Overcoming Public and Political Challenges for Natural Hazard Risk Investment Decisions

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Abstract

The cost of natural disasters continues to rise around the world, in part because 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 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 weaker structures is demonstrating a need to the public and its political leaders, who may have difficulty extrapolating personal experiences to low-probability, high-consequence events. Review of recent research and examination of case studies has led to the identification of five key issues that seem central to effective risk and retrofit communication: (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. These issues provide a framework for understanding the challenges to promoting retrofit and for developing communication strategies to overcome these challenges. The resulting risk-communication strategies can be used to improve long-term sustainable policy with recognizable benefits to society. The San Francisco Community Action Plan for Seismic Safety (CAPSS) team is presented as a case study that effectively addresses many of the issues identified here.

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1.0 Introduction

Humanity is becoming more vulnerable to natural disasters, in the sense of increasing frequency of fatal or costly events. The increase is attributable at least in part to population growth and urbanization. According to the EM-DAT International Disaster Database (2005), the rate 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 fatal natural disasters, and led the world in the cost of these events (EM-DAT, 2005). Advances in building codes and their enforcement have periodically improved the expected performance of individual new buildings. However, the increasing concentration and value of exposed infrastructure, and perhaps changes in the frequency and size of earthquakes and hurricanes seem to have produced this trend to more-frequent and more-costly earthquakes in the US West Coast and hurricanes in the US Gulf and Atlantic coasts.

Consider: 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, 2010). Within these areas, the largest population growth has been in developed urban regions, where construction has increased already high densities and in some cases led to building on more vulnerable lands. While the US population grew on average by 12% each decade since 1950, 89% of the population growth has been in urban areas (Olshansky, 1999). Rapid urban growth based on short-term rewards can come at the cost of natural-hazards risk management, impairing long-term sustainability (Corotis, 2010).

Addressing this incompatibility between a short-term decision agenda and long-term sustainability will facilitate the implementation of hazard mitigation actions in current and future planning. To reverse the trend toward increasing frequency and severity of infrastructure damage in natural disasters, changes must be made in hazard mitigation and land use planning that overcome these fundamental incompatibilities. That is, changes are required to make infrastructure more resistant faster than population growth adds to the quantity of infrastructure out there to be damaged. The consequences of previous natural disasters have shown that in order to improve the infrastructure's disaster resistance, it is important to focus on anticipated needs and preparedness for future hazards instead of responding to yesterday's events. We are suggesting here a possible future in which natural hazards are no longer viewed as unexpected events to which society responds after a disaster occurs, but rather as an integral part of a community's future long-term planning as if they *will* occur. It seems likely that, to realize such a future vision, it is 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 body.

Many of the tools necessary to mitigate natural hazard risk are known, but their implementation is met with political and public challenges, including psychological biases and political rationale. In order to overcome these practical challenges in mitigating natural hazard risk, these issues must be addressed and incorporated into an inclusive plan of action.

This paper presents a new framework for community natural hazard risk communication. It is based on five key elements that have been found to form the essential basis in linking public sentiment and decision-making: (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. By focusing on these five issues, an effective risk-communication strategy can be developed for optimal long-term sustainable community policy, bringing identifiable benefits to society.

2.0. Historical Perspectives and Reassessment of Risk Communication Issues

The five key elements mentioned above have been observed to differentiate the varying levels of success related to hazard mitigation investment. Each of these five is explored and its importance discussed in this section based on current literature. An assessment is then presented in the form of questionnaires, representative case studies, and interviews to provide further insight and develop conclusions with respect to the five outlined elements.

2.1 Public Risk Perception

2.1.1 Public Risk Perception – Review of Current Knowledge

While several 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. 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 to fully understand the risk of un-experienced low-probability, high-consequence events (Kahneman and Tversky, 2000). There are specific psychological barriers and biases related to this issue that can cause decision makers and the public to ignore or misjudge the likelihood and consequences of a natural disaster. In the domain of earthquake risks, participants often underestimate the probabilities of occurrence associated with the risks with which they are faced (Kahneman and Tversky, 2000), which creates issues in not only homeowner safety, but also in allocating financial support toward public safety measures in proportion to the benefit that the measures would produce.

According to Keller et al. (2006), a first step in risk communication is to gain people's attention to risk by addressing their emotional response to it. The affect heuristic, in which a current emotion influences a decision, can be used as a framework or prod to increase risk perception (Slovic et al. 2004). 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. That is, a stronger emotional response to a hazard can produce a higher estimate of the probability of the hazardous event occurring.

Past experience is an important factor in people's perception of natural hazard risk and in adopting preventive strategies (Keller et al., 2006). 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 that arises from experiencing a natural hazard plays a large role in increased risk perception of an event.

However, the affect from past experiences may fade as time passes. Kunreuther and Michel-Kerjan (2010) suggest that there is a tendency to discount past unpleasant experiences. 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 scenario, many people end up canceling their flood insurance if they haven't 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 in the fact that the general public has difficulty thinking in probabilistic terms (Patt and Schrag, 2003). According to Kahneman and Tversky (2000), small probabilities (frequently associated with high-consequence natural-hazard events) are often underestimated, and occurrence probabilities of less than a few percent are often classified as equally unlikely, with no chance of occurring. This issue is particularly important in the political arena, where a politician's career may be measured over a period of just a few years. Since a natural hazard event's small probability is viewed as almost impossible, measures taken to prevent it may go unrewarded.

