Tele-work as Mitigation of Natural Disasters for Continuity Planning

Nan Carstens
Department of Resource Analysis, Saint Mary's University of Minnesota, Minneapolis, MN USA 55404

Keywords: GIS, Telework, Tele-work, Natural Disasters, Mitigation, Inoperability, Planning, Wildfires, Earthquakes, Floods, Business Continuity Planning, San Diego County, California USA, FEMA, Emergency Management, ArcGIS, ESRI, Spatial Analyst, Risk Assessment

Abstract

Damaging natural disasters cause major disruptions to critical infrastructure, telecommunications, transportation, emergency services, and businesses. Many companies have disaster plans, but do they know how to prepare for one? This project details steps for using Geographic Information Systems (GIS) to determine natural disaster risk areas where tele-work could be used as a mitigation strategy for a company's continuity plan. This project develops a scenario for an anonymous company located in San Diego County California and maps natural disaster risk areas to learn disaster potential on business logistics. A backup site and tele-workers were identified to determine their ability to keep the company operational during and after a natural disaster. The results of this study show which areas in the county are at higher risk of experiencing a natural disaster. Businesses can use information such as this to determine if they need to consider a secondary work site and to identify which employees could work from home.

Introduction

Over the last decade, the cost of natural disasters to the United States has risen considerably. According to the U.S. Department of Health and Human Services (USDHHS), from 1989 to 1993 the average annual losses from disasters were $3.3 billion. This was due in part to the greater development in vulnerable locations, a place where people live or work that is more prone to natural disasters. Natural disasters are defined by USDHHS as "naturally occurring events, which can directly or indirectly cause severe threats to public health and/or well-being." They can pose an ever-present threat, which can only be dealt with through mitigation planning (U.S. Department of Health and Human Services, 2010). The nation will always be vulnerable to natural disasters; it is only sensible to invest in mitigation plans limiting damage and promoting diminished losses from such things as disruption of utilities, transportation lifelines, businesses telecommunications, and emergency services (Multihazard Mitigation Council, 2005). San Diego County, California is known for its many types of natural disasters. Many companies face this reality every day. How do they keep their business operating and their employees working during and after a natural disaster? As companies prepare for natural disasters, they may look at different solutions such as alternative work sites. Tele-work may be a

Carstens, Nan. 2010. Tele-Work for Continuity Planning for Natural Disasters. Volume 12, Papers in Resource Analysis. 15 pp. Saint Mary's University of Minnesota University Central Services Press. Winona, MN USA Retrieved (date) http://www.gis.smumn.edu

possible solution if it is included in the business' mitigation continuity plans and is done in advance. According to the Department of Communications (2005), tele-work is a flexible working place that allows work to be done at a location other than the central worksite. Disaster mitigation is defined as continuous improvements taken to decrease or remove the danger to people and property before natural disasters (Federal Emergency Management Agency, (FEMA), 1996). Continuity planning is a complete written preparation plan to maintain or carry on business in the occasion of a disruption (Federal Financial Institutions Examination Council, 2008).

Using GIS to map and analyze an area's natural disaster risk, companies can see how areas have been affected in the past as part of their planning process. GIS is defined as a great set of tools for collecting, storing, retrieving, altering and displaying spatial data (Environmental Science Research Institute (ESRI), 2005). This information could be very useful for a company to determine which workers could work remotely and where to locate a backup site if the main facility is in a high-risk area. Risk is the possibility or chance of a disaster to happen (Johnson, 2000). An area's risk level is determined by how often disasters occur, their severity, and the nature of the disaster of the event.

As a result of mapping disasters and their risk levels, companies, cities, county, and state offices might be able to determine if they are in a high-risk region and where employees live in relationship to the natural disaster areas. With this information, they might then strategically deploy tele-workers who are outside of the high-risk areas. A company needs to also find a location for a backup site that is in a low risk area.

Mitigation Continuity Planning

To reduce the impacts of natural disasters, a strategic mitigation continuity plan is essential (Van Westen, 2000). Mitigation planning process should include identifying disasters, creating maps to locate disasters and their geographic area, placing a value to structures and landmarks in the areas, assessing vulnerability, and analyzing development trends and population growth to determine potential threats (URS Project, 2004).

Mitigation continuity planning is a cost-effective method to reduce or prevent losses, especially when it is integrated into the way a company operates. Actions that have shown to be cost effective include selecting property in a less vulnerable risk zone, building stronger facilities, reinforcing building components that can fall or break during an event, strengthening support systems, elevating buildings or critical equipment above flood levels, and have a backup site out of high-risk areas (FEMA, 1998).

Business interruption is often attributable to factors originating outside the company's property such as lifeline failures. This demonstrates companies need to be concerned about risk factors throughout their community as well as mitigation of their own facilities (FEMA, 1996). Companies can prevent some of the effects of lost of business, lost employee production, and lost supplies if they perform a risk assessment. This requires the collection and analysis of natural disaster information in order to identify and prioritize mitigation actions. Knowing what natural disaster risk zone a business is located in as well as the other high-risk areas nearby can help a company to plan their mitigation continuity plans accordingly.

Tele-work as a Mitigation Strategy

Tele-work can improve the environment; it can cut down on road congestion, energy demand and business efficiencies. It can improve economic opportunities for regional industry, work/life balance for workers and other major community problems while creating economic rewards for the company (Sanger, 2009; Department of Communications, 2005). If tele-workers are set up before a disaster occurs, a business can also decrease or avoid inoperability during and after a disaster.

