Assessing the Impact of a Web-Based GIS Application to Promote Earthquake Preparation on the University of Southern California University Park Campus

by

Krista McPherson

A Thesis Presented to the
Faculty of the USC Graduate School
University of Southern California
In Partial Fulfillment of the
Requirements for the Degree
Master of Science
(Geographic Information Science and Technology)

December 2016

Acknowledgements

I would first and foremost like to thank my parents, Mary and Phil McPherson, who have supported me in my every endeavor. Without their unconditional love and encouragement, I would not be the person that I am today. I am grateful to Dr. Jennifer Swift for guiding me in my original idea for this project, to Dr. Robert Vos for helping to foster my technical writing skills, and to Dr. Wilson for providing me with the feedback to complete my work. I am thankful to Professor Sarah Feakins for introducing me to the field of GIS. I am eternally grateful to every educator I have encountered at the University of Southern California, especially in the Earth Sciences Department and Spatial Sciences Institute, for each one has been an integral part of my educational journey.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GIST	Geographic Information Science and Technology
LAC	Los Angeles County
REST	Representational State Transfer
UCERF3	Uniform California Earthquake Rupture Forecast, Version 3
UPC	University Park Campus
URISA	Urban and Regional Information Systems Association
URL	Uniform Resource Locator
US	United States
USC	University of Southern California
USGS	United States Geological Survey
WGCEP	Working Group on California Earthquake Probabilities

Abstract

The Southern California region faces the constant threat of earthquakes due to the hundreds of faults that lie just beneath this region's surface. As earthquake prediction technology is limited, it is important that residents, including students at the University of Southern California, are prepared for an earthquake event. This project develops and assesses the impact of an interactive web-based Geographic Information Systems (GIS) application, titled USC Earthquake, as an educational tool for communicating information about earthquake preparedness on the University of Southern California University Park Campus.

This study incorporated previously conducted research regarding the use of GIS as a tool for emergency preparation, the implementation and assessment of educational programs for emergency preparation, and the description of other earthquake-related mapping applications. The application created for this project included data from the USC Department of Fire Safety and Emergency Management and the Los Angeles County GIS Data Portal to communicate information about the location of emergency supplies and assembly areas on campus. The author processed this data using Esri's ArcMap as well as ArcGIS Server and constructed the application using ArcGIS Web AppBuilder. This study assessed the educational impact of this tool by surveying two groups of undergraduate student participants: an experimental group, who were asked to use the application, and a control group, who were asked to view a stationary map. The data collected for this survey ultimately showed that both map visualizations are useful in communicating information about earthquake preparedness. However, analysis of the results demonstrated that users preferred the static map to the interactive visualization. The thesis concludes by providing recommendations regarding the use of this application as well as concerning future studies similar to this.

Chapter 1: Introduction

Geographic Information Science (GIS) has provided new ways to use available technology to visualize and analyze spatial data. In 1993, the Xerox Corporation developed the first web-based map viewer, an innovation that marked the beginnings of a new branch of spatial technology, which would come to be known as "web GIS" (Fu and Sun 2010). Since its invention, web GIS has become a commonly used technology for sharing and visualizing multiple types of spatial information. This project focuses on using web GIS to display information about disasters and emergency preparation, particularly as it relates to earthquakes. The goal of this project is to determine the impact of an interactive web GIS application on an individual's disaster awareness and sense of preparation.

The remainder of Chapter 1 introduces the subject, motivation, methodology, and structure of this thesis. Section 1.1 provides an overview of the project by introducing the research question and hypothesis of the study. The motivation for this study is described in Section 1.2, and an overview of the project methodology is provided in Section 1.3. Finally, Section 1.4 provides an outline of the structure of this thesis.

1.1 Project Overview

This project focused on two main objectives in order to evaluate the impact of an interactive web GIS application. The first objective was to develop the application, titled USC Earthquake, which is meant to encourage earthquake awareness and preparation in the University of Southern California (USC) student community. This web-based mapping application provides users with information that is unique to the USC community regarding the location of emergency supplies and assembly areas on the university's main University Park Campus (UPC). The second objective was to assess the impact of the interactive visualization on awareness and sense of preparedness by surveying two groups of student participants. The first group of participants, the experimental group, was asked questions about their level of earthquake awareness and sense of preparedness before and after using the USC Earthquake application. The second group, the control group was given the same set of questions, but instead provided with a stationary map visualization. The stationary visualization, without an interactive component, included the base map and legend from the USC Earthquake application. The results for the two groups of survey participants were then compared in order to determine the overall impact of the USC Earthquake application. Due to the interactive nature of the application and the use of information that is specific to the USC community, the author hypothesized that the interactive web GIS application would increase awareness about earthquake preparation in survey participants and that this increase would be more significant in the experimental group than the control group.

1.2 Motivation

This study focused on the visualization and communication of spatial data regarding disaster awareness and preparation on the USC campus with particular attention to earthquake preparation. Earthquakes are one of the most common natural hazards in the southern California area and, therefore, it is important for individuals who live in this area to be aware of how to prepare themselves and where to locate emergency supplies (SCEC 2011). The author chose to focus this study on USC's UPC in order to create an application that was unique to a single community in this area. The remainder of this section provides an explanation of the earthquake risks in USC's UPC and a description of the study area.

1.2.1 Earthquake Risk

Earthquakes pose the greatest risks for natural disasters in the Southern California region (SCEC 2011). The state of California contains thousands of faults beneath its surface, with the largest and most well-known fault in the area being the San Andreas fault. The San Andreas fault begins east of San Diego and runs north through California, ending just south of Eureka. A map of the San Andreas Fault can be seen in Figure 1 (Lynch 2006). This fault has the capacity to produce very large earthquakes, as evidenced by the 1906 San Francisco earthquake which ruptured with a magnitude of 7.9 on the moment magnitude scale (Mw). The moment magnitude scale measures the amount of energy released in an earthquake (U.S. Geological Survey 2012). As of 2016, the San Francisco earthquake occurred over 100 years ago and represented the last rupture larger than 7.0Mw on the San Andreas fault. According to Fumal et al. (1993), due to the earthquake recurrence rate on the San Andreas fault, it is likely that the next large earthquake on this fault will occur in the southern California region. Many studies cite the recurrence pattern on the San Andreas fault as evidence that the Los Angeles area may be vulnerable to a large earthquake in the near future.

Figure 1: Map of the San Andreas fault (Source: Lynch 2006)

Seismological studies have assessed the risk of earthquakes in California by studying the faults throughout the state. In 2014, the Working Group on California Earthquake Probabilities (WGCEP) along with the U.S. Geological Survey (USGS), created a long-term earthquake forecast model in order to quantify the rate of earthquake occurrence on the San Andreas Fault as well as all other known faults in the state of California. An image of this model displayed on a map of the state can be seen in Figure 2 (Field et al. 2014). This model, known as the Uniform California Earthquake Rupture Forecast Model Version 3 (UCERF3), demonstrates that the southern San Andreas fault is nearly twice as likely than many other faults in the area to experience an earthquake with a magnitude greater than 6.7Mw before 2040 (WGCEP 2015). While the San Andreas fault poses the most risk for earthquakes larger than 7.0Mw, the many faults throughout the state are also capable of producing strong earthquakes with the potential to cause damage.

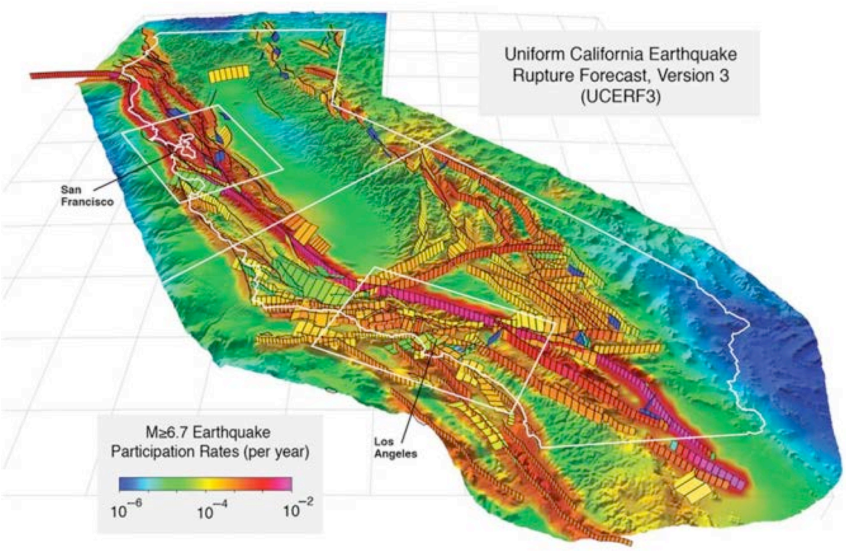

Figure 2: Map showing UCERF3 model sample output (Source: WGCEP 2015)

While the Los Angeles area faces a significant risk of earthquakes due to the presence of many faults, the impacts of seismic ruptures in the region are amplified by its geological setting. This area lies on top of a sedimentary basin, known as the Los Angeles basin, which contains mostly soft soils (Hillhouse, Reichard, and Ponti 2006). Soft soils amplify seismic waves making the Los Angeles region susceptible to increased shaking in the event of an earthquake. This study focuses on the Los Angeles region because it has proven to have a high risk for earthquake events while housing a large population.

1.2.2 Study Area

The research described above has established that Los Angeles is a region of southern California that is especially vulnerable to earthquake risks due to rupture patterns on the San Andreas Fault, the presence of many faults in the area, and the geological setting of the region. As a result of the increased risk at this location, it is important that Los Angeles residents have the resources to prepare themselves for an earthquake event. The population of Los Angeles, which has reached nearly 4 million people as of 2015, includes the students of USC (U.S. Census Bureau 2015).

This study focuses on USC's University Park Campus (UPC), which lies 3 miles south of Downtown Los Angeles. USC is a privately-funded research university and was ranked 23rd in the nation in 2016 according to U.S. News & World Report (2016). As of the 2015-2016 academic year, USC hosted a combined undergraduate and graduate population of 43,000 students (University of Southern California 2015). A map of UPC and the surrounding region can be seen in Figure 3.

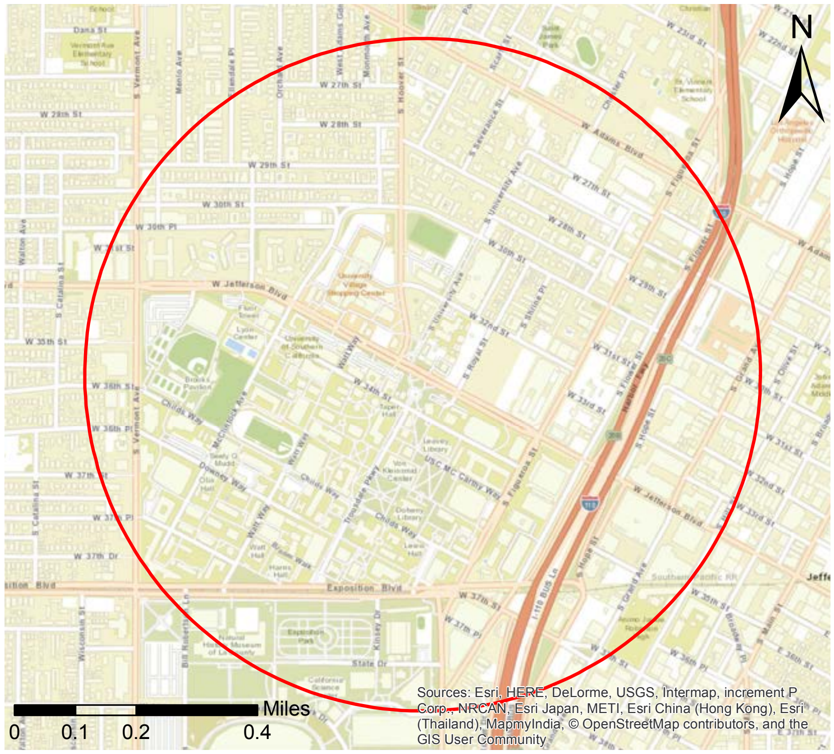

Figure 3: Map of USC's University Park Campus

The student population at USC, as with the population at any university, is constantly changing. These students come from different locations all over the world and may not have experience with earthquake events or earthquake preparation. It is important to introduce USC students be introduced to the idea of earthquake hazards and be given them the resources and information they need to be prepared for an earthquake.

As this project seeks to create an interactive tool that could be used by USC for educating current and incoming students, it is important that this tool is proven to be effective. For this reason, this project has developed a method to determine the educational impact of the application. The author assessed the impact of this tool by surveying volunteer undergraduate student participants, as students are the intended audience who will benefit from the use of the application.

1.3 Methodology Overview

The goal of this project was to assess the educational impact of the USC Earthquake application, which aims to increase earthquake hazard awareness and encourage earthquake preparation. In order to make such an assessment, this study began by creating an interactive web-based mapping application that communicates information about the location of emergency supplies and assembly areas on USC's UPC. The author then surveyed experimental and control groups of participants about the use of the application, then the survey results were compared in order to determine the educational impact of the USC Earthquake application.

1.3.1 Application Construction

The USC Earthquake application is intended to communicate information about the location of emergency supplies, emergency assembly areas, and disaster routes on USC's UPC. Data for this application were collected from the USC Department of Fire Safety and Emergency Management and the Los Angeles County Data Portal. These data were processed for use in the application with the ArcMap program in ArcGIS for Desktop and shared using ArcGIS for Server. The application was constructed with the ArcGIS Web AppBuilder program within the ArcGIS Online platform. Once the application was completed, a link to the application was shared with survey participants in the experimental group.

1.3.2 Survey Design and Analysis

This project surveyed 120 undergraduate student participants in order to assess the impact of the USC Earthquake Application. The author asked for volunteer participants in several general education classes on USC's UPC. The goal was to include students from diverse majors and disciplines. The survey included questions about the participant's earthquake awareness and level of preparedness before and after viewing a visualization. The participants in the experimental group were given a link to the USC Earthquake application as their visualization, while participants in the control group were given an image of a stationary web map. These results were then compared in order to assess the educational impact of the interactive web-based mapping application.