Keller et al. propose various approaches to increase public risk perception and overcome such challenges in communicating low-probability risks. To begin with, they hypothesize that when problems are formulated in terms of frequency of occurrence as opposed to probability of occurrence (e.g., expected number of events per year versus probability of at least one event in a year), the perceived threat of the risk may increase, even though the two values are virtually the same for probabilities of less than about 1 in 10. The time period for which a risk is given also has an influence on how it is perceived. For example, it was shown that presenting the risk of flooding over 80 years increased the homeowners' perceived risk, as opposed to presenting the corresponding probability of risk faced each year. Finally, Keller et al. (2006) suggest that risk perception can be influenced by experimental manipulation, supplementing the affects and feelings associated with past experience. The use of photographs or figures associated with a hazard event (i.e., building damage from an earthquake) may evoke undesirable emotions in participants, which therefore heighten the negative feelings people have for the event. These negative feelings may be induced prior to the decision making associated with sustainability against natural hazards, and may influence the participants' perceived risk.

Some researchers believe that it may be beneficial to eliminate the probability of an event entirely when communicating risk. Taleb (2010), for instance, states that instead of forcing the understanding of the probabilities and frequencies associated with a rare event, which may be beyond people's capacity, it is advantageous to focus on the consequences or benefits (avoided costs) of an event if it were to take place. 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.

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."

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 or immediate feeling associated with an event results in a greater perceived risk. A preliminary study will be discussed below which assesses the contributing factors related to how people perceive risk. Next, a study will be presented that analyzes the effectiveness of various communication approaches listed above and their relation to increased risk perception.

2.1.2 Public Risk Perception – Reassessment of the issues

Contributing Factors to Public Risk Perception

Risk is traditionally defined as a function of the likelihood of event occurrence and the resulting consequences, generally measured as mortality, morbidity, and economic loss. Hazard researcher John Twigg, however, notes that, "Events relating to hazards interact with a variety of social, psychological, institutional and cultural processes in ways that can heighten or attenuate perceptions of risk and thereby shape risk behavior" (Twigg, 2003). Civil engineering design has traditionally ignored the effects of human perception, however, in the event of a natural hazard, human reaction is incredibly important to consider. Paul Slovic has conducted significant studies on how people perceive risk (Slovic, 2000), in which through factor analysis he has concluded that the perception of risk is based primarily on three parameters: dread, familiarity, and voluntariness. Slovic's research does not include how people perceive risk from natural hazards, and this preliminary study attempts to relate his methods to the area of hazard mitigation.

Slovic began with 90 everyday risks and asked people to rate their perceived risk and perceived benefit on a scale of 0-100. He also asked the subjects to describe why they perceived such risks. The data showed that 18 characteristics were given most frequently when describing risk. Factor analysis was used to reduce the number of characteristics, and the first factor described various aspects and attributes of dread. Continuing the process, the factor that explained the second highest amount of variability in the data was termed familiarity.

The first notable factor in Slovic's study, dread, implies fear, and in the case of hazards it is associated with terms such as uncontrollable, difficult to prevent, or disastrous. These definitions were the basis for describing dread in terms of measurable quantities. Three characteristics are utilized in this research to compute dread. The first characteristic is taken from previous work at the University of Colorado (Hammel and Corotis, 2010), in which the authors concluded that lead time, or time to react, was used as a characteristic of dread. The second characteristic, as extended from Slovic's description of dread as fatal, is the number of people who die during each event. In other words, the number of people who die in one event contributes greatly to an individual's fear for future similar events. The third characteristic is taken from Twigg's analysis of risk perception and is based on physical harm and the amount of people affected during a hazard event. This characteristic of dread includes the effects of injuries and property damage. Calculating dread involves the combination of the three characteristics just discussed. As lead time increases, an individual's dread decreases. Therefore, an inverse relationship was used in relating lead time to dread. The number of deaths per event and the number of people affected per event are directly related to dread.

The second factor used to measure risk is familiarity. An individual's level of familiarity with an event significantly changes his or her perception of risk. For instance, a person who has lived on the coast of Florida for 50 years has likely experienced hurricanes many times, whereas those from other parts of the United States probably have not. The number of occurrences of major events per year was used to characterize familiarity.

The dread and familiarity factors as defined above for natural hazard risk were applied to natural hazard data for various regions of the United States, and used to create a Cartesian coordinate system with Dread on the abscissa (risk perception increasing with increasing Dread) and Familiarity on the ordinate (risk perception increasing with decreasing Familiarity, so graphed with decreasing Familiarity for the ordinate). On this coordinate system, each hazard was located, with three concentric circles: one representing the number of deaths per event, one representing the number of injuries per event, and one representing the amount of dollar loss per event. This analysis was conducted for each of the eight geographical regions of the United States. A typical result, this on for the Pacific region, is shown in Figure 1.

