be on the low 1% risk of a significant earthquake each year. She comments that if the probability was expressed over a more effective time period, her perception of risk may change. Porter agrees, adding, “If I am a real estate investor and plan on holding the building for a normal investment period (3-10 years) ... I find the investment unconvincing in any case. Reason is that it is an investment with only a 3-10% chance of producing any benefit. I do not believe the retrofit will have a market value when I sell the building.”

The next discussion subject focused on the concept of a “scenario event”. Instead of incorporating probabilities and discounting into a cost presentation analysis, many studies have been basing their analysis on a particular earthquake scenario occurring at a specific time. For example, the CAPSS study which will be presented in a case study later in the paper focuses their analysis on the scenario that the earthquake will happen today. All participants in this study agreed that this simplification is beneficial for communicating risk to the general public and policy decision makers. According to Harris, “When you are dealing with real risks in a time frame that people can’t relate to, the scenario event tends to get around that.” Porter and Samant agree that while statistically savvy groups such as insurance actuaries do prefer probabilistic

measures, a simpler approach is more effective to motivate public policy. Samant adds, “When using a discount rate in general you’re losing a bunch of people.”

All of the participants did note the limitations of using a scenario event. According to Samant, such a simple approach where one avoids the discount rate all together may present a slightly inaccurate picture in terms of a cost-benefit comparison, but it provides an intrinsic sense of risk to those who may not be familiar with probability and the time value of money. As a caveat, Samant adds that earthquake and retrofit scenarios do make a lot of assumptions, which may provide a range of error to a study. Tierney agrees, adding her own caveat that “Scenario events are beneficial for the average decision maker, provided there is a range presented.”

It was also discussed that the way risk should be communicated would depend on the specified audience. According to Samant, “For a sophisticated audience, like an insurance company or staff of economists, risk can be communicated in a more complex and accurate form” (Samant, 2011). Accuracy is particularly important during risk mitigation policy making when finances, careers, and politics are involved. However, Samant adds, “When motivating public policy where the public doesn’t think about discounting and probability on a daily basis, go much simpler on your approach.” Therefore, the scenario approach is only appropriate in certain circumstances.

The next discussion question elicited the participants’ thoughts on the use of an infinite planning period versus a finite one. This question relates to previous discussion of Corotis’ (2009) hypothesis that longer design lifetimes provides additional political reward, and Keller et al.’s (2006) notion that longer time periods provide increased risk perception. Discussion participants were presented with the same previous scenario of owning a commercial building and were presented with the discounted annual costs and benefits of retrofit given a structure

with a 50-year lifetime and one with an infinite lifetime. Samant and Porter agree that the use of an extended lifetime is appropriate for large institutions. According to Samant, “For an academic building, an infinite lifetime may make sense. But in the real world it may seem a little unconnected.” Professor Porter discussed that he would tend to choose some middle ground between 50 and infinite years for the lifetime of large institutions. He offers reference to the lifetimes of various government institutions including the London County Hall which is nearly 90 years old and still in service as well as the Paris Hotel de Ville (its city hall) which is now 380 years old. Using these and others as reference, Porter explains that a 250-year lifetime seems to be an appropriate compromise, which is long enough to be effectively infinite in a cost-benefit analysis.

Harris and Tierney offer another direction when responding to this question, both agreeing that people have difficulty thinking in terms of infinite years. According to Harris, “I think that people who make decisions about cost-benefit ratios probably prefer to make decisions on a deterministic time frame, not an amorphous time frame. It is similar to talking about a fireproof or earthquake-proof building; there is no such thing.”

Finally, the last question in this study elicited any additional comments on cost presentation methods. Porter provided a very interesting response, explaining that he does not believe that a benefit-cost analysis is a sufficient basis for making natural-hazard risk-mitigation decisions. According to Porter, “The most compelling reason is that it pays no attention to scale: a 4:1 benefit-cost ratio means something very different when the absolute value of the benefit is \$4 at a cost of \$1, versus when the benefit is \$4 billion at a cost of \$1 billion. The former is a trivial issue, the latter very serious, but they both have a 4:1 benefit-cost ratio.” Porter also explains that presenting benefits in a benefit-cost analysis does not offer a way to quantify the

existential threat some natural disasters can pose to a city or state. Porter offered the following example: In the May 27th 1995 Sakhalin Island earthquake, the town of Neftegorsk was effectively destroyed: approximately 2,000 of the 3,176 residents in the town were killed, and the settlement has not been rebuilt (Ivashchenko et al., 1997). Porter explains that it is unclear how a benefit-cost analysis can address such existential threats which are larger than the value of avoiding the individual fatalities and property value loss.

While the responses to the discussion questions produced both similar and varying views from the participants, this discussion does conclude that these topics remain controversial for a reason. The engineering and social science professionals who participated in this study base their responses on different views and experiences, which provide different insight into the cost presentation topics discussed. Many professionals also added several caveats to their responses, indicating the general open nature of such topics. For example, some participants support a constant discount rate to discount monetary benefits in hazard mitigation benefit-cost analysis, but the rate may vary per event and individual. Some participants support a time varying discount rate, but there is debate on what is a proper time period. Perhaps an appropriate conclusion to draw from this discussion is that there are no prescriptive definitions or rules when using financial-based methods to communicate risk and return in risk mitigation decision making. While the use of financial-based methods is essential in communicating risk, each cost comparison method used in risk mitigation must take into account the various standards used to assess future benefits and risks, specific to the decision making audience. As concluded in this discussion, these standards may vary.

## Chapter 4

### CAPSS Case Study

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San Francisco is currently considering mandating the rehabilitation of soft-story, high-occupancy, wood-framed residential buildings to mitigate the potential for catastrophic loss of housing in future earthquakes (Samant et al., 2009). Such buildings represent 7% of the housing units in San Francisco and housing for 8% of the city's population. These are the types of buildings that suffered extensive damage in the 1989 Loma Prieta Earthquake and are at high risk in future earthquakes (see Figure 4.1).



*Figure 4.1 - Two multi-unit, wood-frame soft-story buildings that collapsed in the Marina District during the 1989 Loma Prieta earthquake. (ATC, 2009: Image courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley)*

Soft-story wood-frame buildings are among San Francisco's most numerous, most vulnerable and most readily-retrofitted residential building type; hence the city's interest in the risk posed to them. In 2008, Mayor Gavin Newsom directed the Department of Building

Inspection (DBI), through its project entitled The Community Action Plan for Seismic Safety (CAPSS), to provide the City with a plan of action to reduce earthquake risks to this class of building, and to produce guidelines for repair and rebuilding after an earthquake.

In order to develop a plan to reduce earthquake risks to soft-story buildings in San Francisco, the CAPSS project team set the objective to identify how many multi-family wood-frame soft-story residential buildings exist, in which neighborhoods, and how they are used. The team then designed prototype structural retrofits to increase the structural safety of the soft-story buildings to varying levels and calculated the costs of such retrofit options. The team studied economic and safety implications of either retrofitting or not retrofitting and finally identified various policy approaches to improve the seismic performance of such soft-story buildings in a major earthquake. Details of the risk analysis can be found in Porter and Cobeen (2009).