Before a natural disaster occurs, connectivity needs to be in place to allow workers to continue to work (Aalst and Burton, 2002). Connectivity requires having available communications through an internet service provider or direct dial phone line as well as the needed equipment at both ends to establish and maintain communications. In light of a disaster, every company should be prepared with a backup location such as satellite offices, available space in another facility, or various locations where employees can carry out essential functions (Sanger, 2009; Department of Communications, 2005).

Geographic Information Systems (GIS)

GIS assessment of disasters and risk factors in mitigation planning and its use is one of the best ways to protect a company from the natural disasters (Van Westen, 2000). To prepare for natural disasters, all divisions of a company should share information through a single database. Without this capability, planners have to gain access to a number of departments and get their maps and data. In most disasters, there is not enough time to gather these resources. This results in having to guess, estimate, or make decisions without adequate information. This costs time, money, and in some cases lives. GIS provides a mechanism to centralize and visually display critical information during an emergency (Johnson, 2000). Using GIS for disaster mapping and data analysis also contribute to proper mitigation planning for companies (Morrow, 1999).

San Diego County

San Diego County, California USA was chosen because of it geographic location, climatic variations, and its many natural disasters. The county stretches 65 miles from north to south and 86 miles from east to west. It covers 4,261 square miles. Elevation ranges from sea level to about 6,500 feet. The county's total population in 2000 was approximately 2.8 million with a median age of 33 years (U.S. Census Bureau, 2000).

Three natural disasters have been chosen for this study: earthquakes, floods, and wildfires. Each of these disasters affects different parts of the county but there are overlapping areas as well.

Earthquakes

An earthquake is an unpredicted movement of the earth’s surface that is caused by a discharge of power within the Earth’s crust or along the edge of the tectonic plates that creates seismic waves (URS Project, 2004). The county has many active fault zones that pass through the county making earthquakes a big risk.

Approximately 2,813,000 people and 8,322 commercial buildings with a potential exposure of $37,297,326 are at risk from the annualized earthquake and earthquake-induced liquefaction (Table 1).

Floods

FEMA defines flood risk by a 100-year flood zone which is a 1% chance of flooding in any given year. Any area that lies within the 100-year floodplain is identified as high risk. Any area found in the 500-year floodplain is identified as low risk (FEMA, 1998).

Approximately 134,000 people and 782 commercial buildings with a potential exposure of $3,419,080 are at risk from the 100-year flood (Table 2) and another 215,000 people and 1,212 commercial buildings, with a potential exposure of $570,012 are at risk in the 500-year flood zones (Table 3).

Wildfires

A wildfire is an uncontrolled fire spreading through different types of foliage and destroying structures (FEMA, 1998). San Diego County's topography consists of semi-arid coastal plain and rolling highlands. When fueled by shrub overgrowth, occasional Santa Ana winds, and high temperatures, wildland fire is a serious threat.

Approximately 2,685,000 people and 7,867 commercial buildings with a potential exposure of $35,255,020 are at risk from wildfires in San Diego County (Table 4).

Project

Mitigation planning plays a crucial role in the aftermath of a regional crisis. The effect of planning can have a huge benefit to a company. A need for developing mitigation continuity plans for a company in advance is important. If the company plans to be operational during and after a disaster, it needs to have a disaster plan in place. This project uses GIS to create a model showing natural disasters risk areas for San Diego County. Using this model

Table 1. Potential exposure and losses due to annualized earthquake events from 100-year and 500-year earthquakes estimation for the county (URS Project, 2004).

Potential Exposure and Losses from Annualized Earthquake Disaster County						
		Residential Buildings at Risk				
	Exposed Population	Building Count	Potential Exposure	Potential Loss Shaking	Potential Loss Liquefaction	Potential Loss Landslide
Total	2,813,739	757,137	$213,168,040	$67,943	$3,050	$16,126

Commercial Buildings at Risk				
Buildings	Potential Exposure	Potential Loss Shaking	Potential Loss Liquefaction	Potential Loss Landslide
8,322	$37,297,326	$21,860	$832	$7,202

Table 2. Summary of 100-year flood zone impact for disaster estimation exposure and losses for the county (URS Project, 2004).

Potential Exposure and Losses from 100 Year Flood Disaster County					
		Residential Buildings at Risk			
	Exposed Population	Building Count	Potential Exposure	Potential Loss	Loss Ratio
Total	134,567	36,525	$10,131,667	$946,011	2.36

Commercial Buildings at Risk			
Buildings	Potential Exposure	Potential Loss	Loss Ratio
782	$3,419,080	$355,852	245.12

Table 3. Summary of 500-year flood zone impact for disaster estimation exposure and losses for the county (URS Project, 2004).

Potential Exposure and Losses from 500 Year Flood Disaster County					
	Exposed Population	Residential Buildings at Risk			
		Building Count	Potential Exposure	Potential Loss	Loss Ratio
Total	215,103	57,004	$15,819,713	$1,527,875	2.34
Commercial Buildings at Risk					
Buildings	Potential Exposure	Potential Loss	Loss Ratio		
1,212	$570,012	$5,344,920	2.44		

Table 4. Summary of wildfire disaster estimation exposures for the county (URS Project, 2004).

Potential Exposure from Wildfire (Moderate, High, Very High Combined) Disaster County					
	Exposed Population	Residential Buildings at Risk		Commercial Buildings at Risk	
		Building Count	Potential Exposure	Building Count	Potential Exposure
Total	2,685,417	717,391	$201,924,328	7,867	$35,255,020

a company can identify the level of risk their facility, backup site, and tele-workers incur. A scenario for a company, its backup facility, and tele-workers will be placed in the risk model to determine which tele-workers might provide the greatest disaster mitigation continuity planning.