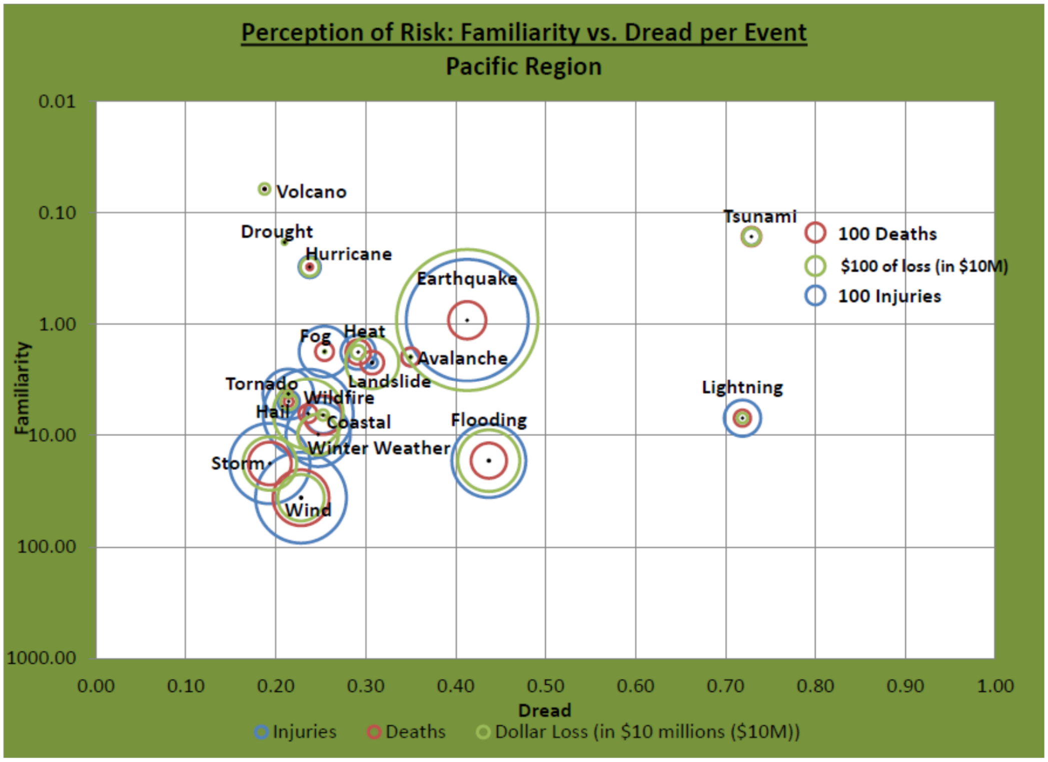

Figure 1. Natural Hazards Consequences Measured in Circles Representing Deaths, Injuries and Monetary Losses, Graphed on Cartesian Coordinates of Familiarity and Dread (Pacific U.S.)

Risk Communication and Perception

As discussed earlier, the way in which natural-hazard risk information is presented influences the perception of risk. When promoting hazard mitigation, public and political risk perception can drive the acceptance of long-term policies. Therefore, the choice of details and parameters for presenting risk is an opportunity for gaining people's attention and promoting accurate risk perception. Many studies have suggested that the affect bias, which is linked to strong emotions about a hazard, may play an important role in risk perception.

Keller et al. (2006) hypothesize that risk perception can be influenced by experimental manipulation, supplementing past experience. As mentioned previously, small probabilities do not evoke as much of an emotional affect as high probabilities. Since probabilities of risk vary depending on the time period under consideration, 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 corresponding annual probability. They also postulate that the affect associated with natural hazards can be manipulated by using photographs associated with the hazard event. They 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.

For the current research, a questionnaire was distributed to undergraduate and graduate engineering students, as part of their coursework, exploring Keller's hypothesis that inducing a negative affect through experimental manipulation results in an increased level of perceived risk. This questionnaire focuses on the communication of seismic risk and uses the experimental manipulation of both time period and photographs. A total of 115 students from the University of Colorado at Boulder participated in this activity. All students are enrolled in the civil engineering program, which entails some experience with probability and natural-hazard risk perception. Participants included 74 junior and senior level undergraduate students and 41 graduate students, mostly masters students.

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 the house, which is only partly covered by insurance. Half of the participants received the risk information based on the annual probability, 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 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. 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) and 5 (very risky).

Study Results: "How Risky Would You Consider Living in this House is?"
Ratings 0 (not risky at all) to 5 (very risky)

	Reference Period for Probability Calculation	
	1 Year	30 Years
Control group (no photos)	2.5	3.4
Experimental group (with photos)	2.7	3.6

Table 1 - Study Results for Experimental Manipulation on Risk Perception

The average response is presented in Table 1. Keller's hypothesis that a longer time period influences risk perception is supported at the α=1% significance level (i.e., the hypothesis that there is no effect between time period and risk perception can be rejected for all significant levels down to 1%) . 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 increased their risk rating by 0.2 for both groups which does not strongly support the hypothesis.

The results of the University of Colorado study are consistent with the views of Kahneman and Tversky (2000) and Slovic et al. (2004) presented earlier: the affect bias increases the perception of risk.

2.2 Public Involvement

2.2.1 Public Involvement – Review of Current Knowledge

Public involvement of various forms has always been a fundamental feature of politics in the United States. While public involvement has been popular in many political arenas, it has recently become important in environmental decision-making processes as a means of increasing public accountability for long-term decisions (NRC, 1996), improving decision-making processes (Beierle, 1999 and Gamper and Turcanu, 2009), and reducing opposition to such risk-mitigation decisions (Beierle, 1999).

According to Beierle (1999), the national environmental focus has been shifting from imminent large point sources of environmental catastrophe, to more distributed long-term disaster issues. Such issues may not be suitable for current hierarchal political decision making, but instead may require the commitment, knowledge, and involvement of the government and general public over time. Beierle (1999) believes that experts and the general public bring different and unique perspectives to the risk decision-making process. Given the uncertainty and variability of risk-reduction decisions, even the most fundamental analytical methods include a high degree of subjectivity. According to Gamper and Turcanu (2009), participation is essential in public issues, particularly when there are conflicting objectives and 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). Furthermore, if public opinion is omitted from the decision-making process, it is likely that environmental decisions will be postponed. 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.

For these and many other reasons, the National Research Council argues 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." As a result, public participation in the development of local plans is increasingly a requirement by federal, state, and local laws. While public involvement is desirable, people are not always interested in participating.

