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Perception of Risk of Natural Hazards: A Hazard Mitigation Plan Framework

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Perception of Risk of Natural Hazards

A Hazard Mitigation Plan Framework

By

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Perception of Risk of Natural Hazards: A Hazard Mitigation Plan Framework

Thesis directed by Professor Ross B. Corotis

Within this thesis is a new way for policy makers to incorporate sociology and human perception of risk into their hazard mitigation plans. Previous methods used only dollar losses from natural hazard events as the statistic by which to make decisions. Disregarding how people view natural hazards can cause lack of compliance of emergency plans. This could lead to an even greater disaster. New graphs have been created that combine the typical risk assessment factors, such as death, injury, and economic loss, and human perception of risk. The framework includes risk perception by plotting natural hazards on the axes of dread versus familiarity. These two created parameters represent the largest range of an individual's risk perception as studied by social scientists. Knowing where a hazard stands in terms of risk perception can help policy makers adequately prepare for future events.

Table of Contents

Table of Tables

Table of Figures

1 Introduction

1.1 SYNOPSIS

This chapter will introduce the study on how people perceive the risks of natural hazards. It will discuss the overall purpose and the order in which the information will be covered.

1.2 INTRODUCTION

The purpose of this report is to combine the mathematical, objective approach of engineering to the emotional perception of sociology to direct natural hazard mitigation to more comprehensive and realistic decisions. Including human perception of risk of natural hazards is necessary to provide public direction in emergencies that complements their natural response. Unfortunately, policy makers have a hard time quantifying how someone will react and often resort to only considering the dollar loss associated with each natural hazard event. This may seem easier at first, but preparing for how the public reacts can make or break a well thought out mitigation plan. A new framework has been created recently to quantify the public's perception of risk while including the typical loss statistics (Corotis and Hammel 2010). The term framework refers to the layout and components of the graph. Based on the research of the social scientist Paul Slovic, two main factors contribute to someone's perception of risk: dread and familiarity. A graph of dread versus familiarity was produced, including losses due to deaths, injuries, and damages, to give policy makers the information they need to make an informed decision. Previous research created this framework for the United States as a whole. This report regionalizes the data as well as extends the definition of dread in order to make this framework more accurate and applicable. The purpose of these new, regionalized graphs is to visually

represent all the information that a policy maker needs to develop a plan for dealing with natural disasters. This will allow for greater public compliance in emergency situations as well as adequate preparation by authorities due to anticipation in human response.

1.3 LAYOUT

The thesis will begin in Chapter Two with a discussion of the appropriate background knowledge on each of the important subjects. That chapter will discuss engineering and sociology separately. Chapter Three will discuss how others have combined these areas of study in the past and what their findings were. In Chapter Four the main results of the thesis are presented and supported. Chapter Four contains all of the data and graphs. Chapter Five will conclude the study and its findings. There will also be a discussion of further research that is suggested.

2 Background

2.1 OVERVIEW

Proper background information is essential when presenting new information. The subject of hazard mitigation is very involved and complicated. The basics will be explained along with the typical factors used to assess risk in hazard mitigation plans. Also, with any engineering-based study come large sets of data that need to be reformatted and manipulated. Problems can arise from combining these values into one metric. Finally, the perception of risk will be discussed. This subject is based on sociological studies of human perception. Being able to combine the mathematics and objectivity of hazard mitigation with the sociology and subjectivity of human perception is the goal. Thus a proper background in each subject is given.

2.2 DECISION MAKING IN HAZARD MITIGATION

Hazard mitigation plans provide the foundation for a community's response to a disaster. Being able to adequately prepare for natural hazards has been a topic of concern for many years. Hurricane Katrina brought a lack of planning to the forefront. Engineers were blamed for the inadequate design of the levee system that caused major flooding in New Orleans. How does that event affect the perception of risk of the people of New Orleans? How will that community react to hurricanes in the future and what tool can be used to properly plan for such events?

"Mitigation Plans form the foundation for a community's long-term strategy to reduce disaster losses and break the cycle of disaster damage, reconstruction, and repeated damage. The planning process is as important as the plan itself. It creates a framework for risk-based decision making to reduce damages to lives, property, and the economy

from future disasters. Hazard mitigation is sustained action taken to reduce or eliminate long-term risk to people and their property from hazards" (Multi-Hazard Mitigation Planning).

FEMA requires that local governments develop a hazard mitigation plan for their area. This will allow them to receive disaster assistance or funding if an event occurs. Currently, local agencies develop plans based primarily on the numbers associated with property damage, injuries, and loss of life in their area due to certain hazards. FEMA 592 2007 outlines the country's goals for hazard mitigation. Section 203 discusses preparation that can be done before a hazard hits. Part (b) of this section specifically describes that local governments will receive assistance, "…in the implementation of predisaster hazard mitigation measures that are cost-effective and are designed to reduce injuries, loss of life, and damage and destruction of property" (FEMA 592 2007). This document allows for performance-based engineering to give local governments flexibility in their analysis in establishing a hazard mitigation plan. Hazards affect different areas in different ways, and each area reacts in its own way to hazardous situations. FEMA does not have a prescribed method that produces a completely effective hazard mitigation plan. As stated before, the *process* is just as important as the final product. There are many sources that city planners and engineers use to create hazard mitigation plans for their area.

FEMA 386-2 2001 outlines specific measures communities should use to assess risk. Understanding the risks in specific areas can be achieved by a simple step-by-step risk assessment. First, the hazards that will affect a particular area must be determined. This is often based on historical records of which hazards have affected the area in the past. Next, it is important to assess which assets are most at risk to those hazards. Spending time and money on

hazard prevention in areas that are not vulnerable to that hazard is a waste of resources. Determining at risk areas is an important way to prioritize. Furthermore, governments need to be aware of what assets will be damaged. Funds should be further prioritized towards important or irreplaceable items, injuries, or loss of life. Lastly, FEMA describes that a community should determine, "to what degree they will be affected, as measured through dollar loss" (FEMA 386-2 2001). Many problems arise when all types of losses are assigned a dollar value and are combined to make decisions. This will be discussed further in a later section.

A cost-benefit analysis was done on the effectiveness of FEMA hazard mitigation grants. This study gives insight into the positive effects of hazard mitigation plans. They determined that the, "…overall benefit-cost ratio for FEMA mitigation grants is about 4 to 1, though the ratio varies from 1.5 for earthquake mitigation to 5.1 for flood mitigation" (Rose, Porter and Dash 2006). Therefore, on average, one dollar spent on hazard mitigation will save four dollars in losses from a natural hazard. Even more interesting is that these results show that money put into mitigation on hazards with a low risk perception (typical of the flood hazard in contrast to earthquakes) yields very high return. In contrast, hazards with a high amount of associated fear, such as earthquakes, receive a higher level of attention and mitigation funding, and hence do not yield as great a benefit from money put into hazard mitigation. Note that the value of life in this study was $3.5 million back in 2006.

2.3 TYPICAL RISK ASSESSMENT FACTORS

2.3.1 SHELDUS

Records of natural hazards and their reported losses are documented in different ways. The Hazards and Vulnerability Research Institute at the University of South Carolina has

compiled all these records into a single, publically accessible database. The database is referred

to as the Spatial Hazard Events and Losses Database for the United States (Hazards and

Vulnerability Research Institute 2009). It provides comprehensive records of natural hazard

events from 1960 to 2009 and is updated frequently. SHELDUS used to require that the event

cause at least $50,000 in damages or 1 death to be recorded. It has since changed that

requirement to include events of all loss ranges, monetary and human. They are currently in the

process of adding smaller events and thus the data from SHELDUS may be incomplete in some

areas. There are a few drawbacks of SHELDUS. First, the system uses 18 natural hazards under

which losses are catalogued. The sources for these hazard losses are reported. However, the

definitions of each hazard are not given, thus causing some ambiguity. For instance, coastal is

one of the hazards they use. There seems to be no clear definition of what a coastal hazard is.

Hurricanes and tsunamis are already their own category so losses from these events are not

included in coastal. Further research found that storm surge would be a likely component of a

coastal hazard. Also, the severity of injuries is not given. This takes some meaning from the

effects of each hazard event. Knowing the severity of the injuries of an event could contribute to

this study in the area of risk perception. A separate study was found to supplement this

shortcoming. Finally, as mentioned, the database is in the middle of removing the minimum loss

threshold and including all events. This causes a spike in smaller events in the already updated

portions whereas the other portions contain only larger events. This database was used as the

primary source for data on the typical risk assessment factors – death, injury, and dollar loss –

familiarity, and dread. Another source used to find a small portion of data was EM-DAT

managed by the Center for Research on the Epidemiology of Disasters (CRED 2009). The

values from these databases were collected and will be reported as averages.

6

2.3.2   Losses due to Death

Quantifying the value of a life has proven to be very difficult for scientists and governments alike. This designation comes with emotional ties, as many people feel that it is desensitizing to quantify a life in dollars. The federal government is even considering doing away with their concept of the "value of a statistical life" to get rid of any implications that they are defining how valuable someone is in society. The EPA has proposed changing the terminology to the value of mortality risk. This is quantified as, "willingness to pay for a reduced risk of 1/1,000,000 or a 'micro-risk'" (Environmental Protection Agency 2010). This new terminology is aimed at reducing confusion and concern in policy making. The idea could eventually be applied to the area of natural hazards; however, further research and studies need to be done to discover its applications in such areas. Agencies and researchers around the Unites States have had trouble dealing with this concept. The same value is rarely used in different applications. Some have tried to use a scaling system in which they decide whose lives are more important than others. Often, the value assigned to death in dangerous jobs, such as on a construction site, is lower than for jobs where death is very unlikely. The EPA has even considered using a weighting system to reflect fear associated with the manner of dying, incorporating, "…a cancer differential into mortality risk valuation guidance" (Environmental Protection Agency 2010). This would place a higher value on risk due to cancer than other ways of dying. This weighting system can get very complicated and is frequently seen as unethical. None of these weighting systems will be used in this application.

For this study, a typical dollar value will be assigned for each death as a comparison mechanism to alternative methods (although this study will also present the actual number of deaths, separate from injuries and property loss). The Federal Aviation Administration wrote a

guide on the economic values to be used in decision-making, including the value of life and injuries, which will be discussed later. Their data come mainly from analysis done by the U.S. Department of Transportation. The study shows that a value of $2.5 million was used in 1993. Converting for inflation yields a value of about $3.77 million, which was rounded to $4 million for simplicity. The U.S. Department of Transportation reached this amount, "…in order to value the benefit of investment and regulatory decisions" (Rose, Porter and Dash 2006). The study most closely resembles the type of application used here.

2.3.3   Losses due to Injury

Injuries are equally difficult to quantify into a dollar value. Although it does not introduce ethical issues to the extent of deaths, the severity of the injury is often taken into account as well as the future effects of that injury. The designations are show in Table 1. The Federal Aviation Administration (FAA), which defined the value of a life, also defined the value of injuries as a percentage of the total value of a life. These percentages are shown in Table 2 below.

Table 2-1: Selected Sample of Injuries by the Abbreviated Injury Scale (AIS)

AIS Code	Injury Severity Level	Selected Injuries
1	Minor	Superficial abrasion or laceration of skin; digit sprain; first-degree burn; head trauma with headache or dizziness (no other neurological signs).
2	Moderate	Major abrasion or laceration of skin; cerebral concussion (unconscious less than 15 minutes); finger or toe crush/amputation; closed pelvic fracture with or without dislocation.
3	Serious	Major nerve laceration; multiple rib fracture (but without flail chest); abdominal organ contusion; hand, foot, or arm crush/amputation.
4	Severe	Spleen rupture; leg crush; chest-wall perforation; cerebral concussion with other neurological signs (unconscious less than 24 hours).
5	Critical	Spinal cord injury (with cord transection); extensive second- or third-degree burns; cerebral concussion with severe neurological signs (unconscious more than 24 hours).
6	Fatal	Injuries, which although not fatal within the first 30 days after an accident, ultimately result in death.

Table 1: FAA Injury Level Categories (GRA, Incorporated 2004)

8

Table 2-2: WTP Values Per AIS Injury Level
(2001 dollars)

AIS Code	Description of Injury	Fraction of WTP Value of Life	WTP Value
AIS 1	Minor	0.20%	$6,000
AIS 2	Moderate	1.55%	$46,500
AIS 3	Serious	5.75%	$172,500
AIS 4	Severe	18.75%	$562,500
AIS 5	Critical	76.25%	$2,287,500
AIS 6	Fatal	100.00%	$3,000,000

Table 2: FAA Values for the Percentage of the Value of Life Due to a Certain Injury Level (GRA, Incorporated 2004)

These fractions and willingness-to-pay (WTP) values are determined due to the level of injury a person sustains under the Abbreviated Injury Scale (AIS). Similar numbers were used in a study of the value of injuries in the Northridge Earthquake using the AIS scale (Porter, Shoaf and Seligson 2006). The values in the FAA study were used as the data are more recent. This introduces some uncertainty, as the classification of injuries is very subjective. However, the SHELDUS database, which has provided all the data for this study, defines an injury simply as, "Number of injuries associated with an event" (Hazards and Vulnerability Research Institute 2009). There is no distinction as to the severity of the injury.

To better estimate the cost of an injury in fraction of life value, it would be helpful to know the probability that a certain injury will fall under one of the above categories. A study by Kaneda in 1994, geared toward a medical audience, was performed to show the number of injuries that are likely to occur in each category of severity during two Japanese earthquakes. His data were collected from the Sendai City Medical Association and the Journal of the Akita Medical Association. The results are summarized in Table 3 below.

Extent of Injury	Miyagi Earthquake	Percentage of Total Injuries	Japan Sea Coast Earthquake	Percentage of Total Injuries	Average Percentage
Major	235	8%	31	10%	9%
Moderate	1431	49%	92	29%	39%
Minor	1257	43%	193	61%	52%
Total	**2923**	**100%**	**316**	**100%**	**100%**

Table 3: Probability a Specific Injury Will Occur in an Earthquake (Kaneda 1994)

These results show that of the injuries sustained in these earthquakes, it is more likely to be
minor and least likely to be major. Due to a lack of injury data, the average of these percentages
will be used as an estimate for percentage of injury type during a representative earthquake. The
injury severity categories are not the same as determined by the FAA. Also, Kaneda did not
explicitly define his injury categories. To combine the FAA study describing fractional costs to
Kaneda's study which found probabilities that certain injury levels were likely to occur, the
common factor of severity categories must be connected. Two possible ways of equating these
differences are proposed and listed in Table 4.

Option 1		Option 2	
Kaneda	FAA	Kaneda	FAA
Major	Critical & Severe	Major	Critical
Moderate	Serious & Moderate	Moderate	Severe & Serious
Minor	Minor	Minor	Moderate & Minor

Table 4: Comparison of Injury Severity Categories

Using basic probability in each case, a value for a single fraction of life was computed to
represent the cost of injuries. The probability that an injury will be major, moderate, or minor
was taken from Table 3, while the fractional cost of each injury was taken from Table 2.

$$Average\ Fractional\ Cost\ of\ All\ Injuries$$

$$= P[Major][Major\ Fractional\ Cost]$$

$$+ P[Moderate][Moderate\ Fractional\ Cost]$$

$$+ P[Minor][Minor\ Fractional\ Cost]$$

In the case where two FAA categories represent one category from Kaneda, the fractional costs are averaged. Inserting the known values for each option yields a range of 6% to 12% of the $4 million assigned to the loss of a life. Reasonably, a value of 10% was chosen from this range, intended to be somewhat conservative and not underestimate the value of injuries. The problems with this method include the fact that the number of injuries in each category was only found for certain Japanese earthquakes and could vary for different earthquakes, as well as from hazard to hazard. Also, the definitions of the categories for Kaneda and the FAA are difficult to equate. Finally, Kaneda's values represent a very small number of events and injury distributions.

2.3.4   Direct Economic Losses

Direct economic losses are the easiest to quantify as they are a direct consequence of the natural hazard. This metric is typically used in most hazard mitigation plans as it is very straightforward and does not present any moral complications. SHELDUS splits these losses into two categories: property damage and crop damage. Total damage will be used, since the distinction is not necessary in this study. Still, direct losses only partially represent the economic impact from a natural hazard. Often indirect losses far outweigh the initial costs.

2.3.5   Indirect Economic Losses

Economic losses reported in the SHELDUS database are only direct losses associated with a certain hazard event. Indirect losses, such as the effects on local businesses when roads are closed, are not included. It is common for such losses to be combined in engineering

applications; however, they are seen very differently from a sociological standpoint. Often when a person considers the risks of a natural hazard, their familiarity and dread associated with that hazard are based heavily on the direct costs. Perception of risk focuses on the immediate consequences as opposed to the long term effects. Since the human risk perception of natural hazards developed in the study does not account for long term effects, it would be misleading to use indirect costs in the framework. Another confounding issue with indirect costs is that they vary significantly from hazard to hazard and situation to situation. Some have proposed that indirect costs be calculated as a certain percentage of the direct costs. However, these percentages would have to be a result of long term studies specific to each hazard in order to be accurate. This study uses only direct costs, in order to avoid misleading people about the effects of indirect costs. On the other hand, the reader should keep in mind that there are indirect costs associated with each hazard and they may be even more costly than the direct costs.