1.4 Thesis Structure

The remainder of this thesis is divided in four chapters. Chapter 2 discusses previous studies and work that is related to disaster awareness, assessing educational disaster programs, and earthquake-related mapping applications. Chapter 3 provides a detailed explanation of the data sources and methodology employed in the project. Chapter 4 compares and contrasts the results collected from both the experimental and control survey groups. Chapter 5 draws some conclusions and discusses opportunities for future work.

Chapter 2: Related Work

Earthquake hazards and disaster preparation are global issues that many researchers work to address. This chapter provides a detailed overview of scholarly work related to this study. Section 2.1 discusses previous studies that have utilized GIS and spatial data to analyze local earthquake hazards and promote disaster preparation. Section 2.2 addresses studies that discuss the implementation of disaster awareness programs around the world. Section 2.3 reviews studies that have assessed the impact of these education programs in various communities in order to determine effective methods of communicating information about disaster preparedness. Finally, Section 2.4 describes several web-based applications, which provide users with information about earthquake hazards and preparation. This study seeks to incorporate similar GIS techniques and educational assessment methods to the studies presented.

2.1 GIS for Emergency Preparation and Safety

GIS is a diverse technology that can be used to assess disaster safety and to create visualizations for emergency preparation. A 2009 study by Abbas, Srivastava, and Tiwari implemented a geodatabase with a collection of biological, meteorological, hydrological, and socio-economic spatial data that was meant to model flooding vulnerability in the Allahabad Sadar Sub-District in India (Abbas, Srivastava, and Tiwari 2009, 38). The study concluded that the implementation of a spatial database assisted in creating a comprehensive disaster management plan within the community. This study successfully used spatial databases to implement a preparedness plan, but spatial data can also be used to create visualizations for the purpose of safety and emergency preparation.

USC has used spatial data visualization as a means of increasing risk awareness with the release of the Trojan Mobile Safety App. This application allows users to view recent incidents of crime with respect to the user's current location (USC Department of Public Safety 2015). It also allows users to report crime incidents directly to the USC Department of Public Safety, providing a link between the users and the organization. This application uses spatial data as a powerful tool for communicating information about safety and emergency preparation. This project used spatial datasets in the same manner to provide application users with information about emergency supplies and assembly areas.

Several organizations and studies have applied GIS to hazard awareness and education. The Urban and Regional Information Systems Association (URISA) dedicates its efforts to providing educational programs that teach individuals how to utilize GIS tools to improve disaster planning within their organization (URISA 2015). While URISA focuses on using GIS analysis tools for preparation within an organization, the Earthquake Country Alliance works on providing GIS visualizations to a public audience in an effort to increase earthquake awareness. In 2013, the Earthquake Country Alliance released a series of videos, called Northridge Near You, which demonstrates earthquake scenarios from the UCERF3 model. The UCERF3 model was discussed previously in this thesis and can be seen in Figure 2 (Earthquake Country Alliance 2013). These videos display maps of potential causalities and monetary losses that have been calculated using an ArcGIS plug-in developed by the Federal Emergency Management Agency (FEMA). These visualizations are available to the public and are meant to increase awareness of local earthquake hazards in southern California. As GIS tools and visualizations have been found to be effective in increasing awareness of safety hazards and managing disaster preparation, this project has incorporated similar visualization strategies in an effort to create a better understanding of earthquake hazards.

2.2 Emergency Preparation Education

Many researchers have conducted studies on disaster awareness in communities throughout the world in order to determine the most effective method of educating individuals about disaster preparation. A study by Karanci, Aksit, and Dirik (2005) investigated the impact of a disaster awareness program in Istanbul, Turkey, which is a very seismically active region. The program consisted of an 8-hour training program and a 10-page brochure about earthquake preparation. The study then compared surveys from 400 program participants and 400 non-participants one year after the program and found that preparation behavior was significantly higher in participants who received this training and visual aid than in non-participants. This study used the same method of comparing survey results from participants who did and did not use the targeted program.

A similar natural hazard education study was conducted in northern India, which is a seismically active region due to the presence of the India-Asia plate boundary. Researchers investigated the impact of an earthquake education program called the School Earthquake Laboratory Program (SELP) (Bansal and Verma 2012). This program included the implementation of seismic receptors that recorded seismic activity and allowed participants to visualize seismic data. This study concluded that giving the participant the ability to visualize the collection of monitoring data was an important factor in increasing awareness about earthquake risks. In accordance with these studies, this project anticipated that using data visualization and individual participation would help to increase an individual's understanding of seismic hazards and encourage preparation.

Many organizations have implemented various applications and educational programs that attempt to encourage earthquake preparation. FEMA has released a mobile application that provides safety tips for multiple types of natural disasters, including earthquakes. The FEMA Mobile App, which is accessible through the organization's website, provides a list of recommended emergency supplies and explains what to do before, during, and after an earthquake event (FEMA 2015). The FEMA application simply distributes written information, but other programs include visualization and interactive components. The Southern California Earthquake Center (SCEC), which is headquartered on USC's UPC, has implemented a program called The Great ShakeOut which is meant to encourage organizations and individuals across the country to participate in a national earthquake drill. Over 21 million individuals across the U.S. participated in the 2015 earthquake drill during October 2015 and SCEC provides additional resources to help families, businesses, and organizations prepare for a disaster (SCEC 2016). These resources include visualizations of a potential earthquake scenario on the southern section of the San Andreas fault, which they call the ShakeOut Scenario, seen in Figure 4. These programs provide an example of bringing awareness of earthquake risks to various communities in order to encourage preparation. Similar to the Great ShakeOut, this project uses similar GIS visualization techniques in order to educate the USC community about earthquake preparation.

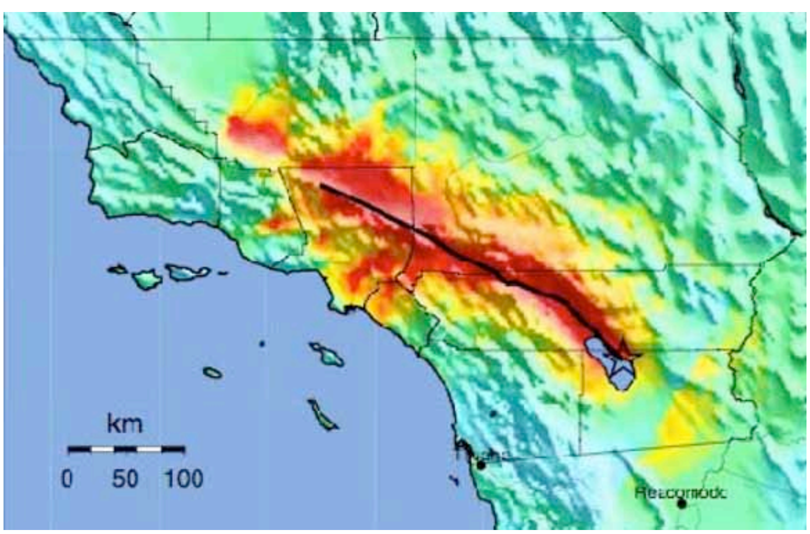

Figure 4: Visualization of the SCEC ShakeOut Scenario (Source: SCEC, 2016)

2.3 Assessing Educational Impact

While organizations have worked towards creating disaster preparation programs, researchers have conducted studies that assess the impact of their curriculum. Earthquake and general disaster awareness is an issue across the globe and many researchers have attempted to implement disaster education programs. Several studies have investigated the most effective ways to assess these programs in various communities. A 2011 study by Tekeli-Yesil and colleagues, surveyed over 1,000 people in Istanbul, Turkey, and reported that there is a 62% chance of $\geq$7.0Mw earthquake occurring by 2040 (Tekeli-Yesil et al. 2011, 428). Participants were asked a series of questions regarding their perceptions of preparedness and asked to provide demographic information, including their educational and socio-economic level. These questions, which included what an earthquake is and how prepared participants felt, indicated an individual's overall level of preparation. Another study utilized a similar survey method in Japan, a region that is also susceptible to large earthquakes. The researchers polled 1,065 first grade students on their knowledge of earthquake risks, perception of risk, and willingness to take steps to prepare (Shaw et al. 2004). The study viewed willingness as an indication of how well individuals are likely to respond to educational training. This project included a survey of self-reported perceptions of awareness and preparedness.

Simpson (2008) conducted a study in the Midwestern U.S. regarding disaster preparation and concurred with Shaw et al. (2004) that involving many individuals from the community helps increase overall community preparedness. Simpson (2008) sought to give the community a tool to assist in disaster preparation. Bourque et al. (2012) also assessed the factors that impact preparedness and found that, along with knowledge and education, an individual's perceived level of control in a disaster situation has an important influence on preparedness behavior.

These studies concur that personalized tools and community participation are effective methods for encouraging disaster awareness and preparation. The USC Earthquake project aimed to give individuals the tools they need to learn about earthquake risk and prepare for an earthquake event. The application provides personalized information for the USC community, in an effort to increase the student body's level of earthquake preparedness.

2.4 Earthquake-related Mapping Applications

Several organizations have created earthquake-related mapping applications that are meant to help individuals become more aware of earthquake hazards and how to prepare for them. The American Red Cross has released a series of applications for various types of disasters, including an application providing earthquake information. The Red Cross earthquake application provides users with advice for planning ahead and preparing for a disaster and allows them to add a location of their choosing in order to receive emergency updates for that location (American Red Cross 2016). The user can examine a zoomable global map that has points marked for each earthquake incident that has occurred in the past month, an example of which is reproduced in Figure 5. Additionally, the application connects the user to the USGS website where they can report any seismic shaking they feel.

Another earthquake application, known as QuakeFeed, also incorporates location-based earthquake information from the USGS (USGS 2016). QuakeFeed is a popular application developed by Artisan Global and Esri, and it provides users with a visualization of location and magnitude of seismic events through several different USGS data feeds on a map of the globe that have occurred in the last seven days. The application allows users to set up notifications for seismic events based on location or magnitude of event (Esri 2015).

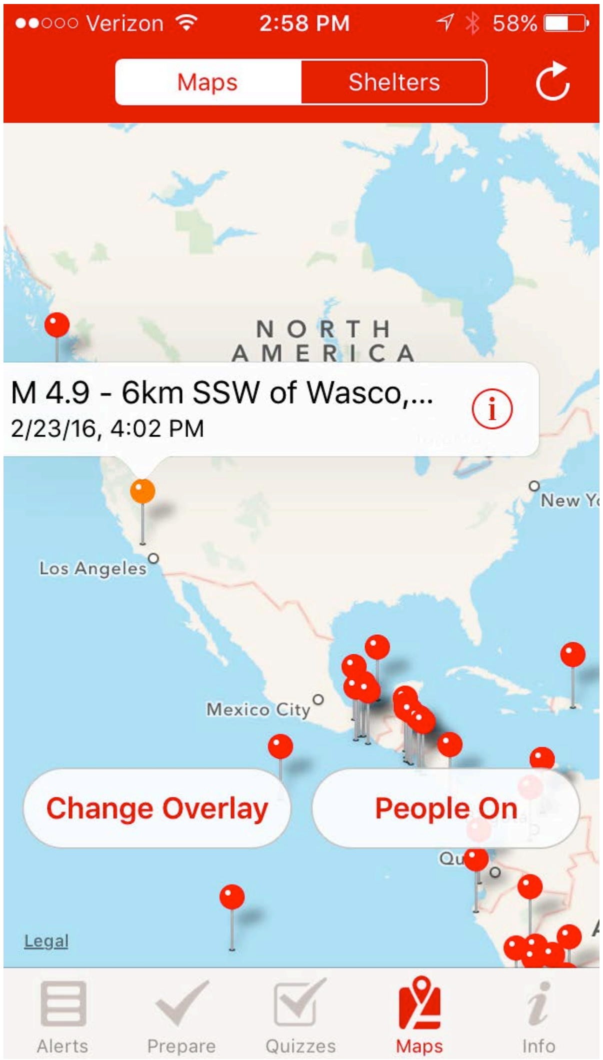

Figure 5: Red Cross Earthquake Application sample image (Source: American Red Cross, 2016)

The University of California Berkeley Seismological Laboratory developed an application very similar to QuakeFeed called MyQuake. This application also considers the user's location and allows them to view a map of the location and magnitude of recent earthquakes. MyQuake does have a unique feature that allows the user to view maps of historic earthquakes near their specified location (UC Berkeley Seismological Laboratory 2016). These applications provide general visualizations of earthquake hazards, but do not necessarily create a personalized view of earthquake risk. The USC Earthquake application provides a personalized, practical tool that can by members of the USC community.

A few studies have explored the development of earthquake-related mapping applications for the use of earthquake hazard awareness. A 2014 study describes the creation of an application that aimed to educate users about earthquake hazards by allowing them to choose a location on a map and learn facts about the history of that location (Chatterjee 2014). The author built this application using the Map Objects Java Edition toolset provided by Esri (Chatterjee 2014, 4). This type of application construction requires a high level of proficiency with the Java programming language. Another study produced an application meant to encourage building owners to seek seismic retrofits by allowing users to search for a building in the Los Angeles area and to view information about the likelihood of a structure to withstand an earthquake (Moffett 2015). This application was developed using Esri's ArcGIS Web AppBuilder. This platform allows application builders to input their own data, to choose from a variety of themes, and to add and configure pre-made widgets. The methodology developed for the USC Earthquake application was also constructed using the Esri Web AppBuilder platform due to the ease of construction and customization.

The studies described in this section have each attempted to increase awareness of earthquake hazards and earthquake preparation in order to create safer communities. This project incorporated the visualization of spatial data that is relevant to a specific community in an interactive environment. The conclusions of the abovementioned studies support the hypothesis that the USC Earthquake Application will have an impact on the user's sense of earthquake preparedness.