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. They examined five 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. The authors extracted factors common to each case study that led to a decrease in public interest in natural hazard reductions. Primarily, communities and government parties perceived hazard-mitigation planning to involve technical issues most effectively addressed by trained experts. 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.

Since people did not perceive that natural-hazard reduction would impact their daily lives, they did not feel it necessary to focus on such issues.

While research has shown that public involvement in risk decision making is both vital and beneficial, that involvement must somehow be brought about in a method where people are willing to participate to work towards a sustainable community.

2.2.2 Public Involvement – Reassessment of the Issues

Various methods have been developed that enable the public to actively participate in policy deliberations and often in policy decision making. Methods include focus groups, town-hall meetings, open houses, advisory committees, and surveys (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 the public is often dissatisfied with the quality and credibility of stakeholder input in environmental risk-management decisions (Stave, 2002).

This paper now briefly summarizes three case studies evaluated on the framework of three goals for 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. In the second case study, related to the cleanup and protection for the Tillamook Bay in northwestern Oregon, public involvement was initially ineffective, but subsequently improved to ultimately be successful. The third case study illustrates ineffective community participation in Papillion Creek watershed planning. The comparison of methodologies and outcomes in the three case studies is hoped to provide insight into key components which lead to successful public involvement in environmental issues.

Case Study: Hazardous Waste Facilities in Canada

While efforts to resolve siting of hazardous waste facilities are often met with limited success (Gray, 1989), this first case study is evidence of successful waste facility placements in Alberta, Canada. Its success is attributed in part to public involvement and education. The following summary of events is taken from Gray (1989).

In 1980, Alberta's provincial government launched a province-wide public siting and education process as a strategy to overcome the challenge of community opposition to the placement of the hazard waste facilities. The education portion comprised 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 Province then 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 succeeded because of 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. The fact that the provincial government negotiated incentives for the community that volunteered to host the facility may have also aided the success of public involvement. As a result of this 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, the Tillamook Bay National Estuary Project (TBNEP) was given the task of developing a science-based, community-supported management plan including cleanup and protection options for the Tillamook Bay watershed in northwestern Oregon. The following project description is summarized from Gregory (2000).

Leading up to the official beginning of the TBNEP project, there were many limited public-involvement programs used for managing the Tillamook Bay watershed. Open meetings were held to seek citizen ideas and concerns on the watershed. Since the TBNEP project had not officially begun, there was no way to process or respond to public concerns. Without response and communication with stakeholders on matters discussed in public meetings, the community lost interest in the project issues and attempts at public involvement in the planning stages of the project were deemed unsuccessful (Gregory, 2000).

When the TBNEP project officially began, it focused on educating the community about the issues of the Tillamook Bay as well as the tradeoffs of proposed actions. The team performed individual and group interviews with members of the community, asking participants what they cared about in terms of possible actions taken in managing Tillamook Bay. The team elicited various community values regarding the bay including water quality, jobs, flooding, and social impacts. 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.

By educating the public on various alternative actions, as well as focusing on specific community values in regard 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 a decision-making methodology evaluated by Irvin and Stansbury (2004) regarding new management alternatives for the Papillion Creek Watershed located in Omaha, Nebraska.

The Papillion Creek system gathers pollutants from agriculture and urban runoff and covers 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 was asked to improve the creek's environmental impact and its effects on regional development, recreation, and flood protection. Through newspaper articles, brochures, direct contact with landowners, phone calls, and catered meetings, the advisory committee attempted to develop a participatory working group comprising rural and urban residents, recreational users and developers. These efforts were unsuccessful. Of the 15 citizen representatives who promised to attend the first forum, 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 (2004) attributed 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 never defined the problem with the bay or 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. In addition, 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.

Case Study Comparison

While the a major goal of public involvement is to provide policy makers with improved insight and support for a decision at hand, these case studies have shown that attaining such public involvement can be challenging. Throughout the presented case studies, it is apparent that educating the public on environmental issues and alternatives helps to draw interest to such issues. Focusing 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, which has lessons for 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.

2.3 Focus on Asset Values in Communities

2.3.1 Focus on Asset Values in Communities – Review of Current Knowledge

As explained by the National Research Council (1996), to communicate risk, one must first identify which affected parties are at risk and which values are most relevant. 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 affected party.

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 it values more than others. For example, citizens of San Francisco, California may be more concerned about rent control and neighborhood character, while people in 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) conclude that people were more concerned with neighborhood issues as opposed to wide-scale natural-hazard risk-reduction policies. Godschalk et al. (2003) write, "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."

Personalizing an issue to the intended audience may entail focusing on the social and physical make-up of a community. This could include the local economy, education, housing stock, architecture, vacancy rates, or other features. Focusing on assets specific to communities elevates the understanding of risk to a direct and personal level, and creates the ambiance of immediacy for the taking of action. An example of communicating natural hazard management in terms of community values is presented later in the CAPSS case study.

Effective risk-communication may also focus on the future value of assets to a community (Tobin, 2011). Since major earthquakes pose a low annual probability, it is possible that the benefits of mitigating now may not be seen for decades. These benefits might need to be assessed in light of future community values. For example, a 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 might accompany seismic activity would not only set back the community value of "green living" today, but would hamper the future community asset of becoming 100% recyclable.

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, development, and maintenance (Godschalk et al., 2003; FEMA 2002). Incorporating hazard mitigation into additional prominent issues can provide an opening for building mitigation in policy making at an early stage.