2.4   EXPECTED VALUES

When creating a hazard mitigation plan, policy makers typically use the expected values of natural hazard data to make decisions. Typically the average number of earthquakes per year or the average number of deaths per event is used. Expected values may represent a readily available statistic, but there are several problems that arise from using them. Expected values of natural hazard losses are averages of many outcomes and events, and do not represent people's perception of risk. Individuals may react very differently to a small but relatively frequent hail event that causes minimal amounts of damage and injuries versus a large, infrequent storm that blows out car windows, destroys roofs, and injures their loved ones. An average of losses does not tell a policy maker the distinction between small events that are more likely to occur and

large events that seldom happen. Yacov Haimes describes that, "In the classic expected-value

approach, extreme events with low probability of occurrence are each given the same

proportional weight/importance regardless of their potential catastrophic and irreversible impact"

(Haimes 1998). For example, Iowa may have hundreds of small flooding events per year. In

July of 2010, they had record flooding that caused millions of dollars in damage (CBS News

2010). That single event pushed what was a low average of dollar loss per year in flooding to a

much higher level. If the mitigation plan was revised, it might instead plan for more severe

floods even though they are very unlikely.

Another problem with expected values of natural hazard data is the way scientists use

them to create scenarios. Probabilities are often difficult for the general public to understand.

Thus, scientists may resort to creating scenarios with characteristics derived from the expected

values of the data. For example, a study was done by the Geological Survey of Canada and the

United States Geological Survey (USGS) on scenario-based risk analysis. They graphed the

likelihood of an event happening versus the amount of dollar loss due to building damages if that

hazard were to occur. This graph represents probabilities of certain events occurring. The

general public may have a hard time understanding these values and what they really mean. A

scientist could report this probability data to the public in a way that presents only the expected

value outcome. The graph is shown below in Figure 1.
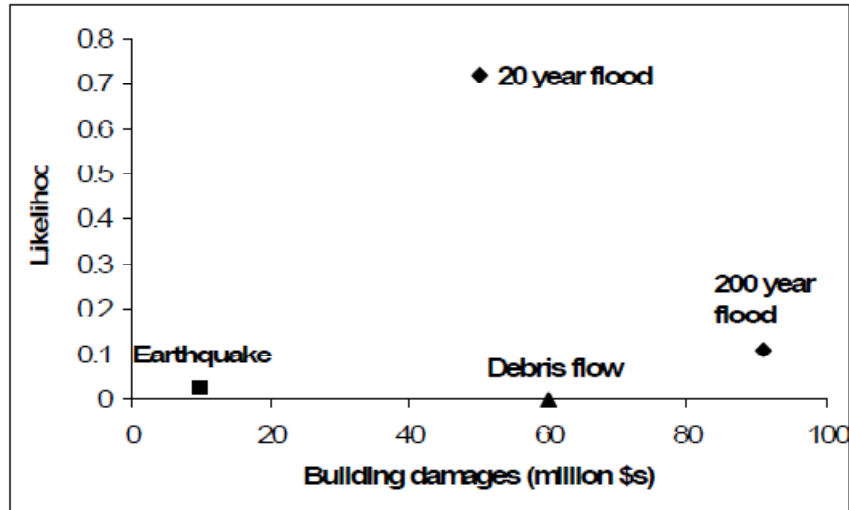
Likelihood (probability of at least 1 hazard scenario over 25 years) and severity (building replacement costs) of multiple natural hazard scenarios in Squamish

Figure 1: Likelihood vs. Building Damages for Squamish, Canada (Wein, Journeay and Bernknopf 2007)

For example, looking at the 20-year flood, it has over a 70% chance of occurring in the next 25 years. The scenario under which policies may be based would include that in the next 25 years a flood is likely to occur that will cause $50 million in damages to the buildings in Squamish, Canada. The scenario allows policy makers and the public to get a better understanding of the probability of events; however, it does not include the uncertainty in this outcome. This flood could occur in three days, or it could occur in 50 years. Also, the damage values used here are estimates. Showing a distribution of damages associated with a 20-year flood, or even providing the standard deviation, could help remedy the issue of expected values of losses or events used in scenarios. Without some sort of information on uncertainties, policies could be made based on this scenario and could lead to unnecessary preparation.

Finally, using expected values does not take into account how people feel about or react to the various components that comprise the average. As described above, a certain hazard may

have a modest average due to low probability, high consequence events, or to high probability, low consequence events. Someone may feel more nervous about that average if they knew what contributed to it. For example, the expected value may be a 50-year flood. The public may vote for policies to prevent the consequences of a 50-year flood or larger. If the public was informed that the expected value was an average of hundreds of 10-year flood events and one severe event, they may react differently. People may even choose to move away from an area without understanding the frequency and severity of the floods. Using expected values fails to address these issues and can cause miscommunications. The data that have been collected for this study were taken from the Spatial Hazard Events and Losses Database for the United States (SHELDUS 2009). The data were collected in an expected value approach due to the volume of entries. Policy makers should keep the above information in mind when considering the information presented in this paper.

2.5   RISK DEFINED BY MONETARY LOSSES

It is typical in engineering to convert factors that are being compared to a common unit of measure. This is often done in hazard mitigation in an attempt to show decision makers how much money they might lose from a certain hazard event. Monetary loss is a convenient basis to understand and base decisions. On the other hand, several problems arise when death, injury, and economic losses are described in dollar terms. As discussed above, setting an accurate price for a life is difficult and forces policy makers to make moral decisions about the importance of losing a life. Depending on what value is chosen, results can vary significantly. A recent New York Times article explained how the value of life differs greatly among different departments of the government (Applebaum 2011). Below is a complied table of notable departments and the

15

value of life that they use to make decisions. Professor Viscusi is a longtime expert on the subject of the value of a life. He began his studies as an undergraduate at Harvard in the early 1970s and has continued this research for his professional career. His work is often the basis that agencies use to determine their own value. In order for engineers to make informed decisions, the value of life must be estimated to reasonably reflect how a death will affect the community and local government.

Agency	Value of Life (US Millions)
Environmental Protection Agency	$9.1
Food and Drug Administration	$7.9
Transportation Department	$6.0
Bush Administration	$6.8
Professor Viscusi	$8.7

Table 5: Value of Life from Different Sources (Applebaum 2011)

It can be noted that there are even differences within agencies. As mentioned in section 2.3.1, the Federal Aviation Administration, part of the Department of Transportation, is using a figure that is around $4M. The variability in the dollar values of death and injury should be considered when creating hazard mitigation plans.

2.6   PERCEPTION OF RISK

Risk, as used in engineering is, "… a function of the likelihood of event occurrence and the resulting consequences" (Nafday 2009). These consequences have been defined above as mortality, morbidity, and economic loss. Engineers strive to define a problem so as to best plan for the future. Often, emotions are set aside and replaced by models, computer programs, and equations created to explain certain occurrences and phenomena. Hazard researcher John Twigg describes 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). People are in many ways individual and unpredictable, and thus 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 is a social scientist who has conducted significant studies on how people perceive risk. He outlines his studies in his book, *The Perception of Risk* (Slovic, The Perception of Risk 2000), in which he creates a new framework on which to measure risk based on human perception. From a statistical factor analysis conducted in his work, he discovered that the perception of risk is based primarily on three parameters: voluntariness, familiarity, and dread.

Slovic realized that, "The basic assumption underlying these efforts is that those who promote and regulate health and safety need to understand the ways which people think about and respond to risk" (Slovic, The Perception of Risk 2000). Civil engineering is one of the primary players in the reduction of risk due to natural hazards. Providing properly designed infrastructure and incorporating how people perceive risks is crucial to reducing hazard consequences. Slovic's research does not include how people perceive risk from natural hazards. Thus, this study attempts to relate his methods to the area of hazard mitigation.

The basis of this study comes from Slovic's use of Factor Analysis. He 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.

Dread	Not Preventable
Affects Future Generations,	Catastrophic
Potential for Global Catastrophe	Involuntary
Certain to be Fatal	Many Exposed
Increasing	New
Affects Me	Immediate
Inequitable	Unknown to Exposed
Not Easily Reduced	Not Observable
Uncontrollable	Unknown to Science

Table 6: 18 Risk Characteristics (Slovic, The Perception of Risk 2000)

The data were plotted in an 18 dimensional space of all the characteristics. Typically, a correlation matrix of these characteristics would be created to describe their relationship. However, Factor Analysis was used to simplify and reduce this confusing matrix. Kline (1994) describes Factor Analysis as, "a dimension or construct which is a condensed statement of the relationships between a set of variables" (Kline 1994). Factor Analysis provides a reduced basis aligned with the principal directions of variance among the data. As such, a limited number of factors can often be substituted to represent most of the variation among the observed data. Analyzing the data, Slovic determined a reduced set of new factors that sufficiently described the great majority of the variability among the risks. He then examined factor loading to determine the original characteristics that were most highly correlated to his new factors. The first principal factor is the direction that describes the largest amount of risk variability. Using the factor loading of these characteristics on the first factor, he determined that this factor described various aspects and attributes of dread. Continuing the process, he used axis rotation to find the factor which explained the second highest amount of variability in the data, and again through loadings of the characteristics on this factor he termed this second factor familiarity. By keeping the factor axes orthogonal he assured that these two factors were independent in the space of the

original 18 characteristics. The third most important factor was associated with aspects of voluntariness. This parameter will not be used in this study, which will be explained below.

Dread is the first factor that Slovic found to be a good gauge of risk perception. The word dread implies fear, and in the case of hazards it is associated with terms such as uncontrollable, difficult to prevent, or disastrous. Dread is expected to vary regionally. For instance, winter storms in the Southeast are usually mild and don't cause major losses, whereas winter storms in the Mountain Region are often very severe, uncontrollable, and sudden. The level of dread will vary from the Southeast to the Mountain Region due to the different characteristics of the storm hazards seen in those regions.

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. A woman who has lived on the coast of Florida for 50 years has likely experienced hurricanes many times. This will in general reduce her perception of risk because she is familiar with the events. If a man from Kansas moved right next door to her, he is likely to perceive a higher level of risk from hurricanes because he has never experienced one. This factor varies considerably from region to region, especially due to the large geographical spread of the United States.

The final parameter that was found to dictate an individual's perception of risk was whether or not they voluntarily entered into that risky situation. For instance, there is not a high perceived risk for smokers because they voluntarily smoke cigarettes, despite proven negative health effects. Fortunately for our study, voluntariness has little relevance. Natural hazards strike whenever and wherever, frequently without warning. Theoretically, it would be possible to apply voluntariness in a manner that accounts for where people choose to live. If people decide they want to live in California, they may have already considered the risk of earthquakes.

On the other hand, many people do not necessarily choose where they live. They may get a job that requires them to relocate to a region where specific risks are high. The prospect of a good job may outweigh the risks of moving to that area. Due to this presence of so many other factors is selecting location, and the lack of information, this factor of risk perception will not be incorporated.

3 Previous Framework for Natural Hazard Risk Analysis

3.1 OVERVIEW

This section describes previous work that was done in this area of study. Applying the perception of risk to the area of natural hazards is not a new concept. Many emergency planners have realized the large effects that human perception can have on successful mitigation plans. If a plan is created that works against the typical response of the public, the plan will fail. For example, when a disaster strikes, one of the first reactions people have is to call their loved ones. Phone lines are then tied up with the general public trying to communicate with each other. In many instances, this has prevented emergency personnel from being able to communicate. Knowing this human response can save many lives. Emergency responders should create a plan that includes this response. Many steps have been taken to prevent situations like this. The following explanation will give a background of what has been done in the past so that the extension of this study in Chapter Four is well understood.

3.2 PRIOR STUDIES

Slovic's study was modified and applied to natural hazards in this research. Evan Hammel investigated risk perception associated with natural hazards in 2005 (Corotis and Hammel 2010). His thesis and subsequent papers addressed how sociological work such as Slovic's can be applied to natural hazards to create a better framework for decision making. A total of 18 risks were assessed, as defined by SHELDUS and shown in Table 7.

Hazard	Abbreviation	Hazard	Abbreviation
Avalanche	**A**	Landslide	**Ls**
Coastal	**C**	Lightning	**Lt**
Drought	**D**	Storm	**S**
Earthquake	**E**	Tornado	**Tr**
Wildfire	**Wf**	Hurricane	**Hr**
Flooding	**Fl**	Tsunami	**Ts**
Fog	**Fg**	Volcano	**V**
Hail	**Hl**	Wind	**Wd**
Heat	**He**	Winter Weather	**Ws**

Table 7: 18 Natural Hazards as Defined by SHELDUS (Hazards and Vulnerability Research Institute 2009)

The two factors Slovic found that best described an individual's perception of risk, dread and familiarity, were used to create a framework. Since these parameters are not specific to natural hazards, their definitions were modified by Hammel. He attempted to relate the descriptive definition found by Slovic to a practical, mathematical way of calculating dread. From interviews he deduced that the time it takes for a hazard to strike is a major contributor to how dreadful people perceive that natural hazard to be. This value is typically called lead time and is carried over from Hammel's work into this study. Hammel also defined that familiarity, in relation to natural hazards, could be measured as the number of occurrences per year. If floods happen often, people will be very familiar with them. On the other hand, if certain areas rarely experience floods, the public will react very differently when one occurs. This definition is also carried over into this study. Below are the values Hammel used to create his framework.

Hazard	Dread (s)	Familiarity (occurrences/yr)
Avalanche	2	3.20
Coastal	2160	13.98
Drought	4320	8.78
Earthquake	2	1.07
Flooding	120	106.20
Fog	720	3.44
Hail	7200	111.80
Heat	5760	9.27
Hurricane	1440	5.51
Landslide	4	2.82
Lightning	4	96.98
Storm	1440	127.29
Tornado	18	92.93
Tsunami	1	0.24
Volcano	10080	0.07
Wildfire	2880	14.47
Wind	729	148.20
Winter Weather	5760	47.33

Table 8: Dread and Familiarity Data for the United States (Corotis and Hammel 2010)

The number of occurrences per year was collected from SHELDUS, which was used again in

this study. The values for dread were taken from an article published by USA Today. This study

extends Hammel's work to make it more realistic and practical, both by specializing it to

different regions of the country, so that it might be used as a practical risk communication and

management tool, and by including more aspects of the hazards in the definition of dread.

Hammel's main purpose was to create a user friendly, multi-attribute framework that could be

used to make decisions when creating hazard mitigation plans. His framework was created for

the United States as a whole. The issues that arise with the assumption that everywhere in the

United States has the same dread and familiarity will be discussed later. He also developed a

graphical system was effective in displaying all the necessary information. Below is a visual

description of how he presented information such as deaths, injuries, and dollar loss.
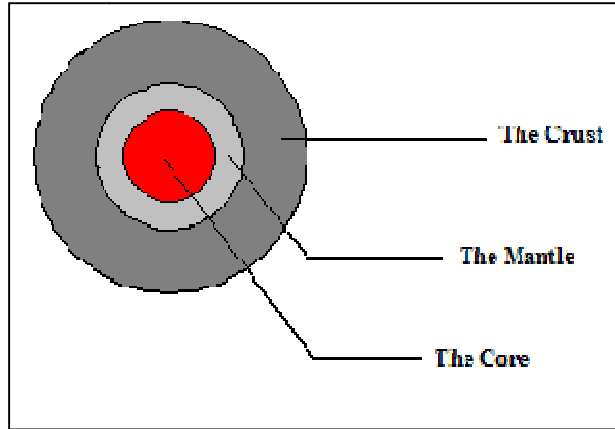
Figure 2: Hammel's Graphical Representation of the Typical Risk Assessment Factors (Corotis and Hammel)

He proposed a set of three concentric circles, with an analogy to the earth, in which the radius of the core corresponded to the number of deaths, the thickness of the mantle from the core to the crust represented the number of injuries, and the thickness of the crust showed the amount of dollar loss. The hazards in the graph are labeled with abbreviations as shown in Table 7. Below is the final form of Hammel's framework.
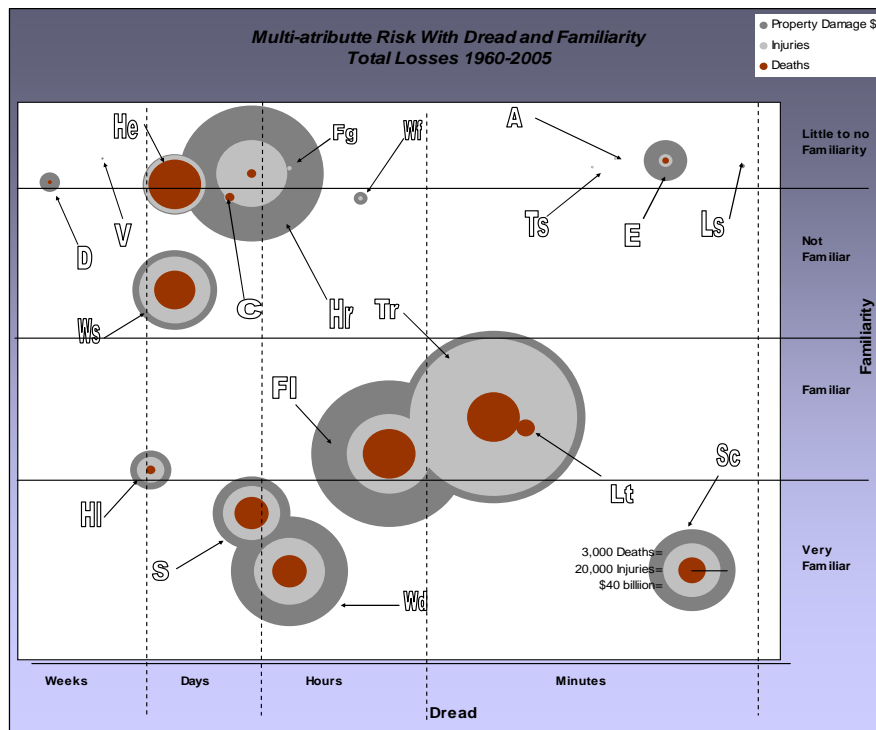
Figure 3: Original Graph of Multi-Attribute Risk with Familiarity and Dread for the United States

24

Displaying information graphically can be very misleading, depending on how the information is presented. Some of Hammel's data points cannot even be seen as they are overlapping. In addition, people have a hard time distinguishing between a large circle with a small thickness and a small circle with the same thickness. Due to the increased size of the circle itself, individuals will see the information differently even though it represents the same loss value. Changes were made to this system to improve the visual quality and provide a more accurate display.