Methods

Software Requirements

The software used to perform the tasks for this study on the natural disasters in San Diego County were Environmental Systems Research Institute’s (ESRI) (2010) ArcGIS 10, Microsoft Access, and Microsoft Excel.

Data Acquisition

Historical data for earthquakes, wildfires, and floods were obtained from FEMA, First American Proxix Solutions, the United States Geological Survey (USGS), the State of California, and the San Diego County web-site. Data files were obtained as shapefiles.

Shapefiles were used to display natural disasters according to their risk value. The population shapefile layer for 2003 was used to illustrate the population of each Metropolitan Statistical Areas (MSA) within the county as outlined as black polygons on figures in this paper. The MSA is a geographical region with a relatively high population density at its core and has close economic ties throughout the area (U.S. Bureau of Labor Statistics, 2010).

Historical data on natural disasters were imported into Microsoft Access where queries were created for the Earthquakes, Floods, and Wildfire history. Excel tables were developed to illustrate the past 100 years of the three natural disasters with the number of natural disaster and costs, if any, for that particle disaster. Totals were figured for these disasters and the associated costs for the destruction for the past 100 years.

The company’s facility, backup site, and tele-workers were point shapefiles created for risk modeling. Flood zones, urban, and rural zoning were polygon shapefiles obtained from and San Diego County web site.

First American-Proxix Solutions, a provider of a broad range of insurance and financial services to the public and private sectors provided an Earthquake Risk Layer shapefile risk model utilizing Peak Ground Acceleration (PGA), soil liquefaction, soil type, depth to water table, geologic ear, and particle size to determine the overall earthquake risk ranging from none to extreme risk. The PGA earthquake probability data were derived from the 2008 National Seismic Hazard data provided by the USGS. The shapefile was provided in an unprojected coordinate system in the WGS 84 datum. This data provided a countywide risk factor ranging from one to four with four being the highest risk. This layer incorporated the most current earthquake science and data available to produce a probabilistic risk model. The layer is intended to serve as an indicator of the potential for structural damage to occur in the event of seismic activity (First American Proxix Solutions, 2009a).

Proxix's Brushfire Risk Database model that scores relative brushfire risk was also used. This model combines four factors: vegetation, slope, aspect, and composition class to score relative brushfire risk. Each of these elements is evaluated for its individual fire risk and assigned a risk factor. The individual risk factors were then weighted and combined to determine an overall brushfire risk. Digital Elevation Model (DEM) data and Satellite Imagery consisted of 30-meter cells. The combined and weighted layer file was kept in raster format to produce the final brushfire risk polygons (First American Proxix Solutions, 2009b).

Both models (earthquakes and wildfires) use historical event data to predict the likelihood of future events. In the case of the brushfire model, an area that has burned recently would have a low level of fuel and as a result would have a much lower chance of burning again. Neither model gives frequency numbers since it is impossible to accurately predict when an event might occur. Instead, each focuses on relative risk of a location.

Analysis Procedure

The three shapefiles of earthquakes (Figure 1), floods (Figure 2), and wildfires (Figure 3) were created for a visual comparison of the disasters by risk value. The three disasters provide a base to compare with the Total Risk Model.

A table was created in Microsoft Excel to illustrate the number of earthquakes, floods, and wildfires (Table 5) for San Diego County per decade over the past 100 years. Destruction costs were included when available. Totals were calculated for the number of disasters and destruction cost. This data helps to build a base of understanding of past disasters so that one might explore for the possibility of patterns of destruction.

Next shapefiles were converted into rasters based on their risk values. Map algebra was used to compute the sum of the squares of the individual risk values into a total risk raster:

TR = Total Risk
EQ = Earthquake Risk
FLOOD = Flood Risk
FIRE = Fire Risk
TR =EQ^2 +FLOOD^2 + FIRE^2

The values of each cell were squared to more heavily weight high-risk areas to more accurately portray the risk. The three squared values where then added together to produce a total risk value. As an example, a straight sum could have factors of:

1 + 1 + 4 = 6 and 2 + 2 + 2 = 6.

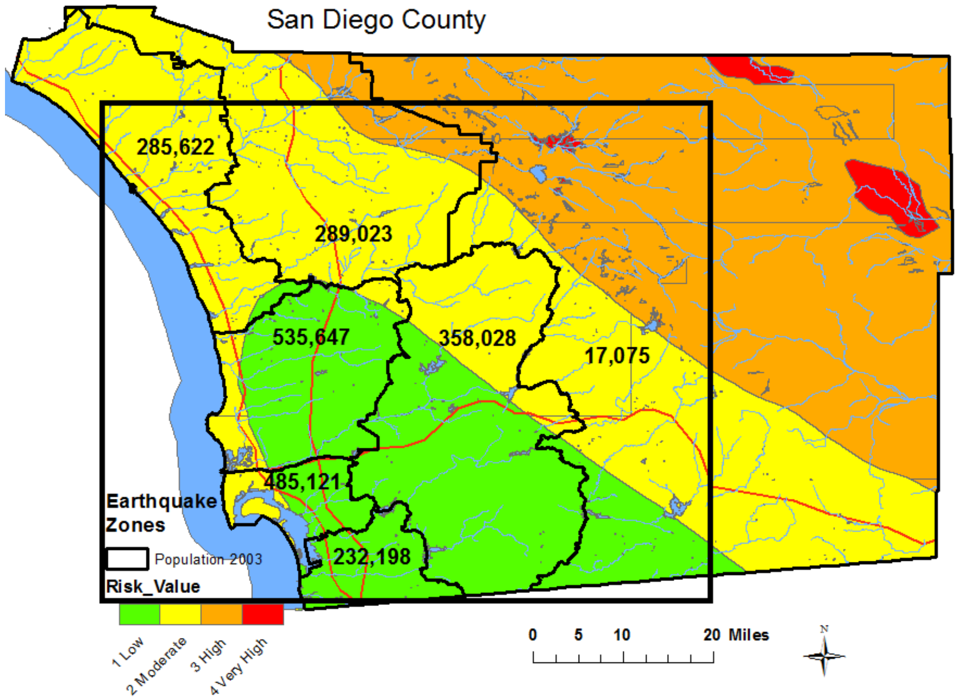

Figure 1. Map illustrating earthquakes risk zone using black lines to enclose 2003 population for each MSA in the county. The risk values for earthquakes are low (green/1) - light shaking with little damage, moderate (yellow/2) - strong shaking with moderate damage, high (orange/3) - severe shaking with heavy damage, and very high (red/4) violent shaking with very heavy damage. The area in the rectangle is the location of the study area.