Completed in January 2010, the soft-story portion of the CAPSS project was successful in providing the City with a plan to reduce earthquake risks to soft-story buildings. While San Francisco has yet to mandate the retrofit of seismically-deficient buildings as suggested by the CAPSS team, the project was successful in showing that the suggested risk mitigation is important to the City, and therefore encouraging change. In a CAPSS Advisory Committee Meeting (2010), Laurence Kornfield, Chief Building Officer of San Francisco's DBI, stated "The CAPSS work was a groundbreaking step translating technical knowledge into new forms for policymakers." There were many strategies that led to the successful completion of the CAPSS project with promising intentions to improve seismic safety and sustainability to the city San Francisco. Such approaches implemented by the CAPSS team are discussed in light of the five major strategies discussed in this paper: public education, public involvement, community

values, overcoming incompatibilities of lifetimes, and employing successful financial based methods.

In a CAPSS Advisory Committee Meeting (2008), it was stated that one of the biggest goals of the CAPSS project is to educate the public to the consequences of earthquake damage and the meaning of resiliency. The team was able to achieve this goal by both involving the public in most facets of the project as well as employing various communication strategies to educate the public on San Francisco's seismic risk.

As discussed earlier, a challenge in effectively communicating risk arises in the fact that the general public has difficulty thinking in probabilistic terms (Patt and Schrag, 2003). Studies have shown that since people often underestimate small probabilities, which are frequently associated with natural hazards (Kahneman and Tversky, 2000), it is often advantageous to simply focus on the consequences of an event as if it did occur as opposed to focusing on the probability (Taleb, 2010). A similar approach was employed in the CAPSS soft-story study. The CAPSS soft-story team decided to assess the benefits of the retrofitting by examining losses to the entire stock of multifamily soft-story wood-frame dwellings, given the occurrence of four scenario earthquakes, as opposed to performing a probabilistic risk assessment that would consider all possible earthquakes and their likelihood of occurrence (ATC, 2010a). While the analysis presentations to the public included mention of the likelihood of each earthquake scenario under investigation, it was emphasized that each of the earthquakes had happened in the past and could happen again at any time. The study was further simplified by focusing on the costs and benefits of retrofitting against one scenario magnitude 7.2 earthquake on the San Andreas Fault as if it did occur. By simplifying the presentation to one earthquake of a similar magnitude to previous earthquakes, and explaining "this may happen tomorrow," the



imaginability and “realness” of the event is likely to increase. This increase in availability often correlates to a heightened risk perception (Slovic et al., 2004).

Past experience is an important factor in people’s perception of natural hazard risk (Keller et al., 2006) and it has been shown that relating to past experiences has also influenced the adoption of seismic hazard precautions (Jackson, 1981). The negative affect associated with natural hazards may also be aroused through experimental manipulation (Keller et al., 2006). As an aid to effectively communicate risk, the CAPSS presentations included images of the damage to buildings similar to those existing in San Francisco today, from the 1906 San Francisco and 1989 Loma Prieta earthquakes. By including photos of the damage and collapse in previous earthquakes and explaining that such an earthquake could happen again, the public is presented with a negative affect that can influence their perception of risk.

Public involvement was widely used in the CAPSS project and as a result, increased public education, addressed public concerns, and increased support for the program. The CAPSS project was referred to as a community effort, and was guided by a volunteer Advisory Committee, which included representatives from a number of neighborhood and community groups, earthquake engineers, and officials of the City of San Francisco (CAPSS E-Newsletter #2, 2009). The CAPSS Advisory Committee held monthly meetings open to the public where all interested parties could provide input on the project and critical issues could be addressed. The Committee also hosted various workshops, which were used to both educate the public and gain public insight and concerns (CAPSS E-Newsletter #2, 2009). Local engineers, representatives from neighborhood and community organizations, officials from the City of San Francisco and members of the public participated in the extended discussions and many of the comments and

questions raised during the workshop were incorporated into the recommendations released in various reports.

The options and analysis outcomes performed by the CAPSS team were presented to a community group of building owners and tenants to consider what policy options ought to be recommended to the City. While DBI officials, engineers, and other technical experts were in attendance, the discussions and choice of policy recommendations were led by the community group, not the technical personnel. The policy recommendations developed by the community group were also strongly based on the framework of public education and involvement. In the “Here Today Here Tomorrow: Community Action Plan Report” (2010) the CAPSS team suggests the City of San Francisco inform the public of risks and ways to reduce risks through focused education and outreach campaigns. The report says the campaigns should focus on “...building owners, tenants, realtors, and others to improve their understanding of earthquake risks and measures to manage the risks, and to facilitate the market for retrofiting” (ATC, 2010b).

A critical aspect of presenting the results of the CAPSS studies was consideration of which metrics of seismic performance would be of greatest interest to the City. As discussed earlier, people want to know how they will be directly affected by a decision. Accordingly, case studies have shown that it is important to focus on what the affected parties believe to be at risk in a particular situation (NRC, 1996; Olshansky, 2003; and Godschalk et al., 2003). Therefore the question is: What community values matter most to the City of San Francisco? The CAPSS soft-story team decided to focus analysis results on post-earthquake safety tag color (whether residents would be allowed to re-enter their homes and businesses after the earthquake), whether the dwellings would be repairable, and what the cost of repairs would be. The table below

presents estimates of the estimated damage and loss to multifamily, soft-story wood-frame residential buildings in a Magnitude 7.2 earthquake on the San Andreas Fault (ATC, 2010a). These impacts only consider damage from shaking and do not include the impact from fires following an earthquake.

Building Occupancy	Number of Buildings in Various States of Damage <sup>a</sup>			
	Usable, Light Damage	Usable, Moderate Damage <sup>b</sup>	Repairable, Cannot be Occupied	Not Repairable <sup>c</sup>
Single-Family Houses	45,000	54,000	11,000	1,700
Two-Unit Residences	8,200	7,400	3,200	290
Three-or-More-Unit Residences <sup>d</sup>	7,200	7,500	7,200	1,100
Other Residences <sup>e</sup>	300	400	80	40
Commercial Buildings	1,600	2,400	630	290
Industrial Buildings	750	820	320	210
Other <sup>f</sup>	330	280	60	30
<b>Total<sup>g</sup></b>	<b>63,000</b>	<b>73,000</b>	<b>23,000</b>	<b>3,600</b>

Table 4.1: Estimated Damage to City’s Housing After M7. 2 San Andreas Fault Scenario (ATC, 2010a)

The authors estimate that after such an earthquake, 85,000 dwelling units would be unsafe to occupy and of these approximately 11,000 dwelling units would need to be demolished. This will leave only about 74% of the housing units safe enough to occupy and provide shelter for those without housing (ATC, 20010a). Note these figures are for the San Francisco housing stock as whole, not just soft-story wood-frame dwellings. The study also estimates that economic losses could total as much as \$40 billion. Additional effects due to damage to businesses and infrastructure life lines would also add a large economic impact on the city (ATC, 2010a).

The study results also focus on more local community values, including the effects on affordable housing, small businesses, historic buildings, and the overall unique character of the city (ATC, 2009). In the first of four reports titled “Here Today-Here Tomorrow...Potential Earthquake Impacts” the CAPSS team explains:

“The next major earthquake that strikes San Francisco will change the City and its people. San Francisco is a world-class city with many special attributes that draw businesses, innovative people who want to live here, and visitors from around the world. In the long-term, San Francisco will recover and thrive, but it will be a different San Francisco.”

