Spring 2011

A global assessment of large scale earthquakes: The impact of mitigation and preparation policies on the loss of human life

Derek Hayward
University of South Florida

A global assessment of large scale earthquakes: The impact of mitigation and preparation policies on the loss of human life

By Derek Hayward
Mentors: Dr. Kiki Caruson & Dr. Michael Miller

Honors Thesis – Spring 2011

[1] http://www.jyi.org/news/nb.php?id=271

ABSTRACT

This research examines emergency management mitigation and preparation polices in the hazard area of seismic events. With major earthquakes receiving high profile attention in the media, these events have caused widespread fear, physical damage to buildings and infrastructure and loss of life. This research evaluates the weaknesses that are currently affecting areas where earthquakes remain a constant threat. This study uses cases to provide rich description regarding several events and looks in-depth at six seismic events. Variables are sourced from the United Stated Geological Survey and show the magnitude of the earthquake and the official death and injury count for each event. Data for each event comes from local new reports, geological surveys, and other scholarly sources that examine each local event. Data analysis uncovers specific issues that pertain to mitigation and preparedness efforts in regards to earthquakes. As a result of examining these cases, this research will show several areas where mitigation and preparation efforts and policies could be improved so as to save human lives. In both mitigation and preparation, there exists room for improving methods and this research highlights steps that should be taken by any emergency management organization operating under the threat of earthquakes.

INTRODUCTION

Professional emergency personnel cannot respond immediately. In the event of disaster, you will be on your own for anytime between three days and two weeks. You need to prepare.

Naomi Zack – "Ethics for Disaster"

Earthquakes are dramatic natural events and are potentially devastating to regions hit by them. Yet, despite the notoriety of the Haitian earthquake in early 2011, seismic events are more common than many realize; The National Earthquake Information Center locates approximately 12,000 to 14,000 earthquakes each year which averages out to 50 per day and most do not result in mass casualties and widespread property loss (USGS, Common Myths about Earthquakes, 2009). Every region in the world is susceptible to some degree to a seismic event (Figure 1). The USGS expects about 18 major earthquakes (Magnitude 7.0-7.9) and one great earthquake (Magnitude 8.0 or greater) in any given year and this trend has remained static over the past century (USGS, Common Myths about Earthquakes, 2009). In 2010-11 alone Haiti, Chile, and Japan experienced major earthquakes. The deadly March 2011 earthquake that struck Japan occurred in a nation where disaster mitigation and preparation are comparative rigorous. In contrast, the January 2011 earthquake in Haiti illustrates how devastating an earthquake can be in a place where mitigation and preparation policies have gone unattended. In 2011, both

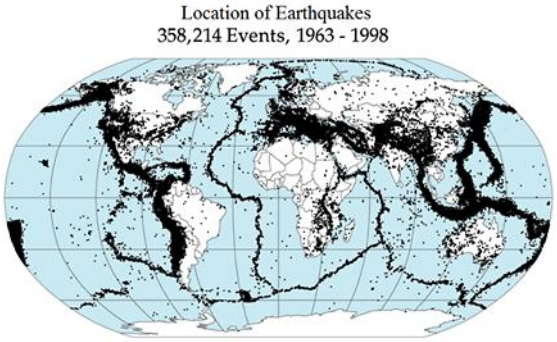


Figure 1: Location of Earthquakes Epicenters from 1963 to 1998.
http://www.dephx.com/2010/12/358214-earthquake-epicenters-plotted-on.html

Haiti and Japan experienced earthquakes of a approximate magnitude (7.0 and 8.3 respectively) and yet the resulting loss of life, human injury, and structural damage was dramatically different across the two countries. The meltdown at the Fukushima nuclear reactor in Japan has complicated recent recovery efforts, but Japan has a long history of successful earthquake management including an 8.3 magnitude earthquake in 2003 where no human lives were lost. This outcome is in stark comparison to what the world witnessed on the tiny island nation of Haiti. Understanding how to strengthen earthquake resiliency in countries prone to seismic events is a matter of life and death. Large scale earthquakes do not inevitably lead to large scale loss of life.

Understanding how mitigation and preparation policies—and specifically which policies—create the best environment for earthquake resiliency is an important issue for the global community. Using case study data from six large scale seismic events across the globe (Japan, China, Algeria, Haiti, El Salvador, and Chile) this research investigates which mitigation and preparation activities have the biggest effect on preserving human life in the event of an earthquake. For emergency managers, it is important to protect property, treat injuries, and maintain order. However, the highest priority is to protect human lives. Mitigation and preparation policies set the stage for successful management of earthquake events. Failure to implement mitigation and preparation plans costs lives. Despite this fact, many countries remain at serious risk should an earthquake strike their region. The research presented here will identify the mitigation and preparation policies that are essential to the protection of human life.

LITERATURE REVIEW

Emergency management is an ever evolving field. As new research and technologies emerge, they are integrated into what is called the emergency management cycle. The four stages of the emergency management cycle are mitigation, preparation, response, and recovery (Lindell, Prater, & Perry, 2006). In mitigation, the objective is reducing or eliminating danger to people and property from the effect of hazards (Haddow & Bullock, 2006:57). The second stage is preparation. In this stage the concept is to train people what to do in the event of a disaster and purchase the equipment that will be used in the immediate aftermath (Coppola, 2007:209). The third stage is response. This stage takes place when a disaster is approaching or has struck (Coppola, 2007:251-252). At this point disaster plans are enacted and responders attempt to save as many lives as possible (Coppola, 2007:252). The final stage is recovery. This is the period where life returns to normal and any damage is repaired (Coppola, 2007:299). Recovery allows for weaknesses that were exposed in the disaster to be corrected and risk from future disasters to be curbed, which leads back to mitigation efforts (Coppola, 2007:323).

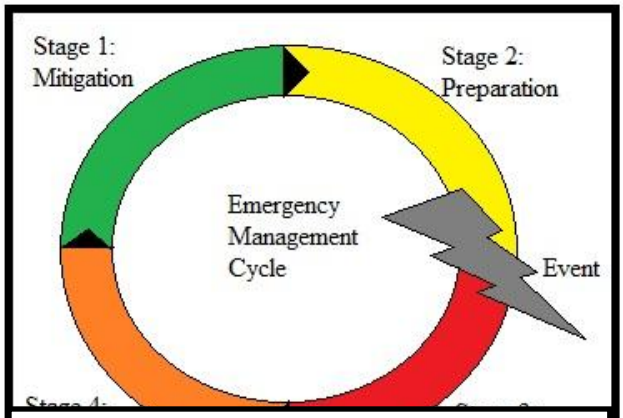
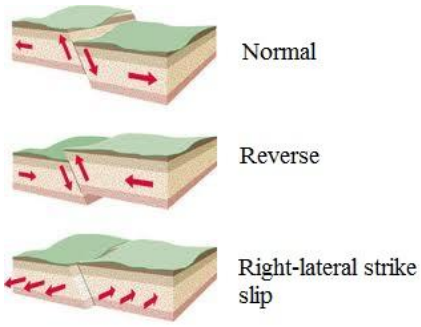


Figure 2: The emergency management cycle. (Original Graphic created by Author)

Seismic activity is unique in disaster preparation because there is little to no warning about when an event will take place. An earthquake is “the result of sudden movements of the Earth, caused by the release of strain that has accumulated over a long time” (NOAAwatch,

2010). There is no scientific method to predict where an earthquake will strike at a certain time (USGS, Common Myths about Earthquakes, 2009). The United States Geological Survey studies the probability that an earthquake will strike in a given area and reinforce that area with stronger structures through stricter building codes and the uses of better materials. (USGS, Common Myths about Earthquakes, 2009). Lack of concrete warnings about when an earthquake will strike leaves citizens who are exposed to potential earthquakes powerless in knowing when disaster will strike Preparation is key to curtailing the damage of an earthquake. If a hurricane is threatening an area, people can be moved out of the area. With several days of warning of where a hurricane may strike, those people who do not have the shelter to protect themselves from the storm can be evacuated to a place outside the hurricane's path. In the case of an earthquake, people are completely reliant on preventative measures for an event, since seismic events are predicted simply on the basis of probability.

Figure 3: Diagram of the movement of tectonic plates.



From: http://www.crustal.ucsb.edu/~susana/research/research.html

The earthquakes that this research evaluates are ground-shaking as a result of movement along faults (Brumbaugh, 2010:50). There are three types of fault movements that cause ground-shaking which most people identify as earthquakes. (See figure 3): Right-lateral strike slip, reverse, and normal (Brumbaugh, 2010:55). Right-lateral strike slip faults are when two tectonic plates are moving horizontally against each other (Brumbaugh, 2010:51-53). Reverse faults are when two tectonic plates push against each other and one is pushed upwards towards the surface (Brumbaugh, 2010:53). Normal faults are when the tectonic plates a moving away from each other (Brumbaugh, 2010:53). There is no accurate way to predict an earthquake; the only model

to determine whether an earthquake will happen is a forecast which gives the probability of an earthquake in a given area over the course of several years (Brumbaugh, 2010:209). A possible side effect of an earthquake is a tsunami, which means "harbor wave" in Japanese (Singh, 2006:104). These occur when a fault movement results in a piece of the sea floor pushing upwards to a degree that disturbs the surrounding waters (Singh, 2006:104). These waves can travel at speeds up to 220 mph and when coming onshore reach heights of more than one hundred feet (Singh, 2006:107). Another possible side effect of an earthquake is a land-slide, which is the movement of soil from steep embankments (Evans & Bent, 2004:28-29).