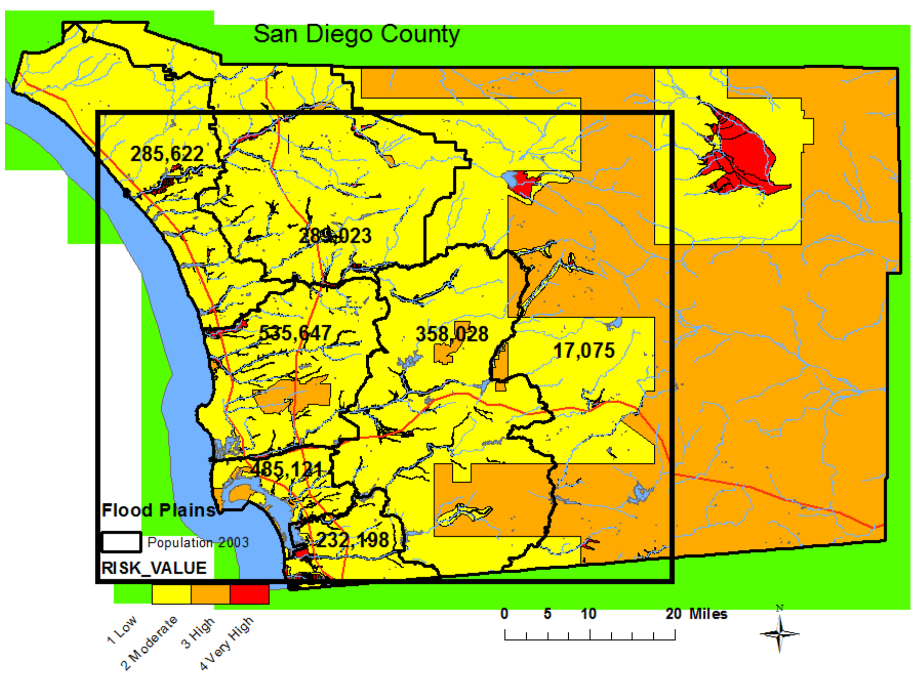

Figure 2. Map illustrating flood zones using black lines to enclose 2003 population for each MSA in the county. The risk values for flood s are low (green/1) –areas inundated by 500-year flooding; moderate (yellow/2) - identifies areas inundated by 500-year flooding; high (orange/3) –areas inundated by 100-year flooding, and very high (red/4) – areas inundated by 100-year flood with velocity hazard. The area in the rectangle is the location of the study area.

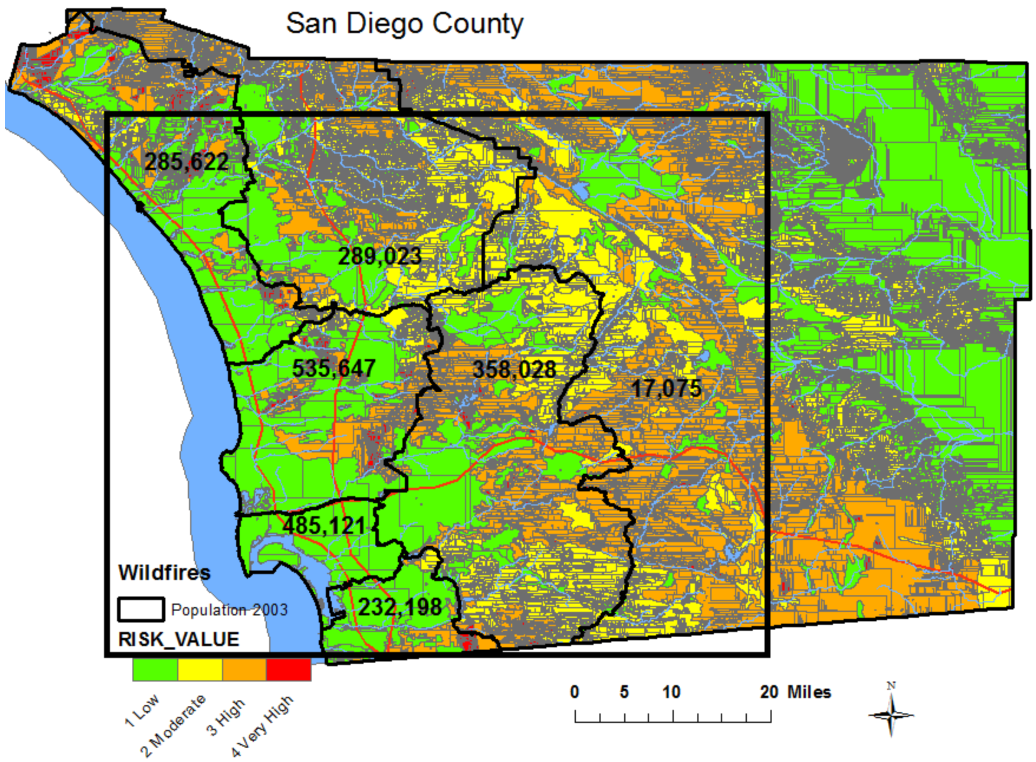

Figure 3. Map illustrating wildfires using black lines to enclose 2003 population for each MSA in the county. The risk values for wildfires are low (green/1) – urban or agriculture, low density; moderate (yellow/2) – moderate density; high (orange/3) – high density: very high (red/4) – very high density. The area in the rectangle is the location of the study area.