4 Additions to Proposed Changes in Risk-Based Decision Making

4.1 OVERVIEW

Hammel's research introduced a new way of assessing risk perception from natural hazards. In this section, his work will be extended to make his original framework more practical and realistic. His definitions for dread and familiarity have been modified. Also, the data were analyzed here in a regional manner to better explain people's perception and provide a more realistic hazard management tool. This will aid policy makers in deciding on a course of action since natural hazards vary tremendously over regions of the United States. To reduce confusion, the data representation was modified in Excel to better show the sizes and locations on the graph. Finally, a discussion is presented on how population and gross domestic product (GDP) affect the data collected in SHELDUS.

4.2 FAMILIARITY

4.2.1 Memorability

Whether or not the public is familiar with an event is extremely important when considering human perception of the risk that the hazard poses. A person who is completely unaware of the risks could act in a way that inhibits the emergency plan. Actions could range from extreme panic to complete lack of concern. There are many aspects of psychology and sociology that dictate how someone perceives risk. Many are related to how familiar they are with that risk. Slovic concluded that, "any factor that makes a hazard unusually memorable or imaginable, such as a recent disaster, heavy media coverage, or a vivid film, could seriously distort perceptions of risk" (Slovic, The Perception of Risk 2000). Memory is one of the

strongest drivers of people's actions and emotions. In order for a natural hazard event to be memorable, it must happen. Therefore, familiarity is defined as the number of times a hazard event has occurred per year in a specific region. When people in a region are unfamiliar with the particulars of a hazard due to a lack of prior occurrences, the concepts shown in Slovic's research would lead them to have a greater fear and perception of that hazard's risks. Occurrences are divided regionally as it is assumed that an event that happens in one part of the region affects everyone in that region in terms of familiarity. Often, natural hazards cover large geographic areas. The regional divisions of the United States, discussed later, were made in an effort to group states with similar hazard statistics and mitigation practices.

4.2.2   Imaginability

Slovic found that people's perception of risk is often very inaccurate despite proper education. He says that, "Risk judgments are influenced by the memorability of past events and the imaginability of future events" (Slovic, The Perception of Risk 2000). As described above, memory is how one has experienced a natural hazard in the past. Imaginability, on the other hand, is how one sees that hazard happening in the future. Memory often guides a person's imagination. The number of occurrences, or events the public has experienced, allows them to have a more realistic view of what experiencing that hazard at a later date would look like. When creating a hazard mitigation plan, knowing how familiar the community is with specific hazards will allow the plan to include people's instinctive reactions. If a hazard is unfamiliar, imagination will be based on information gathered from a wide range of sources including friends and family, media, film, or government agencies. These sources' information may not be based on fact or typical events but are more frequently describe extreme events.

Mathematically, this information is hard to quantify and add to the parameter of familiarity. This is especially true as Slovic describes that a person with preconceived notions has a hard time modifying those perceptions, whereas someone with no thoughts on the matter is greatly influenced by any information received. The geographic location of a person's family and friends is essentially random, as well as the level of communication among them. Those closest to someone can have a profound impact on one's perception of risk. However, with the uncertainty and lack of data, this study has not found a way to incorporate that effect into the factor of familiarity. Government agencies have a responsibility to provide education to the public about hazards in their area and how to deal with them properly. Education programs such as these are used to increase awareness of threatening hazards in the area. For example, depending on the region, school systems may educate and train the students on how to respond when a tornado hits. This increases the public's level of awareness and provides important information on how to react. Certain cities may have educated the public very effectively and thus this may change their perception of risk. These educational programs were not incorporated into the factor of familiarity but should be considered when planning for hazard mitigation. Each natural hazard calls for unique strategies for avoiding that hazard's risks. Local agencies can greatly reduce the typical risk assessment factors by accounting for the public's perception of risk in their area using the framework created in this research. The role of media in risk perception is an interesting topic that has been studied in depth. Its effects on risk perception are a controversial, with ongoing discussion.

Unfortunately, the strongest examples of the public reacting in irrational ways to natural hazards come from developing countries. Disasters such as the Haiti earthquake or the tsunami in the Indian Ocean show how being unfamiliar with a hazard and the warning signs can greatly

28

increase the devastation to the public. People in Haiti were unaware of such a large earthquake risk and therefore did not take the steps to build according to earthquake codes or enforce building standards. Thus, the damage was catastrophic even though the earthquake was weaker, with only a magnitude of 7.0, than many other earthquakes that have caused much less damage. Tourists in the Indian Ocean were actually attracted to the beach as the water drew back before the tsunami hit. Had tourists and locals been educated about the warning signs they might have reacted very differently, and many lives could have been saved. Many people in the United States have not experienced a hurricane or tornado; however, most have heard about them and even seen what they can do. News reports continually state what types of emergency measures people should be taking. Even those small encounters can provide a person with enough information to react in more appropriate ways. Providing hazard mitigation to a country such as Haiti seems like a natural and necessary next step after the 2010 earthquake. Consequently, without an effort to familiarize the country about earthquakes and how to react to them, hazard mitigation plans will not be followed.

4.2.3   Impact of the Media

The role of the media in familiarity cannot be ignored. Most of the United States has access to media sources such as television, newspapers, radio, and internet. With the level of data being circulated through these sources, people's perception of risk is greatly affected. It may seem obvious that media has an impact, but how is risk perception affected by the media? The media can positively affect the way the public is receiving information by getting the word out quickly of the event and how to properly react. One negative impact is the exaggeration of the event, making people more scared than necessary. The media also has the ability to pick and choose what events it will cover. There are thousands of flood events every year and yet only

large and damaging floods are covered. The familiarity of large and/or devastating events is, "a

constant battle for the newest and best headlines, and, thus, includes the potential for negligent

research and even modified stories" (Niedek 2003). This topic has divided researchers and

policy makers on whether the media aids in reducing risk or poses a larger threat.

Supporters of the media argue that the powerful impact it has on today's society can be

extremely helpful in emergency situations. Professor Calvi, President of the European Center for

Training and Research in Earthquake Engineering at the IUSS of Pavia, explained in an

interview that, "With mass media and communication people will take into account risk because

they are familiar with it from anywhere" (Calvi 2009). It could be seen as an advantage that so

many people can be reached through media sources in such a short period of time. Personally

warning the public of a natural hazard requires an infeasible amount of man-power and takes

more time than a hazard would allow. If a warning message was sent by radio or television, a

large quantity of people could be reached in seconds. This is especially important as many

hazards can only be detected seconds before they strike. As seen in the devastation from the

tsunami that hit in the Indian Ocean over 6 years ago, the lack of communication using sources

such as radio and television provided almost no warning. Had villagers and tourists been warned

15 minutes before the wave hit, not only would they have understood what was happening but

they would have had time to react. Ample warning time is crucial in situations such as tsunamis.

With sufficient warning time comes the need for proper education. People in the areas that were

hit didn't know what was happening until they saw a wave coming towards them. Officials must

have known what the potential for a tsunami was after hearing of the 9.0 earthquake. Towns

closest got the worst of it with little to no warning time. However, the news should have traveled

as each city was hit. In many towns the water receded so much that tourists were out taking

pictures. National Geographic reported that, "Experts say that a receding ocean may give people as much as five minutes warning to escape to high ground. There may have been enough time for many of the people who were killed by the 2004 tsunami to save themselves, if only they knew what to do" (National Geographic News). Some places in Thailand many miles from the earthquake's epicenter sent military ships into the harbors to stand watch. If they had spent their time warning and evacuating the people, hundreds of lives could have been saved. This example shows how failing to use resources such as the media to distribute warning messages quickly can be extremely devastating.

On the other end of the spectrum are those who believe the media can worsen a natural disaster situation. Slovic cites several separate studies that have shown, "Content analysis of media reporting in… the domain of hazards in general has documented a great deal of misinformation and distortion" (Slovic, The Perception of Risk 2000). These situations have led to public overreaction of risk, which means they will spend more time and money than authorities recommend to prevent a risk that isn't really there. For example, experts determine that people within a certain radius need to be evacuated due to a tsunami warning. The media chooses to exaggerate the problem to get the best news story which causes more people than necessary to evacuate. This interrupts emergency personnel since the large volume of people evacuating was unexpected. There is also the possibility that if the media consistently gives people distorted or misinformation, they will no longer be trustworthy. This discredits the media as a source for real information. Thus, it is no longer effective to send out warning messages as no one will believe them. The impact of the media with respect to natural hazards is very controversial. The best case scenario would be for the media to report factual information without exaggeration for their own gain. The power they have can either be used for good or

could turn into complete disregard. Unfortunately, there is currently no clear cut way of

applying the impact that media has on the parameter of familiarity, and as such its effects will be

omitted in the calculations.

4.3   DREAD

As described in Section 2.6, dread best described the variability of the data of risk

perception from Slovic. He described this risk perception as catastrophic, hard to prevent, fatal,

inequitable, threatening to future generations, not easily reduced, involuntary, and personally

threatening (Slovic, The Perception of Risk 2000). Risk perception and human reaction is a well

studied subject. Twigg, a senior research fellow for the Aon Benfield UCL Hazard Research

Center in Germany, stated, "that the experience of risk is … one of physical or potential physical

harm…" (Twigg 2003). These definitions were the basis for describing dread in terms of

measurable quantities. Three quantities are utilized in this research to compute dread. As

continued from Hammel's work, lead time, or time to react, was used as a measure of dread.

Hammel referred to these values as temporal response time, but further research indicated that

lead time was the term most commonly used, whereas response time was more often the time for

emergency crews to respond. These values were refined with new information from recent

studies and advancements in weather prediction technology. The second parameter, as extended

from Slovic's description of dread as fatal, is the amount of people that die during each event.

The amount of people who die in one event contributes greatly to an individual's dread. The

third measurement is created from Twigg's analysis of risk perception as derived from physical

harm. This factor is the amount of people who are affected during a hazard event.   This

accounts for dread from injuries and property damage, two of the three typical risk assessment factors. These three measurements will be described in detail.

4.3.1   Lead time

Lead time plays an important role in the perception of risk. The smaller amount of time a person has to react usually increases adrenaline and forces people to make rash and spur of the moment decisions. When combined with natural hazards, the outcome can be described as levels of dread. A person, on average, has a few seconds to react to an earthquake. Compare this to the 3 days people have to prepare for hurricanes. It is common for people in hurricanes to board up their house, obtain emergency supplies, and wait out the storm, rather than evacuate. On the other hand, when an earthquake hits, people's first reaction is to run. Emergency personnel and seismic experts would advise the public to stay inside, as buildings in the United States are seismically designed, and people have a lower probability of being hit by falling hazards. With little time to consider the best options or obtain better information from officials, people generally panic and think that being on the ground will be safer. This is the first important piece of the new dread parameter which was carried over from Hammel 2005.

Criticism of Hammel's work included the sources used to find lead time values. This study sought to remedy that problem by providing extensive research of these values from experts specific to each hazard. Lead time for natural hazards collectively has not been studied very extensively. As a result, these values could not be found regionally for the United States. On the other hand, lead times can be expected not to be greatly affected by region of the country. There are some differences, however. For example, based on the geographic layout of the United States, it is common for hurricanes to hit the southeast part of the country first and then possibly move up the east coast. Regions farther from the Gulf of Mexico may experience

longer lead times for hurricanes. Even a hazard as predictable as a hurricane may suddenly change course without warning. Other hazards unrelated to weather are very random. Earthquakes can be predicted very generally, but exact place, time, and magnitude are unknown. Several regions of the United States have experienced earthquakes in the past. Due to the random nature of earthquakes, there is no evidence to show that lead time on the Pacific coast, for instance, is significantly different from lead time in the southeast. This is a recommended topic for future study.

Each hazard has very specific lead times depending on technological advancements in areas such as weather reporting. These lead times are measured in seconds and are listed below in Table 9.

Hazard	Lead Time (sec)	Source
Avalanche	5	(United States Search and Rescue Task Force)
Coastal	900	(Gutierrez 2003)
Drought	7776000	(Zillman 2003)
Earthquake	10	(Lee and Espinosa-Aranda 2003), (Lomnitz 2003)
Flooding	28800	(Todini 2003)
Fog	3600	Estimated from individual reports
Hail	1800	(Zillman 2003)
Heat	604800	(UNEP/GRID-Arendal 2005)
Hurricane	86400	(UNEP/GRID-Arendal 2005)
Landslide	5	(United States Search and Rescue Task Force)
Lightning	1	Estimated from individual reports
Storm	1800	(Zillman 2003)
Tornado	3600	(UNEP/GRID-Arendal 2005)
Tsunami	900	(Gutierrez 2003)
Volcano	259200	(Tilling 2003)
Wildfire	2880	(Corotis and Hammel 2010)
Wind	43200	(Zillman 2003)
Winter Weather	1800	(Zillman 2003)

Table 9: Lead Times for Each Hazard

As discussed, these values are specific to each hazard and have been found from experts in each field. Certain hazards will be discussed alphabetically as some deductive reasoning is needed to

extend the research findings. One specific source, a compilation of related journal articles from Zschau and Kuppers 2003, was especially helpful in gathering lead times. To begin, avalanches and landslides are grouped in regards to lead time due to their similar nature. A lead time of five seconds is chosen based on general statements such as, "Landslide and mudflows usually strike without warning" (United States Search and Rescue Task Force). Considering an avalanche or landslide, lead time depends on an individual's position in relation to the slide. If that individual initiates the slide, as back-country skiers sometimes do, the time to react is next to nothing. If one is at the bottom of a hill, he or she could have maybe 10 seconds to react depending on how far away the slide is. Therefore, five seconds is chosen as a reasonable estimate. Next, SHELDUS describes coastal hazards typically as storm surge. Storm surge is similar to a tsunami in that it, "is a large dome of water, often 50 to 100 miles wide, that sweeps across a coastline…" (National Hurricane Center 2002). Coastal hazards typically occur during large storm events or wind events, especially hurricanes. Since damage caused by coastal hazards resembles damage cause by tsunamis, they will be taken to have the same lead time. An article by Dante Gutierrez studied earthquakes off the Chilean coast and determined that, "No more than 15 minutes and 20 minutes between earthquake and maximum tsunami waves arriving to the coast have been estimated…" (Gutierrez 2003). To be conservative, the lower estimate of fifteen minutes is used. Obviously the lead time would be much greater for tsunamis traveling across an open ocean to another continent. Following that is the lead time for earthquakes. Earthquakes are a well studied phenomenon but the average warning time is not easily found. Each event is so different with respect to time, place, and magnitude that an average value is very general and carries a large amount of uncertainty. Some research experiments in Taiwan showed that, "In the experimental earthquake early warning system in Hualien, Taiwan, a 10-

second or less response time has been achieved for earthquakes occurring inside or near the

dense array with sensor spacing of about 2km" (Lee and Espinosa-Aranda 2003). This is very

much an estimate and could vary extensively. Nevertheless, the level of damage caused directly

by earthquakes increases as the distance to the epicenter decreases. Therefore, a value of ten

seconds is reasonable. For many other hazards, the lead times depended on standard weather

reporting technology. Hail, storm, and winter weather are assigned the same lead time, as

specific warnings are issued roughly thirty minutes in advance (Zillman 2003). In addition, a

graphic was taken from the United Nations Environmental Program which describes the general

timeline of meteorological hazard prediction with respect to early warning systems. The graphic

is displayed in Figure 4 and was used to find lead times for heat (highs and lows), hurricanes,
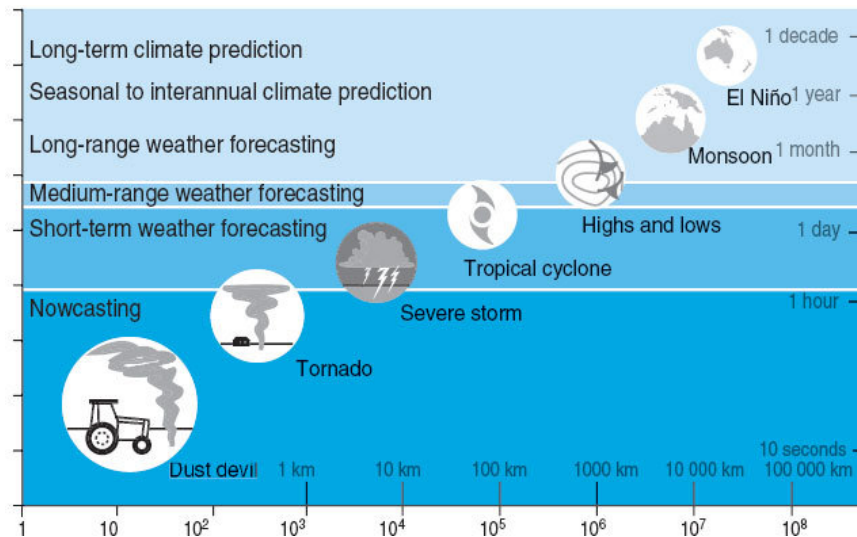
and tornadoes.