Zack (2009:87) in her text on *Ethics for Disaster* finds that the moral imperative for a government is to protect the lives of its citizens, even during an absence of government, for example during a disaster. A government is created to protect it people from the dangers of the state of nature and a government ought to prepare for these conditions (Zack, 2009:87-88). Thus, before an earthquake a government should implement protective policies because they have the moral responsibility to do so.

Since earthquakes are unpredictable, mitigation and preparation are the two stages in the emergency management cycle that are absolutely critical. Mitigation is hardening of physical structures, to prevent collapse of buildings, and maintaining the safety of household items. After a disaster, during the response stage, mitigation when properly implemented, should prevent emergency responders from searching through rubble to save people and ensure that road ways are clear to move injured to medical care centers. In the recovery phase, damaged structures should be less expensive to repair than to remove the rubble from collapsed structures. The most effective response will come from emergency personnel who are adequately trained in dealing with the disaster; robust preparation and planning are critical for this. During the response phase

there are fewer casualties when mitigation and preparedness policies pave the way for an effective and efficient response.

Mitigation

Mitigation is fundamental to the protection of lives in the event of a disaster and focuses on actual structures or objects. Mitigation, in simpler terms, is risk reduction or attempting to prevent the disaster from causing a higher level of damage (Coppola, 2007:175). With regard to earthquakes, it is not possible to reduce the force of the event; thus the environment must be built to withstand the effects of ground-shaking. For the purpose of this research, mitigation is divided into two categories: mandatory-structural mitigation and nonstructural mitigation based upon commonly accepted mitigation standards.

In mandatory-structural mitigation, a government attempts to reduce dangers through improved building codes or mechanical changes (Coppola, 2007:179). Coppola (2007:179) describes this as a "man controlling nature" strategy. There are many aspects of mandatory-structural mitigation, however, only some are pertinent to earthquakes; among these are: resistant construction of "new stock", building codes and enforcement, and structural modification of "old stock" (Coppola, 2007:179). In the area of resistant construction, Haddow & Bullock (2006:59) state that designing and constructing is the preeminent cost-effective means of addressing risk. In the area of building codes and enforcement, it is important to enforce the mitigation efforts that are in place (Coppola, 2007:180). In structural modification, it important to not build and forget about existing structures; it is critical to update the resiliency of buildings that are already built so that they do not fall prey to the next disaster (Coppola, 2007:181).

The counterpart to mandatory-structural mitigation is nonstructural mitigation. These policies focus on people and non-permanent household items rather than physical structures. In nonstructural mitigation, the aspects that are important are: nonstructural regulatory measures, community education programs, and nonstructural physical modifications (Coppola, 2007:185). In regulatory measures, land-management was one of the first ways to practice mitigation and this policy is designed to remove people from a land areas where hazards present a danger (Haddow & Bullock 2006:60). Coppola (2007:186-187) also suggests community awareness and education programs which synthesize both mitigation and preparation efforts. Informing the public of proper actions to take during a disaster is critical to control disaster behavior among citizens (Coppola, 2007:186-187). Finally, nonstructural physical modifications are extremely important; this is the area where people place furniture in their house where it will not fall on them when an event happens; an excellent example of this would be a bookshelf tipping over onto a person trapping them underneath. These many factors make up the concept of mitigation (Coppola, 2007:187-188).

In dealing with seismic events, each of these individual facets of mitigation work to ensure that structures do not collapse and kill citizens or trap people beneath them. As is the main tenet in emergency management, mitigation seeks to prevent a disaster from turning into a catastrophe. Mitigation focuses on structures, but it is essential in preventing the loss of human life.

Preparedness

In preparedness, actions that are taken before a disaster strikes to ensure satisfactory response to the relief and recovery of the disaster's consequences; a multifaceted approach,

training both professionals and the average citizens, is taken to reduce the loss of life (Coppola, 2007:209). Preparedness involves the people who will be in disaster response. Coppola (2007:209) identifies three conditions that are necessary for successful preparation for the individual: knowing what to do, knowing how to do it, and having the correct tools to do it. To do this, a government must implement programs to ensure that these three aspects are met. The areas where government programs are critical are: planning, exercise, training, equipment, and clearly defined functional responsibly across emergency management agencies and first responders. On the individual level, citizens must be educated and proper use of the media must be utilized to inform the public.

In planning, Coppola (2007:210) comments that the initial stages of a disaster is too late to start planning the response. Every government should have an Emergency Operations Plan (EOP); a plan which goes into detail about which agencies and what responders involved in those agencies are supposed to do during a given emergency (Coppola, 2007:210). Another program that first responders need to be involved in is exercise. In this area, the EOP is put into practice; Haddow & Bullock (2006:160) point out that exercises allow for evaluation as to whether the plans that are on paper will meet the demands of the disaster. The area of training is a way for people to know how to do their jobs better (Coppola, 2007:217). Coppola (2007:218) argues that disaster response will be blunted if resources are spent on emergency personnel who are injured in the aftermath of a disaster because they are injured during the rescue process. Haddow & Bullock (2006:175) point to the terrorist attacks of September 11th in the United States as a way a disaster can quickly deplete supplies. Having the proper equipment and stocked supplies are important in responding to disaster. First responders need to have vehicles, fire suppression systems, interoperable communication equipment, and public information systems

(Coppola, 2007:219-220). Finally, the government must develop clearly defined functional responsibility for emergency management agancies; in other words, the government needs to ensure that the legal framework to ensure that disaster funds and agencies are able to operate legally and quickly in the event of a disaster (Coppola, 2007:221). If there is no authority for a government or agency to respond, the government response could be stagnated by its inability to effectively operate in a post-disaster situation; a similar situation could occur if multiple agencies perform the same response action.

On the citizens' level, the responsibilities are different during an disaster's response; public education is the corner stone of public preparedness and information conveyed to public before a disaster helps citizens to stay safe (Coppola, 2007:222-223). The media can also help in this area by increasing awareness as to what to do during the event of an earthquake; thus people can modify their behavior accordingly (Coppola, 2007:231).

Preparation is vital when an earthquake occurs because there is no time to buy equipment, train personnel, or create a plan. Information must be in place before the disaster so there can be near instantaneous action during the response. Time that is wasted after an earthquake strikes means that someone who is injured could expire from their wounds, go without sustenance, or be trapped in the destruction.

VARIABLES OF INTEREST

In the absence of international, universal emergency management standards, in general, several specific mitigation and preparation strategies are widely recognized as fundamental to disaster management. The dependent variable in this study is the human death toll as a result of an earthquake. Explanatory variables represent essential mitigation and preparation activities.

Data concerning loss of life is sourced from the United States Geological Survey's record of earthquake events. In emergency management, as important as physical objects are, the main focus is the number of human lives lost or damaged. The purpose of all aspects of emergency management, whether it is building stronger structures or ensuring that emergency personnel are able to respond, is protecting human life. Thus this is the most important factor for this research.

The independent variables are *mandatory-structural mitigation* (resistant construction of "new stock" buildings and the structural modification of "old stock" buildings, building codes and regulatory measures), *nonstructural mitigation* (nonstructural regulatory measures, nonstructural physical modifications, and community education programs) *emergency management preparedness* (planning, exercises, training, and equipment, functional responsibilities of agencies), and *community preparedness* (public education and media awareness). Each of these variables is commonly identified as inherently important in mitigation and preparation of the emergency management cycle (Coppola, 2007);(Haddow & Bullock, 2006);(Singh, 2006).

Mandatory-structural Mitigation

Resistant construction "New Stock" refers to the constructing of buildings that are capable of withstanding ground-shaking. This variable will be measured by looking at the opinions of experts as to what materials function the best during a disaster. To measure this variable, the researcher will examine statements by experts to determine if newer buildings in the target area are constructed of materials that are able to withstand ground-shaking.

Structural modification "Old Stock" is the physical changing of older structures with newer technologies to ensure that they are capable of with-standing ground-shaking. This

variable will be measured by examining whether countries attempted to retrofit older structures with materials designed to help them withstand ground-shaking. Dorwick (2009:485) emphasizes that buildings have a lifetime risk that increases the longer a building is used. As newer technologies emerge, it is important to update building to modern standards, which will ultimately reduce casualties in the event of an earthquake.

Building codes and enforcement refers to the enforcement of legislation that is designed to compel owners of buildings and contractors to guarantee that their buildings are in compliance with local building codes. This variable will be measured by looking at whether there is evidence that that the government or a regulatory agency is ensuring that local building codes are being enforced. Dorwick (2009:267) states that in recent decades building codes have become more important in reducing casualties in larger earthquakes. Thus, enforcement is using enacted legislatively to examine compliance. Each nation should have some sort of legislation and inspectors. This researcher will look at both the aftermath of the event and expert insight will identify whether a location has completed this variable.