2.3.2 Focus on Asset Values in Communities – Reassessment of the Issues

As previously discussed, risk communication must address what interested and affected parties believe may be at risk (National Research Council, 1996), which often includes local values and assets specific to a community. Three examples involving seismic retrofit in San Francisco are presented. Two examples illustrate successful hazard mitigation through the retrofit or removal of public infrastructure. Both successes can be partially attributed to assessing the benefits of reducing risk to specific community assets. The third example presents a successful seismic safety measure piggy-backed on decisions involving other regional issues.

Case Study: San Francisco-Oakland Bay Bridge

After a 50-foot section of the east span of the San Francisco-Oakland Bay Bridge collapsed during the 1989 Loma Prieta Earthquake, it became clear that the state needed to make seismic improvements to the bridge. One of the longest bridges in the world, the Bay Bridge carries over 280,000 vehicles daily (TBPOC, 2010). The 2.2-mile east span connects Emeryville and Yerba Buena Island. The original 2-deck steel truss system has been replaced with a single-decked precast concrete system containing a novel 1,300-ft self-anchored suspension span at its Yerba Buena end.

The new design adds many features to the bridge that enhance both its seismic safety and add beauty generally felt to be lacking in the original structure. The new bridge provides motorists with more expansive views of the Bay (TBPOC, 2010). The new bridge also includes 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 project is also increasing the bridge's value to the neighboring communities.

Case Study: San Francisco City Hall

Built in the late 1800's and then rebuilt in 1915 after its destruction in the 1906 San Francisco earthquake, San Francisco City Hall is considered one of the finest examples of classical architecture in the country (Malloy, 2011). While the structure remained standing after the 1989 Loma Prieta Earthquake, cracks in its walls and slabs rendered it seismically unsafe. In November 1995, San Francisco voters approved a $63.5 million general-obligation bond issue to fund additional improvements to City Hall (SEAONC, 2011).

Retrofits included the installation of 530 lead-rubber base isolators, a new ground floor constructed above the isolators, additional reinforcement to the tower walls, installation of steel braces and shotcrete walls at various levels of the dome, and various improvements to the building's mechanical, electrical, and plumbing systems (SEAONC, 2011). While seismic safety was a main objective of the City Hall's reconstruction, restoring the building and its dome to their original architectural beauty and improving its functionality as a modern office building were important to the City. The structural engineers worked from copies of the original blueprints to restore the ornate beauty of the post-1906 City Hall.

By incorporating seismic safety, the community asset of architectural beauty and historic preservation, and the need to modernize the building's functionality 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, 2011).

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 the public. This strategy is illustrated in the events surrounding the removal of the Embarcadero Freeway in San Francisco. Originally intended to connect the San Francisco-Oakland 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).

After the freeway was damaged during the 1989 Loma Prieta Earthquake, it was clear that the overwhelming visual distaste of the bridge would oppose any hopes of repair work. 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 to motorists was reduced.

Reclamation of the waterfront view was likely a contributing factor to local industries flourishing. Tourism grew following the freeway removal. Between 1995 and 2000, visitor spending citywide increased 39% (Seattle Urban Mobility Plan, 2008). The double-deck freeway was 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 overwhelming dislike for the visual barrier that came along with the Embarcadero Freeway left little need to promote 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 more easily be able to achieve seismic safety through future planning.

2.4 Overcoming Incompatibility of Lifetimes

2.4.1 Overcoming Incompatibility of Lifetimes – Review of Current Knowledge

Local governments are sometimes reluctant to adopt risk-reduction policies. Corotis (2010) asserts that local officials tend to focus on decisions with short-term costs and benefits, as opposed to decisions that promote long-term sustainability. The US political system is based on electoral cycles of 2-4 years, and officials' tenure in any given position on the order of 4-8 years. By contrast, the design life of public and private infrastructure can be 50 to 100 years, and its actual lifetime significantly greater. Partly as a result of long design lives, the recurrence period of damaging natural-hazard events in any particular location can also be 100 years or more. (A long design life leads to facilities that effectively resist more-frequent, less-severe loading.) Therefore, the probability that a major disaster will occur during a local official's term in office can be low. As a result, a political leader may reasonably conclude that spending resources to achieve short-term benefits instead of investing in long-term sustainability is the best way to satisfy constituents. Prater and Lindell (2003) explain that issues such as crime and education usually absorb governments' attention, time, and money, to the detriment of long-term risk-reduction issues. For example, 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). 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.

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. They show that the public often reward politicians for delegating disaster relief spending only after the disaster occurred, but not for investing in disaster preparedness. Because the public does not acknowledge or reward officials for preparing for disasters before they occur, politicians are rarely accountable for such issues, which jeopardizes community sustainability. Politicians are instead rewarded for responding post-disaster, after damage has occurred and lives have been lost.

The apparent challenge is how long-term sustainability can be incorporated into the political agenda, such as by ensuring recognition and support for politicians who make such long-term decisions. Birkland and Waterman (1998) argue that an effective way to get hazard mitigation on the public agenda is to use a focusing event such as a disaster that gets public attention. He notes that people's concerns when their household is recovering from a disaster are different from other times. However, that recovery period is brief; Kunreuther and Michel-Kerjan (2010) point out that the public's attention to disaster issues decreases quickly and may soon switch to other issues. 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." Regarding 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."

Corotis (2010) asserts that to get hazard mitigation on the political agenda, it is necessary to design policies and reward systems that encourage long-term sustainability. 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. 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 enable the public to perceive the benefits associated with risk mitigation decision making and therefore reward such political action. Examples of such published reports, and the methodologies behind them, are discussed and analyzed in the following section.

2.4.2 Overcoming Incompatibility of Lifetimes – Reassessment of the Issues

In this paper, 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 method, entitled Infrastructure RATE card, 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.