2.5 Mapping Visualization Comparison

A similar study conducted last year by Benjamin Anderson, compared user results for "knowledge-extraction tasks" while viewing a static map to the results for the same tests while viewing an animated map as a means of visualizing violent crime data (Anderson 2015). The intention of this study was to determine which map allowed for greater accuracy and efficiency in answering the questions presented as well as to determine which of the maps users preferred. In Anderson 2015, the static map displayed homicide hot spots in the city of Chicago from 2009 to 2013 between 12:00 AM and 3:59 AM. The animated visualization displayed a time-lapse of the same data and allowed the user to navigate between time periods (Anderson 2015). Study participants clicked through the visualization and answered content questions about the information displayed on the map. Additionally, the web-form used for this study recorded the amount of time that the user spent on each question. Finally, participants were asked questions "designed to gauge user-preferences" and responded based on Likert scale responses, which rank the respondents level of agreement (Anderson 2015). The results of this study found that respondents using the static map demonstrated greater accuracy and efficiency in answering the questions. Although, the author found no relationship between the users' performance and their preferences.

This study will use a very similar comparison process between a stationary and interactive map visualization and seeks to answer similar questions about visualization techniques. Additionally, this study utilizes the Likert scale as a means of measuring user preferences. However, the conclusion in Anderson 2015 does not concur with the hypothesis of this study. This study will incorporate these techniques as a way to determine which type of visualization is more effective in communicating information about earthquake preparedness.

Chapter 3: Methodology

This chapter provides a detailed description of the research methodology that was used to complete the application and assessment for this project. The goal of this project was to determine whether or not the newly constructed USC Earthquake Application is effective at communicating information about earthquake preparedness. In order to make this assessment, an experimental group of survey participants tested the application and a control group viewed a stationary map visualization. Section 3.1 describes the steps that the author took to construct the USC Earthquake application. This includes explanations of the data sources for the application, the stages of processing each dataset in ArcMap for use within the application, and the development of the application using the ArcGIS Web AppBuilder platform. Section 3.2 explains the process of selecting participants for the survey and reviews the methods used to analyze the survey results in order to assess the educational value of the USC Earthquake application in comparison to a stationary map visualization.

3.1 Application Construction

The first objective of this project was to build an interactive web-based application for communicating information about the location of emergency supplies and assembly areas on the USC's UPC. This section describes the data sources and data processing for the application as well as application development and configuration.

3.1.1 Data Sources

The author collected data for this project from the Los Angeles County GIS Data Portal and the USC Department of Fire Safety and Emergency Management. The Los Angeles County GIS Data Portal was the source of the Building Outlines and the Disaster Routes datasets. The

USC Department of Fire Safety and Emergency Management provided information for the Emergency Supplies and Assembly Areas datasets.

3.1.1.1 Los Angeles County Data Portal

The Los Angeles County GIS Data Portal provides access to spatial data that is relevant to the administrative processes of Los Angeles County and makes datasets available for public download when possible. Available datasets include street network datasets, geologic maps, and city boundary shapefiles (Los Angeles County GIS Data Portal 2015). For this project, the author used the Los Angeles Region Imagery Acquisition Consortium Building Outlines dataset and the Los Angeles County Disaster Routes dataset.

The Los Angeles Imagery Acquisition Consortium (LARIAC) Building Outlines dataset utilizes satellite imagery to create a polygon dataset with outlines for the nearly 3 million buildings in Los Angeles County (LAC GIS Data Portal). This dataset, which was updated in 2014, includes information about building height, building age, elevation, and building identification number. For this project, the author extracted the building outlines within the study area of the UPC region. These building outlines provide a means to create the most accurate spatial representation of the buildings and were used to add information about the emergency supplies located in the buildings. This is explained further in the description of the emergency supplies dataset. An image showing a portion of the LARIAC building outlines dataset can be seen in Figure 6.

Another dataset provided by the Los Angeles County Data Portal is the Los Angeles County Disaster Routes, which was made available to the public in 2015. This dataset provides a visualization of roads and streets that are designated for transportation of emergency vehicles and for emergency evacuation. The Disaster Routes dataset includes the name of the road, road type, road surface, driving direction, and length of the road. This project used this dataset in order to allow users to visualize potential evacuation routes that would be used in the event of a disaster. An image displaying part of this dataset and its attribute table can be seen on the map below in Figure 7.

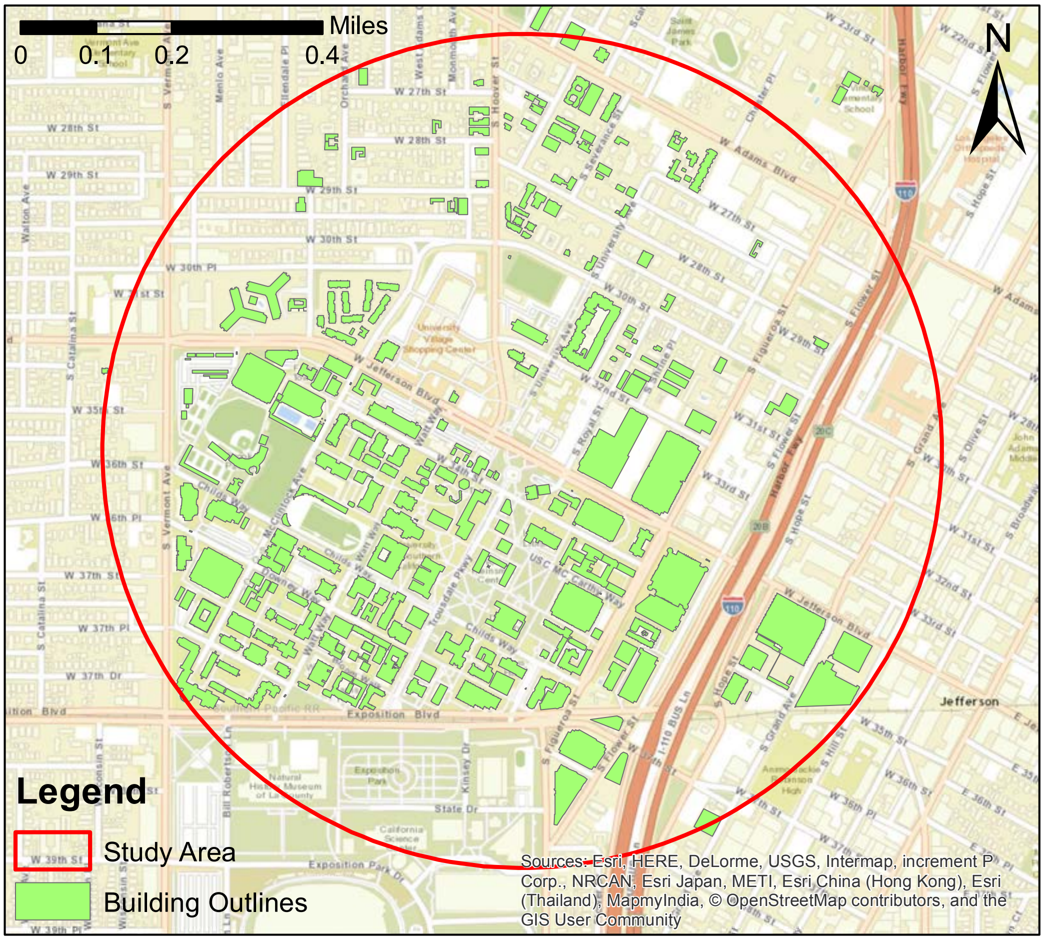

Figure 6: LARIAC Building Outlines dataset

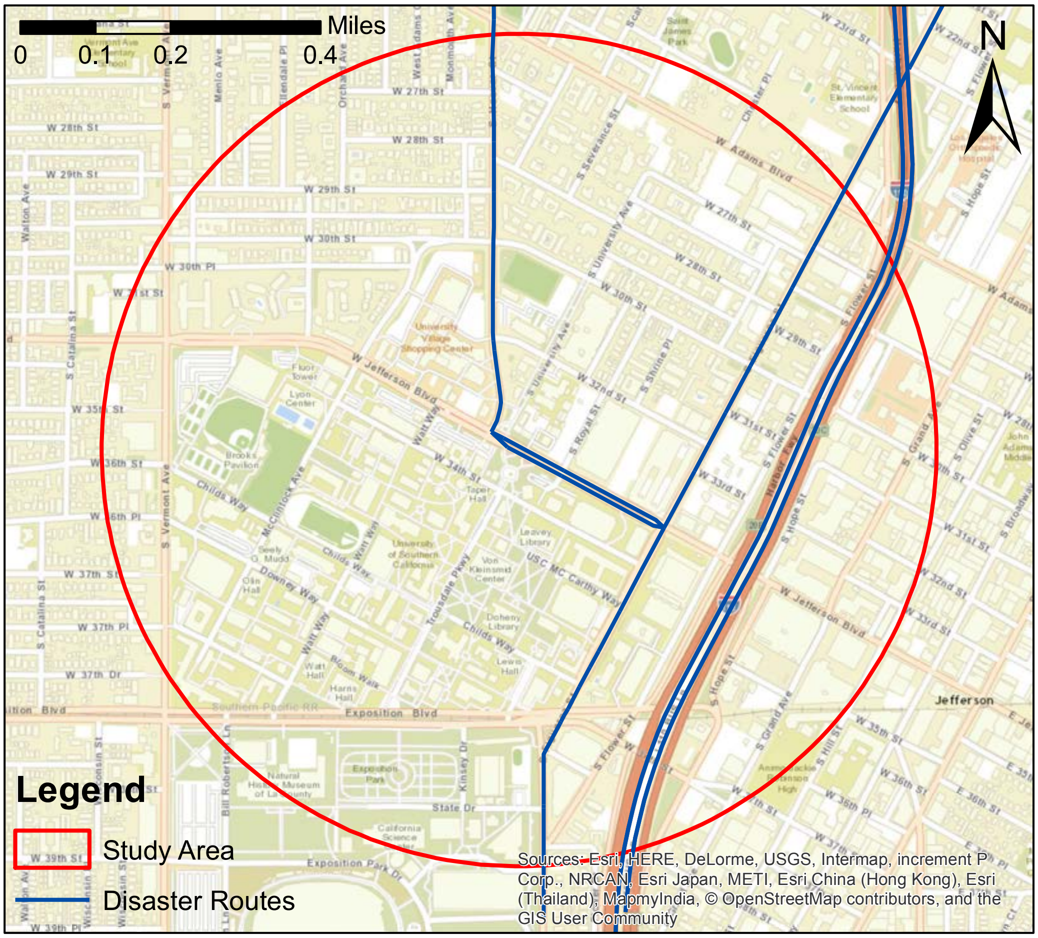

Figure 7: Los Angeles County Disaster Routes dataset

3.1.1.2 USC Department of Fire Safety and Emergency Management

The USC Department of Fire Safety and Emergency Management supervises all emergency services operations on the USC campus, including disaster drills and safety operations. This organization's website provides what they call "Building Information Sheets" for each building on campus. These information sheets list the location of emergency supplies within each building as well as the name of the area where individuals in that building are meant to congregate in the event of an emergency. For this project, the author created two spatial datasets from this information and titled these datasets "Emergency Supplies" and "Assembly Areas."

The Emergency Supplies dataset is a polygon dataset that was created in March 2016 using the Create Features tool in the ArcMap Editing Window. Each shape in the dataset represents a building on the USC's UPC and was produced by copying the relevant building outlines from the LARIC dataset. The author used the USC Maps web application to identify the buildings listed on the USC Department of Fire Safety and Emergency Management's building information sheets. The attribute table for this dataset includes the name of the building, the room where emergency supplies are located, the assembly area for that building, the address, and the three-letter code used by the university to identify the building. This dataset can be seen below in Figure 8 and the attributes included in this dataset can be found in Table 1.

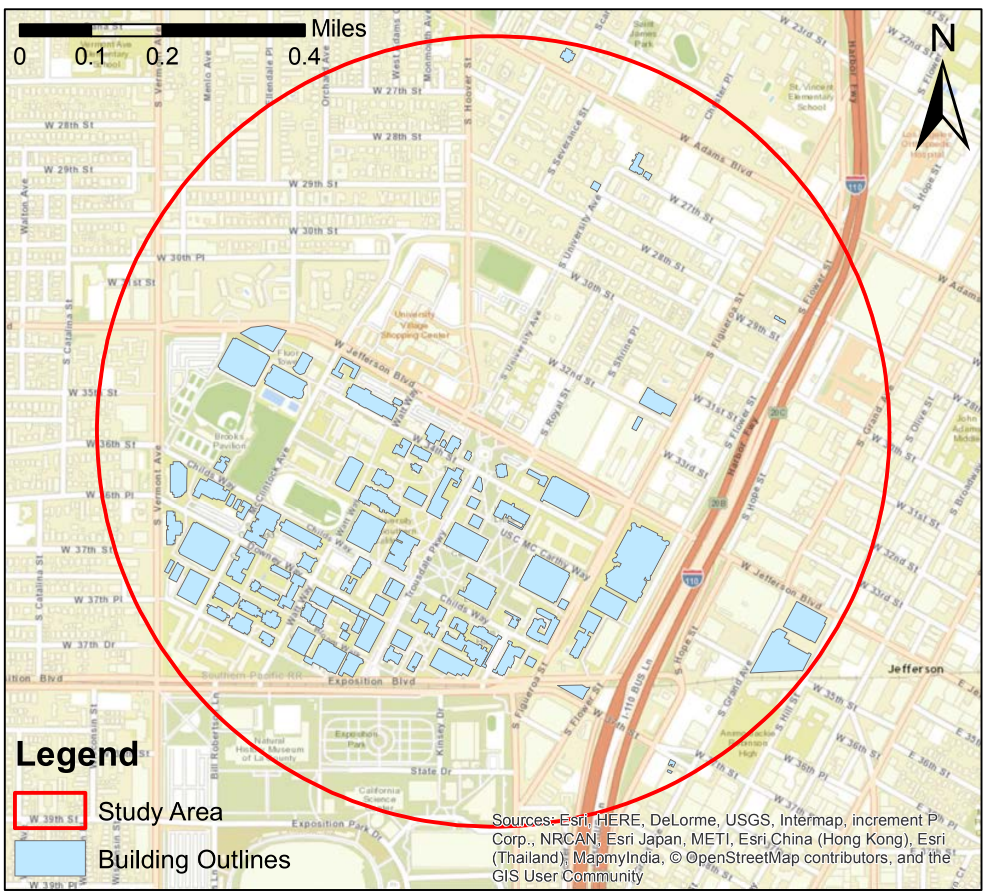

Figure 8: Emergency Supplies dataset

Table 1: Attribute fields for Emergency Supplies dataset

Field Name	Data Type	Field Explanation
Bdg_Name	Text	Name of building on UPC Campus
Emergency_Supplies	Text	Location of emergency supplies within building
Assembly_Area	Text	Emergency assembly area assigned to building
Address	Text	Address of building
Building Code	Text	Three letter identification code of building

The Assembly Areas dataset is a polygon dataset, created in November 2015, which represents the general location of the assembly areas on the USC campus as listed on the Building Information Sheets. This dataset was also constructed using the Create Features tool in the ArcMap Editing Window. The attribute table for this dataset includes the name of the assembly area and the list of names of each building whose inhabitants are meant to assemble in that location. This dataset can be seen below in Figure 9 and the attributes for this dataset can be found in Table 2.