Nonstructural Mitigation

Nonstructural regulatory measures try to ensure that people are not living in disaster prone areas. In the realm of earthquakes, this would ensure that high risk structures are not built in areas that pose a significant danger of collapse from soil or other comparable danger. This variable will be measured by examining if there is legislation or policies that ensure that people do not overtly settle in dangerous areas. This can include refusing to issue building permits for certain area if a country is unable build stronger buildings to counteract the natural dangers. Coppola (2007:185) states that nonstructural regulatory measures will reduce casualties by

physically preventing people from inhabiting an area where a disaster strikes repeatedly. For some countries where the threat covers an expansive area, this may include evacuating people only during emergencies.

Nonstructural Physical Modifications works to secure physical household items that have the potential to cause bodily harm during the event of ground-shaking in non-household areas. These could include bookcases, entertainment centers, planting pots on outdoor window sills, and chandeliers. This variable will be evaluating by assessing whether if governments have legislation or rules in place that mandate people secure these objects in area outside the home. As people secure objects that could pose a danger to them during an earthquake, casualties will decrease (Coppola, 2007:187-188).

Community education programs are activities that educate citizens about the dangers of inhabiting areas that are earthquake prone and the safety issues that unsecured household items can pose in the event of ground-shaking. This variable will be measured by looking to see if there are any programs in a country that encourage people to secure household furniture, appliances, or lighting fixtures. Coppola (2007:186) states that people are most able to protect themselves from disaster when they are informed of the strategies of what to do during disaster.

Emergency Management Preparedness

Planning mandates that local governments implement a set of operational actions that are employed in the event of an earthquake by emergency personnel. This could be evacuations of coastlines residents, calling up first responders or military forces, or activating warning systems. Sikich (1996:5-6)shows how response, the phase immediately after a disaster strikes, exposes

confusion if plans are not in place and people don't know what their position in the plan is; response's success or failure depends upon planning.

Exercises are actual drills in which emergency personnel practice responding to scenarios of disasters. These exercises do not have to be earthquake specific, but there has to be some level of cooperation across agencies working together to save lives in the event of a disaster. This variable will be evaluated by examining if responders practiced in some way to prepare for a disaster. Gillis (1996:2) postulates that exercising an emergency response plan engages capabilities, improves coordination, identifies resources needs, and demonstrates to the public of the response plan's effectiveness.

Training includes teaching emergency responders skills to use in a disaster and how to use equipment effectively. This variable will be measured by looking to see whether nations trained their emergency responders to respond to disaster. Haddow & Bullock (2006:157) point out that training is fundamental to any organization with a strong preparedness capability.

Equipment refers to local government ownership of equipment to conduct emergency response activites. This can include trucks to transport supplies, equipment to search for citizen trapped under rubble, or adequate medical supplies to treat wounded citizens. This variable will be measured by showing that nations or agencies have purchased equipment to respond to a disaster. Equipment does not necessarily need to be earthquake specific because some purchase; for example, ambulances and EMS could be used in more than one type of response. Collins (2004:27) points out that agencies should make hazard assessment and determine if the equipment they possess will be able to function effectively if disaster strikes; if not, purchases need to be made so that emergency personal can respond in the event of disaster.

Functional Responsibility decrees that there must be clearly defined goals for emergency responders. To employ functional responsibility, there must be some set of legislation or rules that identify who is responsible for what parts of the response so that responders can respond effectively. Collins (2004:21) points out that if jurisdictions are not matched with real condition on the ground and statues do not reflect the conditions on the ground, then the response will fail. Agencies must know their individual responsibilities before disaster strikes (Collins, 2004:21).

Community Awareness

Public Awareness raises awareness so that citizens understand what to do in the event of an earthquake. Citizens need to understand the dangers of tsunamis if they live by the coast, they understand not to enter structures until they have been deemed safe, and to not flood hospitals unless they are actually injured. This variable will be measured by assessing whether there are programs that inform people of the specific dangers that are posed to them by the threat of earthquakes or side effects of seismic events. Singh (2006:319) states that having emergency plans at the village level allows for the response to work more effectively; the people are informed of the possible effects of a disaster and people form plans that utilize local resources to prepare them for unexpected emergencies.

Use of media comprises using the media to inform citizens of what to do during a disaster and to inform them of what disasters they might be at risk for. To measure this variable, this researcher will look to see if governments used the media to inform their citizens of what to do during a disaster or of what disaster they are at risk for. Coppola (2009:231) cites studies that show the use of media during preparation helps to elicit a certain behavior in the event of a disaster; this safeguards the response from distractions like looting or additional injured citizens.

Control Variables

Mitigation and preparedness strategies must also consider other important factors that impact the ability for a population to protect human life in the event of an earthquake. These factors include population density, the time of day of the earthquake (daytime or nighttime), and the magnitude of the quake.

Population density is a critical control variable. Places that are denser will have greater casualties as a result of having more people inhabiting the area. Thus we should expect the earthquake data to show higher casualties at higher population density levels. However, as the number of people increases there is also the possibility that mitigation and preparation efforts will increase due to the urgency of the population's needs to prepare.

Physical location and the time of day of the event of the earthquake are also important. An example of the impact of location is that a tsunami cannot take place when an earthquake strikes a landlocked location. An earthquake that occurs in the middle of the night will strike people who are mostly asleep and slower to take action; however, an earthquake that occurs during a holiday or during rush hour could be equally dangerous.

The magnitude of the earthquake and the depth of the earthquake are also critical factors. The stronger the earthquake and the more shallow the depth, the greater the ground-shaking that will occur. This research utilizes cases that are of similar magnitude and depth.

HYPOTHESES

The relationship between earthquakes and the loss of life should be inversely related. That is to say that as mitigation and preparation policies increase the number of human lives lost

from any seismic event should decrease. The following hypotheses postulate that strong mitigation and preparation policies work to save lives.

As mandatory-structural mitigation policies (resistant construction of new housing stock, disaster resistant building codes and enforcement of those codes and structural modification of older housing stock INCREASE the number of human lives lost will DECREASE.

As nonstructural mitigation policies (regulatory measures, community education programs, and nonstructural physical modifications ,such as securing furniture and property INCREASE the number of human lives lost will DECREASE.

As emergency management preparedness policies (planning, exercises, training, equipment, and clear lines of responsibility across emergency management agencies) INCREASE the number of human lives lost will DECREASE.

As community preparedness policies (including public awareness programs and the use of all types of media to communicate disaster information) INCREASE the number of human lives lost will DECREASE.

RESEARCH DESIGN

There is little international comparative data on earthquake mitigation and preparedness standards. For this reason, national building codes and mitigation policies are not necessarily interchangeable across countries and individual provinces within nations have their own strategies for preparing for emergencies. This research uses case studies to examine six large scale earthquakes in an attempt to better understand which mitigation and preparation strategies help save the most lives at the local level.

Case Study Analysis

Yin (1994:20) describes a good case study research study as having five components: "A study's question, its proposition, if any, its unit(s) of analysis, the logic linking the data to the prepositions, and the criteria for interpreting the findings." This case study will use a method that Gerring (2007:91) puts forward as the typical method to choose cases. This type of methodology looks to find a representative sample of cases to paint an overall picture (Gerring, 2007:91).

This study will examine similar cases from different parts of the world to examine what effect mitigation and preparation policies have on limiting the number of human deaths that occur in an earthquake. The preposition of the research is that rigorous mitigation and preparation will positively affect the number of human lives protected during an earthquake. The logic linking both disaster mitigation and disaster preparation with the death count in that since earthquakes are sudden events, it would be difficult for the latter two phases of the emergency management cycle (response and recovery) to have as great an impact on protecting human life. Finally, the method of interpreting the data is to use detailed descriptive analyses of each event supported by descriptive statistics that allow the researcher to compare across events.

The criteria for selection of the cases in this study are based upon three principles. The first principle is to identify earthquakes that occurred along a known fault line. The second principle includes the selection of large scale earthquakes—approximately 7.0 magnitude. Minor shifts in the earth's tectonic plates are taking place constantly; it would be of little use to examine seismic activity which does not represent a sizeable threat. The third criterion is that the United States Geological Survey identifies the event as activity resulting from movement of tectonic plates. Although sustained movement to structures could occur from other sources, like a large

explosion, this research has chosen to focus on movement that takes place naturally and thus is easily comparable across events. This research has drawn a pool of possible cases from the USGS database on seismic activity. The list is comprised of all recorded seismic activity from January, 1 2000 thru April 2010. The total number of cases in the overall data set is 622 and the range of magnitude is 1.6 to 9.0. From the larger pool of cases, six are selected for special investigation. The range of magnitude of the six cases examined is 6.8 to 8.8.

Data

Much of the data for this research is sourced from the United States Geological Survey's earthquake data base. This information includes the time, location, intensity, depth, number of lives lost, and number of injured (See appendix A for visual and data compilation).

The information for the individual cases comes from multiple sources. Japan's information is from international news reports and studies regarding earthquake mitigation and preparation efforts written by Japanese scholars. Chile's information comes from international media articles. El Salvador's information comes from a study by the Geological Society of America who sent researchers to the area after this seismic event to study the disaster and policies surrounding it. The information for Algeria comes from studies on the earthquake vulnerability of the area and international news reports. The information for China comes from international news reports. The information for Haiti also comes from international news reports.