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. As a method to guide the authors when evaluating the infrastructure, the first reporting system titled *Fragile Foundations* took the form of a report card and assigned letter grades based on infrastructure performance and capacity.

Nearly a decade after the first report card was published, 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 based on 14 different categories, and also provides solutions for improvement. Each state can focus on specific infrastructure categories that are of most importance, and develop individual goals and objectives. With the primary goal of educating the public and political leadership, the desired outcome of the ASCE report cards is to essentially raise public accountability for such risks and increase support of infrastructure funding initiatives and fees (ASCE California, 2011).

The second reporting system is in the form of a financial-based report card for accounting infrastructure risk to society (Corotis, 2010). On a regular basis, the proposed report, titled Infrastructure Risk and Accountability Trust Evaluation card (Infrastructure RATE card), 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), a benefit is that at the time of elections, “If nothing had been done to improve the efficiency and lifetime safety of existing infrastructure, this would be reflected in the report.” The report would also include the total risk and expected future maintenance and operation cost imposed on the public. The basic concept of such a financial risk report card could eventually be used as a public trust report and a framework to influence political decision making. Table 2 shows what this Infrastructure RATE card might look like.

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 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. 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 policy maker more attuned to 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 the community level. It has been noted that communities may focus their concerns on local policy issues, and 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.

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.

2.5 Cost-Presentation Methods

2.5.1 Cost-Presentation Methods – Review of Current Knowledge

Fischhoff et al. (1979) catalog several methods to compare risk and rewards. Among the most commonly used of these for natural-hazard or environmental risk-mitigation decisions is cost-benefit analysis (CBA). The primary output of CBA is the ratio of the discounted expected present value of benefits (which can include reduction in future losses) to the discounted expected present value of costs. When benefit-to-cost ratio (BCR) exceeds 1.0, the measure under consideration can be considered cost effective. Using CBA presents a serious challenge when benefits accrue over decades, as in natural-hazard or environmental risk mitigation: BCR can be highly sensitive to the discount rate. Any positive discount rate reflects a preference for immediate benefits over future ones. The higher the discount rate, the lower the present value of future benefits. There are intense debates about what discount rate should be used (Percoco, 2002). In many financial decisions, the discount rate can be conveniently taken as the cost of capital, i.e., the interest rate that would be paid to borrow the money required to pay the cost of the risk-mitigation measure. But it is unclear that benefits should necessarily be discounted at the same rate as costs, or that the benefits should be discounted at a constant rate. There are psychological issues in addition to the financial ones that can be taken into consideration when selecting an appropriate discount rate (Corotis and Gransberg, 2006).

Unlike pure economic discounting, with its typically constant discount rate, the discount rate associated with social or psychological factors can be better represented by a hyperbolic curve that decreases with time (Percoco, 2002). 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).

Newell and Pizer (2001) performed research on climate-change mitigation in which they examined the implications of using different approaches for the discount rate used in a CBA. They argue that future rates are uncertain, and show that by including the effects of discount rate uncertainty, the present value of risk mitigation decisions could be raised by as much as 95 percent relative to conventional discounting. The application of time varying discounting could be used for infrastructure decisions to significantly increase projected benefits of natural-hazard risk mitigation.

A second issue of using CBA for natural hazards is what time period should be used to recognize costs and benefits. When quantifying the cost of hazard-mitigation investments, it may be more appealing to amortize the cost of the project over the lifetime of the infrastructure, or conversely to recognize the present value of benefits that accrue over the expected lifetime of the infrastructure. Either way, the cost is viewed as an investment that pays off in the long run. In addition, longer design lifetimes provide a political reward that is consistent with long-term sustainable design. The use of infinite or very long design lifetimes may be 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.

There are different presentation methods that can be used when presenting a cost-benefit analysis which may influence the perceived cost to benefit ratio of a hazard mitigation investment. 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. Given the fact that 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 that 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 since the use of a longer design lifetime may decrease the equivalent annual cost of an investment by amortizing the high initial costs over a longer period of time.

There is a wide range of assumptions of discount rate and time period associated with a cost-benefit analysis as well as the presentation format of costs to a society that can vary the projected payoff of a project. The sensitivity and high impact these financial variables have on a cost-benefit analysis can affect the perceived benefit and therefore support for such a project; of which may be vital for the sustainability of a community. Given these sensitivities and varying views, clear definitions of such variables are yet to be determined and instead are treated on a case by case basis.

2.5.2 Cost-Presentation Methods – Reassessment of the Issues

To explore the varying views of the assumptions behind these financial variables further, discussions were held with four experts in natural-hazard risk and risk mitigation fields with respect to their views on the topics of discount rates, time period used in a cost-benefit analysis, and cost presentation methods. The participants were engineers Keith Porter (Associate Research Professor at the University of Colorado at Boulder), Jim Harris (Principal of J.R. Harris and Company), Laura Samant (Earthquake Risk Mitigation Consultant), and social scientist Kathleen Tierney (Director of the Natural Hazards Research and Applications Information Center, University of Colorado at Boulder). 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.

As discussed previously, the use of a constant discount rate for environmental consequences is controversial since over a longer time horizon, the present value of future monetary and life-safety benefits become trivial more than a decade or so in the future. The first question of the discussion elicited 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. Tierney's response agreed with Harris in regard to a different 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 the Tierney, "In light of the fact that there is a commensurability problem around benefits and costs, discount rates should be used with caution."

Previous discussion in this paper introduced the incorporation of a psychological time varying 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."