Retrofitting vulnerable buildings would not only preserve the cultural and architectural character of the city’s neighborhoods, but also affect housing affordability for low and middle income residents (ATC, 2010b). After extensive earthquake damage, rent-controlled apartments may no longer be under rent control once rebuilt. The study estimates that more than 900 commercial buildings and 500 industrial buildings would not be able to be occupied after a Magnitude 7.2 San Andreas Fault scenario along with \$4 to \$11 billion in damage costs to commercial buildings (ATC, 2010a). In addition to the property repair costs, the closing of businesses creates direct and indirect business-interruption losses in the local economy across all economic sectors. The CAPSS reports estimate the business-interruption losses due to a Magnitude 7.2 San Andreas Fault earthquake would generate a loss of approximately \$650 million in indirect activity, or business-to-business lost expenditures within the City of San Francisco (ATC 2010b).

The presentations also included a socioeconomic analysis of who lived in the subject buildings: residents' ethnic, income, and other demographic characteristics; renter versus owner occupancy; how many units are rent controlled; citywide residential vacancy rates; and other relevant parameters. That is to say, the presentations focused on the concrete, specific, accessible, and tangible parameters. In presentations, workshops, and reports including the ATC-52-2 Report, *A Community Action Plan for Seismic Safety*, the CAPSS team explains that much of this damage is preventable. Now that the risk of a major earthquake is presented in light of the city's values, it is up to San Franciscans to decide how much to invest in mitigation efforts to reduce the consequences of future earthquakes.

In addition to focusing on public education and community values, overcoming the incompatibility between political short-term goals and long-term planning is crucial in risk mitigation decision making (Corotis, 2010). An interesting sequence of events unfolded in the early stages of the CAPSS project that both increased political accountability and as a result, helped overcome the chasm between political rewards and long-term sustainability. The CAPSS project originally began work in 2000, but was suspended in early 2003 just before publication of the study, reportedly due of a political rivalry unrelated to CAPSS. One of the rivals eventually retired, and in 2006 the CAPSS project resumed. Some urgency was added in July 2008, shortly after the May 2008 Sichuan, China earthquake. In an alarming news article in the San Francisco's major daily newspaper (Selna, 2008), a leading structural engineer shared his opinions on the lack of risk mitigation in the City. As a result, Mayor Newsom issued an order (Newsom, 2008) that directed CAPSS to quickly develop a mitigation policy for soft-story residential buildings.

The mayor's reaction may be viewed as an exigent political situation versus acting to protect the public, but the notable aspect is that he took a proactive stance. This situation is an example that decision-making outcomes are affected when the decision maker knows he or she is being observed (Kerjan and Slovic, 2010). The Mayor was facing a public accusation of hiding natural hazard risk, and he acted in a responsive manner.

Strategies in overcoming incompatibilities between political and infrastructure lifetimes can also be seen in CAPSS final recommendations to the City of San Francisco. In the "Here Today Here Tomorrow ... Community Action Plan for Seismic Safety," the CAPSS team recommends important actions directed towards San Francisco's government leaders to reduce the consequences of future earthquakes. Many of these actions are intended to increase political and public accountability in risk mitigation, and therefore encourage long-term planning.

According to the CAPSS authors, "Implementing earthquake mitigation measures needs to be an ongoing concern of the City with standing equal to other programs" (ATC, 2010b). The authors suggest that San Francisco establish a clear responsibility within city government for preparing for and reducing the risk from earthquakes. The CAPSS team hopes that this will clarify risk mitigation as a long-term effort and will not fade as people retire and other issues emerge. The team recommends the City identify a single official within the Chief Administrative Officer's Office who will be responsible for achieving earthquake resilience by carrying out current recommendations of the CAPSS project as well as working towards additional risk mitigation strategies (ATC, 2010b). The report states that the office should also work with an advisory committee comprised of neighborhood groups with varying interests. Representative insights and concerns can provide valuable perspective and improved accountability for the projects performance (ATC, 2010b).

Ideally the goal of the CAPSS project is to increase the number of seismic retrofits voluntarily conducted by owners (ATC, 2010b). However, knowledge gained from the Unreinforced Masonry Law (CSSC, 2006) indicates that many owners will not evaluate or retrofit their buildings until required to do so. Under the Unreinforced Masonry Law, the California Seismic Safety Commission recommended that the state legislature allow each jurisdiction to establish its own loss-reduction program with the intentions of allowing each jurisdiction to tailor the program to meet the community specific political, economic, and social needs. Three main types of loss reduction programs emerged, including (1) mandatory strengthening, (2) voluntary strengthening, and (3) notification only (CSSC, 2006). In the California Seismic Safety Commission's 2006 report on the status of the Unreinforced Masonry Building Law, it was noted that 87% of the unreinforced masonry buildings in Mandatory Strengthening Programs have either been retrofitted or demolished compared to 24% in voluntary programs (CSSC, 2006). It was also noted that while voluntary programs were rarely successful, they saw a higher success rate when incentives were established for retrofitting. While there was a 20% rate of retrofit for the eight cities with voluntary programs and economic incentives, the 31 jurisdictions without incentives had a 14% rate of retrofit (CSSC, 2006). This lends to the conclusion that economic incentives can increase the rate of seismic risk reduction.

Taking this into consideration, the CAPSS team suggests that deadlines requiring evaluations and retrofitting of weak buildings are needed to provide urgency to the issue. The team believes that, "Requirements and deadlines show that earthquake risk is an issue the City government takes seriously; in contrast, a purely voluntary program suggests that this issue is not viewed as important" (ATC, 2010b).

The CAPSS authors also recommend offering incentives for retrofit of buildings. While the owners are ultimately responsible for the seismic performance of their buildings, the City also has an interest in reducing the amount of direct and indirect damage to San Francisco's privately owned building stock. Therefore, it only makes sense that the City should enact various programs to encourage owners to retrofit and to increase their ability to afford the cost of retrofitting. Incentives recommended by the CAPSS team include modifications to zoning regulations, tax rebates, loans, and fee waivers (ATC, 2010b). The team also recommends providing technical assistance and training programs to make retrofitting easier (ATC, 2010b).

In addition to political awareness and incentives to retrofit, public knowledge and accountability also help provide political recognition for long-term planning (Corotis, 2010). The CAPSS team suggests that all building owners should be required to get an engineering evaluation of their buildings and compare the results to a designated minimum seismic retrofit standard (ATC, 2010b). The results can then be shared with tenants and prospective buyers and made part of the public city records, along with a required plan of future actions which will reduce any seismic deficiencies. The seismic evaluation will allow prospective buyers and building occupants to consider seismic issues when making decisions about purchasing, renting, or using the building. The CAPSS team recommends the recorded seismic risk to be used to assist in making decisions to retrofit and also be available as an input for market pricing of real estate (ATC, 2010b). Publicizing seismic risk provides building owners with heightened accountability for mitigating seismic risk for their buildings.

Finally, the CAPSS project utilizes strategic financial-based methods as a means of providing an understanding to the public on the balance of risk and return for retrofitting. The CAPSS authors decided to assess the risks and benefits of retrofitting by examining losses to the



entire stock of soft-story wood-frame multifamily residential buildings, given the occurrence of four varying scenario earthquakes. The team also decided to examine four retrofit options, from the do-nothing alternative, to an intensive ground-floor strengthening option. The CAPSS authors believed the most meaningful way to interpret the economic losses and benefits due to retrofitting is to compare the financial impact from the various earthquake scenarios and retrofit schemes (ATC, 2010a).