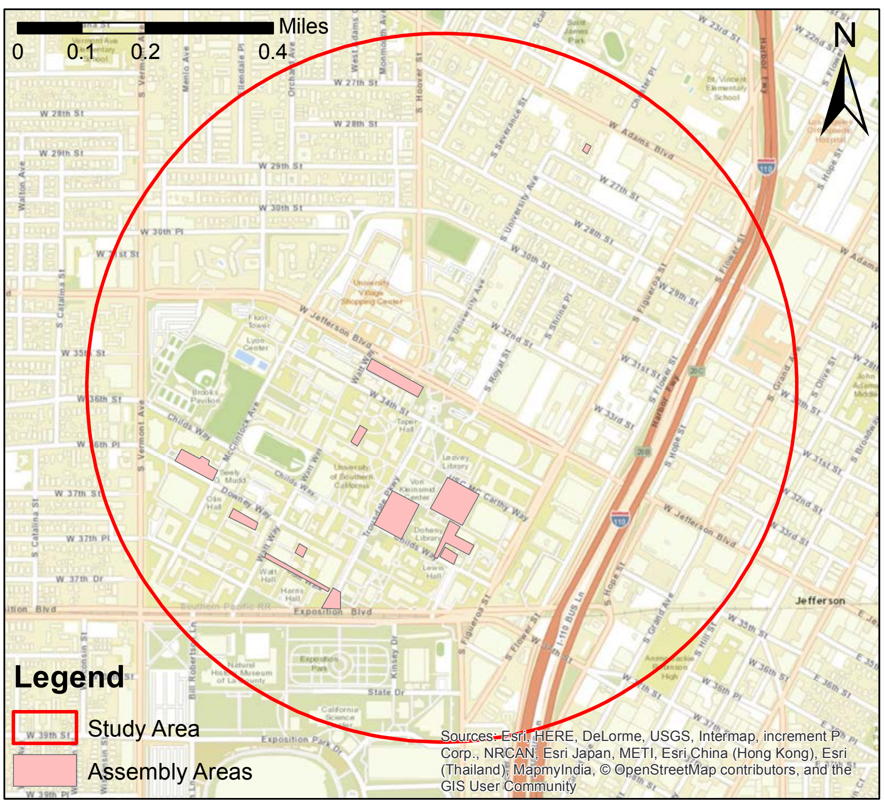

Figure 9: Assembly Areas dataset

Table 2: Attribute fields for Assembly Area dataset

Field Name	Data Type	Field Explanation
Assembly Area	Text	Name of Emergency Assembly Area
Blg1-7	Text	Names of Buildings Assigned to Assembly Area, ≤ 7 Buildings

3.1.2 Data Processing

All data for this project was prepared using the ArcGIS platform. Two datasets were extracted and two were created using ArcMap. All data was shared using ArcGIS Server in preparation to be displayed on a map within ArcGIS Online and to be incorporated into the ArcGIS Web AppBuilder platform. This section provides a detailed explanation of each step towards preparing the data so it could be added into the application constructed for this project.

3.1.2.1 Data Extraction

The Building Outlines and Disaster Routes datasets contained thousands of records that spanned the entirety of Los Angeles County, which is more than was necessary for this project. Both datasets were imported as shapefiles and displayed in ArcMap. The author then used the Clip tool in ArcMap and highlighted only the data present within the study area. The result of this process was two new feature classes that included only the data within this area and were ready to be exported to ArcGIS Server.

3.1.2.2 Data Creation

The information for the Emergency Supplies and Assembly Areas datasets was acquired in the form of lists from the USC Department of Fire Safety and Emergency Management with no spatial component. Therefore, it was necessary to create new spatial datasets from the information provided. The author created two new feature classes before using the Editing Window in ArcMap to create polygon features and populate the attribute table with the relevant information. Polygons for the Emergency Supplies dataset were modeled off the polygon features from the Building Outlines dataset. The Assembly Areas dataset is meant to represent general areas on campus rather than clearly defined spaces and, therefore, the polygons for this dataset are based on areas found on the Esri World StreetMap available as a basemap in ArcMap. Once these datasets were complete, they were ready for export to ArcGIS Server.

3.1.2.3 Data Export

In order for datasets to be displayed in ArcGIS Web AppBuilder, they first needed to be exported to ArcGIS Server. Each dataset was shared as an individual Map Service to a personal ArcGIS Server account. A new map was created in the My Content window of this account. Within the new map, the Add Data From Web button was chosen from the Add Data menu and used to add the REST Services URL from the ArcGIS Server account for each dataset. The map was then saved and the sharing settings adjusted so that the map could be viewed publicly on ArcGIS Online. An image of the final map in ArcGIS Online is displayed in Figure 10.

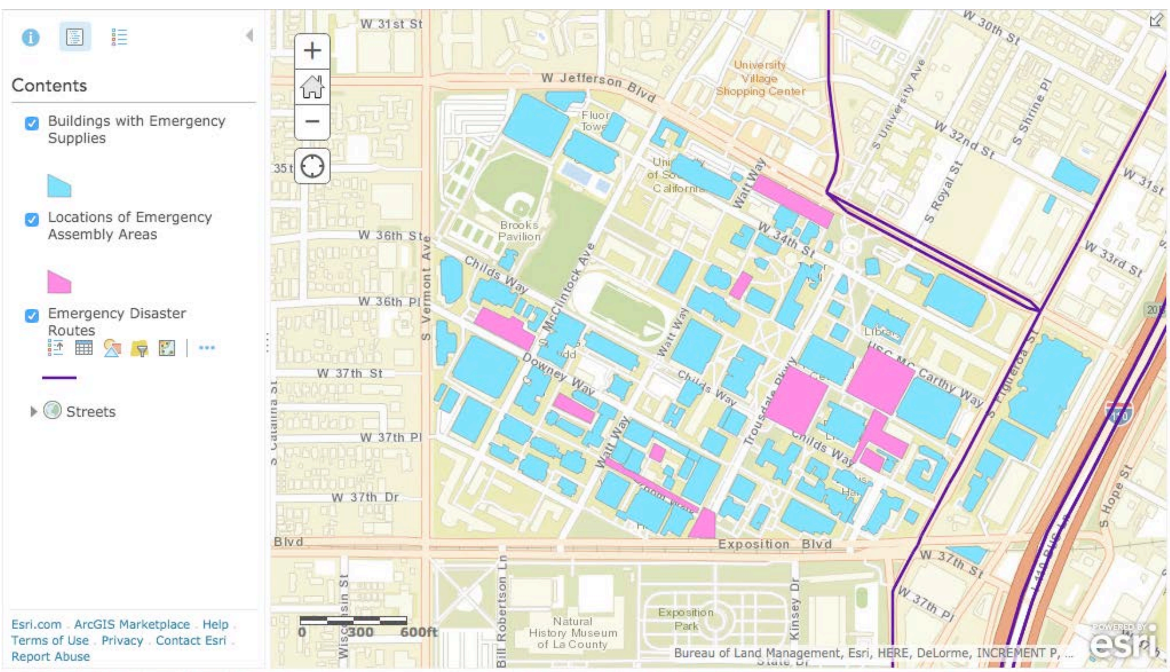

Figure 10: Image of dataset in ArcGIS Online

3.1.3 Application Development

The USC Earthquake application was constructed using the ArcGIS Web AppBuilder platform in the ArcGIS Online environment. Using the personal ArcGIS Online account described above, the author selected the New Item button and then chose App and Using AppBuilder within the My Content window. Once Web AppBuilder was opened, the author chose to use the Dart Theme, which places all the functions of the application along the bottom of the application window. The author chose a cardinal and gold color scheme for the application, as those are the official colors of the University of Southern California. The application was then prepared to add the datasets described earlier.

The datasets for this project were aggregated into a single map in the ArcGIS Online platform. In the editing window of the application, the author selected the Map tab and added the map containing the Disaster Routes, Emergency Supplies, and Assembly Areas. The author then changed the basemap to the Esri World StreetMap in order to give an improved visualization of the roads in the local area. An image of this map clipped to the application extent can be seen in Figure 11.

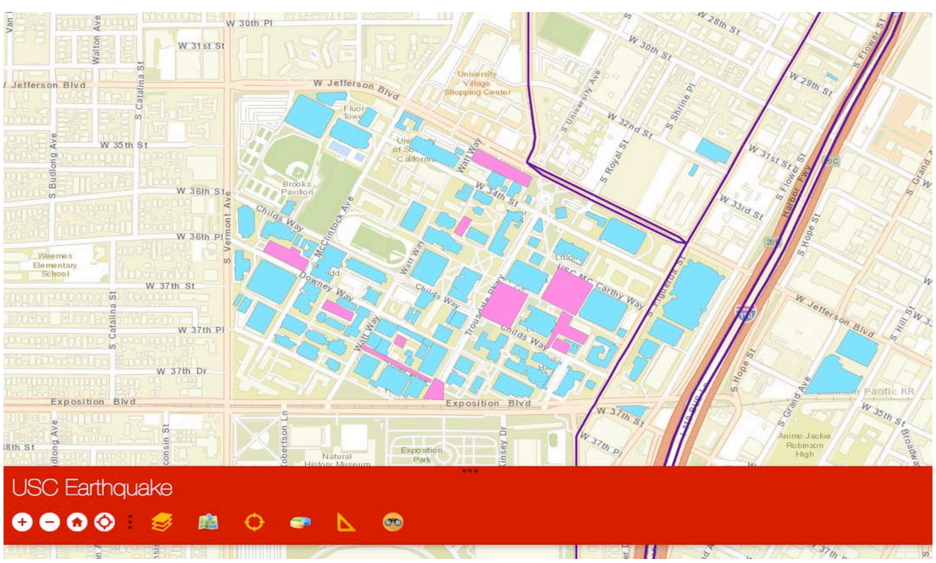

Figure 11: Application user interface

3.1.2 Widget Configuration

The Web AppBuilder platform uses tools called widgets, which can be configured and customized by the creator of the application to allow the user to perform tasks within the application. The widgets that are standardized within the Dart theme include a Zoom Slider, which allows the user to zoom in and out on the map surface, a Home button, which allows the user to return to the default map extent set up by the application creator, and a Location button, which indicates the user's location. These standard widgets are placed on the left side of the widget bar on the bottom of the application as seen in Figure 12 below.

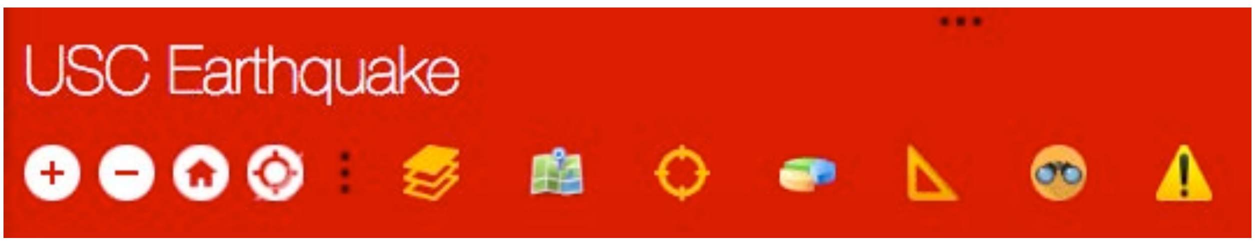

Figure 12: The application Widget Toolbar with the individual icons from the left- to the right-hand-side representing a zoom slider, home button, Layers List, Basemap Gallery, Add Location button, Analysis, Measurement, Locate Nearest, and Help widgets.

This application also contains widgets that needed very little configuration and customization. One of these was the Layers button, which allows the user to see the names and symbology of each layer, as seen in Figure 13. Another one of these simple widgets is the Basemap Gallery, which allows users to choose a new basemap from the ArcGIS Online gallery. Next is the Analysis widget, which includes the Aggregate Points, Calculate Density, Find Nearest, and Summarize Nearby tasks as seen in Figure 14. Finally, the Measurement tool allows the user to measure polygons, straight line distances, and the longitude and latitude of a user-defined point.