Figure 4: Early Warning Times for Weather Related Hazards (UNEP/GRID-Arendal 2005)

The lead time for lightning is inferred from logic. Weather forecasting can predict a storm with

lightning in the times discussed above. Yet, the actual time to react to lightning is the moment it

strikes. Since lightning strikes are instantaneous, but people have reported a feeling of the

atmospheric static charge, a value of one second was chosen. Lastly, volcano warning times are

hard to estimate in the United States; however, a study was done on the 1991 eruption of Mount Pinaturbo in the Philippines which showed that, "The general evacuation order was given on 12 June, three days before the beginning of the climactic eruption" (Tilling 2003). Three days was used as a low estimate since early warning systems in the United States are presumably more advanced. As mentioned, the worst case scenario or lowest lead time value was chosen from the data available. Most of these values come from a source on early warning systems (Zschau and Kuppers 2003). Note that in some areas these systems may not have been implemented yet, although most of the United States has working early warning systems in place, because of its level of development and emergency preparation. For the hazards not mentioned above, a relatively clear value was found in the given sources.

4.3.2 Deaths/event

As discussed earlier, memory can also have a negative effect on a person's perception of risk. Their personal experience during that hazard dictates how they feel and react. Earthquakes may be a familiar occurrence on the Pacific Coast, but if someone living there lost a loved one in an earthquake they may have an unnecessary fear of earthquakes. Being injured in a hazard can cause someone to dread that event. Yet, people are pushed to a new level of dread if they or their loved ones have the potential to die. Knowing how many people are likely to die in a given hazard can provide useful insight into how the public will react. Their perception of risk will increase dramatically.

Using SHELDUS, the number of deaths for each hazard in each region was found. This number was divided by the number of occurrences and used to find the average number of people that die per hazard event. This was included in computing the overall dread. Slovic 2002 studied how risk relates to extreme events. He found that,

37

"When experts judge risk, their responses correlate highly with technical estimates of

annual fatalities. Lay people can assess annual fatalities if they are asked to (and produce

estimates somewhat like the technical estimates). However, their judgments of risk are

related more to other hazard characteristics (for example, catastrophic potential threat to

future generations) and, as a result, tend to differ from their own (and experts') estimates

of annual fatalities" (Slovic and Weber 2002).

Slovic indicates that risk perception relates more to catastrophic potential of individual events

than to total annual fatalities. Natural hazards are understood more clearly in terms of specific

events and not years. Thus, dread will incorporate deaths per event. The values were found for

each region of the United States, and as an example values for the Southeast region of the United

States are shown below.

Hazard	Deaths/event
Avalanche	0.00
Coastal	1.06
Drought	3.43
Earthquake	0.00
Flooding	0.44
Fog	1.06
Hail	0.10
Heat	4.11
Hurricane	2.09
Landslide	6.30
Lightning	0.38
Storm	0.19
Tornado	0.68
Tsunami	0.00
Volcano	0.00
Wildfire	0.02
Wind	0.19
Winter Weather	1.66

Table 10: Deaths per Event in the Southeast Region (Hazards and Vulnerability Research Institute 2009)

Translating Twigg's definition into actual data brought in the parameter of how many

people are affected per event. If a hazardous event is localized, people throughout a region are

less likely to dread it. The catastrophic effects are smaller per event. Hurricane Katrina is one of

the United States' most devastating and memorable natural disasters in the last few decades.

Starting in the Gulf of Mexico, it hit mainly Mississippi, Louisiana, Alabama, and Florida. From

there it continued on a NNE path and caused extreme weather conditions all the way to Canada.

The images below come from NASA and demonstrate the large area that was affected by this

one hurricane.
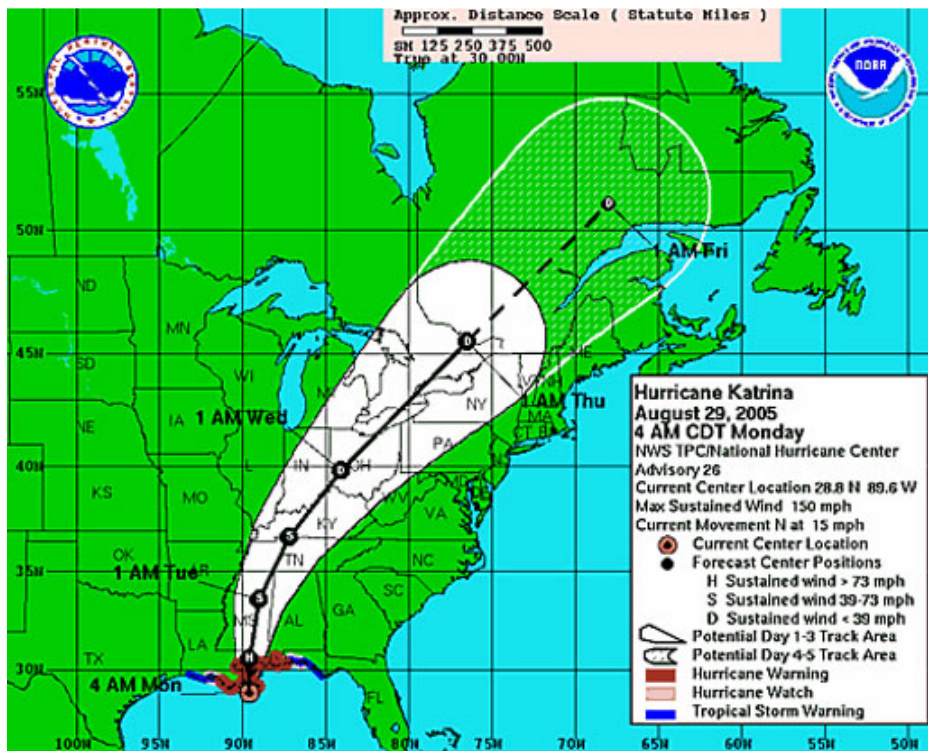
Figure 5: Path of Hurricane Katrina (Dunbar 2006)
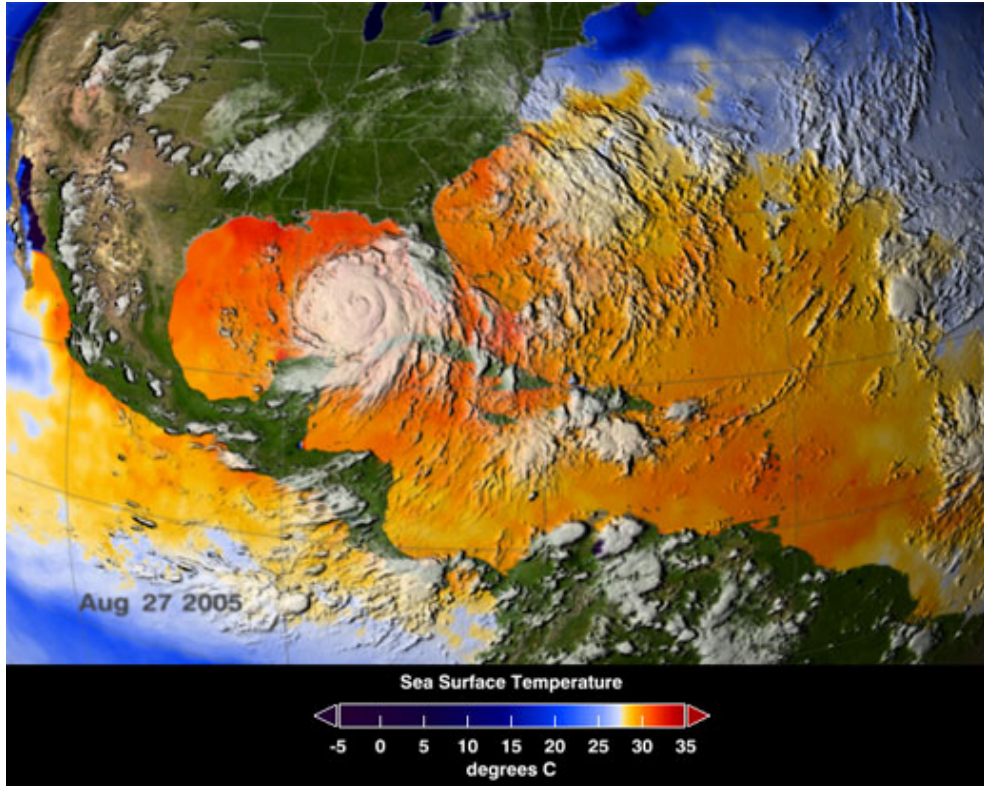
Figure 6: View of Hurricane Katrina over North America (Dunbar 2006)

Hundreds of square miles of the United States experienced losses from Hurricane Katrina.

Compare that to the typical tornado that occurs in the Midwest. Below is an image from the

National Weather Service from a tornado that hit central Illinois on March 12, 2006.
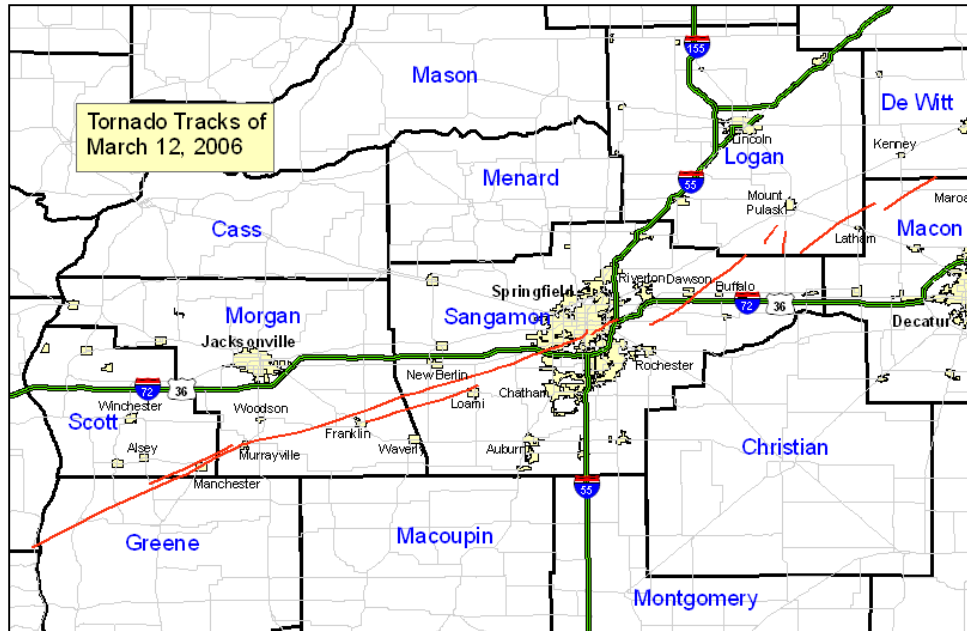
Figure 7: A 2006 Tornado Path in Central Illinois (National Weather Service 2006)

The area that this tornado affected is on the level of counties within a state, whereas Hurricane Katrina's path of destruction covered multiple states. The dread associated with this phenomenon varies significantly. When a tornado occurs, its path is usually localized, and thus people are less likely to think that they will be included in that destruction unless specifically warned or if they can actually see it. When a hurricane hits, people that are anywhere near the path of the hurricane immediately take measures to protect their loved ones and property. This difference is accounted for in the dread parameter by including how many people are affected during each hazard event. These values were hard to find and were only for major hazards. The table below shows these values, which were taken from the Center for Research on the Epidemiology of Disasters (CRED).

Hazard	People Affected/event*
Earthquake	1,878
Flooding	134,287
Landslide	35
Storm	1,548
Volcano	1,250
Wildfire	27,594

Table 11: People Affected per Event (CRED 2009)

The definition for people affected as used in the CRED database is, "people that have been injured, affected and left homeless after a disaster" (CRED 2009). These numbers are used in the dread calculation as described below.

4.3.4 Weighted Average of Dread Parameters

Calculating dread involves the combination of the three aforementioned considerations. 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. These values have three different units consisting of time, deaths, and people. In order to combine these parameters appropriately, they need to be transformed into a unit-less value with similar averages and variability. First, each mean needs to be adjusted to avoid unintended dominance of one feature over the rest. This is especially necessary if the added parameters are in incomparable units. In this study, lead times are in seconds and are to be inverted and combined with number of deaths per event. If these attributes were simply added, deaths/event would dominate since lead times are fractions of one or less. Adding a number smaller than one to something like 100 deaths per event would be insignificant. Yet, lead time is a very important part of dread. Thus, the values were scaled so that the average of each attribute was the same, 0.5. Second, the data collected for each factor have very different levels of variability. If deaths per event and people affected per event do not have a large

variability but lead time does, it would cause the final summation to have large variability, even though a majority of the parameters do not. This would cause lead time to control variability of the final sum. To avoid this, a non-linear transformation was performed to change all the factors to have the same spread of values, a range of one. The non-linear transformation equation is shown below.

$$y = \frac{x_i - \bar{x}}{x_{max} - x_{min}} + 0.5$$

This equation will transform the factor into new values with a range of one and a mean of 0.5. The variable y represents the new value, x_i represents the value being transformed, $\bar{x}$ is the mean, and x_{max} and x_{min} are the maximum and minimum values, respectively. The parameters are shown below in their initial form and then their transformed value.

Hazard	1/lead time (s⁻¹)	Scaled value	Deaths/event	Scaled value	People Affected/event	Scaled values
Avalanche	2.00E-01	0.62	0.00	0.42		
Coastal	1.11E-03	0.42	1.06	0.51		
Drought	1.29E-07	0.42	3.43	0.71		
Earthquake	1.00E-01	0.52	0.00	0.42	1,878	0.31
Flooding	3.47E-05	0.42	0.44	0.46	134,287	1.29
Fog	2.78E-04	0.42	1.06	0.51		
Hail	5.56E-04	0.42	0.10	0.43		
Heat	1.65E-06	0.42	4.11	0.76		
Hurricane	1.16E-05	0.42	2.09	0.59		
Landslide	2.00E-01	0.62	6.30	0.95	35	0.29
Lightning	1.00E+00	1.42	0.38	0.45		
Storm	5.56E-04	0.42	0.19	0.44	1,548	0.30
Tornado	2.78E-04	0.42	0.68	0.48		
Tsunami	1.11E-03	0.42	0.00	0.42		
Volcano	3.86E-06	0.42	0.00	0.42	1,250	0.30
Wildfire	3.47E-04	0.42	0.02	0.42	27,594	0.50
Wind	4.63E-05	0.42	0.19	0.44		
Winter Weather	5.56E-04	0.42	1.66	0.56		

Table 12: Scaled Values of Each Dread Parameter – Southeast Region

With the new scaled values, each factor can be added together to produce a factor of dread. To be able to control the importance of one factor over another, each value was weighted. Each factor is assigned a weight and all of the weights sum to one.

$$y = w_1 x_1 + w_2 x_2 + w_3 x_3$$

$$\sum_{i=1}^{3} w_i = 1$$

Lead time is proposed to have the most important impact on dread, twice as much as either deaths or people affected. Further, deaths per event and people affected per event are assigned equal weights. The weights were chosen arbitrarily based on judgment at this point. This produces the equation,

$$dread = \frac{1}{2}(lead\ time) + \frac{1}{4}(deaths/event) + \frac{1}{4}(people\ affected/event)$$

These specific weights were proposed for simple calculations and a lack of substantiated data to determine which factor affects dread the most. Where a value was not found for people affected per event, the weights were changed to one half for lead time and one half for deaths per event. Further research in this area could reveal more realistic, exact weights for this function.