Since it is uncertain when an earthquake will occur, the CAPSS authors decided to present the costs and benefits of retrofitting as if the earthquake occurred today. By doing this, the study avoided the issue of discounting future benefits and avoided a probabilistic risk assessment (which would have included a number of uncertainties: the magnitude and location of earthquakes, the date on which they occur, and so on). In reality, the present value of the benefits of retrofitting would depend on when earthquakes occur, the discount rate chosen, etc. By assessing the benefits as if the earthquake occurs today, the present value of the reduction in future losses larger than if it is discounted. According to the CAPSS study, “It is reasonable to expect an earthquake that is closer and, perhaps, larger than Loma Prieta to strike San Francisco soon” (ATC, 2010a). As noted earlier, a statewide assessment of the likelihood of earthquakes estimates that there is a 63 percent chance of at least one magnitude 6.7 or greater earthquake in the Bay Area sometime in the period 2008-2037 (WGCEP, 2008). Therefore, assuming an earthquake will happen in a scenario analysis is not an unrealistic assessment when communicating risk to the general public.

The soft-story element of the CAPSS project examined how earthquake damage would lessen in four scenario earthquakes if all 2,800 multi-unit wood-frame buildings studied were retrofitted to each of the three retrofit schemes in addition to not retrofitting. To reflect the

uncertainty in their loss estimate, the authors present potential losses as a range. The initial loss estimates were calculated using a numerical model derived from the loss estimation software developed by FEMA known as HAZUS-MH, which is based on earth science, engineering, and observations made following damaging earthquakes, combined with assumptions regarding the scenario earthquake, site conditions and responses of representative buildings (ATC, 2010a). The loss estimates were not actually performed in HAZUS-MH, partly owing to the fact that at least two serious programming bugs had been revealed early in the process. Instead, a method documented in Porter and Cobeen (2009) was substituted for HAZUS-MH.

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

Table 4.2 - Expected Damage Before and After Three Retrofit Schemes for a Sample of 2,800 Multi-Unit, Wood-Frame Soft-Story Buildings in Four Scenario Earthquakes (ATC, 2009)

The loss estimates with the three retrofit schemes as well as without retrofit are shown in Table 4.2. It can be seen that seismic retrofits greatly reduce the financial damage expected in this stock of buildings. The CAPSS soft-story authors also mention that these results are based on numerical analysis and professional judgment, and therefore are presented as a range due to uncertainty in such estimates. The ranges are bounded by one value that is the simple output of modeling, and another that was recommended by a review panel, drawn from their own judgment, to reflect uncertainty.

The soft-story element of the CAPSS project also examines the direct construction cost of each retrofit scheme for four representative San Francisco buildings, and then compares it to the reduction in repair cost that retrofitting would produce, conditioned on the occurrence of each scenario. The CAPSS authors do not suggest that the benefits and costs are directly comparable, that is, they make clear that the ratio is not a benefit-cost ratio in the sense of a benefit-cost analysis, since the study did not calculate probabilistic risk, but rather scenario risk. The cost estimates for direct construction costs, based on the representative wood-frame soft-story buildings are listed in Table 4.3. Building owners would initially bear the seismic retrofit cost, though it was recognized that at least some would be passed on to renters (the project report did not quantify how much of these costs would be passed on to renters).

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

Table 4.3 - Direct Construction Costs Estimated for Four Representative Multi-Unit, Wood-Frame Soft-Story Buildings for Each Retrofit Scheme (ATC, 2009)

Retrofitting these wood-frame buildings ultimately saves owners money by reducing damage and post-earthquake repairs, and avoiding business interruption, when a potentially damaging earthquake occurs (ATC, 2010a). The estimated savings due to retrofit varies depending on the magnitude and location of the earthquake and the nature of the retrofit. The CAPSS soft-story authors report that in the four scenario earthquakes examined, “Building owners as a whole save between \$400 million and \$1.5 billion, depending on the level of retrofit, in reduced damage to building structure and contents. The costs of all retrofits (to this class of buildings) citywide would total about \$260 million, to achieve a performance that would allow most residents to remain in their damaged but safe homes after an earthquake” (ATC 2010a). Table 4.4 shows the avoided financial losses to a representative building in a Magnitude 7.2 earthquake on the San Andreas Fault with the various retrofit options.

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

Table 4.4 - Average Loss Avoided Through Retrofit Per Residential Unit in a Magnitude 7.2 Earthquake on the San Andreas Fault (ATC, 2009)

When comparing the retrofitting construction costs and avoided future repair costs (which can also be thought of as benefits), it is obvious that the resources invested in retrofit result in significant savings after an earthquake. By deliberately excluding financial discounting over time as well as ignoring both earthquake probability and other possible earthquakes, the costs and savings of the retrofit options are more easily understood, though at the risk of giving

the illusory impression of immediate financial savings. However, Porter (2011) explained that nobody in the public meetings seemed to think there would be immediate benefits from retrofit and it seemed clear to everyone that the savings would only be realized when an earthquake occurred.

The CAPSS team took many different approaches which led to the successful completion of project. Each of the five major strategies discussed in this paper were addressed in the project, offering both support and new insight to the current knowledge and analysis previously discussed in this thesis. Effective public education and involvement enabled the project to communicate seismic risk to the public, particularly in light of community characteristics specific to San Francisco. The real test to the effectiveness of this communication is whether the public takes action in reducing this risk voluntarily, or by an imposed mandatory retrofit. With future goals of adding political oversight to the program, requiring mandatory structural evaluations of buildings and offering incentives to retrofit, the CAPSS project is intended to not only communicate seismic risk but also improve future seismic safety and sustainability.

# Chapter 5

## Conclusion

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### *5.1 Concluding Remarks and Agenda*

Engineering risk analysis is currently developing from a purely mathematical field to one that incorporates the psychological rationale that drives the political decision maker, and more importantly the public. It is an exciting opportunity for engineers to bridge the gap between low-probability, high-consequence events and the response and motivation of the public and their leaders. In order to accomplish this, effective communication strategies must be implemented to convince the public of the importance of natural hazard risk. In addition to this, financial-based instruments must be developed to justify and promote making decisions now for long-standing sustainability.

The methods presented in this paper provide an important next step for incorporating natural hazard risk into long-term development plans. The solutions and risk communication tools which were developed in this paper are summarized below in the form of an agenda for promoting risk mitigation decisions. While this agenda is only advisory, and does not include concrete rules and steps for incorporating hazard mitigation in policy decisions, it does provide insight and recommendations for the public, engineers, and decision makers alike to overcome many challenges which have limited optimal sustainable planning in the past.

- **Public Risk Perception:** Since people often underestimate the small probabilities associated with natural hazards, risk communication techniques must be developed to raise risk awareness and ensure adequate risk perception. This thesis has shown that expressing probabilities over a longer time period increases the affect and availability of an event which influences the perceived risk. As past experiences often increase the

imaginability of an event, focusing on historical hazard catastrophes and educating the public on such disasters can also effect risk perception. Finally, eliminating probability entirely and presenting risk in terms of a scenario outcome has also been shown to be more impactful for the general public.

- **Public Involvement:** Public participation has been shown to increase citizen interest and support for hazard mitigation. While the discussion in this paper did not review specific modes of public participation, literature review and case study events share characteristics of successful public involvement in environmental policy decision making. This thesis shows that creative participation programs are successful when they include educating the public on the specific issue at hand, incorporating public values into alternatives and solutions, and increasing the importance and credibility of public influence in decision making. Focusing on these key aspects has been shown to increase public interest and acceptance, and add valuable insight in developing environmental alternatives and policies.
- **Incorporating Community Values:** As previously discussed, risk communication is effective when it addresses what the affected parties believe to be at risk. People want to know how they will be directly affected. Beyond financial destruction, fatalities, and injury, there are some direct and indirect losses which are very important to a community. As seen in the case studies discussed, presenting the costs and benefits of a risk mitigation activity based on the framework of specific community assets can be successful for promoting hazard mitigation policy. Incorporating specific regional values localizes the issue and draws public interest and support. This thesis has also presented

illustration of how hazard mitigation can be “piggy-backed”, or accompany more immediate community issues which may draw more attention.