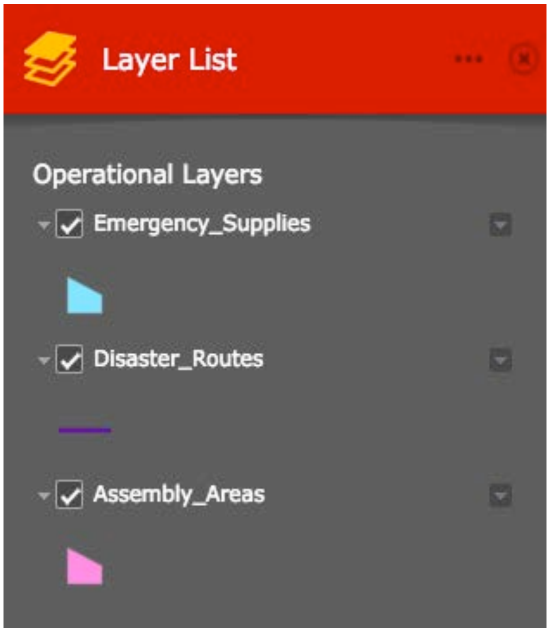

Figure 13: Image showing the Layers Widget

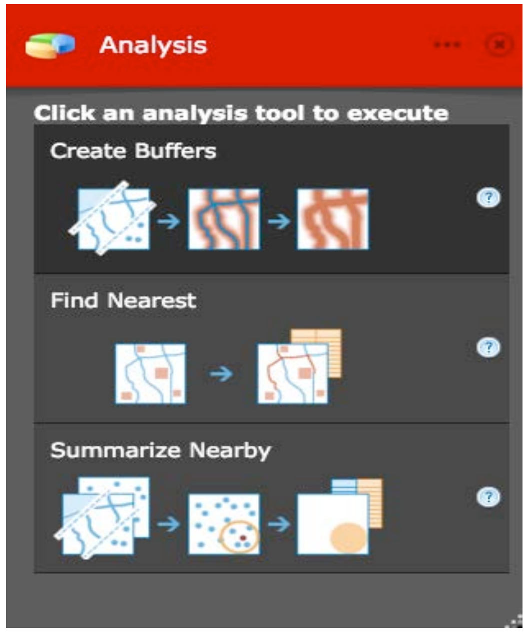

Figure 14: Image showing the Analysis Widget

For the purpose of this project, a few widgets were customized for this particular application. The Draw widget, which is intended to allow the user to add points, lines, and polygons on the map surface as operational layers, was renamed Add Location to make it clear that its purpose is to add a location of the user's choice. Next, the Incident Analysis widget was renamed as the Locate Nearest widget. This widget allows the user to input a location, define a buffer distance, and receive information about the location of emergency supplies, assembly areas, and disaster routes within that buffer. The result of this process can be seen in Figure 15. Additionally, the author added the Help widget in order to give users a resource to explain how to use the application. A further explanation of how this widget can be found in Chapter 4.

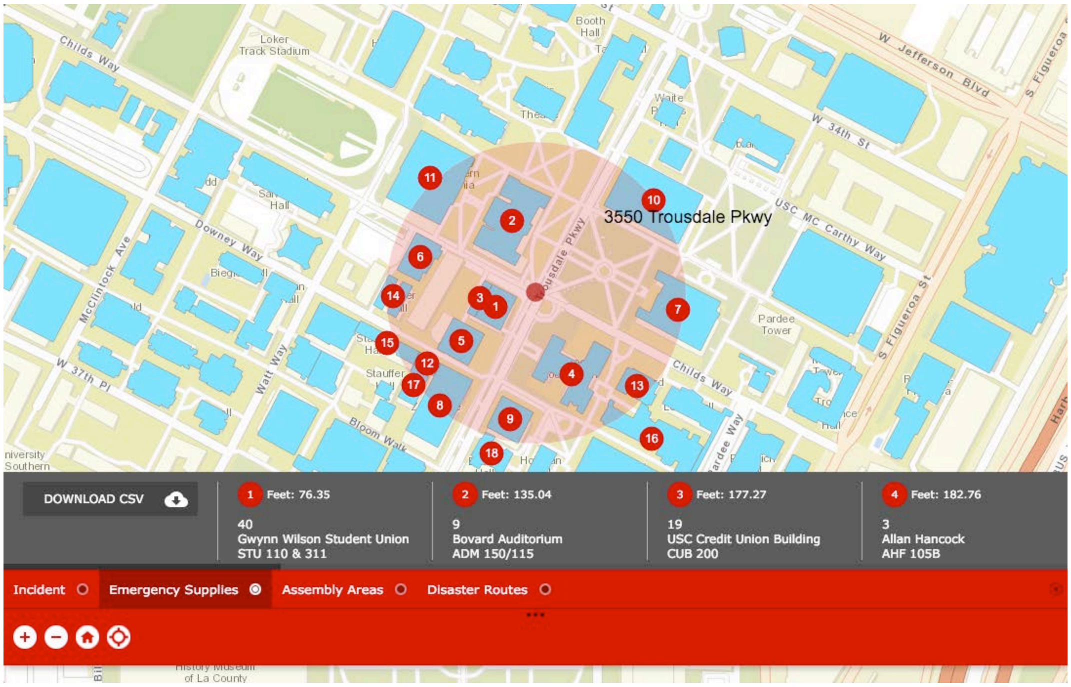

Figure 15: Map displaying a run of the Locate Nearest widget

3.2 Participant Survey

This project sought to understand how the use of the USC Earthquake application can impact the user's sense of earthquake preparedness in comparison to a stationary web map. In order to evaluate the educational impact of the web GIS application, this project surveyed students in the USC community. The survey questions for this project included demographic questions about the participant, their level of risk awareness, and their preparedness.

3.2.1 Visualization Comparison

This project sought to compare two types of visualizations, comprised of the interactive map application constructed for this project and a stationary web-based map visualization. A link to the application was incorporated into a survey constructed with the online program Survey Monkey that was distributed to survey participants in the experimental group. For the control group survey, the web GIS map application was replaced with the stationary map visualization.

The stationary visualization was an image of the map surface from the application without the widgets and tools as shown in Figure 16.

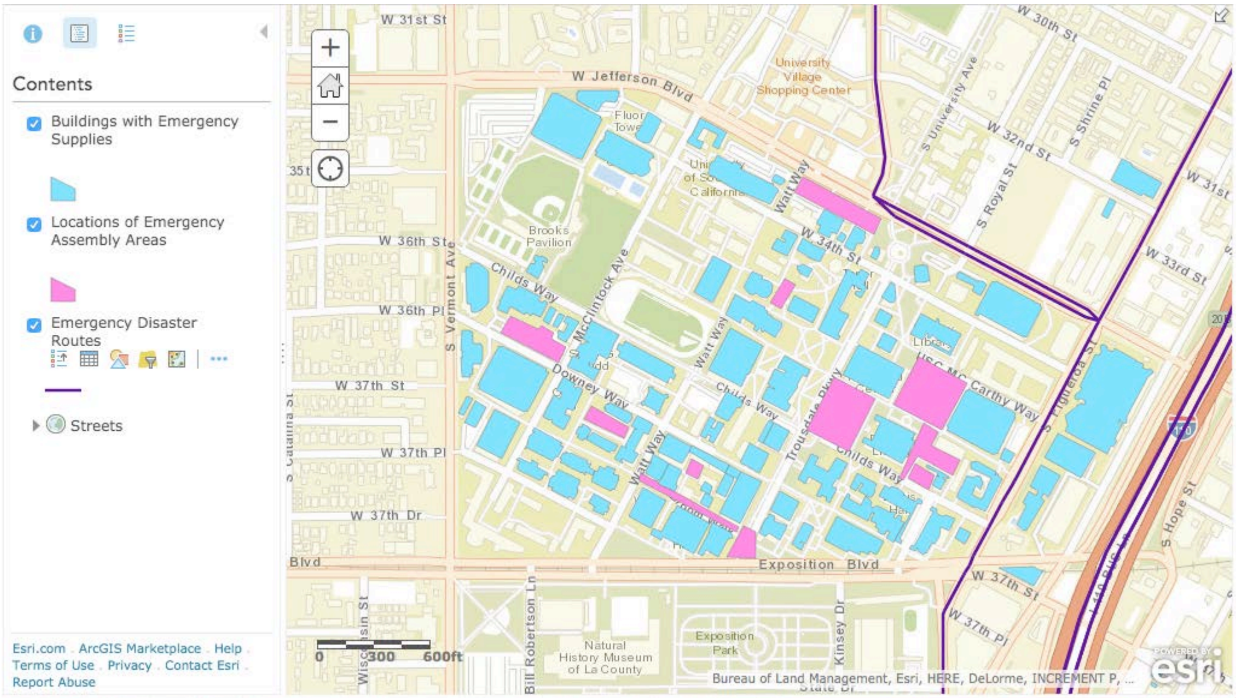

Figure 16: Stationary visualization used in survey

3.2.2 Selection of Participants

In order to collect a sufficient amount of survey data, this project aimed to survey a total of 120 undergraduate student participants with 60 participants using the stationary map visualization and 60 participants using the web GIS map visualization. These participants were asked to volunteer to test the visualizations and take the survey in several General Education courses on the UPC in the final three weeks of Spring Semester, 2016. The solicitation of participants in General Education courses helped to recruit survey participants from multiple different majors, backgrounds, and disciplines.

3.2.3 Survey Creation

This survey was constructed in Survey Monkey so that the link could be distributed easily. Before the survey was distributed, a few individuals field tested the survey and gave suggestions about how to improve the questions and formatting. Several of these suggestions were considered and incorporated before the final distribution of the survey.

Participants were asked the same questions before and after viewing the visualization. The control survey, named USC EQ 1, contained an image of the stationary map visualization and the experimental survey, named USC EQ 2, contained a link to the USC Earthquake application. The author constructed questions that asked participants to rank their level of agreement with the Likert scale, which uses the following phrases: Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree. The questions used in the survey are listed in Table 3.

Table 3: Survey questions

Category	Text	Type
Demographic	What is your major(s):	Open Ended
	What is your year in school:	Select (Freshman, Sophomore, Junior, Senior, Graduate)
	Do you live on the USC Campus?	Select (Yes, No)
	I am likely to experience an earthquake while attending USC:	Agreement on Likert Scale
Risk Awareness Before	I would feel safe if an earthquake happened while I was on the USC Campus:	Agreement on Likert Scale
	I would feel safe if an earthquake happened while I was in my place of residence:	Agreement on Likert Scale
Preparedness Before	I feel prepared for an earthquake:	Agreement on Likert Scale
	I know where to go on campus in the event of an earthquake or emergency:	Agreement on Likert Scale
	I know where to find emergency supplies on the USC Campus:	Agreement on Likert Scale

Risk Awareness After	I would feel safe if an earthquake happened while I was on the USC Campus:	Agreement on Likert Scale
	I would feel safe if an earthquake happened while I was in my place of residence:	Agreement on Likert Scale
Preparedness After	I feel prepared for an earthquake:	Agreement on Likert Scale
	I know where to go on campus in the event of an earthquake or emergency:	Agreement on Likert Scale
	I know where to find emergency supplies on the USC Campus:	Agreement on Likert Scale
Follow-Up	I found this visualization helpful:	Agreement on Likert Scale
	Please provide any comments about how this visualization could be more helpful	Open Ended

3.2.4 Analysis of Results

After at least 120 participants had responded to the survey, the author collected and compared the results to determine the overall impact of the web GIS map visualization relative to the stationary map visualization. The first task was to examine whether or not the respondents showed any increase in the level of risk awareness and sense of preparedness after viewing either type of visualization. Once there was proven to be an increase in these two factors, the author compared the increase in risk awareness and sense of earthquake preparedness between the interactive visualization map participants and the stationary map visualization participants. The results of this comparison can be found in Chapter 4.

The next task in analyzing the survey data was to determine the statistical significance of the differences found in the data. A difference of proportions test was used and the z-ratio was calculated to determine the significance of the difference between results of the survey. The z-ratio is a statistical measurement to determine the probability of a result being achieved by random chance, for the difference between the following aspects of the survey results: before and after the control visualization, before and after the experimental visualization, the control group and experimental group before the visualization, and the experimental and control group after the visualization. In order to calculate the z-ratio for each of these aspects, the author first calculated a variable labeled “p”, which is the ratio of participants who responded Agree or Strongly Agree over the total number of participants for that survey. In this calculation, pA represented the ratio for one group of results and pB the ratio for the second group for a given calculation. The author then calculated the difference between these two ratios, defined as pA – pB. These three calculations were incorporated into the online calculator from Vassar Statistics that returned the z-ratio result (Lowry 2016).

In order to interpret the results of this analysis, the author considered the recommended interpretation of the z-ratio. According to StrataSearch, a z-score of less than 1.64 represents a difference that is not statistically significant and are a result of random chance, a score between 1.64 and 2.33 represents a 1% chance that the results were produced by random chance, and a score greater than 3.09 represents a 0.1% chance of results produced by random chance (StrataSearch 2016). The results of the statistical analysis of the survey results can be found in Chapter 4.

Chapter 4: Results

The survey for this study asked the participants questions about their level of earthquake risk awareness and preparedness cognition. All participants were undergraduate students at the UPC. Participants were separated into two groups that were given the same questions, but different visualizations. The control group was given a stationary map visualization and the experimental group was given the USC Earthquake application visualization. All questions that asked for a level of agreement provide the participant with a list from the Likert scale, which includes the following choices: Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree. For questions that asked respondents to rank their level of agreement, this study hypothesizes that the experiment group would show a larger positive change in Agree and Strongly Agree and a larger negative change in Disagree and Strongly Disagree in comparison to the control group. Section 4.1 gives a brief explanation of the application and 4.2 elaborates upon the respondent count and responses for the demographic questions. Section 4.3 presents the results for the Risk Awareness questions of the survey, Section 4.4 presents the results for the Preparedness questions, and Section 4.5 provides the results of the Helpfulness question. Finally, Section 4.6 presents the results of the statistical analysis tests.

4.1 Application Demonstration

The USC Earthquake Application is intended to communicate information about earthquake risk awareness and preparedness. Once the application is launched in a browser, the user can see a splash screen that gives a brief explanation of the application's intent, provides a description of the Locate Nearest widget, and guides the user to a Help widget if they need further assistance. An image of the splash screen can be seen in Figure 17. In order to move onto the application itself, the user must click on the check box next to “Continue to application” to acknowledge that they have viewed the screen.