Table 5. Table illustrating earthquake, flood, and wildfire history of number in a decade and destruction costs for the last 100 years (URS Project, 2004).

Decade	Number of Earthquakes	Cost of Earthquakes	Number of Floods	Cost of Floods	Number of Fires	Cost of Fires
1910	2	N/A	1	$4,500,000	120	N/A
1920	3	N/A	1	$117,000	87	N/A
1930	1	N/A	2	$600,000	79	N/A
1940	1	N/A	0	N/A	144	N/A
1950	3	N/A	0	N/A	152	N/A
1960	2	N/A	2	N/A	73	N/A
1970	2	N/A	3	$2,766,268	190	$688,820
1980	0	N/A	2	$120,640,500	250	$5,363,200
1990	3	N/A	2	$10,000,000	141	$14,313,101
2000	1	N/A	1	N/A	137	$71,796,385
Totals	18	N/A	14	$138,623,768	1373	$92,161,506

These appear equal but the total risk is greater in the first area since it includes a high risk zone (4) while the second only has areas of moderate risks. Using the squares, the values become:

1 + 1 + 16 = 18 and 4 +4 + 4 = 12

This model more accurately portrays the total risk. The total Risk map of the three natural disasters is shown in Figure 4.

In this study, data were imported into a Microsoft Excel spreadsheet. A histogram was made for the raster by total risk value to illustrate the distribution of risk values ranging from 3-41 (Figure 5).

The next step of the process was to select a company. The anonymous company has 1,800 employees and is located in an area with 535,647 residents. Based on 4.4% tele-worker rate for the region (Omnibus, 2003), 76 employees were randomly plotted in residential areas based on average commuting distance (Omnibus, 2003). The pink dots on Figure 6 indicate the locations where employees might live. A buffer zone of 15 miles was created around the company to show the average distance a person drives one way to work (Omnibus, 2003). A backup site for the company was added to the map.

Population and tele-worker locations were exported to text files and imported into Microsoft Excel. Excel was used to calculate statistical information. A histogram was made for the tele-workers in the study area by the risk value where they live (Figure 7).

Results

The history data from San Diego County (Table 5) provides insight to what has happened in the past. In the last 100 years, there have been 18 earthquakes, 1373

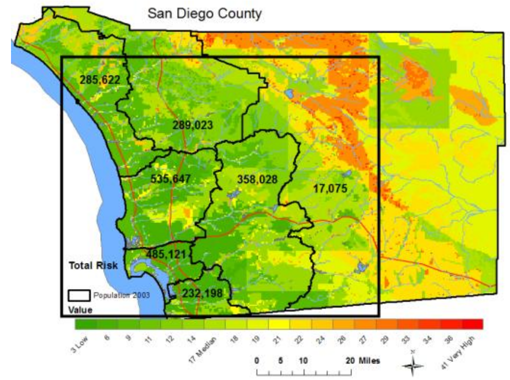

Figure 4. Map illustrating the Total Risk Model results using black lines to enclose 2003 population for each MSA in the county. Risk values from 3 (green/low risk) – 41 (red/very high risk). The area in the rectangle is the location of the study area.

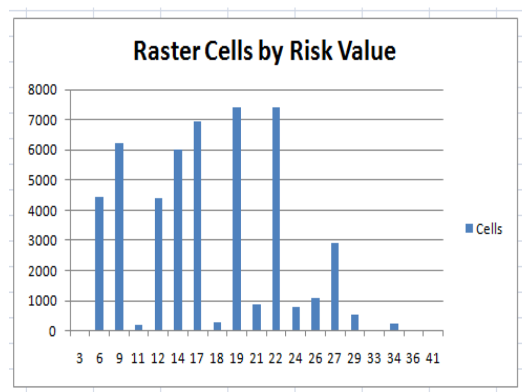

Figure 5. Histogram of raster cells by total risk values.

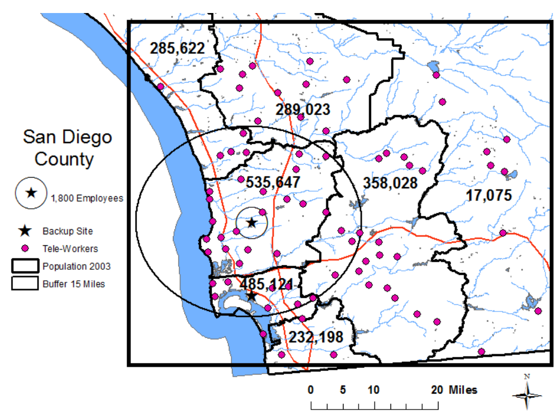

Figure 6. Map illustrating San Diego County with the company (black star with a circle), backup site (black star), employees (pink dots), roads (red lines), lakes and rivers (blue). The large circle represents the 15 miles average driving distance. Black lines enclose 2003 population for each MSA in the county. The area in the rectangle is the location of the study area.