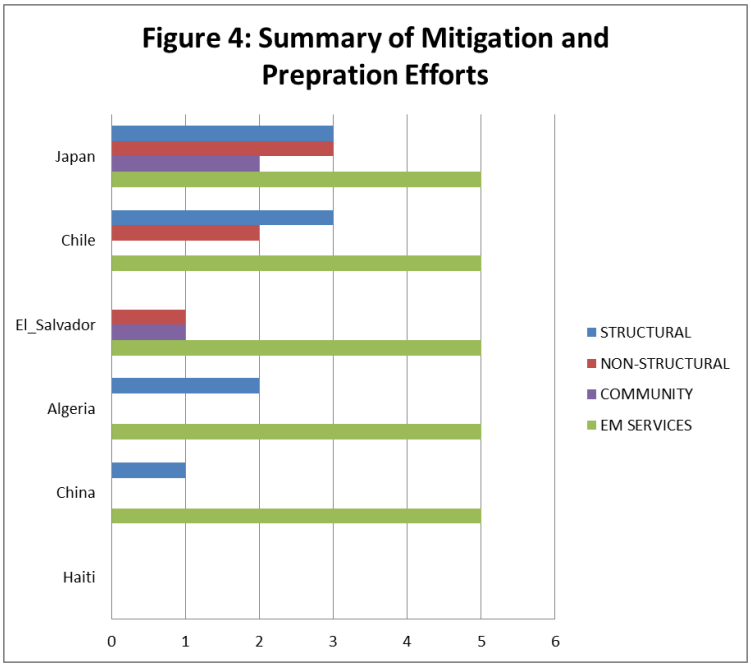
ANALYSIS

In-depth analyses of these six similar earthquakes events produced data for the information presented in Table 1. Each event was scored according to the local government's mitigation and preparation efforts based upon the information collected. Positive scores were given if policies were in place prior to the earthquake event; the country/region then scored a "check" for the specific mitigation or preparation activity (See Table 1). Table 1 reveals that mitigation activities vary widely; preparedness appears to be a more universal practice, but the quality of those activities varies greatly and is discussed in detail in the following sections.

Figure 4 summaries the data presented in Table 1. For a nation to receive a positive point, a local government must have made a recognized effort to complete each identified mitigation or preparation policy. Across the categories of mitigation and preparation activities, a score of three (3) for structural mitigation indicates that a locality had all three identified policies in place at the time of the earthquake (resilient new buildings; modified old stock, and rigorous building codes and enforcement of those codes). In the nonstructural category, again an overall score of three (3) indicates universal adoption of the key policies comprising nonstructural mitigation (regulatory measures, physical modifications, and community education programs). In the domain of preparedness, emergency management strategies include five (5) activities (planning, exercises, training, equipment, and clearly defined functional responsibilities across agencies responsible for emergency management duties). An overall score of five in this category indicates a high level of emergency management preparation. Lastly, in the arena of community awareness, two factors are analyzed, the level of public awareness of what to do in the event of an earthquake and how the media is utilized to provide information to the public. An overall score of two (2)

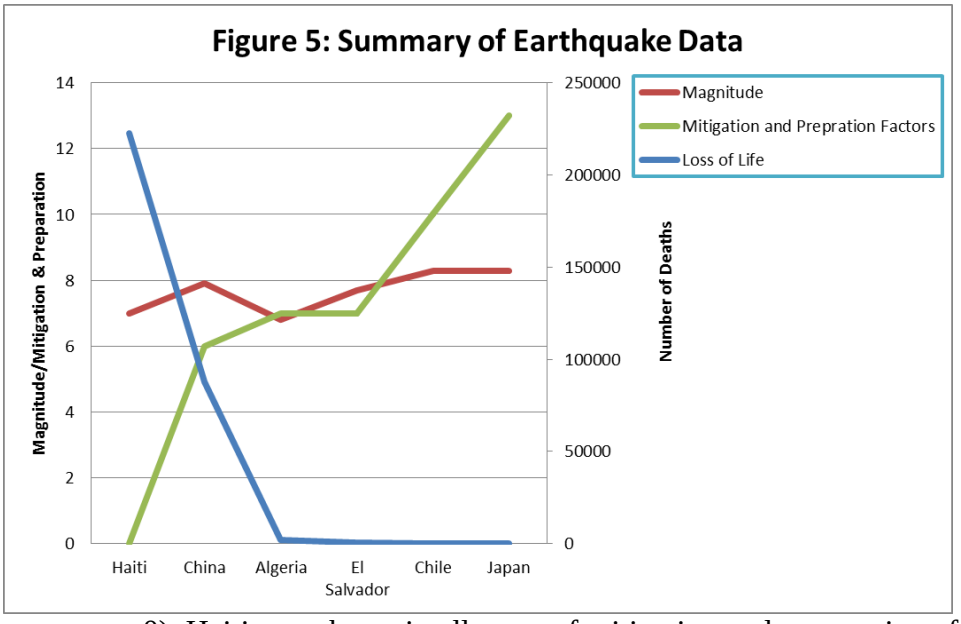
Table 1: This is a visual depiction of data collected for each case represented in the analysis section.

	Japan	Chile	El Salvador	Algeria	China	Haiti
Magnitude	8.3	8.3	7.7	6.8	7.9	7
Pop Density per km^2	72.5	29.8	311	750.00	11,194	735.5
Death Toll	0	297	844	2266	87,562	222,570
Injuries	755	12000	4723	10,261	374,171	30,000
MANDATORY STRUCTURAL MITIGATION						
Resistant Construction (New Stock)	✓	✓	✗	✓	✗	✗
Structural Modifications (Old Stock)	✓	✓	✗	✗	✗	✗
Building Codes and Enforcement	✓	✓	✗	✓	✓	✗
NONSTRUCTURAL MITIGATION						
Nonstructural Regulatory Measures	✓	✓	✗	✗	✗	✗
Nonstructural Physical Modifications	✓	✗	✗	✗	✗	✗
Community Education Programs	✓	✓	✓	✗	✗	✗
EMERGECNY MANAGEMENT PREPAREDNESS						
Planning	✓	✓	✓	✓	✓	✗
Exercises	✓	✓	✓	✓	✓	✗
Training	✓	✓	✓	✓	✓	✗
Equipment	✓	✓	✓	✓	✓	✗
Functional Responsibility	✓	✓	✓	✓	✓	✗
COMMUNITY AWARENESS						
Public Awareness	✓	✗	✓	✗	✗	✗
Use of Media	✓	✗	✗	✗	✗	✗



indicates that localities are both educating their citizens about how to prepare for an earthquake and employing the media to keep them informed.

Japan performed excellently in all areas and achieved a perfect score while also surviving the disaster without a single death (Mandatory-Structural Mitigation: 3, Nonstructural Mitigation: 3, EM Preparedness: 5, Community Awareness: 2). Chile also scored relatively well, with major deficiencies only in community awareness (Mandatory-Structural Mitigation: 3, Nonstructural Mitigation: 2, EM Preparedness: 5, Community Awareness: 2). El Salvador had weakness in their mitigation and preparation efforts before the earthquake studied; El Salvador was weak in both areas of mitigation (Mandatory-Structural Mitigation: 0, Nonstructural Mitigation: 1, EM Preparedness: 5, Community Awareness: 1). Algeria was weak in almost all areas and had nonexistent levels of effort in nonstructural mitigation and awareness (Mandatory-Structural Mitigation: 2, Nonstructural Mitigation: 0, EM Preparedness: 5, Community Awareness: 0). China also was lacking in most policies, which led to a massive number of lives lost (Mandatory-Structural Mitigation: 1, Nonstructural Mitigation: 0, EM Preparedness: 5,



Community Awareness: 0). Haiti was absent in all areas of mitigation and preparation efforts and it experienced the most deaths of any of the cases studied (Mandatory-Structural Mitigation: 0, Nonstructural Mitigation: 0, EM Preparedness: 0, Community Awareness: 0) (See Appendix B for narrative of individual cases).

Figure 5 is a comparative visual of the earthquake magnitude, mitigation and preparedness policies, and the loss of life as a result of each earthquake. There is an inverse correlation between the loss of life and the number of mitigation and preparedness policies while the magnitude of the earthquake remained approximately equal. Thus the case study data supports the proposition that the greater the depth and rigor of mitigation and preparation strategies, the fewer human lives lost.

Overall, Japan, which has the most stringent application of mitigation and preparation policies, experienced the fewest deaths of all the events under study. Haiti, which had no discernable mitigation and preparation policies in place, had the largest number of deaths. The other cases highlight how even basic efforts at mitigation and preparation can save lives.

Mandatory-Structural Mitigation

In this area, Japan and Chile have taken superior measures in building stronger buildings. Japan has focused on improving building codes and buildings that have been built in the country since 1981 have adhered to standards that are specifically designed to withstand earthquakes (Suganuma, 2006:94). Japan has also gone to great lengths to retrofit its older building to resist earthquakes. They have taken measures such as using "equipment to prevent bridge collapses, soil stabilization to prevent liquefaction, and earthquake retrofitting of wood and reinforced concrete structures;" these modifications have proven to have successful in earthquakes since the modifications took place (Suganuma, 2006:95). In Chile, the country has building codes that equate to their risk of earthquakes. There was some damage to structures in Chile, however these were isolated and caused very few death as compared to the nearly two million people who were affected by the event (CNN, Feb 27, 2010). As strong as newer buildings were, Chile still sustained damage with almost a half a million home severely damaged from the quake; these tended to be older homes (CBS, 2010).