4.3.5   Real dread vs. Media driven dread

Similar to the media's effects on familiarity, the media can change an individual's perception of risk as it relates to dread. A major issue that arises comes from an increase in dread due to over-exaggeration by the media. If the news report exaggerates the seriousness of a natural hazard, the public will react in a more urgent and panicked way or emergency personnel may over-prepare. On the other hand, news reports could downplay the situation and cause people not to react at all. This will also produce a lack of trust in the media that could become detrimental. These effects should be considered when preparing for natural hazards.

4.4 REGIONAL ASSESSMENT

The multi-attribute framework brings many important elements together to provide a comprehensive way to evaluate risk and develop a hazard mitigation plan. This framework lacks one important division, geographical regions. Each region of the United States experiences very different hazards. A framework of the United States would be difficult to apply in any specific region. People living along the Pacific coast of the United States are very familiar with earthquakes. People are educated in schools, work, or through the media on how to properly react to earthquake events. Thus, the familiarity of earthquakes on the Pacific coast is significantly higher than in other regions of the United States. This greatly affects the hazard mitigation plans laid out by the local governments in that region. Also, since the Pacific region does not experience hurricanes, it would be incorrect to develop a hazard mitigation plan based on the whole United States, which shows hurricanes causing large amounts of damage. This regional division allows the framework to be more useful in decision making.

Based on the approach of the Department of Energy, the United States was separated into eight regions. These were selected since they each share similarities in natural hazards. The eight regions chosen are shown below in Figure 8.
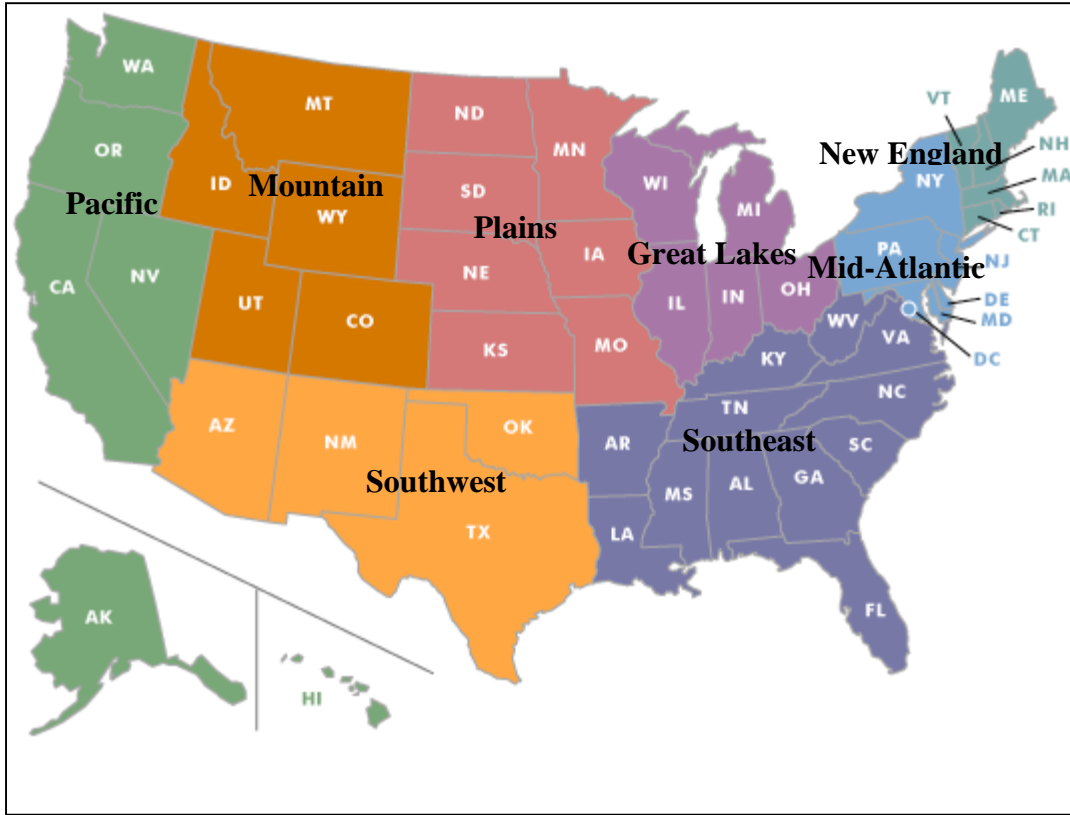
Figure 8: Regional Division of the United States (DOE 2009)

These regions will allow the hazard mitigation framework to be more functional. All results will

be shown in these regions.

4.5   GRAPHICAL ANALYSIS & RESULTS

The goal is to compile all of the work above into a user friendly visual aid to be consulted

when creating natural hazard policies. As discussed above, the way information is presented is

very important. Changes were made to Hammel's visual structure to make it easier to read. His

approach was to create concentric circles in which the thickness represented the value of deaths,

injuries, or dollar loss. To improve this, the each parameter is shown in rings. The area enclosed

within each ring corresponds to the value of one of the three factors. This eliminates the issue

that some circles might be hidden by other larger circles, and not be seen. Also, each factor's

ring size no longer depends on the others for each hazard. Therefore, if the number of deaths is large and the number of injuries is small, the radius of both circles does not have to be large. This was a major concern in Hammel (2005). If the core of the data point was large, then the radius of the mantle became large despite being thin and representing a small value. Now, each factor stands alone, but all three are still centered on their corresponding natural hazard.

The data are graphed along the axes of dread and familiarity. Each hazard will have a different location depending on the values calculated above. This position on the graph represents that region's perception of risk. A hazard located at the top, right corner of the graph indicates a very serious perception of risk. A hazard which falls in the bottom, left corner of the graph indicates a region that does not have a very severe perception of risk from that hazard.

Two graphs for each region were created. The first graph was created with actual numbers of deaths and injuries. The second graph uses monetary values for death and injury. The graphs for all eight regions are shown below in Figure 9 through Figure 28. Also included are graphs of California and Florida separately to show the effect they have on their regions. The color of the graph corresponds to the colors given in the regional map in Figure 8.
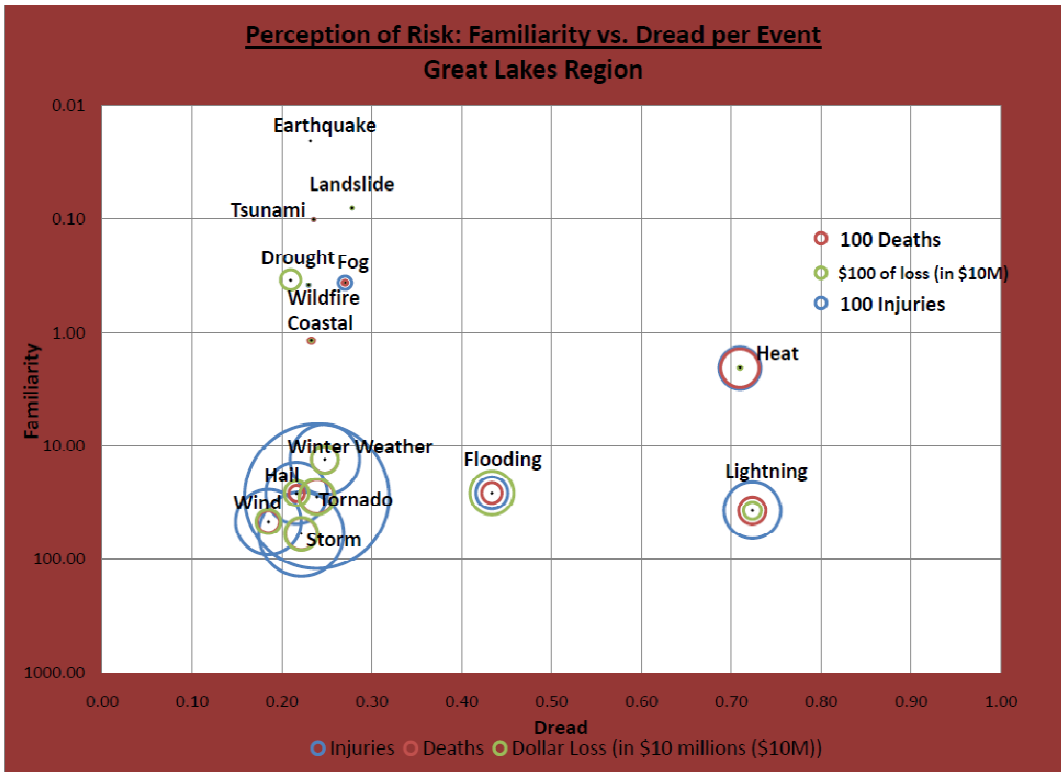
Figure 9: Dread vs. Familiarity per Event - Great Lakes
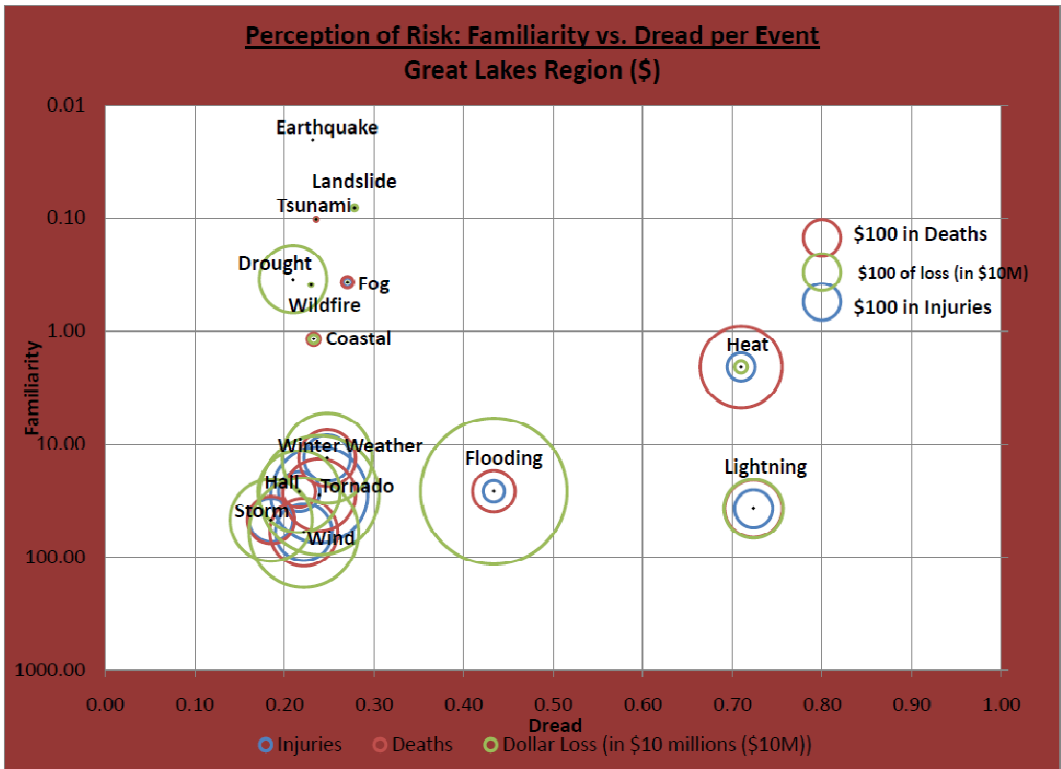
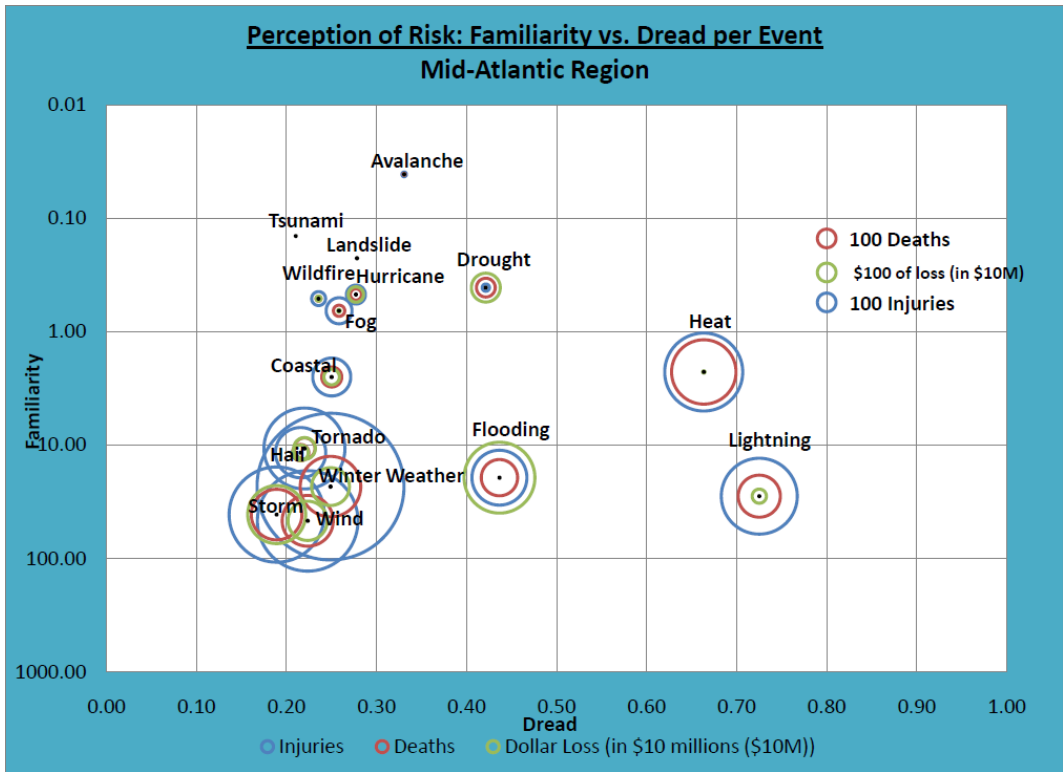**Figure 10: Familiarity vs. Dread per Event - Great Lakes in Dollars**

Figure 11: Familiarity vs. Dread per Event - Mid-Atlantic Region
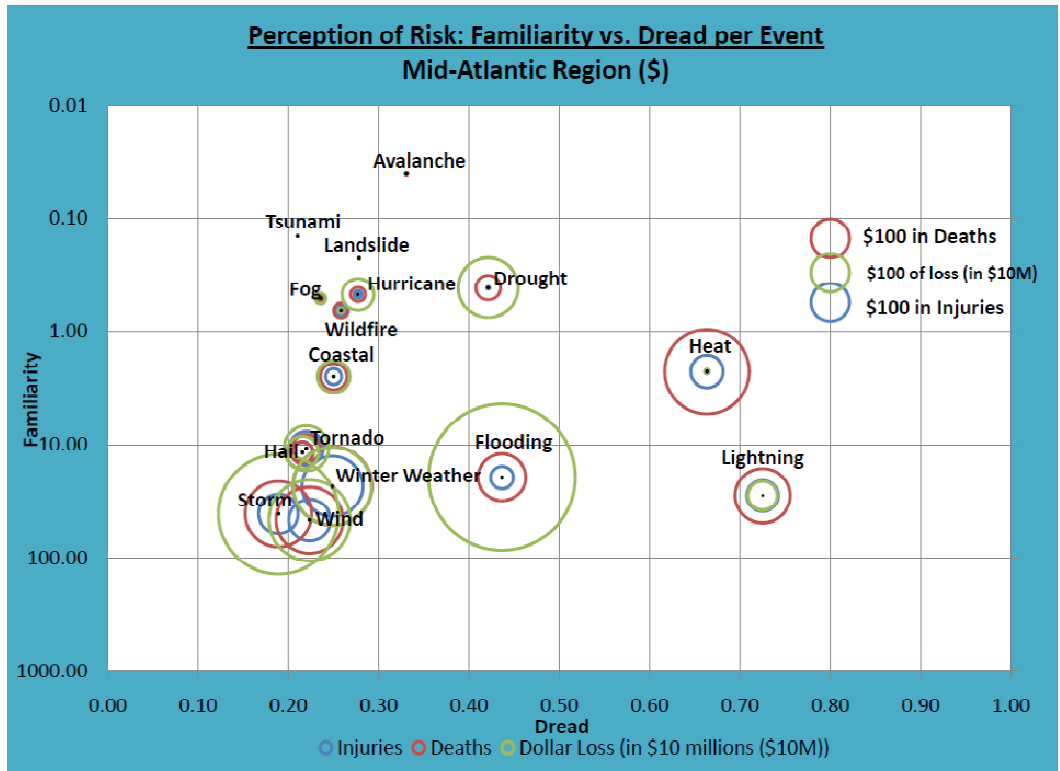