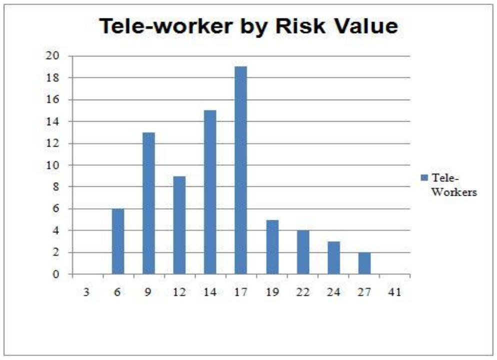

Figure 7. Histogram illustrating the number of tele-workers in the study area by where they live relation to risk value.

wildfires, and 14 floods totaling 1405 natural disasters in the county. Even though 98% of these events were wildfires and only 1% were floods, the total cost of of flooding was significantly greater, with flooding causing $138,623,768 in damage. Wildfires caused only $92,161,506 in damage. This can be attributed to flooding occurring quickly so there is not enough time to advert the disaster in and around heavily populated urban areas, whereas wildfires develop slower and in open rural areas where there are fewer buildings and infrastructures to rebuild. Costs were not available for earthquakes so additional research would need to be undertaken to achieve a full comparison across all three types of disasters.

Tables 6 and 7 illustrate commuting information: type of transportation, number of people, and the distance traveled. The mean travel time is

Table 6. Table illustrating how people get to and from work in San Diego County (U.S. Census, 2000).

Commuting To Work	Number	Percent
Drove Alone	960,065	73.9
Carpooled	169,340	13
Public Transportation	43,757	3.4
Worked at Home	57,182	4.4
Other	69,159	5.3
Mean Time to Work	25.3 (minutes)	

Table 7. Table illustrating household survey questions about how many miles people drive one-way to work. The average one-way travel distance is 15.3 miles (Omnibus, 2003).

Miles one-way	Results	Margin of Error	Population Estimates	Sample Size
1-5	29%	2.32	30.2	578
6-10	22%	2.06	22.3	431
11-15	17%	1.9	17.2	314
16-20	10%	1.42	10.1	205
21-25	7%	1.19	7	146
26-30	5%	1.1	5.1	96
31-35	3%	0.8	3.1	60
> 35	8%	1.34	7.9	148
Avg.	15.3	.8		

25.3 minutes and distance is 15.3 miles (U.S. Census, 2000 and Omnibus, 2003).

Figure 4 represents the total risk value of natural disasters. Values range from 3 (low/green) to 41 (high/red). The median is 17 which would be considered low to moderate (light green). The low risk areas are in the western side of the county and the highest risk are to the east. Mountains and forests are in the east and create a greater risk factor wildfires and earthquakes.

The statistical information calculated from the data gathered concluded that the mean risk value for the county was 16.44, with a standard deviation of 6.15 and standard error of 0.03.

Figure 8 displays the results of the total risk model (Figure 4) and the selected study area (Figure 6) combined to produce the total risk analysis model.

Mitigation - Tele-Work

A carefully targeted mitigation plan holds the promise of reducing the damage caused by natural disasters. While no amount of planning can eliminate business operation interruptions, it is important to consider all options when developing a