In the area of compliance Japan has taken large strides to ensure compliance, earthquakes in the past decades have not caused widespread building collapse which shows that the codes and regulatory measures have been effective in reducing damage caused by earthquakes (Suganuma, 2006:94-95). Welch (2010) points out that in addition to strict building codes, Chile has enforced these building codes as well as any nation could; thus they were able to withstand the earthquake very well. Both of these nations could be used as a model for any country looking to improve their mitigation efforts

El Salvador and Algeria performed moderately well in the area of loss of life, even while performing poorly in some areas of mitigation; however, local conditions played an important

role in this. The nation of El Salvador did not have adequate structures to withstand the earthquake and its effects; over 227,000 homes were destroyed or damaged (Rose et al., 2004:70). Rose et al. (Rose et al., 2004:457) points out that many of the homes that were damaged in the earthquake were made from adobe, the material that was most widely available, and was not properly maintained. However, since structures crumbled as a result of the ground-shaking the risk from large chunks of buildings falling onto people was negated, thus lowering the death toll. Algeria experienced a great deal of building collapses, especially in the area east of the city of Algiers (CNN, 2003, May 22). This shows that there is a substandard level in the city's building long term integrity. Harbi et al. (2004:964) explains that older buildings at risk for collapse during an earthquake, those constructed in the early 1900s have deteriorated over time. Harbi et al. (2004:964) found that many of the buildings in Algiers and its surrounding areas, especially in poorer areas, had deteriorated over time to the point in where they were dangerous. After the earthquake, citizens of Algeria were upset because most of the buildings had passed routine inspection but some buildings collapsed while other did not (CNN, May 24, 2003).

Much of the damage in El Salvador came as a result of the earth movement as a result of the earthquake; these landslides were the source of much of the destruction of the El Salvador earthquake (Rose et al., 2004:70). No effort was made to modify these homes against earthquakes and similar materials are being used again to rebuild destroyed homes (Rose et al., 2004:457). The people of El Salvador

Figure 6, China 2008:
http://www.britannica.com/EBchecked/media/112835/Four-days-after-a-major-earthquake-struck-Chinas-Sichuan-province

built homes out of whatever was most available and many of the structures collapsed in poorer areas because the people of El Salvador used whatever materials they had available because that is what they could afford; most of the material was adobe (Rose et al., 2004:457). The issue of protecting poorer areas raises an important issue for governments; if these areas are not closely regulated by governments, then they could lead to expensive and extended recovery efforts.

In this area China and Haiti have some major deficiencies in the area of mitigation. In China's case, there were widespread building collapses (Bryner, 2008). Structures built to withstand the ground shaking that occurred in the province was missing and people died as a result (Bryner, 2008). China appears to not have upgraded buildings to withstand ground shaking and many older structures added to the collapses of buildings in the province (Bryner, 2008). Haiti's earthquake also resulted in widespread damage caused by serious structural collapse across the island and many deaths occurred as a result (Llana, 2010). Watkins (2010) points out that experts concur that Haiti would have had a similar experience even at a 2.0 magnitude earthquake. Haiti did not use even basic building codes during construction and also did not update structures (Watkins, 2010). China had written building codes that mandated reinforcement of buildings (Bryner, 2008); thus, the level of enforcement was clearly lacking seeing as the country appeared to take few steps to make structures resistant to collapse. Haiti had no discernable building codes or enforcement (Watkins, 2010). Not only did local Haitian structures collapse, but internationally owned structures also collapsed which points to low levels of codes and enforcement (Llana, 2010). These Chinese and Haitian areas were also extremely poor and needed special considerations regarding policy that should have been implemented (Bryner, 2008)(Llana, 2010).

Nonstructural Mitigation

Figure 7, Chile Expo 2010
http://news.injuryboard.com/cpsc-launches-furniture-and-tv-tipover-education-campaign.aspx?googleid=271368

Japan is the leader in nonstructural mitigation policies. Japan has been working on distributing hazard maps to anyone in an area who is in danger from an earthquake; so that they know they are at danger from an earthquake and it potential effects, such as a tsunami or landslide (Suganuma, 2006:105). Japan has worked hard to improve its nonstructural physical modifications. The Japanese have a comprehensive program to educate people about the dangers that are posed from unsecured household objects (TOKYO, 2006). However, the people of Japan said in a survey that they resist securing furniture due to appearance and awareness (Suganuma, 2006:93). Japanese citizens in articles about the earthquake showed that they had worked on some nonstructural physical modifications due to the low number of people being reported injured due to household objects (BBC, Sept 26, 2003). Since Japan experiences earthquakes so frequently, their way of life depends on successfully enduring earthquakes.

Two countries that fare well in this area are Chile and El Salvador. Chile has invested money in researching where soil is weak near cities which might result in ensuring that either those areas will not have large buildings or the soil will be shored up (Welch, 2010). In the aftermath of the earthquake, there are firsthand accounts of furniture moving as a result of aftershocks and shows a deficiency in Chile for nonstructural physical modifications (The Associated Press, 2010, March 1). An area where Chile does well is community education programs; there is evidence that people in the region knew proper procedures during the

earthquake and it probably contributed to lives saved. At the time of the earthquake, El Salvador did not have in place the ability to block construction in high risk areas. They have now empowered local governments to deny construction permits based upon studies conducted about the risks associated with hazards in any given territory (Rose et al., 2004:548). There is no evidence that El Salvador attempted to inform their population about the dangers nonstructural furniture items in a home could pose during an earthquake (Rose et al., 2004). El Salvador has made improvements since the earthquake under review and would most likely perform better if a similar event occurred again. Chile is also a frequent target of seismic events, so it is only natural for them prepare with greater vigor.

Algeria, China, and Haiti all were extremely deficient in nonstructural mitigation. Algerian news outlets pointed out that local government officials allowed buildings to be built on marshy lands that became susceptible to collapse during the earthquakes (BBC.com, 2003, May 24). There was also no evidence that the Algerian government made any effort to educate their population about the dangers that nonstructural mitigation efforts or pass any legislation about the dangers of household items during an earthquake (CNN, May 24 2003; Harbi et al, 2004). There is no evidence that China did anything in the area of non-structural mitigation. In fact, reports from the Chinese disaster indicate that people tried to escape from buildings during the earthquake, which is excursive to what should be done during an earthquake (Hooker & Yardley, 2008). The people of Haiti built wherever with whatever they could; there was no control or oversight by the Haitian government (Watkins, 2010). The Organization of American States worked on a report that hopes to teach builders in Haiti of proper techniques to build structures that can withstand both earthquakes and other natural disasters in the future (Watkins, 2010); however there was little awareness beforehand. There is no evidence that Haiti made any attempt

to inform their population about the dangers nonstructural items in a home could pose during an earthquake (Romero & Lacey, 2010).

Emergency Management Preparedness

In the area of emergency management preparedness, most countries in this selection have some sort of framework in place to complete this section. In reality, most modern nations provide emergency services as a basic need to their citizens. The quality of these services varies greatly. Japan, which has a high level of services, has worked to improve its disaster plans in the last decade; as of 2004 over 75% of municipal governments have reworked their local response plans to respond to changed conditions in emergency management within their country (Suganuma, 2006:102). Japan and the United States participate in annual exercises that simulate a large earthquake in the Tokyo region, these personnel can respond to any event in the country (Vervaeck, 2010). Japan has worked to ensure that personnel are trained and capable to respond to specific needs identified in disaster plans so that basic services are restored to normal and danger is limited by interruption of service (Suganuma, 2006:102-103). In their exercises, Japan and the United States use equipment that would be used in the event of a disaster, including naval warships, communication devices, and practice emergency announcements (Vervaeck, 2010). Japan has reworked laws in recent years to ensure that they are able to deploy the Self-Defense Forces easier and to make disaster response easier to act in the event of a disaster in addition to regular

Figure 8, Chile 2010
http://mediagallery.usatoday.com/8.8-earthquake-strikes-Chile/G1470 (Picture 39)

deployment of emergency personnel (Suganuma, 2006:102). Through the actions that Japan has taken, the government has worked hard to ensure that in any emergency personnel are able to respond effectively and responsibilities are well laid out (Suganuma, 2006);(Vervaeck, 2010).

Chile, El Salvador, and Algeria all performed well in emergency management preparedness, but there is room for improvement. Chile had planned well for this event, however, the government failed to nationally active their tsunami warning system; several local towns activated the system anyways and people were saved because of it (The Associated Press, 2010, March 1). The Chilean military and emergency personnel were able to respond quickly; they were able to save many lives, curb looting, and distribute supplies (USA Today, 2010). Chilean firefighters were able to rescue people from collapsed buildings and this resulted in saving many lives (USA Today, 2010). The military had access to equipment and training in securing the disaster area (USA Today, 2010). This was a military group that had extensive drills to work together to complete their mission. The Chilean government was able to quickly gain control of the situation by deploying their military and enlisting aid organizations (CNN, Feb 27, 2010). The nation of El Salvador was also able to quickly call for international aid (Rose et al., 2004:447). The central government relied upon the National Emergency Committee to plan and respond to the disaster. This organization operates on a low budget but still provides the planning framework for responding to disaster (Rose et al., 2004:467); thus the plans that they put in place operated effectively. There is not any specific information on exercise by the emergency personnel of El Salvador, however, the small number of trained emergency personnel and their rapid response and integration into the armed forces indicate that some level of exercise was implemented before the disaster occurred (Rose et al., 2004:446-447).