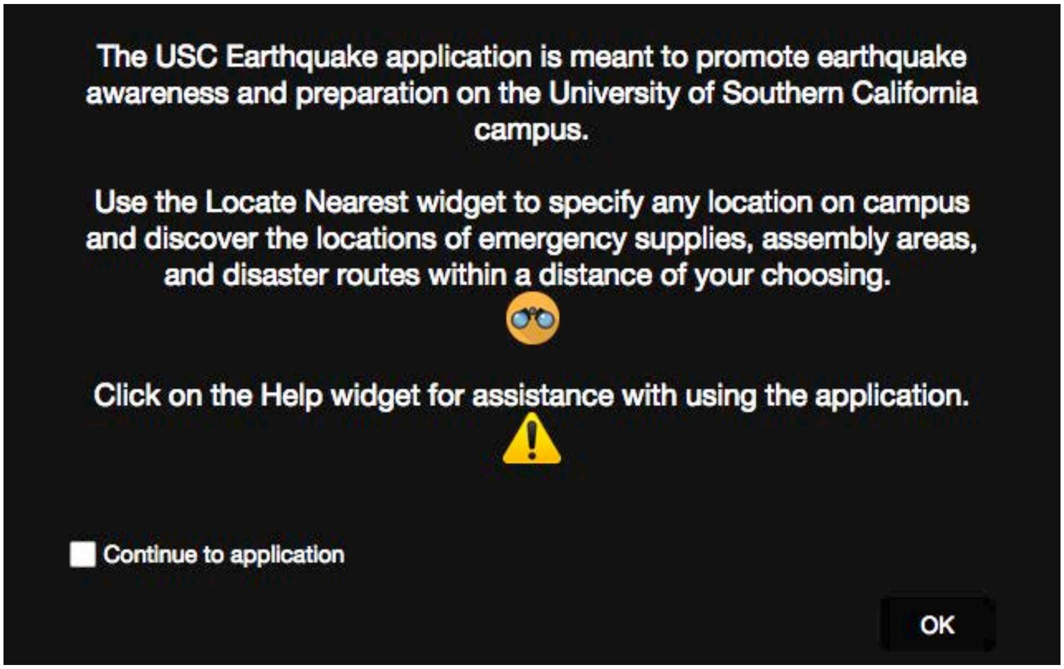

Figure 17: Splash Screen intended to guide user regarding the use of the application

The next step in the use of the application is clicking on the Help widget, which was intended to guide the user in the use of the application. The first portion of the pop-up Help window tells the user to click on the Locate Nearest widget and provides and image of the Locate Nearest icon. Next, it guides the user to choose whether they would like to select a point, line, or polygon feature and gives the icon for each choice. The window then shows the user how to select a buffer distance around the feature that they have created and gives an image of the buffer distance slider. Finally, it tells the user to click on the layer feature that they would like to highlight on the map and shows an image of the three options, which are Emergency Supplies, Assembly Areas, and Disaster Routes. An image of the Help widget pop-up window can be seen below in Figure 18.

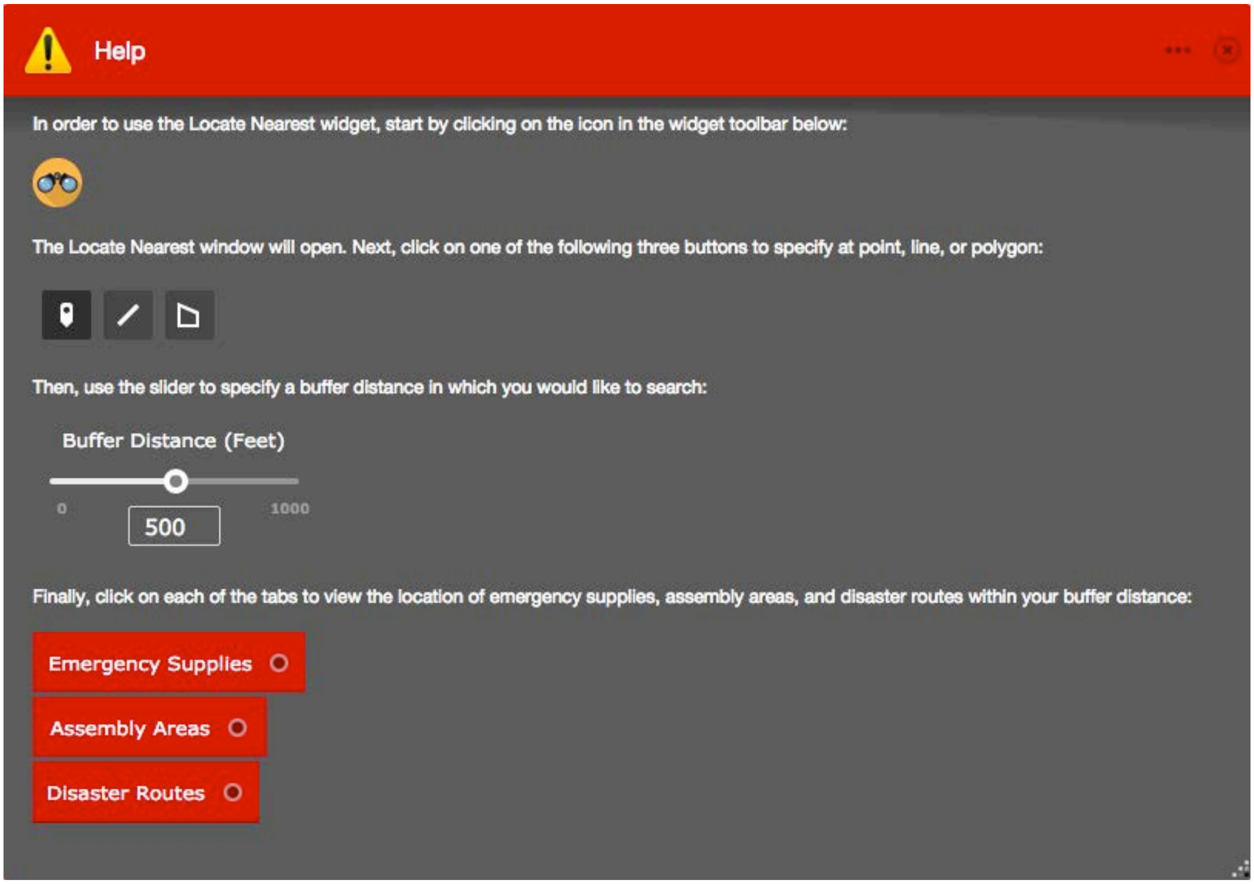

Figure 18: Help Widget pop-up window

Next, the user would click on the Locate Nearest icon, which causes a different window to pop-up on the widget toolbar. This pop-up allows the user to select a type of feature, either point, line, or polygon, and gives the user the ability to select the location of the feature on the map. An image of this view can be seen in Figure 19. The user then would select a buffer distance for the feature they have already created on the map. The range of buffer distances has been set from 0- to 1,000-feet, an image with a 500-foot buffer can be seen in Figure 20. Finally, the user can click on the feature layer that they would like to highlight within the buffer. This returns a list of all features within the selected layer that fall within the buffer and gives the distance to each feature. An image of these results for the Emergency Supplies feature layer can be seen in Figure 21.

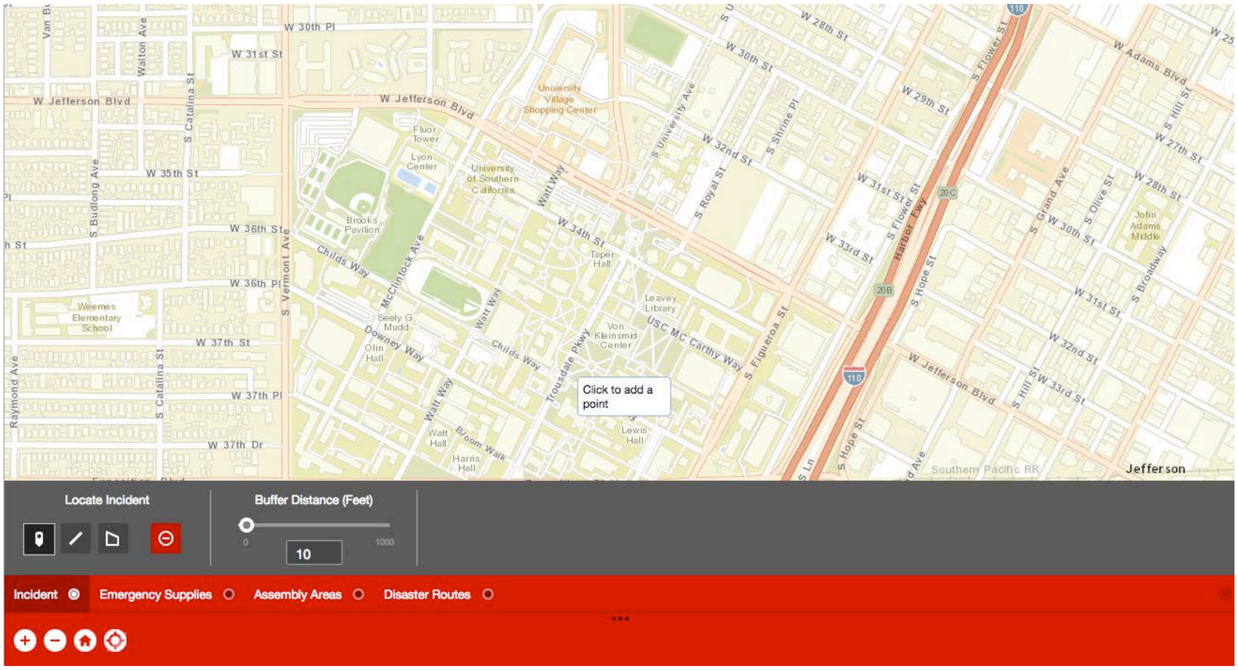

Figure 19: Locate Nearest Widget pop-up

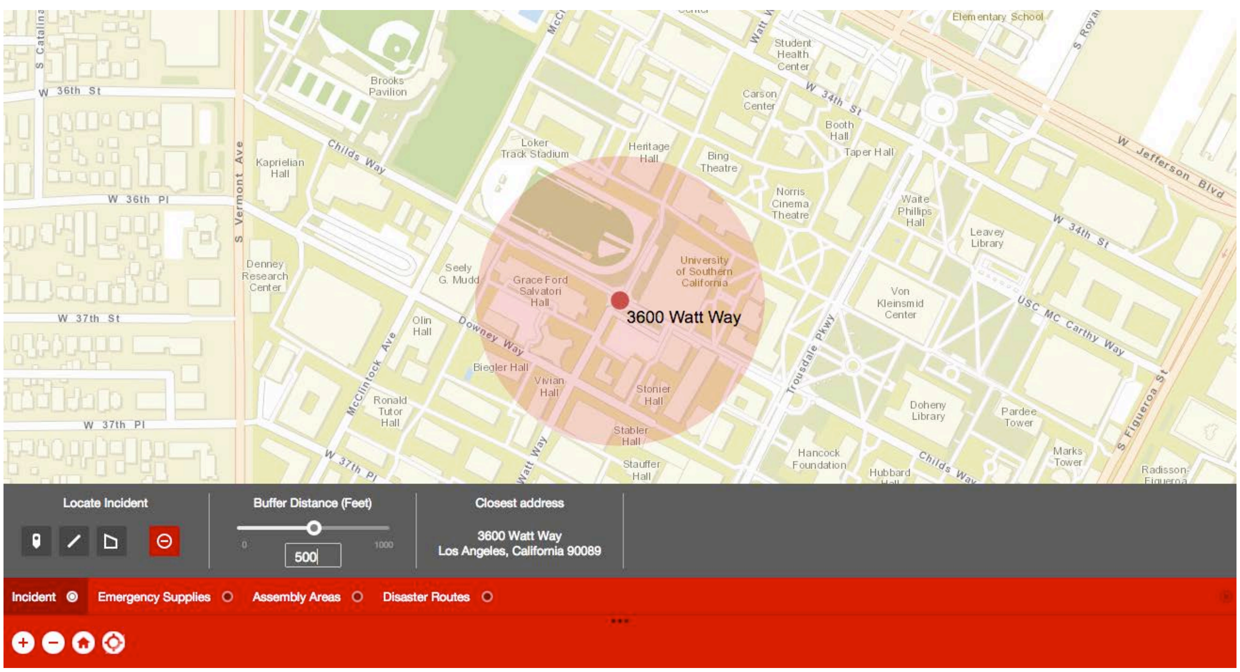

Figure 20: Locate Nearest buffer

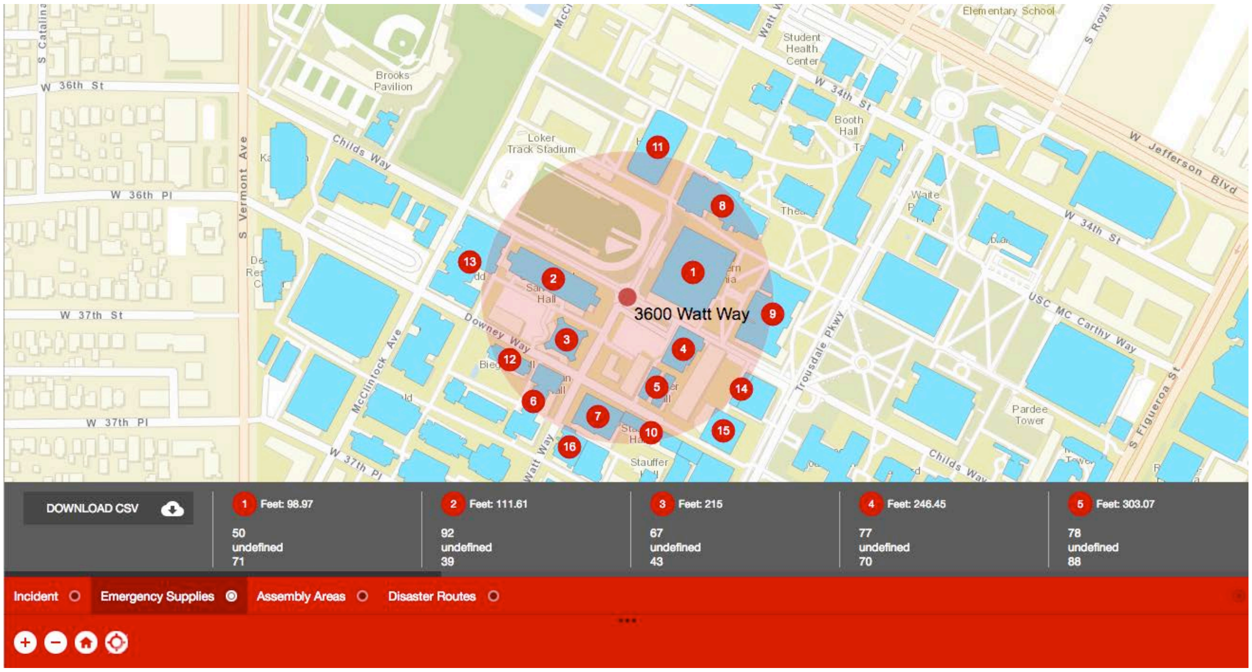

Figure 21: Locate Nearest results

4.2 Respondent Demographics

In total, 138 individuals responded to both surveys. The author collected 67 people responses to the control survey and 71 responded to the experimental survey. However, some respondents only completed a portion of the survey, resulting in 123 completed responses overall. As a result, there were 61 completed responses for the control survey and 62 completed responses for the experimental survey. At the beginning of the survey, participants were asked to answer a few general questions about their major, year in school, where they lived, and how they perceived their likelihood of experiencing an earthquake.