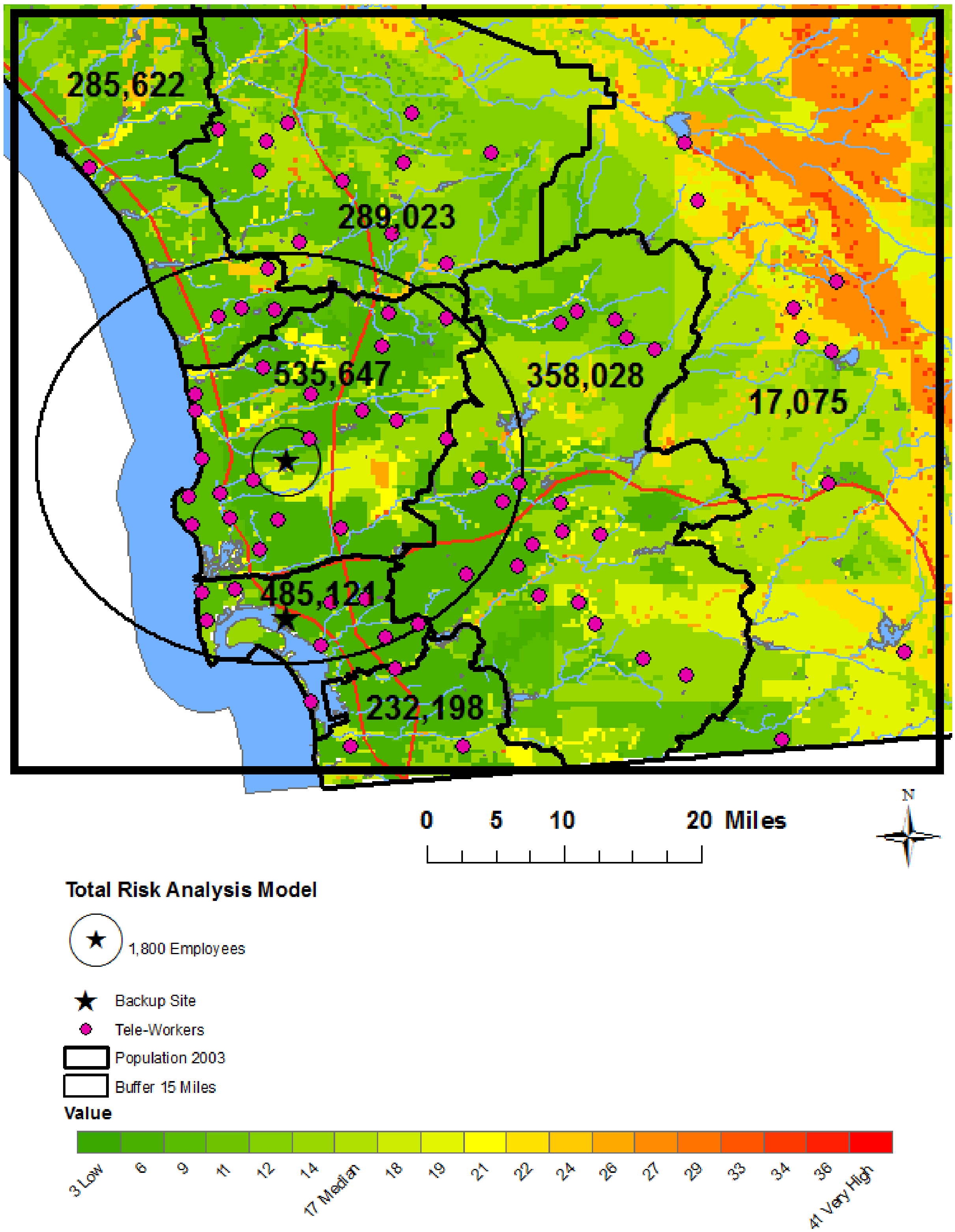

Figure 8. Total Risk Analysis Model illustrating the company (black star with a circle), backup site (black star), employees (pink dots), roads (red lines), lakes and rivers (blue). The large circle represents a 15 mile average distance driven. The black lines enclose 2003 populations for each MSA for the county. Risk values from 3 (green/low risk) – 41 (red/very high risk).

comprehensive mitigation plan. One such option that is becoming more attractive due to technical advancements is tele-work.

Developing mitigation strategies, preparing a backup site, and implementing a strategic tele-workers plan can provide flexibility in the event of a disaster. Many people are living farther away from their place of work than did 20 years ago. This is due in part to people moving away from concentrated employment centers. Travel time has increased from 19 minutes in 1980 to 24 minutes in 2000. Some of this increase is due to increased traffic congestion but it also represents growth in the suburbs (Sourcepoint, 2004). These results are confirmed in Tables 6 and 7.

The relocation of employees in relationship to their employer creates the advantage of employees being removed from the devastation should a natural disaster occur. A company needs to know where its employees are located as it starts to build a strategic deployment. Tele-work could be an essential component of a business mitigation plan. It could be a method to keep a company operating during and after a disaster and diminish the overall impact of the disaster's disruption to the company.

Total Risk Model

This model combines the individual risks of earthquakes, floods, and wildfires, as they pertain to San Diego County (Figure 8). Using the model, it is easy to identify what risk level a company may experience at its location. Employee locations were plotted to identify which, if any, tele-workers might remain unaffected in the event of a natural disaster as well as suitability of locations for a backup center. San Diego County currently has a low to moderate overall risk with a mean risk of 16.44 with a standard deviation of 6.16 giving a 95% confidence range from 10.28 to 22.6. While this is encouraging in the fact that there are few high-risk areas, it does not preclude any area from being natural disaster free.

The company modeled in this project is located in an area with a risk value of 21 composed of high risk of flooding (16), moderate risk of wildfire (4), and low risk of earthquake (1). The backup site is in an area with a risk value of 9 composed of a moderate risk of flooding (4), moderate risk of wildfires (4), and a low risk of earthquake (1). The backup site is located far enough away for the primary site to protect against a single disaster impacting both. These factors suggest the backup site is well suited for mitigating natural disasters.

Figure 7 illustrates the majority of tele-workers for the company living in areas in the range of a 3 to 17 risk levels. This is important in that the lowest score possible for an area with a very high risk is 18=1+1+16. The tele-workers have a mean risk of 14.5, with 88% residing in a lower risk area, 4% in the same risk area, and 6% in a higher risk area than the company. The employees are also scattered through the county, which helps protects against a single event from affecting the majority of employees at the same time.

Data Limitations

Due to the volume of data needed to be considered for the earthquake and wildfires models and the fact that generating data was beyond the scope of this study, the model has limitations and could be refined. Cost was not available for all years and if it were available, it could be useful to better identify the level of threats for San Diego County. The tele-worker deployment is a sampling of locations and is meant to show the effectiveness of each location as oppose to an actual employee. The company's name and address concealed to respect the privacy of the company.

Further Opportunities

In the case where a company feels the Total Risk Model does not represent their perceived vulnerabilities, the model can be modified to remove specific disasters or add additional ones. It is also important to use the most current data to ensure the most accurate model possible

This model could create an ethical dilemma if it is used as a new hire screening tool. Knowing a perspective employee lives in a high risk zone could be a determining factor and the person might not be hired even if they are qualified. More research about this topic could be very interesting.

Additional natural disaster data could be added as well as slope and elevation data. This would allow a company to customize the model to its unique situation to enhance the effectiveness of their mitigation continuity plan. Additional locations could be added to allow a larger scale to be considered. The model could also be developed into a web application that could allow the end user to select which disasters to consider.

Conclusions

Natural disasters are unavoidable; they cause enough disruptions that mitigation planning is vital to a company to continue operations. Mitigation often requires a structuring of incentives and relies on recognition of the risks of natural disasters and the development of new methods to reduce these risks. It should be done in advance of a disaster because there is insufficient time to implement a plan during a disaster.

With advancements in computers, broadband, and wireless communications it has become possible for more people to perform their daily jobs from remote locations. If a natural disaster cannot be prevented, perhaps employees being somewhere else can minimize the disaster's impact. Tele-work has the opportunity to reduce business outages when done strategically.