Next, the participants were given a scenario where they must promote the approval of seismic retrofit of a public building. Given a constant discount rate, design lifetime, and an initial and annual maintenance cost of retrofitting, the participants were asked whether they believed presenting the CBA as a present discounted value or equivalent annual value to be perceived as a better investment. 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.

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. 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 altogether 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, explaining "Scenario events are beneficial for the average decision maker, provided there is a range presented."

The final discussion question elicited the participants' thoughts on the use of an extended or infinite planning period opposed to a shorter reference time frame. 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." Harris and Tierney agree, both stating 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." In regard to an appropriate infrastructure lifetime used in a cost-benefit analysis, Porter indicated that he would tend to choose some middle ground between 50 and infinite years for the lifetime of large institutional buildings. Referencing the observed lifetimes of various notable government buildings around the world, Porter explains that a 250-year lifetime seems to be an appropriate compromise, realistically reflecting these observations while being effectively infinite for use in a cost-benefit analysis.

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. 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.

3.0 CAPSS Project

In this section, a major implementation of risk communication will be presented, based on the San Francisco Community Action Plan for Seismic Safety (CAPSS). The project aimed among other things to produce an action plan to reduce earthquake risks to vulnerable buildings, including guidelines for post-earthquake repair and rebuilding. One project recommendation was to mandate the seismic rehabilitation of soft-story, high-occupancy, wood-framed residential buildings – a particular numerous and vulnerable type that suffered notable damage in the 1989 Loma Prieta earthquake (Porter and Cobeen, 2009). Such buildings represent 7% of the housing units in San Francisco and housing for 8% of the city's population. In 2008, Mayor Gavin Newsom directed the Department of Building Inspection (DBI), through the CAPSS project, 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.

The CAPSS project team began with an inventory of these buildings, including location, number of housing units, number of stories, measures of ground-story openings, and an indicator for corner or mid-block location. The CAPSS authors assessed 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 scenario earthquakes. The team also decided to examine four retrofit options: the do-nothing alternative, a modest ground-floor strengthening option involving the addition of structural sheathing, and two more-intensive options involving more structural sheathing and the addition of either steel portal frames at garage-door openings, or cantilever columns at garage-door openings (Porter and Cobeen, 2009). Details 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 these buildings. There were many strategies that contributed to the success of the CAPSS project. They are discussed in light of the five major strategies presented in this paper: public risk perception, public involvement, community values, overcoming incompatibilities of lifetimes, and easily understood cost presentation.

One of the project's major goals is to educate the public to the consequences of earthquake damage and the meaning of resiliency (CAPSS 2008). 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 each of four scenario earthquakes, as opposed to performing a probabilistic risk assessment that would consider all possible earthquakes and their likelihood of occurrence (ATC, 2010). While 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 considering 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 team increased the ease with which the public could imagine the event, making the *realistic* event seem more *real*. As discussed earlier, this increase in affect tagged with an earthquake event often correlates with heightened risk perception (Slovic et al., 2004).

The CAPSS project thoroughly involved and educated the public. As a result, the project was more effective in understanding and addressing public concerns, and thus increased public support for the program. The CAPSS project was referred to as a community effort. It was guided by a volunteer advisory committee that 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 to the project and critical issues could be addressed. The Committee also hosted workshops, which were used both to educate the public, to better understand its concerns, and to gain insight that the public could offer (CAPSS E-Newsletter #2, 2009). Many of the comments and questions raised during the workshops were incorporated into the recommendations released in various reports. In one workshop, the soft-story team presented analytical results to a community group of building owners and tenants, who were then asked to identify policy options they wished to recommend 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.

An interesting outcome of this workshop was that the community group recommended a mandatory retrofit program, even if retrofit costs had to be borne by owners and tenants, and the recommended upgrade option was the one that produced the largest estimated improvement in seismic performance. This was surprising to at least some of the engineers in attendance, who expected the group to recommend a voluntary retrofit program, or one with less-expensive, more-modest performance goals, and possibly make the program contingent upon financial support from the city or state.

A critical aspect of the soft-story project, which the team felt strongly contributed to the workshop’s outcome, was the choice of which performance metrics to calculate and present to the public. The team focused its engineering analysis on building collapse, post-earthquake ATC-20 safety-tag color, and repair cost. ATC-20 (Applied Technology Council, 1996) documents the methodology that most US cities use to assess the post-earthquake safety of buildings. The safety tag is a placard in one of 3 colors: green for inspected, yellow for limited use, and red for unsafe to enter and occupy. Beyond engineering analyses, the soft-story portion of the CAPSS study also addressed community values of a sociological and economic nature, including the effects of an earthquake on: affordable housing, small business, historic buildings, and the how damage to the building stock could affect the character of the city (ATC, 2010). In addition, the authors performed a socioeconomic analysis of the residents of the subject buildings: their ethnicity, income, and other demographic characteristics; renter versus owner occupancy; how many units are rent controlled; citywide residential vacancy rates; and other relevant parameters. 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. An interesting sequence of events unfolded in the early stages of the CAPSS project that increased political accountability and as a result, helped bridge 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 because 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 San Francisco's major daily newspaper (Selna, 2008), a leading structural engineer expressed startling opinions on the lack of risk mitigation in the City. As a result, Mayor Newsom issued an order (Newsom, 2008) that ultimately directed the CAPSS team 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 CAPSS 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.

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 believed the most meaningful way to interpret the economic losses and benefits due to retrofitting was to compare the financial impact from the various earthquake scenarios and retrofit schemes (ATC, 2010). A summary of this aspect is shown in Table 3 below.