The first question on the survey asked participants “What is your major?” and left space for an open ended response. After the responses were collected, the author organized the majors into the categories listed along with the results seen below in Table 4. The majority of respondents fell into the Social Sciences and Science, Math, and Technology categories with

Business as the next most popular category. Arts and Humanities, Interdisciplinary, and Health and Humanities accounted for less than 20% of the major respondents combined.

Table 4: Major responses

Major Category	Percentage
Arts and Humanities	9.42%
Business	17.39%
Health and Medicine	1.45%
Science, Math, and Technology	28.26%
Social Sciences	36.96%
Interdisciplinary	6.52%

The next question on the survey asked the participants to select their level in school from the following choices: Freshman, Sophomore, Junior, Senior and Graduate. The results of this question can be seen in Table 5. The majority of participants selected either Sophomore or Junior as a response, followed by Senior and Freshman. No participants identified themselves as a Graduate student.

Table 5: Year in School responses

Response	Percentage
Freshman	15.94%
Sophomore	31.16%
Junior	31.16%
Senior	21.74%

Because one of the questions in the survey refers to the respondents' location on campus and at their place of residence, the next question asked the participants whether or not they lived on the UPC. The results of this question are displayed in Table 6 and these results show that the majority of the participants did not live on campus.

Table 6: Living on Campus response

Response	Percentage
Yes	35.51%
No	64.49%

The final question in this section asked participants to rank their level of agreement with the following statement: "I am likely to experience an earthquake while attending USC." This was meant to establish a base level of understanding about earthquake awareness. The results of this question can be seen in Table 7. The majority of respondents selected either Agree or Strongly Agree. Around 10% of respondents marked Undecided and less than 10% marked Disagree or Strongly Disagree. These results establish that the majority of respondents understand that there is some degree of earthquake risk in the UPC area.

Table 7: Earthquake Experience

Response	Percent
Strongly Agree	26.81%
Agree	52.17%
Undecided	10.87%
Disagree	7.97%
Strongly Disagree	2.17%

4.3 Risk Awareness

The first question in the risk awareness section of the survey asked the participant to rank their agreement with the following statement: "I would feel safe if an earthquake happened while I was on the USC Campus." The responses for this question in both groups can be found in Tables 8 and 9. The change category of each table was calculated by subtracting the percentage before viewing the visualization from the percentage after. The control group showed a positive change in the Strongly Agree category and a negative change in the Strongly Disagree category. The experimental group showed a greater positive change in the Agree and Strongly Agree categories and a larger negative change in the Undecided and Disagree categories compared to the control group.

Table 8: Control: “I would feel safe if an earthquake happened on campus”

Response	Percent Before	Percent After	Change
Strongly Agree	15.87%	20.63%	+4.76%
Agree	55.56%	53.97%	-1.59%
Undecided	20.63%	19.05%	-1.59%
Disagree	4.76%	6.35%	+1.59%
Strongly Disagree	3.17%	0.00%	-3.17%

Table 9: Experimental: “I would feel safe if an earthquake happened on campus”

Response	Percent Before	Percent After	Change
Strongly Agree	7.81%	15.63%	+7.81%
Agree	56.25%	57.81%	+1.56%
Undecided	20.31%	17.19%	-3.13%
Disagree	15.63%	9.38%	-6.25%
Strongly Disagree	0.00%	0.00%	0.00%

The next question asked respondents about their risk awareness when they are at their home with the following statement: “I would feel safe if an earthquake happened at my place of residence.” The responses for this question can be seen in Tables 10 and 11. For this question, the control group showed a greater positive change in the Agree and Strongly Agree categories as well as a greater negative change in the Undecided, Disagree, and Strongly Disagree categories in comparison to the experimental group.

Table 10: Control: “I would feel safe if an earthquake happened at my residence”

Response	Percent Before	Percent After	Change
Strongly Agree	10.45%	14.29%	+3.84%
Agree	34.33%	38.10%	+3.77%
Undecided	29.85%	25.40%	-4.45%
Disagree	20.90%	19.05%	-1.85%
Strongly Disagree	4.48%	3.17%	-1.30%

Table 11: Experimental: “I would feel safe if an earthquake happened at my residence”

Response	Percent Before	Percent After	Change
Strongly Agree	2.86%	6.06%	+3.20%
Agree	38.57%	39.39%	+0.82%
Undecided	21.43%	21.21%	-0.22%
Disagree	34.29%	27.27%	-7.01%
Strongly Disagree	2.86%	6.06%	+3.20%

4.4 Preparedness

The first question in the preparedness section asked the respondents to rank their level of agreement with the following statement: "I feel prepared for an earthquake." The results of this question can be seen in Tables 12 and 13. The control group showed a greater positive change in the Agree and Strongly Agree categories as well as a greater negative change in the Undecided, Disagree, and Strongly Disagree categories in comparison to the experimental group.

Table 12: Control: "I feel prepared for an earthquake"

Response	Percent Before	Percent After	Change
Strongly Agree	9.68%	12.90%	+3.23%
Agree	27.42%	43.55%	+16.13%
Undecided	25.81%	22.58%	-3.23%
Disagree	35.48%	19.35%	-16.13%
Strongly Disagree	1.61%	1.61%	0.00%

Table 13: Experimental: "I feel prepared for an earthquake"

Response	Percent Before	Percent After	Change
Strongly Agree	4.69%	7.81%	+3.13%
Agree	29.69%	37.50%	+7.81%
Undecided	31.25%	32.81%	+1.56%
Disagree	31.25%	15.63%	-15.63%
Strongly Disagree	3.13%	6.25%	+3.13%

The next question asked participants how they felt about the following statement: "I know where to go on campus in the event of an earthquake or emergency." The results of this question can be seen in Tables 14 and 15. The control group showed a greater positive change in the Agree and Strongly Agree categories as well as a greater negative change in the Undecided, Disagree, and Strongly Disagree categories in comparison to the experimental group.

Table 14: Control: "I know where to go on campus in the event of an emergency"

Response	Percent Before	Percent After	Change
Strongly Agree	2.99%	17.74%	+14.76%
Agree	25.37%	62.90%	+37.53%
Undecided	8.96%	11.29%	+2.34%
Disagree	43.28%	8.06%	-35.22%
Strongly Disagree	19.40%	0.00%	-19.40%

Table 15: Experimental: "I know where to go on campus in the event of an emergency"

Response	Percent Before	Percent After	Change
Strongly Agree	4.29%	15.63%	+11.34%
Agree	18.57%	43.75%	+25.18%
Undecided	10.00%	20.31%	+10.31%
Disagree	44.29%	17.19%	-27.10%
Strongly Disagree	22.86%	3.13%	-19.73%

The final question in this section asked respondents to rank their level of agreement with the following statement: "I know where to find emergency supplies on the USC Campus." The results for this question can be seen in Tables 16 and 17. The control group showed a greater positive change in the Agree and Strongly Agree categories as well as a greater negative change in the Undecided, Disagree, and Strongly Disagree categories in comparison to the experimental group.

Table 16: Control: "I know where to find emergency supplies on campus"

Response	Percent Before	Percent After	Change
Strongly Agree	1.49%	16.13%	+14.64%
Agree	4.48%	64.52%	+60.04%
Undecided	2.99%	11.29%	+8.31%
Disagree	49.25%	8.06%	-41.19%
Strongly Disagree	41.79%	0.00%	-41.79%

Table 17: Experimental: "I know where to find emergency supplies on campus"

Response	Percent Before	Percent After	Change
Strongly Agree	4.29%	15.63%	+11.34%
Agree	18.57%	43.75%	+25.18%
Undecided	10.00%	20.31%	+10.31%
Disagree	44.29%	17.19%	-27.10%
Strongly Disagree	22.86%	3.13%	-19.73%

4.5 Application Helpfulness

The final section of the survey asked the respondent to assess how helpful they found each visualization. The first question asked participants to rank their level of agreement with the following statement: "I found this visualization helpful." The results of this question can be seen in Tables 18 and 19. In the control group, over 85% of the respondents chose either Agree or Strongly Agree, while only about 64% in the experimental group chose either Agree or Strongly Agree. This section also asked participants to provide any comments about how the visualization could be made more helpful and these comments will be addressed in Chapter 5, which follows next.

Table 18: Control: "I found this application helpful"

Response	Percent
Strongly Agree	30.65%
Agree	54.84%
Undecided	9.68%
Disagree	3.23%
Strongly Disagree	1.61%

Table 19: Experimental: "I found this application helpful"

Response	Percent
Strongly Agree	15.63%
Agree	48.44%
Undecided	20.31%
Disagree	14.06%
Strongly Disagree	1.56%

4.6 Statistical Tests

The first set of statistical measurements that were run for this study involved testing the difference between the responses before and after viewing the visualization for the risk awareness and preparedness questions in the control group. As seen in Table 20, pA represents the ratio of respondents that selected Agree and Strongly Agree before viewing the visualization to the number of total responses and pB represents the same calculation after viewing the visualization. The pA – pB column represents the difference between the two calculations and the final column represents the calculated z-ratio. As stated above, a difference is unlikely to be the result of random chance if the z-ratio is greater than 1.64. All preparedness questions showed a significant difference that is not likely to be the result of random chance.

The second set of tests involves the responses before and after viewing the visualization for the risk awareness and preparedness questions in the experimental group. In this case, pA and pB measurements represent the ratio of Agree and Strongly Agree responses to total responses before and after using the USC application. The results of this calculation can be seen in Table 21. Once again, all preparedness questions showed z-ratios greater than 1.64, which means they are significant and not likely to be the result of random chance. The control group demonstrated a greater increase in Agree and Strongly Agree responses after the visualization than the experimental group.

Table 20: Calculations for Risk Awareness and Preparedness questions in Control Group before and after visualization

pA	pB	pA - pB	Z-ratio
I would feel safe if an earthquake happened while I was on the USC Campus			
0.7143	0.746	-0.0317	0.401
I would feel safe if an earthquake happened while I was in my place of residence			
0.4478	0.5238	-0.076	0.867
I feel prepared for an earthquake			
0.371	0.5645	-0.1935	2.16
I know where to go on campus in the event of an earthquake or emergency			
0.2836	0.8065	-0.5229	5.949
I know where to find emergency supplies on the USC Campus			
0.0746	0.8065	-0.7318	8.397

Table 21: Calculations for Risk Awareness and Preparedness questions in Experimental Group before and after visualization

pA	pB	pA - pB	Z-ratio
I would feel safe if an earthquake happened while I was on the USC Campus			
0.7969	0.7344	0.0625	0.835
I would feel safe if an earthquake happened while I was in my place of residence			
0.4143	0.4545	-0.0403	0.473
I feel prepared for an earthquake			
0.3438	0.4531	-0.1094	1.264
I know where to go on campus in the event of an earthquake or emergency			
0.2286	0.5938	-0.3652	4.305
I know where to find emergency supplies on the USC Campus			
0.2286	0.5938	-0.3652	4.305

The third test compared the difference between the control and experimental responses before each visualization. In this case, pA and pB measurements represent the ratio between the Agree and Strongly Agree responses before the visualization in the control and experiment groups, respectively. The results of this calculation can be seen in Table 22. In this case, only the question about location emergency supplies on campus demonstrated a z-ratio that indicated it was unlikely to be the result of random chance.

Table 22: Calculations for Risk Awareness and Preparedness questions before visualization in Control and Experimental Groups

pA	pB	pA - pB	Z-ratio
I would feel safe if an earthquake happened while I was on the USC Campus			
0.7143	0.6406	0.0737	0.888
I would feel safe if an earthquake happened while I was in my place of residence			
0.4478	0.4143	0.0335	0.396
I feel prepared for an earthquake			
0.371	0.3438	0.0272	0.319
I know where to go on campus in the event of an earthquake or emergency			
0.2836	0.2286	0.055	0.738
I know where to find emergency supplies on the USC Campus			
0.0746	0.2286	-0.1539	2.500

The final test involves the control and experimental responses after each visualization. In this case, pA and pB measurements represent the ratio between the Agree and Strongly Agree responses after the visualization in the control and experimental groups, respectively. The results of this calculation can be seen in Table 23. In this test, questions regarding the location of emergency supplies and assembly areas proved to be significant and unlikely to be the result of random chance. Again, the control group demonstrated a greater difference in after viewing the visualization than the experimental group.