- **Overcoming Incompatibility of Lifetimes:** The conflict between long-term optimal policy and short-term political decision making can be attributed to lack of showing a need for hazard mitigation, and comparatively, lack of public and political accountability for such issues. The implementation of reporting methods similar to the ASCE Report Card and the Infrastructure RATE Card can be used to promote a sense of accountability for risk mitigation decisions of a longer time scale. It was noted that a possible contributing factor to the success of these methods includes more frequent publication and more localized reporting. As shown by the events in the CAPSS study following the Mayor’s response to public concern, public education can also influence political accountability for long-term sustainable planning.
- **Cost Presentation Methods:** While financial-based tools are effective in communicating risk and return, this thesis has shown that there are many sensitivities and varying views when it comes to the components which comprise the financial accounting of costs and benefits. While the use of a set discount rate is currently used to discount economic loss, it should be noted that the value of discounting can be individual to the event, region, type of infrastructure, and owner. By using a scenario event and assessing costs and benefits as if an event occurred now, discounting can be eliminated. While this does have its limitation, many professionals believe this provides a more effective way in communicating the costs and benefits of risk mitigation to the general public and political leaders. Also, it has been shown that expressing the cost of hazard mitigation as an



equivalent annual cost versus a large present discounted value can be beneficial in justifying public long-term spending.

## *5.2 Thesis Limitations*

While the recommendations mentioned above are rather broad with respect to where and for whom they apply, there are certain limitations which would influence the effectiveness of such communication tools. Noticeable limitations discussed below include the financial demographic of those at risk to a hazard and geographic location constraints.

The purpose for developing these communication tools is to promote risk mitigation through retrofit. The recommendations and tools presented in this thesis do not take into consideration the financial capacity of the public at risk to a natural hazard. If homeowners are not financially capable to afford retrofitting, communication strategies for risk perception, public participation, and effective cost presentation methods have little influence on their ability to retrofit. For example, as of 2005, nearly eighty percent of Haitian citizens lived on less than \$2 a day (U.S. Department of State, 2011). It is obvious that rebuilding and retrofit is essential for Haiti, but the vast poverty in the country makes retrofitting impossible without financial assistance. Instead of the communication tools outlined in this thesis, financial solutions for low-income homeowners to afford retrofit must be developed. The recommendations in this thesis are ultimately intended for homeowners who are able to afford retrofitting.

Another limitation to this research is geographic constraints. These communication tools are only effective if people in a region are willing to accept that they are at risk to natural hazards. Even if regions are at risk, lack of previous local disasters provides a limitation to risk perception. For example, while people living in the New Madrid seismic zone in the south-central United States are at risk to future damaging earthquakes, public awareness of such risk

may be low due to the fact that the last destructive earthquake in the region dates back to 1812. This limits the effectiveness of utilizing some of the recommendations with respect to public risk perception presented in this thesis.

Finally, this thesis does not take into consideration the various alternative uses of funds which can be put toward mitigation planning. In both public and private spending, there are various projects, departments, etc. that money can go towards. This thesis is intended to promote risk investment decisions independent of the availability of funds and issues arising from the alternate uses of the same mitigation funds.

Additional challenges to this research may also spur from political instabilities and cultural differences. Many of the recommendations in this thesis are generic and can be modified with respect to a region's social, economic, and political characteristics.

### *5.3 Future Research*

As natural hazard risk communication is a very broad topic, there are many additional issues and factors which were not included in this thesis. Further focus and research on each topic discussed may lend additional insight and conclusions into effective risk communication methods. However, the general goal of this paper is to develop communication techniques that overcome the prevalent gap between short-term planning and long-term sustainability. By focusing on a variety of issues that pose a challenge to risk mitigation, it is possible to develop ways to overcome various incompatibilities affecting risk perception, thus leading to better promotion of the importance of hazard mitigation. The general literature review and reassessment of each topic is intended to give an idea of the main issues involved and possible solutions.

For future research, the next step would be developing a specific tool that would directly increase public understanding, perception, and accountability of infrastructure risk, and also promote retrofit. This could be in the form of a reporting system similar to the proposed Infrastructure RATE Report Card, or perhaps in the form of a marketing tool.

In addition to various communication methods presented in this paper developed to maximize risk perception and promote retrofit, people are often incentivized to retrofit through financial rewards. While many regions already incorporate financial incentives to retrofit in the form of tax rebates, loans, grants, etc., a possible research topic would be the incorporation of hazard mitigation into insurance premiums. Each building owner would be required to get a structural evaluation of his or her structure, which notifies the owner of any structural deficiencies, along with retrofit options. The owner's insurance premiums and resale value would then be adjusted to reflect the level of their building's structural performance against earthquakes. For example, if a structure was built to the current seismic building codes, the insurance premium would be at a minimum. On the other hand, if a building was severely under-designed, the insurance premium would be inflated and the resale value of the building would be much lower than if the structure were built to code requirements. The overall objectives would be to increase public accountability for seismic performance, increase public safety, and provide incentive to retrofit.

Obviously, there is much research that must be done on the economic, social, and political implications behind such a program. This research would begin by investigating the background and effectiveness of similar programs and study various modifications and improvements to such programs. Surveys, questionnaires and discussions with affected building

owners would be necessary as well as incorporating their concerns into the development of the program.

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## APPENDIX A: Earthquake Retrofitting Questionnaire

**1. Where do you currently live?**

	Alameda	Alpine	Amador	Butte	Calaveras
Specify which County	5.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)

Colusa	Contra Costa	Del Norte	El Dorado	Fresno	Glenn	Humboldt	Imperial	Inyo	Kern	Kings	Lake	Lassen
0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)

Los Angeles	Madera	Marin	Mariposa	Mendocino	Merced	Modoc	Mono	Monterey	Napa	Nevada
44.4% (8)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)

Orange	Placer	Plumas	Riverside	Sacramento	San Benito	San Bernardino	San Diego	San Francisco	San Joaquin	San Luis Obispo
0.0% (0)	0.0% (0)	0.0% (0)	11.1% (2)	5.6% (1)	0.0% (0)	5.6% (1)	11.1% (2)	0.0% (0)	0.0% (0)	0.0% (0)

San Mateo	Santa Barbara	Santa Clara	Santa Cruz	Shasta	Sierra	Siskiyou	Solano	Sonoma	Stanislaus	Sutter	Tehama
0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)

[Download](#)

Trinity	Tulare	Tuolumne	Ventura	Yolo	Yuba	Not in California	Response Count
0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	18
<b>answered question</b>							<b>18</b>
<b>skipped question</b>							<b>0</b>

## 2. What is your age?

	<15	16-20	21-25	26-30	31-35
Age:	0.0% (0)	0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)

[Download](#)

36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	>100	Response Count
5.6% (1)	11.1% (2)	11.1% (2)	5.6% (1)	16.7% (3)	22.2% (4)	11.1% (2)	11.1% (2)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	18
<b>answered question</b>													<b>18</b>	
<b>skipped question</b>													<b>0</b>	