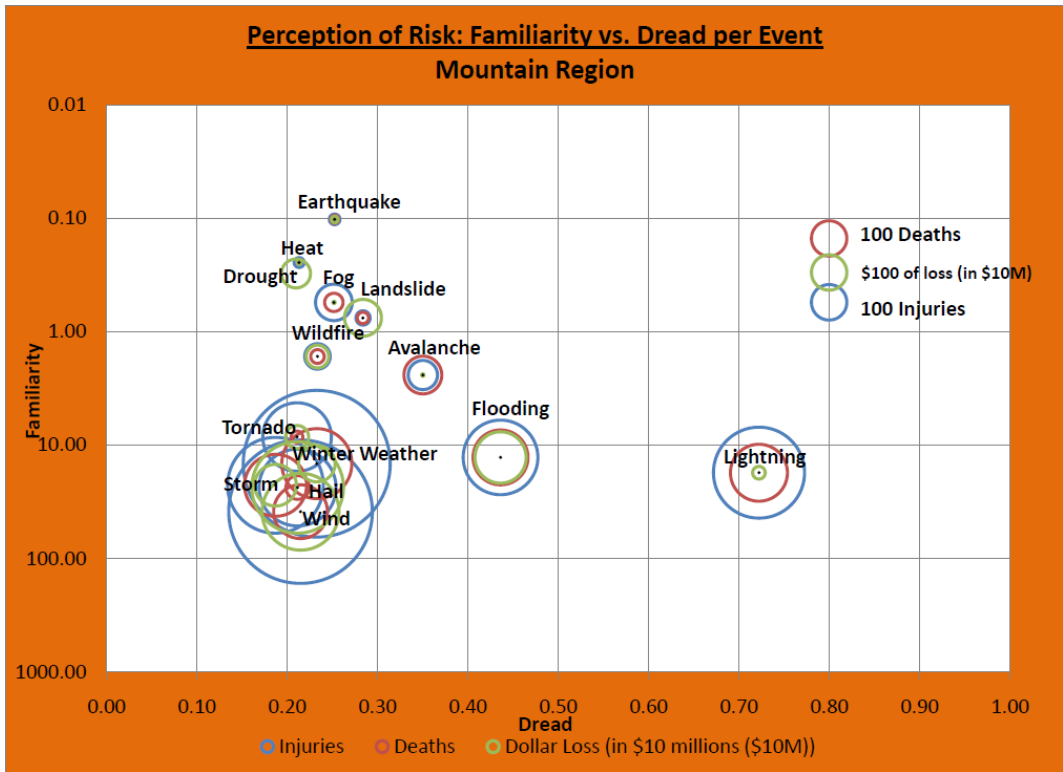**Figure 12: Familiarity vs. Dread per Event - Mid-Atlantic Region in dollars**

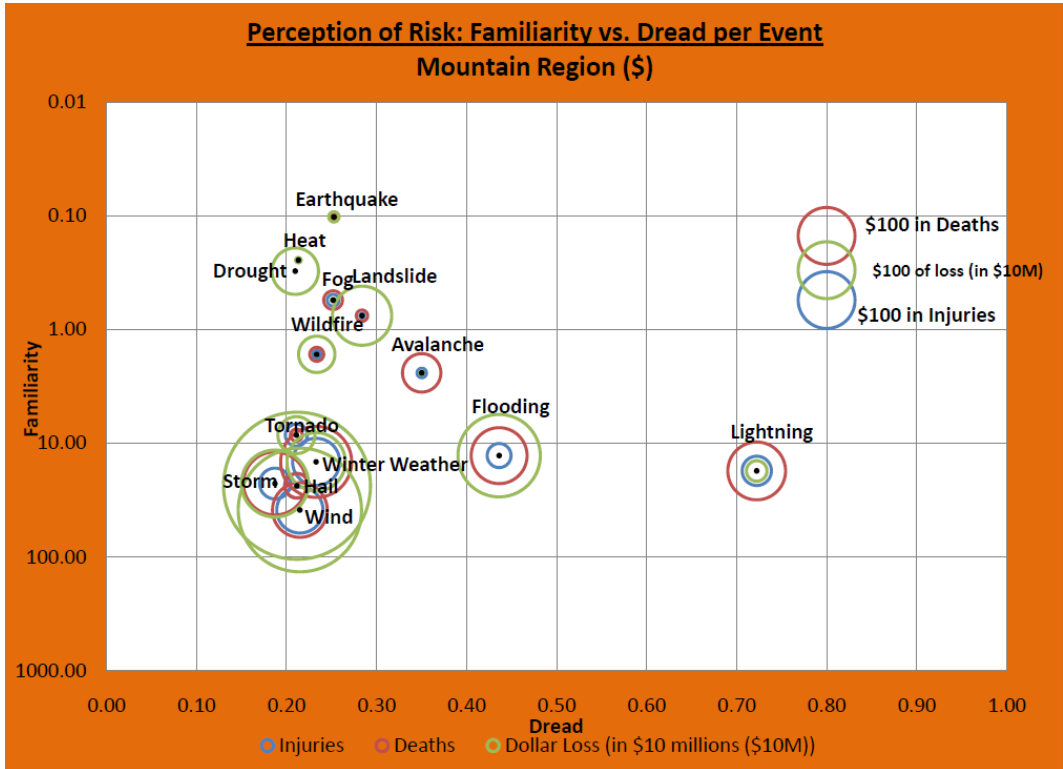**Figure 13: Familiarity vs. Dread per Event - Mountain Region**

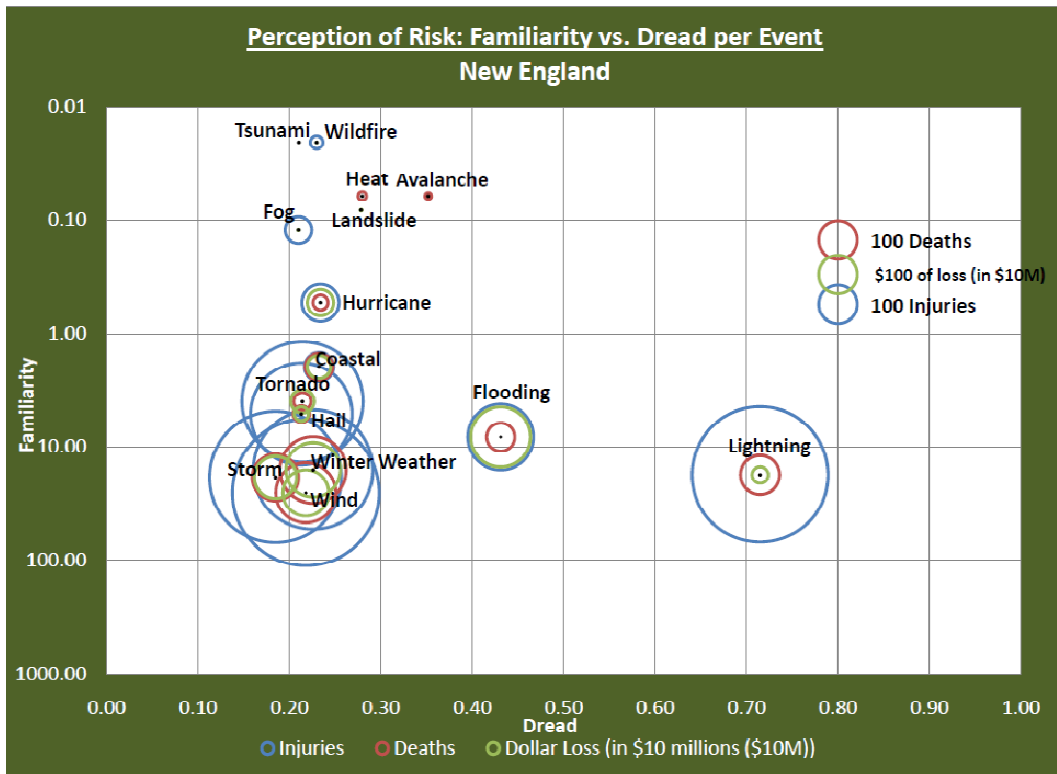**Figure 14: Familiarity vs. Dread per Event - Mountain Region in Dollars**

Figure 15: Familiarity vs. Dread per Event - New England Region
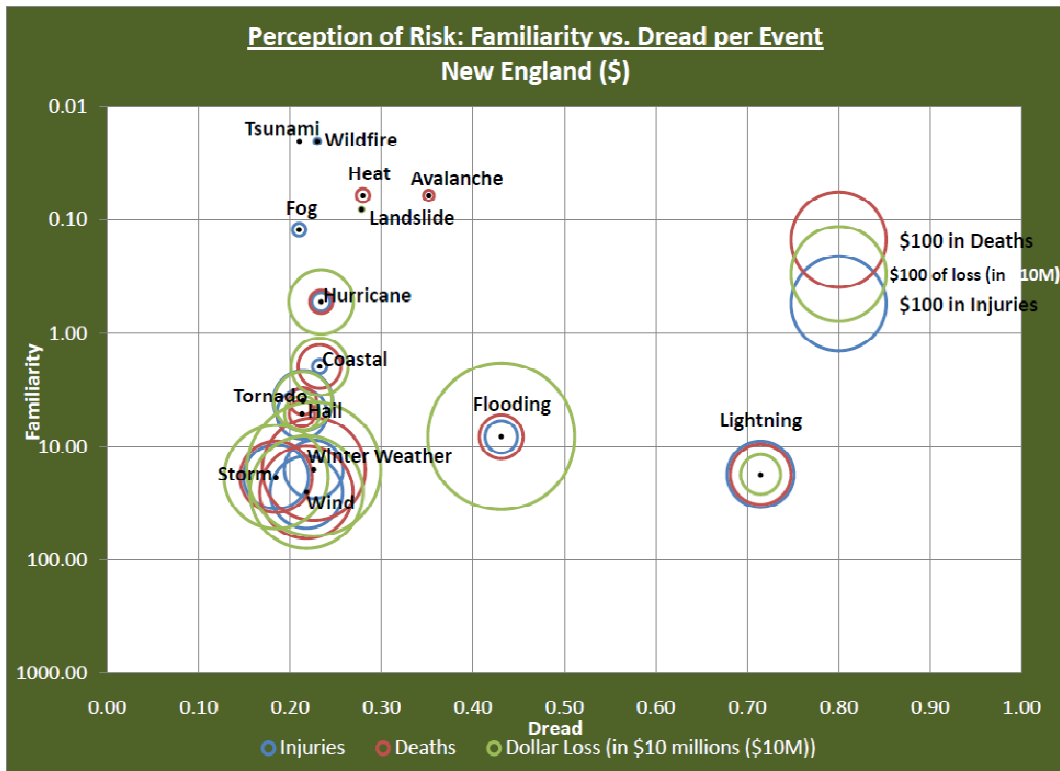
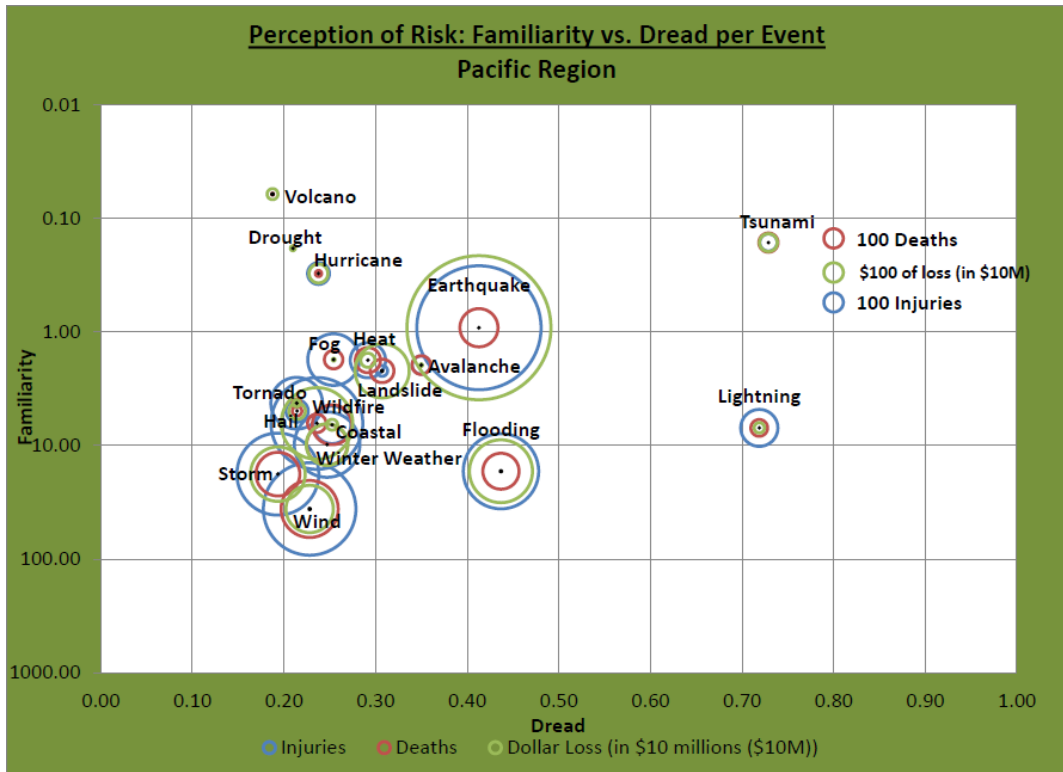**Figure 16: Familiarity vs. Dread per Event – New England Region in Dollars**

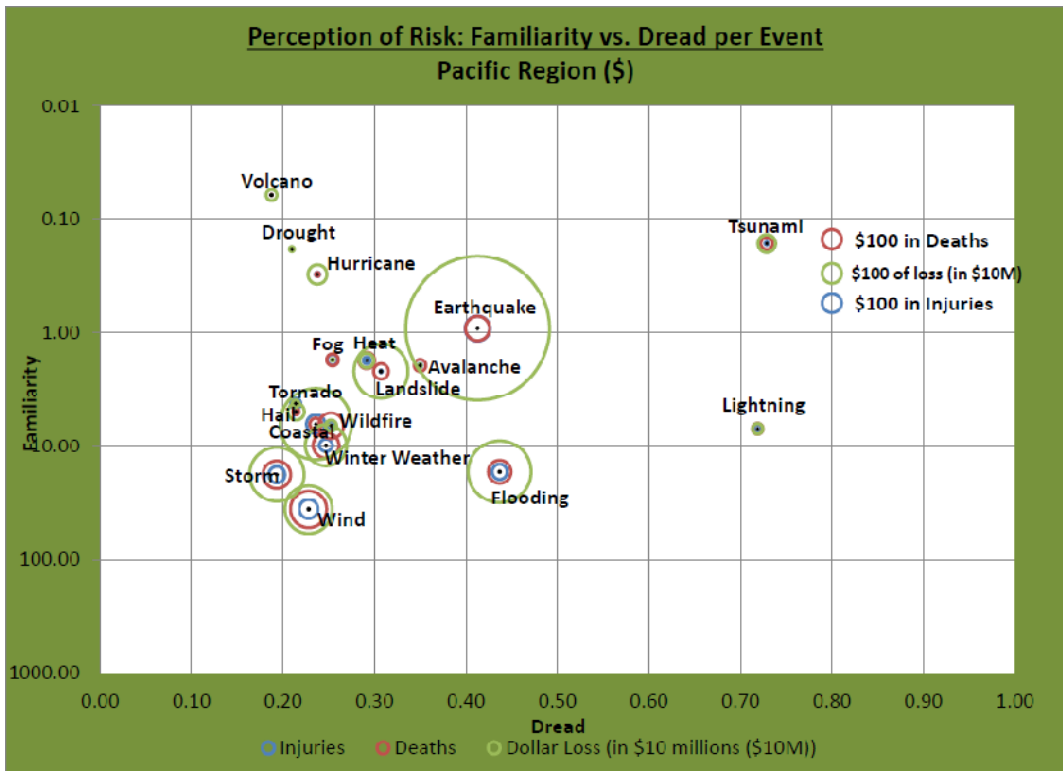**Figure 17: Familiarity vs. Dread per Event - Pacific Region**