Table 23: Calculations for Risk Awareness and Preparedness questions after visualization in Control and Experimental Groups

pA	pB	pA - pB	Z-ratio
I would feel safe if an earthquake happened while I was on the USC Campus			
0.746	0.7344	0.0117	0.150
I would feel safe if an earthquake happened while I was in my place of residence			
0.5238	0.4545	0.0693	0.787
I feel prepared for an earthquake			
0.5645	0.4531	0.1114	1.250
I know where to go on campus in the event of an earthquake or emergency			
0.8065	0.5938	0.2127	2.601
I know where to find emergency supplies on the USC Campus			
0.8065	0.5938	0.2127	2.601

Chapter 5: Conclusions

The objectives of this thesis were to create a web-based mapping application to communicate information about earthquake preparedness for the the USC community and to evaluate the application's impact. Both objectives were achieved in the process of this project and the following chapter draws some conclusions based on the survey evaluation and provides some suggestions for future work for the project. Section 5.1 recaps the major findings from the survey results presented in Chapter 4. Section 5.2 describes future improvements that could be made to the USC Earthquake application and to the survey process to support further evaluation. Section 5.3 discusses next steps for the project.

5.1 Major Findings

The goal of the application was to increase risk awareness and encourage preparedness in USC students. Additionally, the application was intended to reduce confusion regarding the location of emergency supplies and assembly areas on the USC campus. The overall results of the survey demonstrated that the application did have an impact on risk awareness and sense of preparedness. Additionally, the survey results found that the majority of participants found both the stationary map visualization and the interactive visualization to be helpful.

For both risk awareness questions, the control group showed an overall increase in the Agree and Strongly Agree categories as well as an overall decrease in the Undecided, Disagree, and Strongly Disagree categories, which is the desired result. The experimental group also showed an increase in the Agree and Strongly Agree categories for both questions. However, for one question, the experimental group showed an increase in the Strongly Disagree category. Overall, while the differences between the two groups were not significant, both visualizations proved to demonstrate positive results. This shows that different types of map visualizations can be used to help individuals feel safe and prepared in the event of an emergency.

For each question in the preparedness section of the survey, both the control and the experimental group showed an increase in the Agree and Strongly Agree categories as well as a decrease in the Disagree and Strongly Disagree categories, which was the desired result. However, in this section the control group showed greater increases as well as larger decreases. On the surface these results show that the stationary map visualization may have been more effective at communicating the information than the application constructed for this study, but it is important to examine the statistical significance of these results before making a determination.

Upon examination of the statistical analysis of the results, both the control and the experimental groups showed a significant increase in Agree and Strongly Agree responses after viewing the visualization for all preparedness questions, but not for risk awareness questions. This demonstrates that both the stationary and interactive visualizations created a significant increase in preparedness awareness, but not necessarily in risk awareness. When comparing the before results between the control and experimental groups, initial results were relatively similar. No question showed a significant difference in term of the results except the question about location emergency supplies, which showed that the experimental group had a greater occurrence of Agree and Strongly Agree before the visualization. Finally, in comparing the results after the visualization between the control and experimental groups demonstrated that the control group showed significant increases for the questions about emergency supplies and assembly areas, but the control group demonstrated a greater significance.

The final section of the survey was meant to give the respondents an opportunity to assess the application themselves. In the case of both the control and the experimental groups, the majority of respondents found each visualization to be helpful by marking Agree or Strongly Agree. This result demonstrates that the application was successful overall in improving awareness and preparedness cognition. The percentage of respondents marking Agree or Strongly Agree was higher in the control group by about 20%. This result would suggest that the survey respondents found the stationary visualization to be more helpful than the interactive visualization.

Overall, it appears that both visualizations had a positive impact. However, according to the statistical tests the impact of the stationary visualization was greater than that of the interactive visualization. It is possible that participants preferred the stationary position because a static map is simpler and easier to understand. The interactive visualization was more complicated and required more user activity that simply observing a stationary map. This result was consistent with a study previously discussed in this thesis, Anderson 2015. Ultimately, this study found that the stationary visualization was more effective at communication preparedness information and that the stationary visualization is preferred by participants.

5.2 Future Work

While the major goals of this project were achieved there are future improvements that could be implemented for both the application itself and the survey process. These changes could improve the use of the application for the USC community as well as create a stronger evaluation of the final application.

The final question in the survey allowed respondents to give suggestions about how the USC Earthquake Application could be made more helpful. Some of these suggestions involved the application's map surface. Many suggested that the buildings should be labeled by either their name or their building code or both. One respondent suggested that the map have a pop-up feature with a photo of the building so that the location would be easier to find. Other suggestions discussed the clarity of the map and the symbology, including that there should be a list of the assembly areas because there are only a few of them on the map. A few respondents felt that the application itself and the symbols used for it needed more clarification. The application included in the survey did include a splash screen upon loading, but this could provide a greater explanation of each widget. Finally, one participant suggested the addition of an option to change the language preferences on the application to improve access for non-native English speakers. These suggestions are all changes that may be included in future iterations of the USC Earthquake application.

Additionally, it would be useful to include a routing functionality to the USC Earthquake Application to allow students to find a walking path from their location to the nearest emergency supplies or assembly areas. This could be achieved by creating a network routing service in ArcMap and sharing it to ArcGIS Online. This network would need to be able to consider walking paths throughout the USC campus. Another helpful function would be incorporating the ability for the USC Department of Fire Safety and Emergency Management to add locations, such as water and power stations that would be available to students in the event of a disaster. This would useful for marking restricted locations that are off-limits due to building damage following an earthquake event. These capabilities could be added to future iterations of the USC Earthquake Application.

Future improvements for the survey should include a larger group of participants in order to increase the accuracy of the results. In future surveys, there should be more students from many different schools, majors, and disciplines. A wider and more diverse pool of respondents would provide a more accurate representation of the application's overall success. Additionally, the purpose of the study needed to be made clearer to the participants at the beginning of the survey. Some participants were confused about how to complete the survey as well as how to view the visualizations. With these improvements, the survey could produce more accurate results about the impact of the application and the state of map visualization.

5.3 Next Steps

The next steps for this project include making this application available for all students that are a part of the USC community. The most effective way to accomplish this is to reach out to the USC Department of Fire Safety and Emergency Management. Given their responsibility for emergency management on campus, they may be able to use the application to educate students about the location of emergency supplies and assembly areas. This department could give students access to the application at new student orientation and could promote the application yearly during the week of the Southern California Earthquake Center ShakeOut drill, which is intended to promote earthquake awareness and safety. In addition, the USC Earthquake Application's functionality could potentially be added to the already existing Trojan Mobile Safety App so that it can be accessible to students at all times.

Additionally, this application and the methodology behind it could be shared with other universities. Communities that are vulnerable to earthquakes or other natural disasters may be able to use applications similar to this one that include their own unique data. This application could be used as a template to share information about earthquakes and other emergency risks and preparation in many different communities.

Finally, once improvements have been made to the web-based version of the application, the application could be adapted for a mobile platform. Mobile applications are more portable than a web-based platform. Adapting the application for mobile use will allow students to use the USC Earthquake Application from anywhere and at any time on campus and access vital information about emergency preparation.

References

Abbas, S H, R K Srivastava, and R P Tiwari. 2009. "GIS-based Disaster Management: A Case Study for Allahabad Sadar Sub-District (India)." *Management of Environmental Quality: An International Journal* 20 (1): 33-51.

American Red Cross. 2016. *Mobile Apps.* Accessed February 13, 2016. http://www.redcross.org/get-help/prepare-for-emergencies/mobile-apps.

Anderson, Benjamin. 2015. *Cartographic Approaches to the Visual Exploration of Violent Crime Patterns in Space and Time: A User Performance Based Comparison of Methods.* Master’s Thesis, Los Angeles: University of Southern California.

Bansal, Brijesh K, and Mithila Verma. 2012. "Education and Awareness: A Key to Earthquake Risk Reduction." *Journal Geological Society of India* 80: 451-454.

Bourque, Linda B, Rotrease Regan, Melissa M Kelley, Michele M Wood, Megumi Kano, and Dennis S Mileti. 2012. "An Examination of the Effect of Perceived Risk on Preparedness Behavior." *Environment and Behavior* 45 (5): 615-649.

Chatterjee, Moumita. 2014. *GIS Learning Tool for World's Largest Earthquakes and Their Causes.* Master's Thesis, San Diego: San Diego State University.

Cuse, Carlton, Andre Fabrizio, and Jeremy Passmore. 2015. *San Andreas.* Directed by Brad Peyton. Performed by Dwayne Johnson, Carla Gugino and Alexandra Daddario.

Earthquake County Alliance. 2016. *Northridge 20 Virtual Exhibit.* Accessed February 16, 2016. http://earthquakecountry.org/northridge/nearyou/.

Esri. 2015. *QuakeFeed.* Accessed February 13, 2016. http://quakefeed.net/.

FEMA (Federal Emergency Management Agency). 2015. *Mobile App.* May 21. Accessed February 13, 2016. http://www.fema.gov/mobile-app.

Field, Edward H, Ramon J Arrowsmith, Glenn P Biasi, Peter Bird, Timothy E Dawson, Karen R Felzer, David D Jackson, et al. 2014. "Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3)- The Time-Independent Model ." *Bulletin of the Seimological Society of American* 104 (3): 1122-1180.

Fu, Pinde, and Jiulin Sun. 2010. *Web GIS: Principles and Applications* . Redlands, CA: Esri.

Fumal, Thomas E, Silvio K Pezzopane, Ray J Weldon II, and David P Schwartz. 1993. "A 100-Year Average Recurrence Interval for the San Andreas Fault at Wrightwood, California." *Science* 259 (5092): 199.

Hillhouse, John W, Eric G Reichard, and Daniel J Ponti. 2006. *Probing the Los Angeles Basin-Insights Into Ground-Water Resources and Earthquake Hazards.* Fact Sheet, U.S. Geological Survey.

Karanci, A Nuray, Bahattin Aksit, and Gulay Dirik. 2005. "Impact of a Community Disaster Awareness Training Program in Turkey: Does It Influence Hazard-Related Cognitions and Preparedness Behaviors." *Social Behavior and Personality* 33 (3): 243-258.

Lewis, Judith. 2008. *The L.A. Earthquake Sourcebook.* Edited by Gloria Gerace and Alex Carswell. Los Angeles: Designmatters.

Los Angeles County. 2014. *Countywide Building Outlines.* Accessed January 30, 2016. https://egis3.lacounty.gov/dataportal/2014/10/16/countywide-building-outlines-2014/.

Los Angeles County Department of Public Works. 2015. *Disaster Routes: Los Angeles Couty Operational Area.* Accessed February 20, 2015. https://dpw.lacounty.gov/dsg/DisasterRoutes/.

Los Angeles County GIS Data Portal. 2015. *GIS Data for LA County.* Accessed October 17, 2015. http://egis3.lacounty.gov/dataportal/

Lowry, Richard. 2016. *Vassar Statistics.* Accessed July 18, 2016. http://vassarstats.net/propdiff_ind.html.

Lynch, David K. 2006. *The San Andreas Fault.* Accessed March 29, 2016. http://geology.com/articles/san-andreas-fault.shtml.

Moffett, Brittany. 2015. *Data Visualization Techniques for an Interactive Seismicity and Building Response Map Application.* Master's Thesis, Los Angeles: University of Southern California.

SCEC (Southern California Earthquake Center). 2011. *Putting Down Roots in Earthquake Country.* Publication, Los Angeles: University of Southern California.

SCEC (Southern California Earthquake Center). 2016. *Great ShakeOut Earthquake Drills.* Accessed February 16, 2016. http://www.shakeout.org/.

Shaw, Rajib, Koichi Shiwaku, Hirohide Kobayashi, and Masami Kobayashi. 2004. "Linking Experience, Education, Perception, and Earthquake Preparedness." *Disaster Prevention and Management* 13 (1): 39-49.

Simpson, David M. 2008. "Disaster Preparedness Measures: A Test Case Development and Application." *Disaster Prevention and Management* 17 (5): 645-661.

StrataSearch. 2015. *Avarin Systems Inc.* Accessed July 18, 2016. http://www.stratasearch.com/col_c_zratio.html.

Tekeli-Yesil, Sidika, Necati Dedeoglu, Charlotte Braun-Fahrlaender, and Marcel Tanner. 2011. "Earthquake Awareness and Perception of Risk Among the Residents of Istanbul." *Nat Hazards* 59: 427-446.

UC Berkeley Seismological Laboratory. 2016. *My Quake.* Accessed February 13, 2016. http://seismo.berkeley.edu/myquake/.

University of Southern California. 2015. *Facts and Figures.* Accessed March 29, 2016. http://about.usc.edu/facts/.

University of Southern California Department of Public Safety. 2015. *Department of Public Safety.* Accessed October 17, 2015. https://dps.usc.edu/

University of Southern California Administrative Operations. 2015. *Department of Emergency Management and Fire Safety.* Accessed October 17, 2015. http://adminopsnet.usc.edu/department/fire-safety-and-emergency-planning/building-emergency-information.

URISA (Urban and Regional Information Systems Association). 2015. *Workshops & Training Courses* . Accessed February 13, 2016. http://www.urisa.org/education-events/workshops-training-courses/.

U.S. News & World Report. 2016. *National Universities Rankings.* Accessed March 29, 2016. http://colleges.usnews.rankingsandreviews.com/best-colleges/rankings/national-universities/page+3.

U.S. Census Bureau. 2015. *QuickFacts: Los Angeles City, California.* Accessed March 29, 2016. http://www.census.gov/quickfacts/map/PST045214/0644000.

U.S. Geological Survey. 2012. *The Great 1906 San Francisco Earthquake* . July 23. Accessed March 29, 2016. http://earthquake.usgs.gov/regional/nca/1906/18april/index.php.

U.S. Geological Survey. 2016. *Feeds & Notifications.* Accessed August 11, 2016. http://earthquake.usgs.gov/earthquakes/feed/v1.0/

WGCEP (Working Group on California Earthquake Probabilities). 2015. *A New Earthquake Forecast for California's Complex Fault System.* Fact Sheet, Pasadena: U.S. Geological Survey.