By using GIS for mapping natural disasters, the Total Risk Model can visually represent an area's risk. This information shows if the tele-work deployment can mitigate a natural disaster on a localized level. It also allows for the expansion of additional locations and natural disasters to more fully provide the information required to build a successful strategic tele-work deployment as a mitigation strategy for business continuity.

Acknowledgements

I have had the pleasure to work with many individuals throughout my masters program. First, I would like to thank my family for the support they have given me, because without them my goal would not have been achieved. Secondly, I would like to thank Mr. Ebert, Mr. Thorsell, and Dr. McConville of Saint Mary's University of Minnesota Department of Resource Analyses for their guidance and encouragement. Lastly, I would like to thank John Sanger, president of Tele-Commuter Resources for his help in the knowledge of tele-work and the data he was able to provide.

References

Aalst, M. and Burton, I. 2002. The Last Straw: Integrating Natural Disaster

Mitigation with Environmental Management. *Disaster Risk Management Working Paper No. 5*. The World Bank Washington DC. Retrieved February 11, 2010 from http://www.prevention consortium.org/themes/default/pdfs/last_straw.pdf.

Department of Communications. 2005. Telework for Employees and Businesses: Maximizing the Economic and Social Benefits of Flexible Working Practices. Information Technology and the Arts and the Department of Employment and Workplace Relations. *CONSULTATION PAPER for the Australian Telework Advisory Committee (ATAC).* Retrieved February 13, 2010 from http://www.archive.dcita.gov.au/__data/assets/pdf_file/0020/25247/ATAC_Paper_1.pdf.

Environmental Science Research Institute (ESRI). 2005. Geographical Information System for Natural Disaster Management. *ESRI Library,* Retrieved February 11, 2010 from http://proceedings.esri.com/library/userconf/educ05/papers/pap1033.pdf.

Environmental Science Research Institute (ESRI). 2010. ArcMap 10 (computer software). Redlands, CA.

Federal Emergency Management Agency. December 1996. Report on: Costs and Benefits of Natural Hazards Mitigation. Retrieved November 3, 2010 from http://www.femagov/pdf/library/haz_cost.pdf.

Federal Emergency Management Agency. 1998. Protecting Business Operations: The Second Report on the Costs and Benefits of Natural Hazard Mitigation. Retrieved November 3, 2010 from http://www.fema.gov/pdf/library/haz_pbo.pdf.

Federal Financial Institutions Examination Council. 2008. Business Continuity Planning. Retrieved November 5, 2010 from http://www.ffiec.gov/ffiecinfobase/booklets/bcp/bus_continuity_plan.pdf.

First American Proxix Solutions. 2009a. Earthquake Risk Layer. Retrieved January 19, 2010 from ftp://ftp.proxixnetwork.com.

First American Proxix Solutions. 2009b. Brushfire Risk Database. Retrieved January 19, 2010 from ftp://ftp.proxixnetwork.com.

Johnson, R. May 2000. GIS Technology for Disasters and Emergency Management. *An ESRI White Paper* Retrieved November 3, 2010. www.esri.com.

Morrow, B. 1999. Identifying and Mapping Community Vulnerability. *Disasters*, *23*(1), pp. 1–18. Retrieved February 11, 2010 from http://web.ebscohost.com.xxproxy.smumn.edu/ehost/pdfviewer/pdfviewer?vid=4&hid=22&sid=488b5f83-caf8-42ea-bc51-7fe244080387%40 sessionmgr4.

Multihazard Mitigation Council. 2005. Natural Hazard Mitigation Saves: An Independent Study to Address the Future Savings from Mitigation Activities. *Washington, DC: National Institute of Building Sciences.* Volume 1 – Findings, Conclusions, and Recommendations. Retrieved February 9, 2010 from http://www. nibs.org/ MMC/mmcactiv5.html.

Omnibus. 2003. From Home to Work, the Average Commute is 26.4 Minutes. 3(4). Retrieved October 31,2010 from http://www.bts.gov/publications/omnistats/volume_03_issue_04/pdf/entire.pdf.Sandag/.

Sanger, J. 2009. Integrating Telework and Emergency Management. Tele-Commuter Resources, Inc. Retrieved January 13, 2010 from http://www.telecommuter.org/documents/*Integrating* Telework and Emergency Management.pdf.

Sourcepoint. 2004. Info Commute

Characteristics San Diego Region. *No. 6*.Retrieved February 11, 2010 from www.sandag.org.

URS Project. March 2004. Multi-Jurisdictional Hazard Mitigation Plan San Diego County, CA. Retrieved October 28, 2010 from http://www.co.san-diego.ca.us/oes/docs/HazMit_Plan.pdf.

U.S. Bureau of Labor Statistics. 2010. BLS Information. Retrieved December 17, 2010 from http://www.bls.gov/bls/glossary.htm.

U.S. Census Bureau. 2000. Profile of General Demographic Characteristics: 2000. San Diego County, California. Retrieved February 11, 2010 from http://factfinder.census.gov/servlet/QTTable?_bm=n&_lang=en&qr_name=DEC_2000_SF1_U_DP1&ds_name=DEC_2000_SF1_U&geo_id=05000US06073.

U.S. Department of Health and Human Services. 2010. Natural disasters. Retrieved October 15, 2010 from http://www.hhs.gov/disasters/emergency/naturaldisasters/index.html.

Van Westen, C. 2000. Remote Sensing for Natural Disaster Management. International Institute for Aerospace Survey and Earth Sciences, ITC, The Netherlands Division of Applied Geomorphological Surveys International Archives of Photogrammetry and Remote Sensing. *33*(Part B7): Amsterdam. Retrieved June 16, 2010 from http://www.isprs.org/proceedings/XXXIII/congress/part7/1609_XXXIII-part7.pdf.