3. Please check any of the following earthquakes that you felt at the time they occurred or about which you feel well informed. [Create Chart](#) [Download](#)

	Personally Experienced	Well Informed	Response Count
Loma Prieta, 1989	38.5% (5)	69.2% (9)	13
Northridge, 1994	71.4% (10)	50.0% (7)	14
San Fernando, 1971	70.0% (7)	60.0% (6)	10
Northern Baja, 2010	27.3% (3)	81.8% (9)	11
None of the above	100.0% (1)	0.0% (0)	1
	answered question		18
	skipped question		0

4. If you had a seismically vulnerable house requiring approximately \$10,000 of repair work to greatly reduce the chance that your house will fall down, would you support the following retrofit programs? You may check more than one. [Create Chart](#) [Download](#)

	Response Percent	Response Count
Voluntary	66.7%	12
Mandatory, half cost paid by the government	50.0%	9
I would not support a retrofit program	5.6%	1
	answered question	18
	skipped question	0

5. Would you support a one-time \$5000 tax levy to retrofit schools, hospitals, and other public buildings to greatly reduce the chance they would fall down? [Create Chart](#) [Download](#)

	Response Percent	Response Count
Yes	61.1%	11
No	38.9%	7
	answered question	18
	skipped question	0

**6. Rate the following options, if they were available, in terms of how they motivate you to retrofit against seismic destruction.** [Create Chart](#) [Download](#)

	Very much	Somewhat	Not very much	Not at all	Response Count
Financial incentives: rebates, credits, and loans	66.7% (12)	27.8% (5)	5.6% (1)	0.0% (0)	18
Professional assessment on seismic deficiencies of your building, advice on retrofitting, and cost-benefit evaluation	44.4% (8)	55.6% (10)	0.0% (0)	0.0% (0)	18
Certificates of seismic compliance available following retrofit to prospective tenants and buyers	33.3% (6)	38.9% (7)	22.2% (4)	5.6% (1)	18
Mandatory disclosure of seismic deficiencies to potential tenants and buyers	66.7% (12)	22.2% (4)	11.1% (2)	0.0% (0)	18
			answered question		18
			skipped question		0

**7. A community is considering spending \$260 million on one of three possible retrofit options to increase earthquake resistance of seismically deficient housing structures in the case of occurrence of a magnitude 7.2 earthquake. Option (a): The main effect is to reduce home repair costs by \$1.5 billion (From \$4 billion reduced to \$2.5 billion) Option (b): The main effect is to reduce the percentage of people made homeless from 75% of the community to 25% (43500 people made homeless reduced to 14500 people) Option (c): The main effect is to reduce the number of deaths by 500 (1200 deaths reduced to 700)** [Create Chart](#) [Download](#)

	Option (a)	Option (b)	Option (c)	Response Count	
Which would be your first choice option?	0.0% (0)	55.6% (10)	44.4% (8)	18	
Which would be your second choice option?	33.3% (6)	38.9% (7)	27.8% (5)	18	
			answered question		18
			skipped question		0

8. Suppose a retrofit program is under consideration for your community to reduce future possible seismic destruction. You must decide whether or not you support this program. To what extent does the knowledge of these earthquakes motivate you to support the retrofit program? [Create Chart](#) [Download](#)

	Very much	Somewhat	Not very much	Not at all	Response Count
Northern Baja, 2010	0.0% (0)	<b>61.1% (11)</b>	27.8% (5)	11.1% (2)	18
The Great Earthquake of 1906	16.7% (3)	<b>50.0% (9)</b>	16.7% (3)	16.7% (3)	18
Loma Prieta, 1989	33.3% (6)	<b>50.0% (9)</b>	11.1% (2)	5.6% (1)	18
Northridge, 1994	<b>61.1% (11)</b>	38.9% (7)	0.0% (0)	0.0% (0)	18
San Fernando, 1971	33.3% (6)	<b>50.0% (9)</b>	11.1% (2)	5.6% (1)	18
Mexico City, 1985	16.7% (3)	<b>44.4% (8)</b>	33.3% (6)	5.6% (1)	18
Haiti, 2010	27.8% (5)	<b>50.0% (9)</b>	11.1% (2)	11.1% (2)	18
Sichuan, China, 2008	5.6% (1)	<b>44.4% (8)</b>	<b>44.4% (8)</b>	5.6% (1)	18
answered question					<b>18</b>
skipped question					<b>0</b>



APPENDIX B: Risk Perception Questionnaire: Versions A-D

## Risk Perception Questionnaire - A

Imagine you are planning to buy a house in the Bay Area of San Francisco. A statewide assessment of the likelihood of earthquakes estimates that there is a 2 percent chance of at least one magnitude 6.7 or greater earthquake in the Bay Area sometime within the next year (Working Group on Earthquake Probabilities, 2008). This earthquake would cause severe damage to your house which is only partly covered by insurance. How risky would you consider living in a place like this is?

Please rate your level of perceived risk from 0 - 5.

Not risky at all  
0

1

2

3

4

Very risky  
5

## Risk Perception Questionnaire - B

Imagine you are planning to buy a house in the Bay Area of San Francisco. A statewide assessment of the likelihood of earthquakes estimates that there is a 63 percent chance of at least one magnitude 6.7 or greater earthquake in the Bay Area sometime in the next three decades (Working Group on Earthquake Probabilities, 2008). This earthquake would cause severe damage to your house which is only partly covered by insurance. How risky would you consider living in a place like this is?

Please rate your level of perceived risk from 0 - 5.

Not risky at all  
0

1

2

3

4

Very risky  
5

## Risk Perception Questionnaire - C

Imagine you are planning to buy a house in the Bay Area of San Francisco. A statewide assessment of the likelihood of earthquakes estimates that there is a 2 percent chance of at least one magnitude 6.7 or greater earthquake in the Bay Area sometime within the next year (Working Group on Earthquake Probabilities, 2008). This earthquake would cause severe damage to your house which is only partly covered by insurance. The following images were taken in a similar area of San Francisco after the Loma Prieta Earthquake in 1989.



<http://pubs.usgs.gov>

How risky would you consider living in a place like this is?

Please rate your level of perceived risk from 0 - 5.

Not risky at all

0

1

2

3

4

Very risky

5

## Risk Perception Questionnaire - D

Imagine you are planning to buy a house in the Bay Area of San Francisco. A statewide assessment of the likelihood of earthquakes estimates that there is a 63 percent chance of at least one magnitude 6.7 or greater earthquake in the Bay Area sometime in the next three decades (Working Group on Earthquake Probabilities, 2008). This earthquake would cause severe damage to your house which is only partly covered by insurance. The following images were taken in a similar area of San Francisco after the Loma Prieta Earthquake in 1989.



<http://pubs.usgs.gov>

How risky would you consider living in a place like this is?

Please rate your level of perceived risk from 0 - 5.

Not risky at all

0

1

2

3

4

Very risky

5

APPENDIX C: Financial-based Methods Discussion Questions and Reponses

**Questions on financial-based methods used in a cost – benefit analysis for retrofitting against natural hazard risk.**

This questionnaire deals with the costs and benefits of retrofit for natural hazards, such as seismic retrofit. It involves issues surrounding the discount rates used in the analysis. The use of a constant discount rate for environmental consequences and casualty risk is controversial since over a longer time horizon, future life safety benefits become trivial. This questionnaire elicits your thoughts about different cost-presentation modes.