Even though El Salvador had some equipment to respond to disaster, El Salvador simply did not have the right equipment to respond to this type of disaster; they did not have any aerial vehicles to assess damage in a wide scale area nor did they have anything to reach survivors trapped beneath the landslides and rubble (Rose et al., 2004:447).The central government of El Salvador was able initiate preparation programs, call for international aid, and dispatch emergency personnel; all of which point to the government having the laws in place for them to act during a crisis (Rose et al., 2004:447). Algeria showed signs of executing a preplanned deployment of forces as police were on high alert to watch for looters and the integration of international rescue personnel into the hardest hit areas took only a few days (USA Today, 2003). Algeria had both rescue workers and the equipment for the disaster; however, the government was wary of using heavy equipment to search the rubble for fear of killing people who were trapped underneath and delayed deploying heavy machinery for several days after the disaster (USA Today, 2003). The response was coordinated to supply the disaster zones with supplies and showed that some sort of exercises had taken place (USA Today, 2003).

China has a unique approach to preparedness. China deployed military troops instead of using local emergency management. Since China is a communist country, they have the right to set up their functional responsibility as they see fit. The deployment of military forces came from the prime minister of China and was planned after the response to the 1976 earthquake which killed a quarter of a million people (Hooker & Yardley, 2008). The advantage of this tactic was that the responders came from outside of the disaster zone, but this came at the cost of time, several days to reach the most isolated areas (Hooker & Yardley, 2008). Because military forces go through extensive training and have access to many resources, using military forces in the way the Chinese did is crude but accomplishes the goal.

Figure 9, Chile 2010
http://mediagallery.usatoday.com/8.8-earthquake-strikes-Chile/G1470 (Picture 73)

Haiti's government relied on aid organization to make it through typical conditions, the post-earthquake nation continued that reliance and the nation did not have any disaster plans in place, any exercises of personnel, any training of personnel, bought any emergency response equipment, or had the legislation in place to coordinate a disaster response (Llana, 2010). The number of people injured in the Haitian disaster in extremely low for number of deaths that occurred. The USGS gives the injured count as 30,000 (USGS, July 3 2010) and leads this researcher to conclude that very few people were rescued from collapsed building or made it to local medical facilities.

Community Awareness

Community awareness is an area where many nations could stand to improve. Japan is once again the leader. The Japanese participate in mandatory evacuation drills and audible warning systems are tested daily across the country (Petrun, 2007). The government is also hooked up to breaking in instantaneously if there is a tsunami to warn people (Petrun, 2007). In the event of a disaster Japan uses television and other internet sources as a means to get information out (Suganuma, 2006:94).

The only other nation that participates in any community preparedness action is El Salvador. El Salvador provides to its people information booklets and local teachers are trained to practice drills in the event of a disaster (Rose et al., 2004:446). Unfortunately, in El Salvador

the government does not involve the media in dissemination of information for preparing for earthquakes (Rose et al., 2004:446).

The other four nations are noticeably absent in this area. Chile has frequent earthquakes, but there is no evidence that they engaged in awareness in preparation efforts. There may be local efforts that this researcher does not have access to, but this researcher was not able to find any information on them. There is also no evidence that either Algeria or China made any attempt warn their populations of the danger that earthquakes pose beforehand. To their defense, earthquakes seem to occur in their locations about once every ten to twenty years, but this makes education even more important since the people may grow complacent with such long stretches between events. In the aftermath of the Haitian earthquake, emergency management experts stated that educational programs needed to be carried out since none existed in Haiti (Tucker, 2010). There is no evidence that the country of Haiti used media sources to disseminate information about preparation for earthquakes; much of Haiti's knowledge came from aid agencies already in the country, foreign aid sources point to a lack in basic media sources and using these sources for emergency management did not seem likely (PBS News Hour, 2010).

CONCLUSION

Across the six cases studied there is an inverse correlation between mitigation and preparation efforts and the loss of life as a result of an earthquake. As these policies increase, lives lost decreases. Thus, since these efforts seem to work, the following policy changes are recommended to help any locality that is at risk for a seismic event..

In *mandatory-structural mitigation* there are several areas where improvements can be made. In the course of this research, no internationally recognized building codes were

discovered. It would benefit all countries to have an internationally accepted set of standards that they use for building new structures. These codes should be pegged to the level of earthquakes that the area has historically been exposed to. Raising building codes can be expensive; aid organization (USAID, OAS, The United Nations, the World Band, and others) should be encouraged to help poorer nations so that the capital is available to implement these policies.

Older structures also need to be retrofitted. Unfortunately countries have used local materials and standards to build structures that could have been around for more than a century. Each building would need an individualized plan to protect it from an earthquake. For example, St Louis's arch falls in a seismic zone; this structure would need an individualized plan to ensure that the structure is strong enough to withstand an earthquake. Nations need to determine if at-risk structures need to be torn down and rebuilt or if they can be modified. Since technologies are constantly being invented, this should occur multiple times during a building's lifetime or after ground breaking techniques are invented. These efforts will be both expensive and time consuming; thus, aid organization would also need to be involved in this area.

Finally, building codes have to be in place and enforced. Many of the nations in this study performed poorly in this area. In the cases of China and in Algeria, there were reports from citizens stating that agencies had inspected buildings that collapsed and the people trusted those inspectors for building that collapsed during ground-shaking. Inspectors need to ensure that reinforcement of structures is actually taking place and that inspections occur at various stages during construction and not just when viewing a finished product.

Nonstructural mitigation efforts are also important to ensure that people are protected inside structures that are capable of withstanding a disaster. Citizens should secure larger

furniture items that could fall over during an earthquake and governments should write legislation so that public places, like workplaces and public buildings, are secure from ground-shaking. If environments are consistent, then the response of the citizens should be similar for any given location. Individual rights are an important issue here, most nations will only be able to pass legislation that covers public buildings or work places so private homes will continue to have risk. Education programs will have to be used when individual rights are an issue and people will have to be given the choice of whether to secure their belongings.

Governments will need to ensure that people are not placed in danger unnecessary. There are multiple reports in the aforementioned cases of governments being worried about the soil that structures are built on. Governments need to ensure that areas are safe for construction, even if it is unpopular with their citizens. The Chilean government pumped cement into weaker soil areas to fortify them. Governments need to spend the money it takes to examine and reinforce soil if they are unable to control their citizens' living spaces.

Ultimately, education programs need to be in place. Understanding that people are rational and that given the proper education they will generally make a decision that benefits them is an important step for governments. Agencies need to educate people about both the dangers that certain areas of countries pose and the dangers that homes may pose during an earthquake. Education programs to inform citizens are important because this is an area where people need to be willing to make personal changes to ensure their own safety. Governments need to make the determination whether it is cheaper to educate their citizens or rescue them after an earthquake.

Emergency Management Services are an area where there was significant variation in this study. This researcher believes that because these services are ingrained into daily life and reflect the situation of the nation; like trained fire fighters and emergency medical technicians. Emergency services should not be earthquake specific, they should be all hazard encompassing with earthquake specific training and equipment. It would also be useful if nations could join in regional partnerships to buy equipment, train, and participate in exercises. Japan and the United States participate in annual exercises that test new equipment and coordination between the two nations in the event of a disaster; if, for example, Haiti and the Dominican Republic worked together then they would be able to split the costs of the response and it would potentially be more effective.

In addition to this, many nations in this study incorporate military forces into their response; in some cases it was planned and others it was out of necessity. This type of response would not be likely in the United States; however, countries that do not have limitations on military actions with-in its borders should give their armed forces mandatory training in how to respond in the event of a disaster. These forces typically have access to equipment and funds that could be useful in responding to disaster. For this to work, legislation has to be in place to allow for responsibilities to be clearly defined for both emergency responders and military forces. China is the one place where military forces often replace emergency responders. The Chinese chose to sacrifice time in their response for deployment of military forces instead of emergency personnel.

Community Preparedness is an area where many nations could stand to improve. Japan tests a sound system every single day. This may be overkill, but they most certainly want to ensure that their people are protected in the event of a disaster. The El Salvador model is the

most practical for most countries. Teaching children in schools about the dangers of earthquakes and using drills is a way to reach the majority of any country from people which children trust.

In terms of the use of the media as information sources, many governments have their own channels which they could run educational programs on. These may not be the most watched channels, but it gets the information to the public and is there when people go searching for it. Once they create a public show about earthquakes, it makes it easier for media outlets to have access to them and disseminate the message.

Figure 4 shows the total pattern of mitigation and preparation policies in individual nations. In the future, it would be interesting to examine this research as compared to the gross domestic product or type of government of these nations to see what other factors may cause a nation to an implement or improve these policies. Since figure 5 shows that there is an inverse correlation between mitigation and preparation policies and the loss of life, the next goal is to assess what factors incentivize nations to utilize robust mitigation and preparation policies.

Works Cited

Barrionuevo, A. (2010, March 7). *Most in Chile's Capital Unhappy With Quake Response*. Retrieved May 7, 2010, and available at nytimes.com: http://www.nytimes.com/2010/03/08/world/americas/08chile.html.