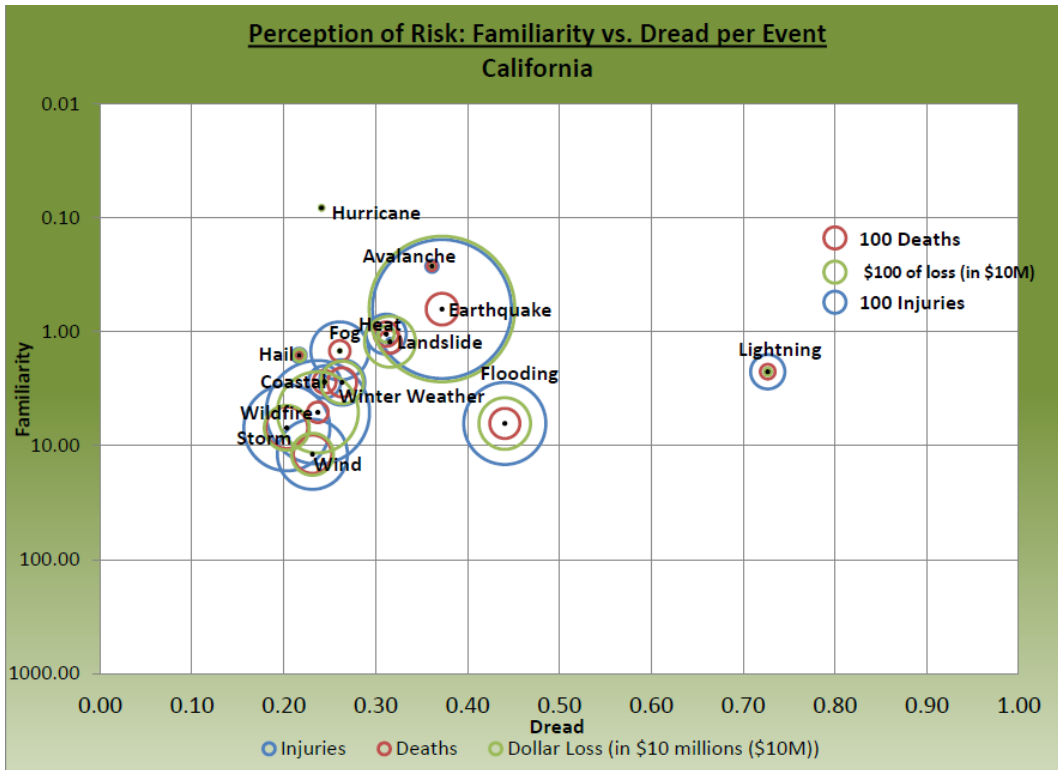**Figure 18: Familiarity vs. Dread per Event - Pacific Region in Dollars**
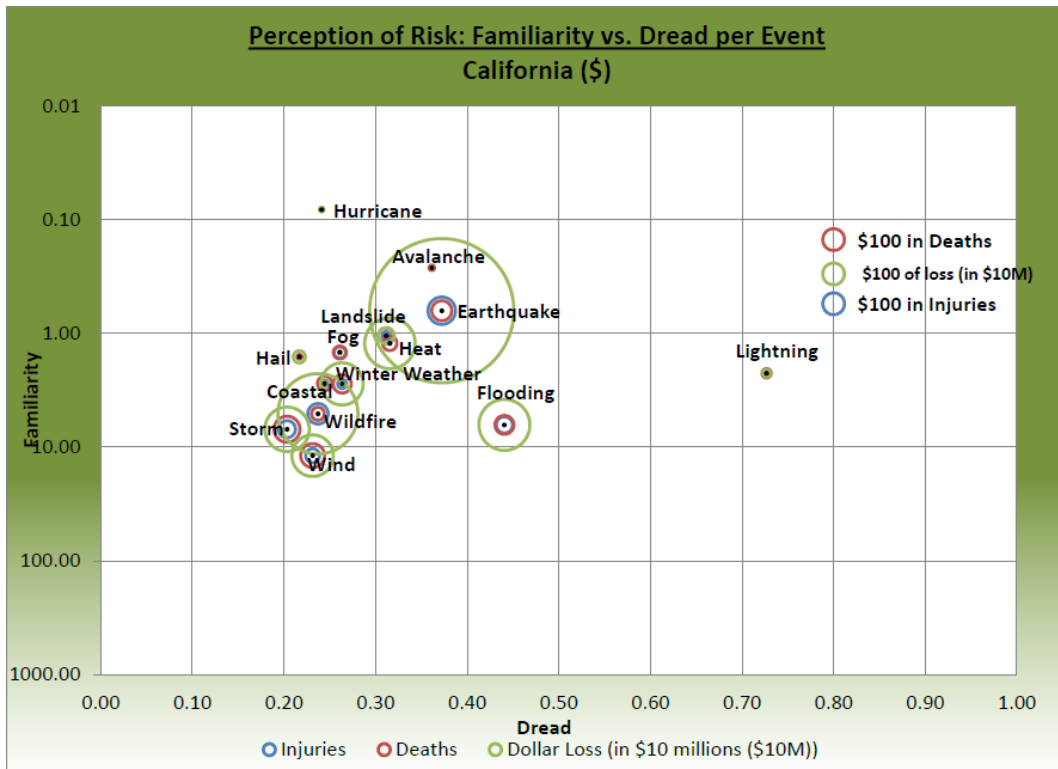
Figure 19: Familiarity vs. Dread per Event – California

Figure 20: Familiarity vs. Dread per Event - California in Dollars
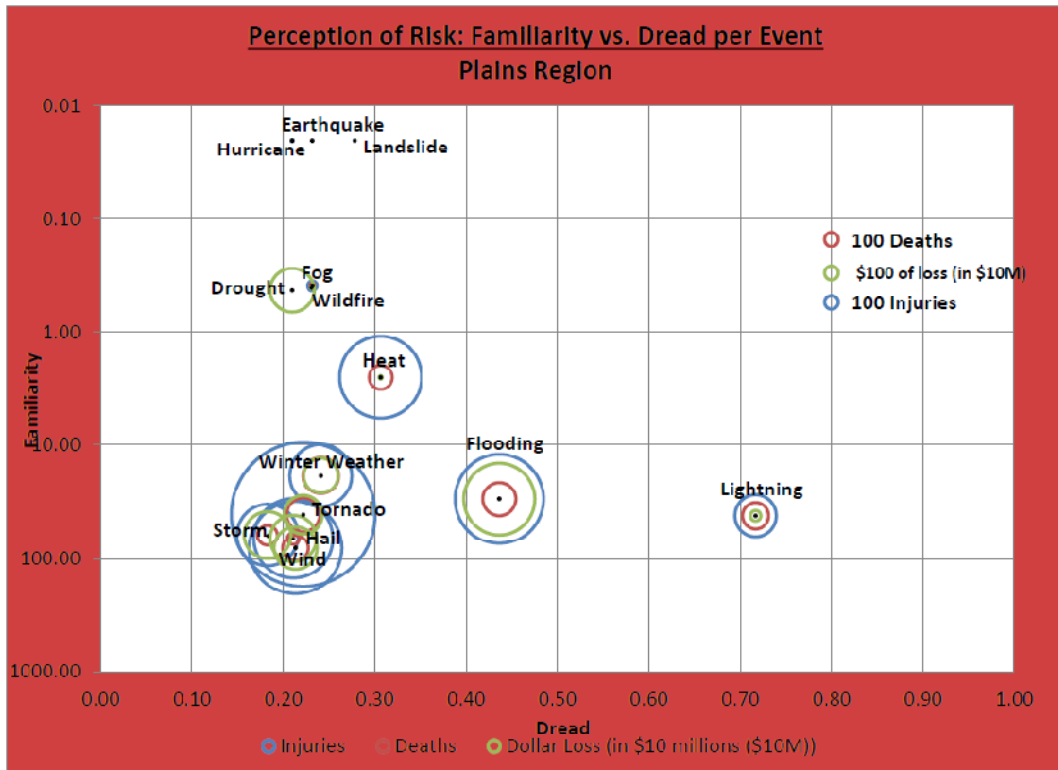
53

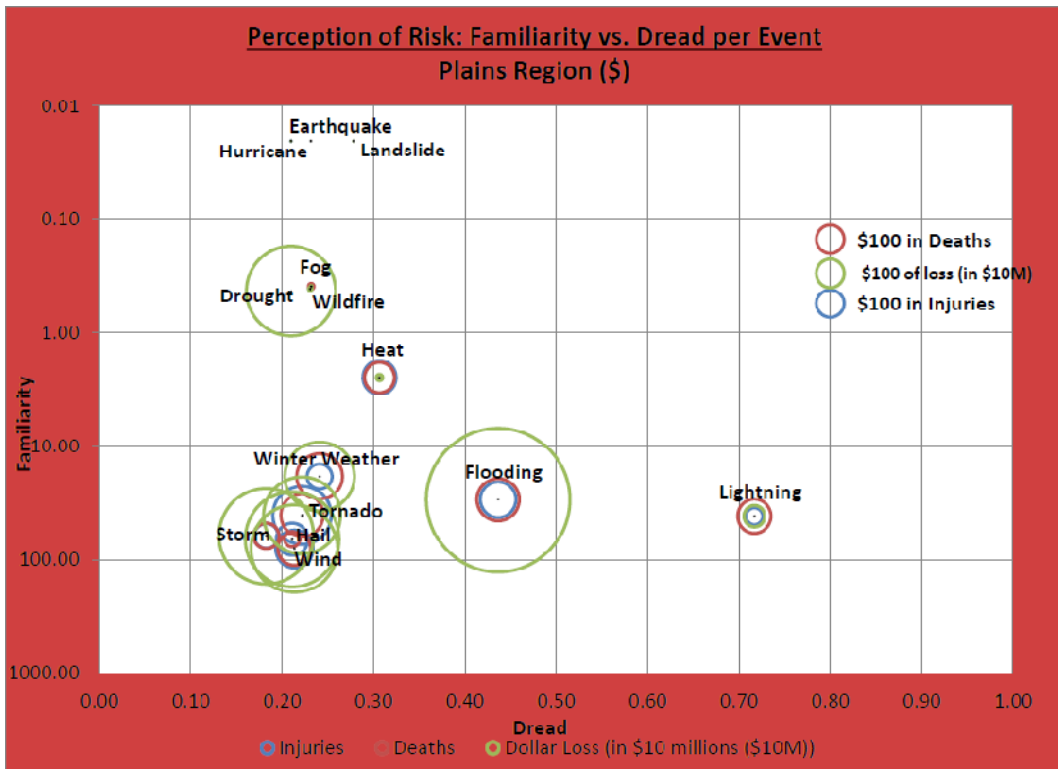**Figure 21: Familiarity vs. Dread per Event - Plains Region**