Jim Harris: I am an advocate of taking in account the time value of money in regards to earthquake design rules that have to do with fundamentally averting future monetary losses. This means the hazard level at which one is going to analyze the cost-benefit is not the 2500 year earthquake since with a constant discount rate, there would be no present value when discounted. I believe they are going to settle between 30 years and 200 years; probably 70-100 years in terms of mean recurrence of earthquake ground motion in terms of economic loss. This is to be used for an average person; society in general. For instance if you're going to spend money to brace things that break and spill fluids but don't threaten life in a serious way, you probably don't want to spend the money if the probability of avoiding a future loss is nil. Thinks it will be a big point of discussion over the next decade in earthquake engineering.

This questionnaire elicits your thoughts about different cost-presentation modes.

1. Discounting: Do you believe using a constant discount rate, for example 3% or some value, to discount all future benefits, including monetary, life-safety and intangible benefits, is appropriate for a benefit-cost analysis of natural-hazard mitigation?

Kathleen Tierney: No. I have a hard time with discount rates in general because of the issue of the cup of coffee. There are multiple costs and benefits that are comparable and not comparable. In light of the fact that there is a commensurability problem around benefits and costs, discount rates should be used with caution. It is also based on the point of view of the person. We should find out an individual's own discount rates. Perhaps the choice of the weighing is individual. An ordinary decision maker does not use cost benefit analysis in the same way as the office of management does. For example, if the property in question is a historic family farm and the owner wants to give it to his children, a much different discount rate may be used in a cost benefit analysis versus a typical house.

Jim Harris: In controlling economic loss, one must pick a discount rate. 3% sounds like an accurate rate. If you are doing private sector investing, you want a bigger rate of return than 3%, but if you go to 10%, you make stupid decisions with respect to future

risks. The discount rate used could vary by the circumstances. You might adopt different discount rates for different kinds of physical elements. For important public infrastructure, you might adopt a lower tolerance for future losses. For instance, in San Francisco or Memphis, there are a few really significant bridges. If you lose those bridges, the overall regional economy is severely impacted. When doing cost benefit analysis, this must be taken into account. On the other hand, if you design a bridge over a little creek that has four alternate routes within 4 miles, the significance of the bridge not collapsing is much lower. Similarly, if you're in a big city with 14 hospitals with trauma centers, you may not need to have the same safety levels on the hospitals versus a city with a one hospital .

Keith Porter: I will split my answer into monetary and life-safety benefits, and ignore intangibles. For monetary benefits, with one caveat that I will explain later, I have no problem with using a constant discount rate equal to the cost of capital minus inflation.

For life-safety benefit, before answering the question, I offer this premise: While the price of something is a quantity that can be observed, the value of something is a personal judgment. The can of tomato paste may be priced at \$1.35, but I have to decide if it is worth at least \$1.35 to me before I buy it. Like the can of tomato paste, the value of avoiding a statistical fatality is a personal judgment. The federal government can set the price it is willing to pay, or cause others to pay, to avoid a statistical fatality, but that decision is typically based on a synthesis of the apparent value that various groups of Americans seem willing to pay. This means that the government price essentially rests on the value that people like me place on avoiding a statistical fatality. Economists can offer rationale for and against discounting human life, but the rationale only matters if I (or others like me) find it compelling and integrate it into the value that we individually assign to a avoiding a statistical fatality 100 years from now. That is to say, the burden rests with the economists or other advocates of discounting to convince me that I should assign a lower value to intergenerational fatalities avoided than to one avoided next year.

With this premise in mind, I offer the following opinion on discounting the value of human life. I have read the rationale offered by some economists for intergenerational discounting of human life, and find what I have read unconvincing, some of it internally inconsistent, and fatally flawed in at least one way: if one accepts any positive discount rate that applies perpetually, then at some point in the future, avoiding the fatalities of 1 million people would be worth less to me now than the café mocha on my table. This conclusion is morally repugnant to me, and I can therefore reject the notion of intergenerational discounting by *reductio ad absurdum*. I also reject the notion of intra-generational discounting of human life (fatalities avoided within the next 25 years) for



natural disaster risk management, because for I suspect that for low-probability events it essentially amounts to reducing the value of avoiding any statistical fatality.

I have no problem assigning a different value of avoiding a statistical fatality based on the peril, i.e., assigning a higher value for avoiding a fatality from cancer than from earthquakes, or even a different value for earthquakes than hurricanes. Thus, I believe in assigning a constant value of avoiding a statistical fatality from a particular kind of natural disaster, and not applying a discount rate to it.

Now the caveat: I do not believe that a benefit-cost analysis is a sufficient basis for making natural-hazard risk-mitigation decisions. The most compelling reason is that it pays no attention to scale: a \$4:\$1 BCR means something very different when the absolute value of the benefit is \$4 at a cost of \$1, versus when the benefit is \$4 billion at a cost of \$1 billion. The former is a trivial issue, the latter very serious, but they both have a 4:1 BCR.

- a. Many authors believe that when discounting the consequences of natural hazards, the discount rate should change with the time horizon, for example, a discount rate that declines beyond a generation (say 25 years), particularly for life safety. What are your thoughts on this idea?

Kathleen Tierney: Again, what do we know about the life expectancy of different structures? This is all subject to debate. We must agree what we are talking about as far as a time horizon goes. Often, a cost-benefit analysis is based on a life expectancy that is shorter than the actual lifetime.

Jim Harris: We have something equivalent built into safety measures. For wind and snow loads, we have importance factors that we apply to the loads that have the effect of reducing the probability of failure on some constant time basis. It is not accurate but it is a very rough approximation to think of risk categories for structure use. There are four in ASCE: Category 1: very little risk to human lives; Category 2: ordinary buildings; Category 3: buildings with 300+ people in one room at a time or a public utility; Category 4: essential facilities or hazardous materials. The time declining approximation takes place since Category 1 affects  $10^0$  people involved, Category 2 affects  $10^1$  and  $10^2$ . Category 3 affects  $10^3$  and Category 4 affects  $10^4$  in terms of people put at risk if the structure failed. If the potential life loss is a larger number, we're going to design for a higher level of safety, making failure a more rare event. That is like saying we are taking a time discount on life safety. I prefer to think of it in a way where the nature of the event is a concentration of loss in space and time; that society's tolerance is less. If you kill 50,000 people a year on the order of 1-3 people in automobile accidents, which is

more acceptable than killing 50,000 in 3 or 4 building collapses. We had 3000 lives lost in Sept 11 2001 in a building collapse due to fire. Even though most of the country put it in terms of an active war, some people put it in terms of a building failure and that the buildings weren't engineered well enough. It is how people react to loss.

2. Presentation of costs: This question is used to compare the response to presenting the costs and benefits of retrofitting as a present discount value versus an annual discounted value. Suppose you are the owner of a commercial building with a 1% risk of significant damage due to an earthquake each year. It would cost \$750,000 to retrofit your building to dramatically increase its strength in an earthquake and the cost of damage without retrofitting would be \$4 million dollars. Which cost-presentation method would you find most meaningful, and why? The following are all equivalent for a 25-year lifetime and 3% annual discount rate (after subtracting inflation).
  - a. The present discounted cost of retrofitting is \$750,000 while the present discounted savings from retrofitting is \$1.9 million.
  - b. The annual discounted cost of retrofitting is \$43,000 while the annual discounted savings from retrofitting is \$110,000.
  - c. You could take a loan at 6% interest and not pay anything now. The annual cost is \$58,000 and the annual savings from retrofitting is \$110,000.