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

Table 3. Average Loss Avoided Through Retrofit Per Residential Unit in a Magnitude 7.2 Earthquake on the San Andreas Fault (ATC, 2009)

The CAPSS authors 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. Because they excluded financial discounting over time and ignored 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. The authors explicitly warned workshop participants and readers of CAPSS reports that the loss reductions and costs could not be directly compared on an apples-to-apples basis. It was the authors' impression that the explicit warnings and the relative simplicity of the results effectively communicated how the risk information could and could not be used. 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 ultimate outcome of the CAPSS soft-story project is not yet clear. The volunteer advisory committee of building owners and tenants recommended a policy of mandatory retrofit, and Mayor Newsom repeatedly attempted to institute such a policy. To that extent, the CAPSS soft-story project demonstrates the effectiveness of many of the principles discussed here. However, the city's Board of Supervisors has so far only approved a voluntary retrofit ordinance, which has (predictably) proven utterly ineffective in producing mitigation.

4.0 Getting Real

The analysis and observations thus far have been aimed at helping risk professionals communicate to the public and to decision makers the advantages of natural hazard planning. This section will take a somewhat different viewpoint from the other end of the spectrum: that of an elected public official, with no quantitative analytical background. Consider yourself in the position of a public decision-maker deciding how much funding to direct to current needs (schools, hospitals, police protection, public facilities, economic stimulation) and how much to divert to long term sustainable planning related to events with 100- to 500-year return periods. Don't forget that you are up for re-election or reappointment in four years. Even though in some risk communication techniques we are forgetting probability, we know that the chance of evading a 500-year event during the next four years is more than 99%.

This is the real world; the one in which decisions on investments for retrofit and natural hazard risk must be judged. All the issues of incompatibility of lifetimes and the social psychologists and perceptions surrounding risks are real, but not quantified, or even mention. As an elected official you are ultimately responsible to the public; a public that generally is unaware of the implications of probabilities.

Fortunately, this situation is changing. There are many positive factors that will bring improved alignment between political realities and hazards planning. The most important change is that engineering risk professionals are assuming a new leadership responsibility in bringing these issues to the attention of leaders, and the public at large. This expansion of the role of structural reliability defines a much broader role for the engineering professional than was usually taken, and will undoubtedly lead to more effective risk understanding among a wider community (Corotis, 2007).

Another positive development is actually the result of the aftermath of the terrorist bombings in the United States in 2001. People recognized that there is structural risk in the built environment, and that it is not reasonable to devote a sufficient amount of society's resources to make this risk vanishingly small. The concept has become more widely accepted that there are tradeoffs of investment in communities, including work environment, aesthetics, and building cost for structures; and between the constructed environment and services such as fire, police and medical in society in general.

A third positive sign comes from the increasing acceptance of life cycle costing, rather than simply initial investment. The fact that the U.S. federal government and many states require this for transportation projects reflects a growing awareness of total present and future costs. As newly effective ways to convey and contrast life cycle costs are developed, it will become easier to incorporate investment savings due to design consideration for low probability, high consequence natural hazard events.

A tool that will also make a difference is that of computer visualization and scenarios. The former can be used to show people vividly what will happen if some natural hazard event occurs. Seeing the devastation is a lot more effective than having an engineer describe it. And alternative effects of structural building codes, land use regulation and mitigation policies can be forthrightly displayed. Similarly, scenarios have a very strong impact on people. Their use must be carefully tempered, however. Only a finite subset of potential scenarios can be presented, often omitting ones more liable to occur but less dramatic.

5.0 Conclusions and Recommended Agenda

Engineering risk analysis is currently developing from a purely technical field to one that incorporates the psychological rationale that drives the political decision maker, and more importantly the public. This provides an opportunity for engineers to bridge the gap between low-probability, high-consequence events and the response and motivation of the public and their leaders. 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 here provide an important next step for incorporating natural hazard risk into long-term development plans. Overcoming the challenges presented by the five main issues discussed in this paper should assist the development and validation of an inclusive plan that leads to improved infrastructure sustainability. The solutions and risk communication tools which were developed in this paper are summarized below in the form of an agenda. 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 paper 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 ease with which one can imagine an event and react to it emotionally, focusing on historical hazard catastrophes and educating the public on such disasters can also effect risk perception. Finally, minimizing discussion of probability and instead presenting risk in terms of particular scenario outcomes has also been shown to be impactful for the general public.
- **Public Involvement:** Public participation has been shown to increase citizen interest and support for hazard mitigation. The case studies presented in this paper show 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 adds valuable insight in developing environmental alternatives and policies.

- **Incorporating Community Values:** Risk communication is effective when it addresses the values that the affected parties believe to be at risk. Beyond financial loss, fatalities, and injury, there are other direct and indirect losses that are important to a community. Presenting the costs and benefits of a risk mitigation activity based on the framework of specific community assets can be successful in promoting hazard mitigation policy. This paper 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 accountability and rewards can hamper hazard mitigation. Reporting methods such as the ASCE Report Card and the Infrastructure RATE Card can be used to enhance political accountability for long-term risk-mitigation decisions. The effectiveness of these methods might be enhanced by more frequent publication and a focus on local issues. As shown by Mayor Newsom's response to a news article, which led to the CAPSS soft-story study, public education can influence political accountability for long-term planning.

- **Cost Presentation Methods:** While financial-based tools are effective in communicating risk and return, there are many sensitivities and varying views when it comes to the components which comprise the financial accounting of costs and benefits. Although a constant 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, the issue of discounting can be sidestepped. While this approach has pitfalls, it can provide an effective way to communicate the costs and benefits of risk mitigation to the public and its political leaders.

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