Figure 22: Familiarity vs. Dread per Event - Plains Region in Dollars

Figure 23: Familiarity vs. Dread per Event - Southeast Region

Figure 24: Familiarity vs. Dread per Event - Southeast Region in Dollars

55

Figure 25: Familiarity vs. Dread per Event – Florida

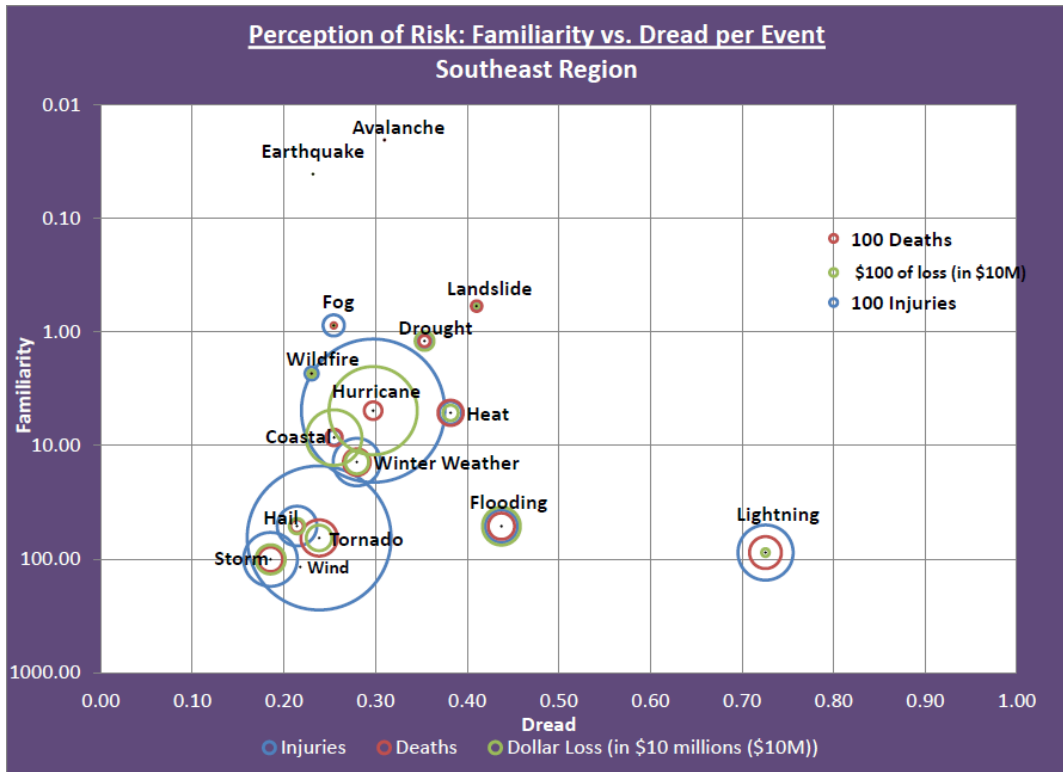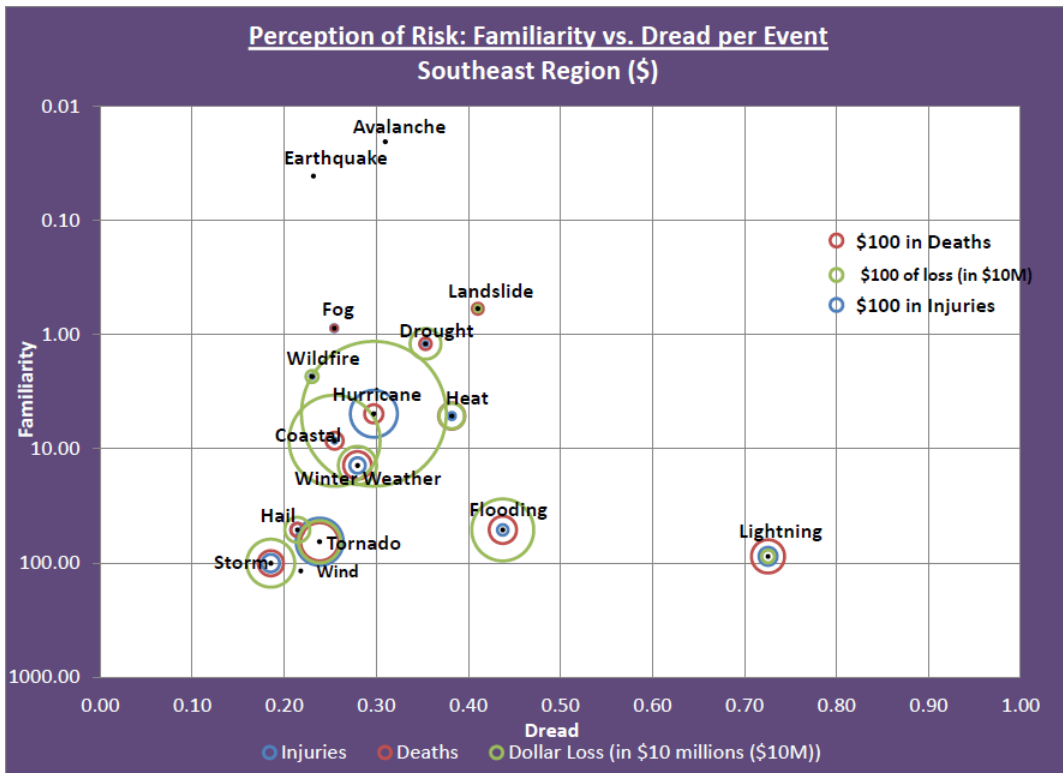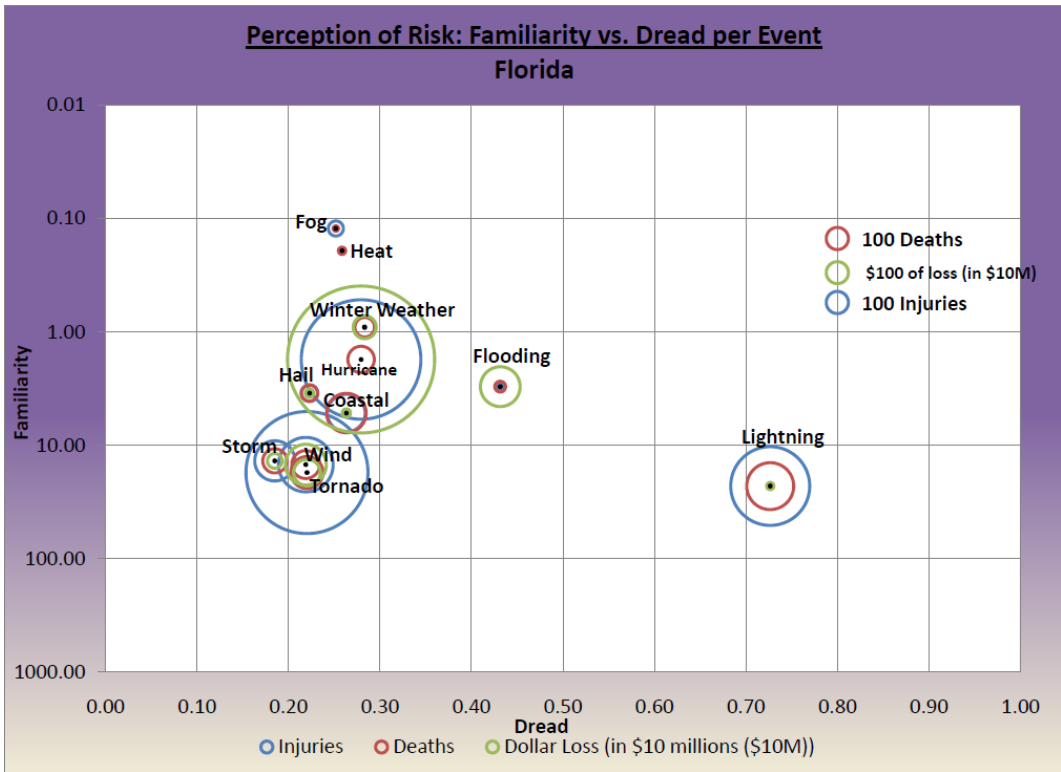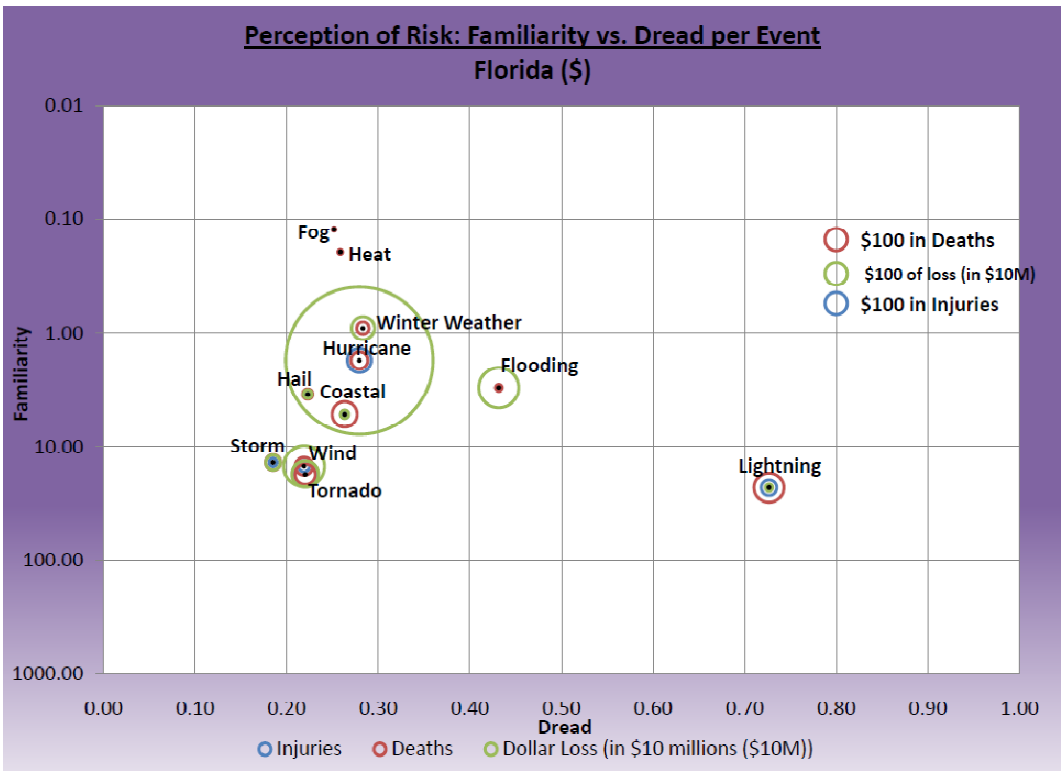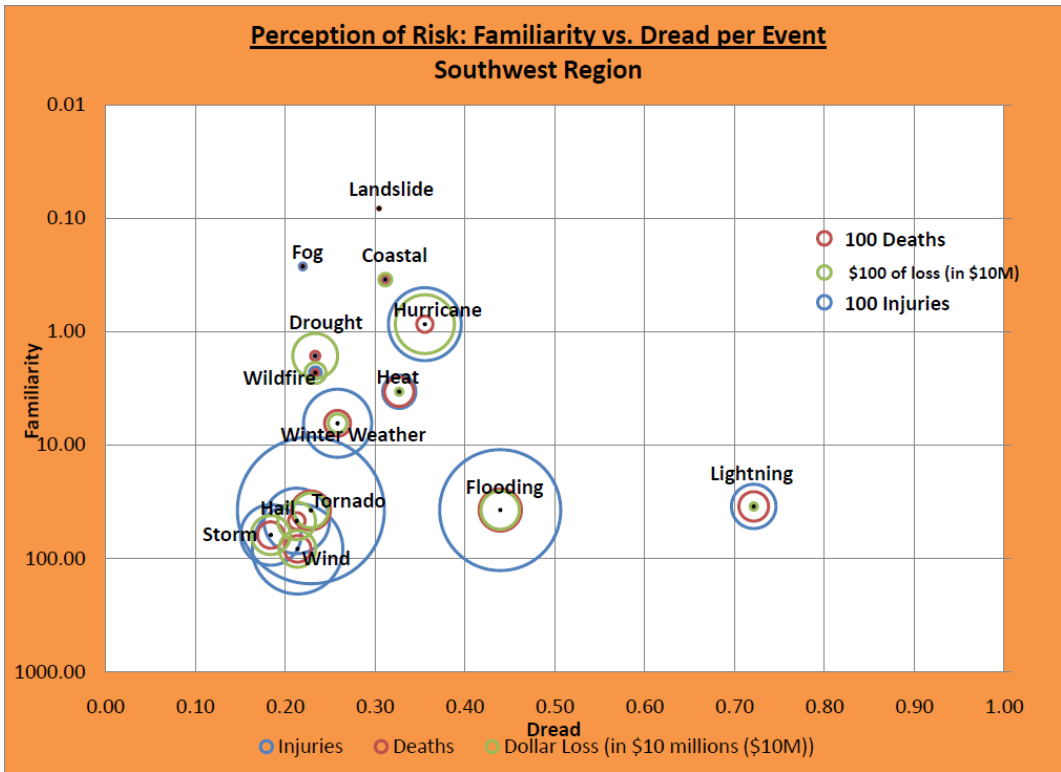**Figure 26: Familiarity vs. Dread per Event - Florida in Dollars**

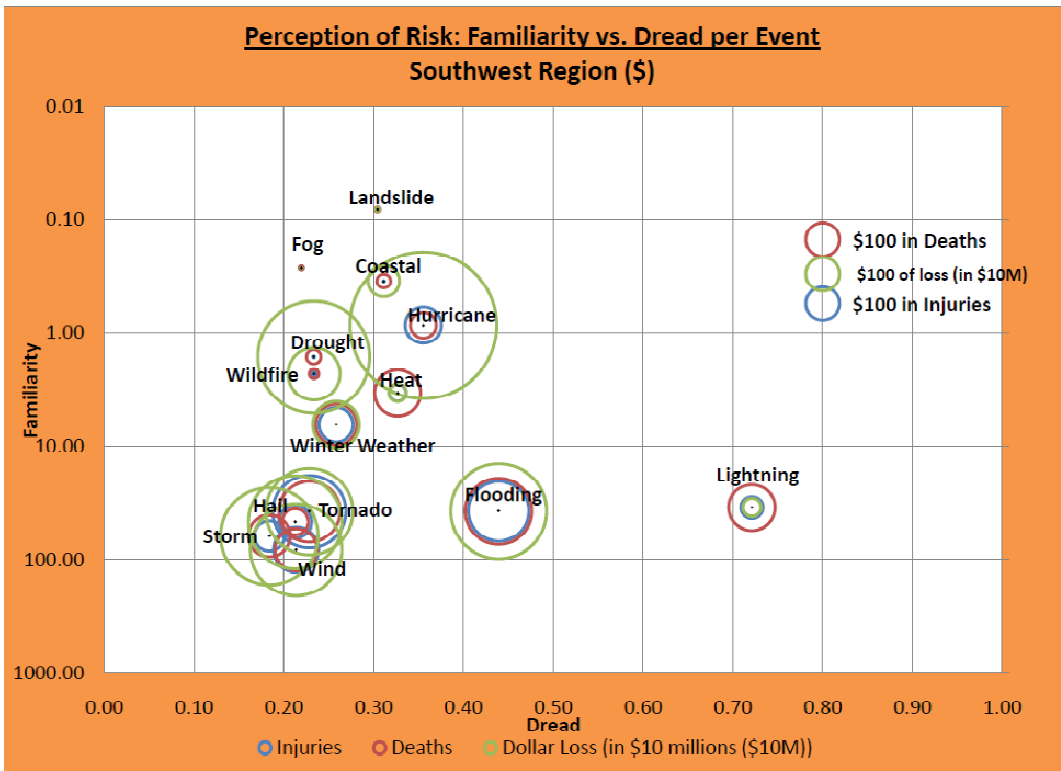**Figure 27: Familiarity vs. Dread per Event - Southwest Region**

Figure 28: Familiarity vs. Dread per Event - Southwest Region in Dollars

The graphs above can be compared to show the differences in dread, familiarity, injuries, deaths, and dollar loss. There are major differences between regions. This supports the regional separation of the data. Also, note the graphs of California in Figure 19: Familiarity vs. Dread per Event – California Figure 19 and Figure 20. If compared to the Pacific region, California accounts for a significant amount of the effects of natural hazards. This provides reason for the other states in the Pacific region to look at their own data without California to get more accurate information. In addition, California's policies would be better taken from data for just that state. Clearly, the methods in this study could be used on a state or even local basis to get the most accurate information possible. Interestingly, Florida, as seen in Figure 25 and Figure 26, did not have a large effect on the Southeast region despite its geographic location. With so much land along the coast, it would be easy to think that Florida would account for most of the data in the Southeast region, but that is not the case. Note that wind data was could not be collected for the Southeast region due to an error in the SHELDUS database.

These graphs were developed for policy makers to make a more informed decision when creating a hazard mitigation plan. Knowing the basics such as deaths, injuries, and damages is important, but including the way people feel about those hazards is also important.

4.6   FRAMEWORK APPLICATIONS

The background research supports the need for a visual representation of both "risk as analysis" and "risk as feelings" (Slovic 2000). The above tools sought to include those pieces of risk to provide a more integrated way to visualize the effects a hazard is having on a community. The next question is, how would a policy maker use this framework to create an emergency plan that will anticipate how the public will respond and use that to its advantage? Perry and Lindell wrote a book entitled *Emergency Planning* in which they specifically deal with this issue. They

explain that, "Experienced planners know that citizen compliance with protective action recommendations (PARs) is much more likely if those protective actions are designed in a way that complements known human response" (Perry and Lindell 2007). Protective action recommendations are a part of mitigation plans that require public compliance. These PARs are used in natural disasters to help protect the public and infrastructure. Perry and Lindell provide the example of Hurricane Rita when the PARs did not complement the public's response. After Hurricane Katrina, there was an increased amount of dread and familiarity associated with hurricanes in the Southeast region. A known human response to this type of situation is described as an evacuation shadow. More people evacuated than authorities recommended because of the severity of Hurricane Katrina. They caution policy makers that, "Ignoring the evacuation shadow produces clogged routes of egress, stalled vehicles (breakdowns and no fuel), and clogged shelters" (Perry and Lindell 2007). This lack of regard for human response does not just apply to evacuation shadows. This deficiency in planning is where the above regional graphs provide the largest benefit. When developing PARs, a community can look at their region to determine how the public perceives the risk from that specific hazard. Knowing that the public has a large amount of dread would lead policy makers to consider effects like evacuation shadow. In contrast, Perry and Lindell found that, "Fear-generating agents often elicit much higher levels of warning compliance" (Perry and Lindell 2007). Someone using the above graphs could conclude that a hazard with a high amount of dread or familiarity may mean that the public would be more compliant than in other situations because they have no prior knowledge of how to react. These reactions are usually specific to each community, hazard, and period of time. Professional judgment is required when making final decisions on hazard

mitigation plans. These frameworks are designed to introduce human perception of risk from

natural hazards in the hazard mitigation planning process.

4.7   RISK EVALUATION AFFECTED BY REGION DEMOGRAPHICS

One important consideration has not been discussed. Losses due to deaths, injuries, and

damages are directly related to the population and the value of the built environment. When

consulting these graphs it should be recognized that storms in New England are not necessarily

worse than storms in the Plains. There are more people and higher property values in New

England, however, compared to the Plains. Thus, any natural hazard that hits will cause more

deaths, injuries, and damages simply because there are more people to affect. Also, it is noted

that dread can vary from town to town depending on the demographics. If a town has one

hundred people and ten of them die, the town will be seriously impacted. On the other hand, if

ten people die in New York City from a hazard event, the city as a whole would not be

significantly affected. There are several ways the above results could be modified to account for

this discrepancy. First, the gross domestic product (GDP) of any region could be used to

measure economic activity and as a representative figure for population and amount of

constructed facilities. Secondly, the data can be compared to population. By comparing the data

to population, it would account for how many people are actually there to be affected. Yet, it

would not include the value of the property those people own. The third metric was developed

by HAZUS, which stands for Hazards United States, and is called the built environment. FEMA

developed HAZUS to have an inventory of information built into the program. This inventory

includes essential facilities, lifelines, general building stock, and demographic data (FEMA

2010). Using the HAZUS inventory would be the best, most complete way to make the data

more realistic. By comparing the data to one of these three metrics, the data would be

neutralized so that no single region stood out above the rest unless those hazards were really the

most severe.

5 Conclusions

5.1 SUMMARY

The methods described in this paper are meant to be used to create a more informed hazard mitigation plan. With the basis of Slovic's research, sociology and engineering are combined to cover a wider spectrum of risk. Slovic points out that, "the higher its perceived risk, the more people want to see its current risk reduced, and the more they want to see strict regulation employed to achieve the desired reduction in risk" (Slovic, The Perception of Risk 2000). For example, millions of dollars have been spent on retrofitting structures on the Pacific coast to reduce risks from earthquakes. Earthquakes rank relatively high on the graph of perceived risk for that region. Far more money is spent on reducing earthquake risk than on reducing risk from wildfires because the perceived risk is higher, even though they both cause significant losses. This framework is meant to be an aid in decision making for these situations.

In a later study by Slovic, he discusses how, "Research within the psychometric paradigm has identified people's emotional reactions to risky situations that affect judgments of the riskiness of physical, environmental, and material risks in ways that go beyond their objective consequences" (Slovic and Weber 2002). This theory of sociology explains how people react to situations such as natural hazards. In the current study, previous work was combined with a new, more accurate way of assessing risk from these hazards.

5.2 FUTURE DEVELOPMENT OF HAZARD MITIGATION AND RISK

ASSESSMENT

This study seeks to further the field of hazard mitigation and risk assessment techniques. Consequently, the topics discussed in this paper have a lot of room to expand. It is suggested that the following sections be studied more in depth. First, Slovic's factor analysis was applied directly to the study of natural hazards. Thus, dread and familiarity are functions of his work in terms of general risks. If sufficient surveys were conducted, a factor analysis could be performed that is specific to natural hazards. This may change the correlation of the characteristics. It might be found that dread is not the most highly correlated to natural hazards. Moving forward, there is a large amount of improvement that can be done for the factors of dread. Since lead times are hazard specific in their accuracy, it would be beneficial to know more exact times that an individual has to react. Also, the values found for the number of people affected per event were not region specific. Being able to find regional values would provide a more accurate measure of dread. The next suggestion comes in the way the dread parameters are combined. Simple weights were chosen based only on judgment. A sensitivity analysis could be performed to determine more accurate weights based on which factor affects dread the most. Finally, familiarity was unchanged from Hammel 2005, but could be expanded. The concept of being familiar with an event is hard to define. It could easily depend on how far away the event was. This study considers regions, but if a person lives on the border of a region he or she may be familiar with an event that happened in the neighboring region. Familiarity is also impacted by how recent the event was. If a volcano erupted thousands of years ago, the perceived risk of the current community will be very low. Yet, this may be compensated by the fact that the media can present information from any era. Finally, there is considerable room for growth

63

when dealing with expected values. Expected values are just averages, but further study could show the range of consequences felt from natural hazards. These are some of the ways that this framework can be improved. Hopefully, researchers will see the benefits of this study and will want to continue pursuing related topics.

6 Resources

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