Kathleen Tierney: I probably would not have a tendency to retrofit with either of them due to anchoring on the 1%. If the percentage was given over 30 years that would be different. The average person would balk at \$750,000 present value retrofit cost given only a 1% probability earthquake per year. They would more likely accept the annual discounted retrofit cost of \$43,000. There is a whole literature on framing and numeracy. It is quite counterintuitive with percentages compared to absolute numbers.

Jim Harris: No input.

Keith Porter: Let's consider two cases: (1) I am a real-estate investor, and (2) I am responsible for institutional property, such as the real estate manager for Stanford University. First case (1), and let us assume the typical case, that I plan on holding the building for a normal investment period (3-10 years). In this case I have a hard time choosing between these options, because I find the investment unconvincing in any case. Reason is that it is an investment with only a 3-10% chance of producing any benefit. I do not believe the retrofit will have a market value when I sell the building.

Case (2) is different. I will make my choice based on the presentation I think will be most compelling or meaningful to the Board of Governors, or whoever I report to on capital investments. I would tend to use presentation method (c), offering (a) as another way to look at the investment, and possibly (b) as a 3<sup>rd</sup> viewpoint if I felt the Board assigned the issue enough importance.

3. Scenarios: Instead of using probabilities and discounting in their cost-benefit analysis, some studies have been basing their analysis on the scenario that the earthquake will happen today. Since the cost of retrofitting and dollars saved are tabulated as if the earthquake happens now, there is no discounting involved in the analysis. Therefore, the perceived benefits may be greater than in an analysis that uses discounting. Do you believe this is an appropriate presentation of the costs and benefits to retrofitting? Do you see a role of certain simplifications when presenting costs to the public (i.e. eliminating discount rate or eliminating costs)?

Kathleen Tierney: For the average decision maker, yes, provided there is a range presented. Refer to RAND robust decision making by Robert Lempert about utility decision making.

Jim Harris: Certainly in the case of earthquakes and hurricanes. Scenario events and walking through the consequences is probably a better way of communicating risk to the public than a probabilistic basis. It's not as attractive as a quantitative method of separating one risk from another when you are thinking of developing engineering standards of practice. The public doesn't do well with probability especially rare probabilities. To some extent, mass media is changing this, but one of the big problems with earthquakes is that unless you live in an area where earthquakes are very frequent, you and no one to whom you are related to that is living has ever been in a serious earthquake. Because of this, it is difficult to think that you need to be planning for what might happen and building things so that they stand up in an earthquake. The earthquake that severely damaged Assisi, a moderately active earthquake area, Italy a few years back knocked down buildings that were 500 years old. So you are dealing with real risks that are in a time frame that people can't relate to. The scenario event tends to get around that.

Keith Porter: I do think this is appropriate, with a few caveats. It is appropriate because, in my experience (CAPSS, ShakeOut, ARkStorm...) the general public finds this presentation method much easier to grasp than loss-exceedance curves, benefit-cost ratios, etc. Some constituencies (firefighters, emergency managers, etc.) explicitly ask for scenarios and say they do not want depictions of probabilistic outcomes. That was the

case in ShakeOut, and seemed to apply in ARkStorm as well. One caveat is that statistically savvy groups such as insurance actuaries do prefer probabilistic measures such as PML or loss exceedance curves. When I have presented probabilistic measures to lay audiences they either ask follow-up questions that relate to scenarios (from which I infer that that is how they prefer to understand a risk estimate), or they do not seem to understand the results. By contrast, when I have offered scenario results, lay audiences seem to understand clearly, and sometimes even intuit the other caveats, which are that: (a) the ratio of scenario benefits to retrofit costs is not a proper benefit-cost ratio, and (b) that many other earthquakes are possible, and that the scenario could happen next year or 50 years in the future.

4. Time period: Discounted benefits are greater assuming an infinite planning period versus a finite one. Given the same scenario commercial building and financial cost/future savings of retrofitting discussed earlier, which cost comparison do you find more informative:
  - a. 50 year lifetime, 3% discount rate: \$30,000 annual cost paid over 50 years
  - b. Infinite lifetime, 3% discount rate: \$22,500 annual cost paid over infinite years but the structure is assumed to last for centuries.

Kathleen Tierney: None of these seem attractive. People have a very difficult time thinking in infinite terms.

Jim Harris: I think that the 50 year time frame sounds better to most people who are in positions to make decisions on an economic basis about buildings. There are occasionally real estate transactions that have lifetimes longer than 50 years. There is sometimes land leased for 100 or 200 years and then buildings are built on that land and are owned by people that have leased land. That gives you an idea that people will spend a large amount of dollars to build a new structure because they think of it in terms of a limited life in a sense. There is a mind set in the real estate world that the value of real estate will go up, generally due to scarcity of land and the reduction in the value of currency due to inflation. Those two ideas contradict each other but they are held in the mind of many people in the real estate world at the same time. For example, I am not going to base my decision on an infinite life of the building but I am going to base my thoughts on the value of the building going up. That can't happen. I think that people who make decision about cost-benefit ratios probably prefer to make decisions on a deterministic time frame, not an amorphous time frame. It is similar to talking about a fire proof or earthquake proof building – no such thing.

Keith Porter: I think this sort of presentation is only appropriate for very large institutions and governments. I would tend to choose some middle ground, neither 50

years nor infinite. If I were a representative of the General Services Administration with authority to set the planning period for presentation to Congress, or some similar role in state government, my preference would be to use a reasonable estimate of the likely future life of the building based on the ages of the oldest comparable buildings in Europe or Asia. For example, let us consider the seismic retrofit of an architecturally important seat of local or state government, such as the San Francisco City Hall or Sacramento Capitol Building. How long is it likely to exist? The London County Hall is nearly 90 years old and is still in use (though no longer as the seat of government). The Paris Hotel de Ville (its city hall) is now 380 years old. One of the buildings in the Moscow Kremlin survived about 600 years before Josef Stalin had it torn down. The Topkapi Palace in Istanbul is about 550 years old. So what planning period would I choose? 250 years seems to be an appropriate compromise, long enough to be effectively infinite for BCR purposes, but short enough to be strongly defensible against “cooking-the-books” attacks.

5. Do you have any additional comments on discounting or cost presentation related to risk mitigation cost-benefit analysis?

Keith Porter: Your questionnaire deals with the parameters used within benefit-cost analysis (CBA), and to how the costs and benefits are best presented. My response here may seem somewhat beside the point, but I'd like to emphasize one of the limitations common to *all* modes of presenting benefits in a BCA. As noted earlier, benefit-cost analyses do not capture scale, but even less do they offer a way to quantify the existential threat some natural disasters can pose to a city or state. By “existential threat” I mean that they can threaten the existence of a city or state. For example, in the 27 May 1995 Sakhalin Island earthquake, the town of Neftegorsk was effectively destroyed: approximately 2,000 of the 3,176 residents in the town were killed, and the settlement has not been rebuilt. On a larger scale, the city of Lisbon was nearly abandoned after the 1755 earthquake, and the AD 79 eruption of Mt Vesuvius permanently destroyed Pompeii and Herculaneum. It is unclear to me how any of the modes considered here for presenting mitigation costs and benefits can address such existential threats. What is the benefit of avoiding destruction of a city or state? Presumably it could be larger than the value of avoiding the individual fatalities and the sum of the property value exposed to loss.