BBC News. (2003, September 26). *Strong quake hits north japan*. Retrieved from http://news.bbc.co.uk/2/hi/asia-pacific/3141074.stm.

BBC.com. (2003, May 24). *Fury and despair fill Algerian press*. Retrieved from http://news.bbc.co.uk/2/hi/middle_east/2934804.stm.

BBC.com. (2003, September 23). *Strong quake hits north japan*. Retrieved from http://news.bbc.co.uk/2/hi/3141074.stm.

Boyle, Alan. (2010, September 3). *Why the n.z. quake is no Haiti*. Retrieved from http://cosmiclog.msnbc.msn.com/_news/2010/09/03/5041063-why-the-nz-quake-is-no-haiti.

Brumbaugh, D. (2010). *Earthquakes science and society*. Upper Saddle River, NJ: Pearson Education.

Bryner, J. (2008, May 15). *Why the China quake was so devastating*. Retrieved from http://www.livescience.com/environment/080515-quake-buildings.html.

CBS News. (2010, February 28). *Lessons learned limited Chile quake damage*. Retrieved from http://www.cbsnews.com/stories/2010/02/28/eveningnews/main6253647.shtml.

CBS News World, . (2010, February 27). *Quake witness: a roar like a freight train*. Retrieved from http://www.cbsnews.com/stories/2010/02/27/world/main6250171.shtml.

CNN. (2001, February 13). *Quake aftershock frightens Salvadorans*. Retrieved from http://archives.cnn.com/2001/WORLD/americas/02/13/salvador.quake/index.html.

CNN. (2003, May 22). *Quake rescuers race against time*. Retrieved from http://www.cnn.com/2003/WORLD/africa/05/22/quake.algeria/.

CNN. (2003, May 24). *Brahimi: survivors angry after algeria quake*. Retrieved from http://www.cnn.com/2003/WORLD/africa/05/24/otsc.brahimi/index.html?iref=allsearch.

CNN. (2010, February 27). *More than 2 million affected by earthquake, Chile's president says*. Retrieved from http://articles.cnn.com/2010-02-27/world/chile.quake_1_magnitude-haiti-quake-chilean-president-michelle-bachelet?_s=PM:WORLD.

Collins, L. (2004). Technical rescue operations volume i: planning, training, & command. Tulsa, OK: Pennwell.

Coppola, Damon. (2007). *Introduction to international disaster management*. Burlington, MA: Butterworth-Heinemann.

Evans, S, & Bent, A. (Ed.). (2004). *The Las Colinas landslide, Santa Tecla: a highly destructive flowslide triggered by the January 13, 2001, El Salvador earthquake*. Boulder, CO: Geological Society if America.

Foxnews.com. (2010, Jan 13). *Haiti Fast Facts*. Retrieved May 7, 2010, from foxnews.com: http://www.foxnews.com/world/2010/01/13/fast-facts-haiti-earthquake/.

Franklin, J. (2010, March 1). *Death toll rises after Chile earthquake*. Retrieved from http://www.guardian.co.uk/world/2010/feb/28/chile-earthquake-death-toll.

Gerring, John. (2007). *Case study research: principles and practices*. New York: Cambridge University Press.

Gillis, Tracy. (1996). Emergency exercise handbook. Tulsa, OK: PennWell.

Global Consciousness Project. (2009). *Algeria earthquake, May 21 2003*. Retrieved from http://noosphere.princeton.edu/algeria030521.html.

Gregory, A. (2010, January 14). *Haiti earthquake left 100,000 dead in 60 seconds*. Retrieved from http://www.mirror.co.uk/news/top-stories/2010/01/14/haiti-earthquake-left-100-000-dead-in-60-seconds-and-toll-could-reach-500-000-115875-21965474/.

Haddow, G, & Bullock, J. (2006). *Introduction to emergency management*. Burlington, MA: Butterworth-Heinemann.

Harbi, A., Maouche, S., Ayadi, A., Benouar, D., Panza, G. F. & Benhallou, H. (2004). *Seismicity and tectonic structures in the site of Algiers and its surroundings: a step towards microzonation*. Basel, Switerland: Birkhauser Verlag.

Hooker, J, & Yardley, J. (2008, May 13). *Powerful quake ravages china, killing thousands* . Retrieved from http://www.nytimes.com/2008/05/13/world/asia/13china.html.

Lindell, M., Prater, C., & Perry, R. (2006). *Fundamentals of Emergency Management* . FEMA.
Llana, S. (2010, January 12). *7.0 Earthquake Rocks Haiti*. Retrieved from http://www.csmonitor.com/World/Americas/2010/0112/7.0-earthquake-rocks-Haiti.

NOAAwatch. (2010, May 16). *Earthquakes*. Retrieved May 16, 2010, from noaa.gov: http://www.noaawatch.gov/themes/quake.php.

PBS News Hour, . (2010, March 1). *Building codes, preparation re-examined after Chile's quake*. Retrieved from http://www.pbs.org/newshour/bb/weather/jan-june10/chile2_03-01.html.

Petrun, E. (2007, February 6). *Japan's earthquakes*. Retrieved from http://www.cbsnews.com/stories/2007/02/06/asia_letter/main2441422.shtml.

Romero, S, & Lacey, M. (2010, January 15). *Government struggles to exhume itself* . Retrieved from http://www.nytimes.com/2010/01/16/world/americas/16preval.html?_r=1&hp.

Rose, W, Bommer, J, Lopez, D, Carr, M, & Mojor, J. (2004). *Natural hazards in El Salvador*. Boulder, CO: The Geological Society of America.

Shimamura, S. (2003, September 24). *Earthquake research in japan* . Retrieved from http://shima3.fc2web.com/fpc-briefing39.htm.

Sikich, G. (1996). Emergency management planning handbook. USA: McGraw-Hill.

Singh, R.B. (2006). *Natural hazards & disaster management*. Jawahar Nagarm, Jaipur (India): Rawat Publications.

Smith, Peter. (2008, May 14). *China's quake: why did so many schools collapse?*. Retrieved from http://www.csmonitor.com/World/Asia-Pacific/2008/0514/p06s05-woap.html.

Suganuma, Katsutoshi. (2006). Recent trends in earthquake disaster management in japan. *Quarterly Review*, No*19*(April), 91-106.

The Associated Press. (2003, September 26). *Japan shrugs off powerful earthquake*. Retrieved from http://www.usatoday.com/news/world/2003-09-25-japan-quake_x.htm.

The Associated Press. (2010, March 1). *Chile: 'giant effort' needed for recovery*. Retrieved from http://www.usatoday.com/news/world/2010-03-01-chile-quake_N.htm.

TOKYO International Communication Committee, . (2006). *Comprehensive living guide for foreign residents living in japan*. Retrieved from http://www.tokyo-icc.jp/guide_eng/kinkyu/05.html.

Tucker, B. (2010, January 14). *The Haiti quake must not be dismissed as an 'act of god'*. Retrieved from http://www.guardian.co.uk/commentisfree/2010/jan/14/preparing-for-earthquakes-building-safety.

USA Today, . (2003, May 24). *Algeria earthquake death tolls reaches nearly 1,600*. Retrieved from http://www.usatoday.com/news/world/2003-05-23-algeria-quake_x.htm.

USA Today, . (2010, March 1). *Chile: 'giant effort' needed for recovery*. Retrieved from http://www.usatoday.com/news/world/2010-03-01-chile-quake_N.htm.

USGS (2010, July 3). *Significant Earthquake Database*. Retrieved July 3, 2010, from noaa.gov: http://www.ngdc.noaa.gov/nndc/struts/results?bt_0=2000&st_0=2010&type_17=EXACT&query_17=None+Selected&op_12=eq&v_12=&type_12=Or&query_14=None+Selected&type_3=Like&query_3=&st_1=&bt_2=&st_2=&bt_1=&bt_4=&st_4=&bt_5=&st_5=&bt_6=&st_6=&bt_7=&st_7=&bt_8=&st_8=&bt_9=&st_9=&bt_10=&st_10=&type_11=Exact&query_11=&type_16=Exact&query_16=&display_look=1&t=101650&s=1&submit_all=Search+Database.

USGS Earthquake Hazards Program. (2001, January 13). *Magnitude 7.7 El Salvador*. Retrieved from http://neic.usgs.gov/neis/eq_depot/2001/eq_010113/http://neic.usgs.gov/neis/eq_depot/2001/eq_010113/.

USGS. (2009, OCT 27). *Common Myths about Earthquakes*. Retrieved May 16, 2010, from usgs.gov: http://earthquake.usgs.gov/learn/faq/?showAll=yes.

USGS. (2010, February 27). *Magnitude 8.8 - Offshore Maule, Chile*. Retrieved from http://earthquake.usgs.gov/earthquakes/eqinthenews/2010/us2010tfan/#summary.

Vervaeck, A. (2010, September 1). *Us military join japanese earthquake relief drill*. Retrieved from http://earthquake-report.com/2010/09/01/us-military-join-japanese-earthquake-relief-drill/.

Warren, Michael. (2010, March 11). *Disaster experts praise Chile earthquake response*. Retrieved from: http://www.macombdaily.com/articles/2010/03/11/news/srv0000007795716.txt.

Watkins, Tom. (2010, January 13). *Problems with Haiti building standards outlined*. Retrieved from http://www.cnn.com/2010/WORLD/americas/01/13/haiti.construction/index.html.

Welch, William, Vergano, Dan, & Hawley, Chris. (2010, March 3). *Chilean earthquake hints at dangers of 'big one' for usa*. Retrieved from http://www.usatoday.com/tech/science/2010-03-01-chile-quake-lessons_N.htm.

Yin, Robert. (1994). *Case study research: design and methods*. Thousand Oaks, CA: SAGE.

Yujia, Ma. (2009, May 26). *Report reveals reasons behind school buildings collapse in Sichuan*. Retrieved from http://www.china.org.cn/china/news/2009-05/26/content_17839434.htm.

Zack, N. (2009). *Ethics for Disaster*. Lanham, MD: Rowman & Littlefield.

APPENDIX
Appendix A

Appendix B: Case Studies

Hokkaido, Japan:

On September 26th, 2003 an 8.3 magnitude earthquake struck near the island of Hokkaido on the northern island of Japan (BBC.com, 2003). Nearly 400 people were injured but there were no deaths reported as a result of the earthquake (BBC.com, 2003). Japan is seen as a leader in earthquake preparation and mitigation because of heavy spending that has taken place in the country to help detect and prepare the country for the next earthquake. In this earthquake, not a single person was killed as a result of the earthquake and the Japanese government was able to initiate the shutdown of several critical government operations, while also informing the population of the island of the most up-to-date information (BBC News, 2003). One of the worst hit areas was Kushiro, the only damage was cracked roads and a caved in section of the city's airport (The Associated Press, 2003). Overall the damage was minimal and life returned to normal very quickly. The Japanese have taken great efforts to refit older buildings with stronger materials and over the years these buildings have been able to withstood earthquakes over the years (Suganuma, 2006:94).

El Salvador:

On January 13th, 2001 a 7.7 magnitude struck the entire country of El Salvador (USGS Earthquake Hazards Program, 2001). The resulting death toll came in at 844 people dying, with 4723 people injured (USGS Earthquake Hazards Program, 2001). Most of the deaths came from landslides as a result of the earthquake and the damage was estimated to be at over $1 billion dollars (CNN, 2001). Approximately 16,000 landslides took place throughout the country after

the earthquake (USGS Earthquake Hazards Program, 2001). The most serious landslide that occurred was the Las Colinas Landslide (Rose et al., 2004, : 74). This caused 585 people to lose their lives (Rose et al., 2004, : 74). Rose et al. (2004, : 86) documents numerous landslides that occurred as a result of the earthquake on January 13th and asserts that soil and rock composition makes this type of outcome to earthquakes something that should be expected in the future. They go even further in predicting that if an earthquake were to occur during the wet season, the weakened rock and soil would have even a great chance at breaking loose and causing a landslide (Rose et al., 2004, :86). In the area of mitigation, there is little evidence of widespread hardening of structures. Rose et al. (2004, : 458) documents that most houses and community structures, especially in rural El Salvador, were made out of adobe and in need of upkeep; these structures quickly collapsed under the assault of the earthquake. El Salvador took preparedness efforts in regards to the dangers of earthquakes. Many of the towns had a disaster preparedness committee , however they were unable to respond because of the severity of the January 13th earthquake (Rose et al. 2004, : 457). They distributed literature on the proper techniques to use in the event of an earthquake and mandate that school teachers practice evacuation drills; however there is no way to verify the follow-through of these actions since the nation does not require the results of such drills to be documented (Rose et al. 2004, : 446). The nation also only has 400 firemen for a population of 5.2 million, and no one trained in the practice of rescuing people from collapsed buildings (Rose et al. 2004, : 446-447). Another characteristic of landslides is that they can block roads and in the case of the 2001 earthquake, rescue efforts were hampered by blocked roads (Rose et al. 2004, : 447). In response to this, Rose et al, (2004, : 458) says that people are being more careful about where they live in regards to how emergency personnel can respond.

China, Sichuan Province:

On May 12th, 2008 a 7.9 Magnitude earthquake struck in the Sichuan Province in the People's Republic of China (Bryner, 2008). The death toll reach 87,652 people, with another 374,171 injured (USGS, July 3 2010). Much of the damage from this earthquake came for collapsing buildings (Bryner, 2008). In this specific event there was shallow ground shaking that caused widespread building collpses; many of these building collapses were believed to come because of the poor building materials that were used in construction (Bryner, 2008). Bryner (2008) suggested that these buildings would have with stood the ground shaking better if they had been reinforced with steel, as Chinese building codes state, and not just the adobe and masonry that the buildings that collapsed were made of. Bryner (2008) makes that point that many coutries developing, like China, are able build some of their new buildings according to advanced structural codes, but they do not update antiquated structures to those codes. Yuija (2009) argues that it was difficult for rural areas to afford building earthquake resistant structures because every level that a building increases on the earthquake resistant scale causes the cost of the building to rise by 5%-10%. Some places in China needed to be at level 9 on the earthquake resistant scale; this would make it nearly impossible for many poorer, rural areas to afford such costs (Yuija,

2009). China was able to send in 20 thousand soldiers to assist in rescue operations in the immediate aftermath of the disaster, which shows an ability for the government to execute their response with efficiency (Smith, 2008).

Haiti, Port-Au-Prince:

On January 12th, 2010 a 7.0 magnitude earthquake struck near the capital of Haiti, Port-Au-Prince (Llana, 2010). The total death toll stands at 250,000, with another 30,000 injured (USGS, July 3 2010). Much of the death came from collapsing of buildings (Gregory, 2010). Cletus Springer, director of the Organization of American States Department on Sustainable development stated that "[y]ou could tell very easily that these buildings were not going to survive even a [magnitude] 2 earthquake" (Watkins, 2010). Because the nation is so poor, many of the people built with whatever materials they could get their hands on; thus they had no discernable building codes (Watkins, 2010). In a comparative study, an earthquake of similar magnitude struck in New Zealand. In this simple study the outcome was determined that "The main difference is that New Zealand has a lot of experience with earthquakes, and they have good construction codes to make sure that their buildings withstand a strong earthquake" (Boyle, 2010). In addition to this, there is little evidence of preparation, since the majority of the rescue effort came from international support and the world community was already lending aid to Haiti (Llana, 2010). Unfortunately, Haiti was unable to prepare or implement any kind of real mitigation or preparation programs; this led to drastic consequences.

Chile, Concepcion Province:

On February 27, 2010 an 8.8 magnitude struck near the Concepcion Province in the nation of Chile (CNN, 2010). The death toll for this earthquake was 528 people (USGS, July 3 2010) with another 12000 injured (USGS, February 27 2010). 350 were killed in one town when after the earthquake, a tsunami also hit the town (Franklin, 2010). This disaster occurred relatively recently after the earthquake in Haiti and many cite the reason that Chile fared so well was that their buildings provided protection from the intense shaking that occurred in the country (Welch, 2010). Andres Garcia, manager of a Chilean construction company, stated that "As the technology and techniques have gotten better, the rules have gotten stricter. And that's what has minimized the loss of life this time around" (Welch, 2010). In addition to this, the Chilean government was able to respond effectively to the disaster with supplies, rescue personnel, and equipment. Disaster planners state that although not perfect, the Chilean response was a model for a situation where communications are knocked out and a response must occur with incomplete information (Welch, 2010). The country was able to repair roads, dispatch supplies to devastated areas, and quash looting (Warren, 2010). The only significant error that the nation made was the inability for the Chilean Navy to broadcast a tsunami warning (Warren, 2010). Still, with-in 10 days after the earthquake struck, 90% of homes without power from the earthquake had their power restored (Warren, 2010).

Algeria, Algiers:

On May 21st, 2003 a 6.8 magnitude earthquake struck Algiers in the country of Algeria (Global Consciousness Project, 2009). The death toll of this earthquake was 2266, with another 10,261 people injured (USGS, July 3 2010). The deaths mainly seemed to stem from collapsing buildings in the city of Algiers. Much of northern Algeria is at risk of a seismic event (Harbi *et al.*, 2004, : 950). In Algiers, earthquakes tend to take place at very shallow depths and due to the soil composite, the structures of the city are at risk (Harbi *et al..*, 2004, : 963). The city of Algiers does have in place a disaster preparedness planning in place, however, many of the structures in Algiers are very vulnerable to seismic activity (Harbi *et al.*, 2004, : 964). Many of the buildings in Algiers have damage from other elements and have not been given proper care in their upkeep (Harbi *et al.*, 2004, : 964). For this reason, mitigation is sorely lacking in the city and poses a danger when earthquakes strike. In the area of preparedness, they seem to be taking the initiative in being proactive. Harbi *et al.* (2004, : 964) points out that Algiers has taken "practical and effective preparedness and prevention measures for the city of Algiers." These efforts seem to be successful in the 2003 earthquake. During the earthquake it was reported that thousands of buildings had collapsed, however, even though the medical services of Algiers seemed to be stretched to their breaking point, they were able to keep the death toll down (CNN, May 22, 2003). They were also able to have rescue teams deployed and searching for survivors, another key indicator that their preparation efforts seemed to pay off.