Risk assessment frameworks of emergency management organizations for multiple natural hazard events with a special focus on wild fires: A comparison study between USA and Austria

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Abstract

Every location throughout the world is susceptible to one or more natural hazards at any given time. With each of these hazards, there is an assortment of devastating impacts, such as loss of life and property, economic disruption, and resident displacement. The entities responsible for minimizing the impacts of these events are emergency management organizations (EMOs). In order to efficiently and effectively complete their responsibilities, all EMOs employ a variety of techniques, i.e. spatial decision support systems, geographic information systems, and spatial data, during each phase of emergency management. However, EMOs continue to be plagued by issues that influence the effectiveness of their management of a disaster.

The objective of this research is to examine the structure, processes, tools, regulating laws, spatial data, and spatial technology of selected EMOs in the United States and Austria. This will lead to the identification of the bottlenecks occurring during the preparatory phase of EMO operations. The research findings will be divided into three prevalent themes (risk identification, governance, and risk management applications) that influence emergency management preparatory activities and their effectiveness. Through examination of various government documents and supplemental interviews, several areas of improvement within the EMO preparatory operations for both EMOs were found. This paper presents matrixes of the three themes identifying areas where bottlenecks are occurring within both San Diego County and Carinthia EMOs. Also the proposed framework to rectify some of these deficiencies will be presented.

INTRODUCTION

Every location throughout the world is susceptible to one or more natural hazards at any given time. With each of these hazards, there is an assortment of devastating impacts, such as loss of life and property, economic disruption, and resident displacement. The entities responsible for minimizing the impacts of these events are emergency management organizations (EMOs). In order to efficiently and effectively complete their responsibilities, all EMOs employ a variety of techniques, i.e. spatial decision support systems, geographic information systems, and spatial data, during each phase of emergency management. However, EMOs continue to be plagued by issues that influence the effectiveness of their management of a disaster, such as breakdowns in communication and coordination due to lack of information sharing, information miscommunication and misunderstanding, and excess of unusable data (Choi, 2008; Tierney, 2007; Piper & Ramos, 2006; Farazmand, 2007). This research will examine how EMOs use technology within their preparatory phase for multiple natural hazards, in order to develop an improved model of spatial decision support.

Natural hazard events are characterized by their impacts to people and the environment. These significant events disrupt local and global economies, displace millions, and destroy the livelihoods of thousands of people each year. Most of the direct and indirect impacts of natural hazards to humans are negative ones, such as loss of life and property. However, the impacts on the environment can be both detrimental and beneficial to the effected locale. For instance, floods replenish soil nutrients making the land more arable, but these events can also destroy the natural vegetation, which may or may not be easily replaced. Unfortunately, the influence people have on the environment has magnified the disastrous impacts of natural hazards to both the people and environment (Huppert & Sparks, 2006). One such modification is by building permanent infrastructure to accommodate the growing population and local economy. However, in order to reduce the impacts from natural hazards, humans have initiated a variety of mitigation strategies that further alter the natural environment (Board on Natural Disasters, 1999). One predominant strategy is building levees along rivers to redirect the natural flow in order to prevent flooding during a natural hazard event. While this and other mitigation strategies can be effective, they can also be devastating as seen during Hurricane Katrina.

The structured activity directed at determining the optimal way to control a natural hazard is emergency management. Emergency management is a systematic process involving multidimensional effort in order to prepare, respond to, recover, and mitigate the consequences of disaster events. EMOs primary objectives are to eliminate, reduce, and control disaster impacts in order to minimize and/or avoid loss of life and property (Haddow, Bullock, & Coppola, 2008; Donahue & Joyce, 2001; Skinner & Mersham, 2002). There are three primary stages of emergency management: (1) preparation; (2) tactical; and (3) recovery. Within each of these phases, EMOs use a variety of technologies, i.e. geographic information systems, database management systems, communication networks, and spatial and socio-economic data (Kohler, Muller, Sanders, & Wachter, 2006; Kosyachenko, Kuznetsov, Kul'ba, & Shelkov, 1998; Laben, 2002; Zerger & Wealands, 2004). Although several studies have been conducted regarding some of the optimal uses of different spatial technology for natural hazards, there have been few studies that have examined the sort of technology that is available and currently used by EMO personnel during each phase of EMO operations in response to single or multiple natural hazards.

There are several technology-related obstacles to effective and efficient natural hazard management. One of the major obstacles that emergency managers are presented with is an effective communication of general hazard information regarding the risk and vulnerability to the public, government officials, and emergency organization personnel. Information technology has significantly improved communication between each stakeholder, but there are still gaps in the relay and use of spatial information and data, which hinder successful management of a disaster (Marincioni, 2007; Pine, 2007; Patricelli, Beakley, Carnevale, Tarabochia, & Lubitz, 2008). For instance, information is available in a variety of media, but it is not well understood which categories of data are most useful to emergency managers when communicating and coordinating response before, during, and after an event (Marincioni, 2007; Kapucu, 2008). It is known, however, that people interpret information differently. Therefore, when communicating data between all involved, it is vital that these communications are understood in the appropriate way so as not to create an adverse effect, such as panic or lack of reaction, during each stage of a disaster event (Garvin, 2001; Quarantelli, 2002; Zimmerman, 1987).

When communication does fall short of success, one of the significant adverse effects is the failure in coordination of resources, response teams, and recovery and no case stands out more than the failures associated with Hurricane Katrina. Although there was adequate and accurate forecasting information available to all stakeholders at least 48 hours prior to landfall, there was a complete breakdown in communication and coordination that led to substantial loss of life and property (Farazmand, 2007; Piper & Ramos, 2006). While hurricanes can be forecast, forest fires unfortunately cannot, which magnifies the necessity to proficiently communicate and coordinate spatial information and data in the least amount of time and in a way that can be understood by all stakeholders.

The objective of this research is to examine and compare the structure, processes, regulating laws, tools, spatial data, and spatial technology of EMOs in the United States and Austria. This will lead to the identification of the bottlenecks occurring during the preparatory phase of EMO operations. In the initial stage of this research, information from an EMO in the USA will be collected. This data will be centered within five categories of EMO operations: the (1) spatial data and tools that are available, the (2) extent to which the spatial data and tools are used within these organizations, the (3) laws and regulations that govern emergency preparedness and planning, the (4) applications of risk management for multiple natural hazards, and the (5) information, technological, and overall gaps that occur during the preparatory phase of emergency management. During data collections, a special focus will be given to wildfires, as this hazard is currently very prominent in the USA but not in Austria, however, as global warming and climate change it is expected that the threat of wildfire in Austria will also change. Because of this predominant occurrence of wildfire in the USA, sophisticated methods have been developed to conduct wildfire risk assessments which will be utilized as a guideline to develop a mechanism for creating a wildfire assessment for a study area in Carinthia, Austria. These methods will be discussed and applied to a pilot project area in Austria and described within the results section. The second stage of the research project will mimic the previous but will examine EMOs in Carinthia, Austria, who is also highly susceptible to multiple hazards. The final stage of the research will be a comparative analysis of the two EMOs approaches in order to identify similarities and differences between the two systems. This will assist in determining the causes of the deficiencies in emergency management operations and potentially lead to suggestions of ways in which to rectify those deficiencies. In order to provide a theoretical background, the following sections will describe hazard effects, emergency management, and how technology is utilized within emergency management. A brief explanation of the methodology, research results, and a discussion explaining the results will follow.

LITERATURE REVIEW

The following review of literature is structured into three main sections. The first section concentrates on identifying the effects natural hazards have on humans and the environment. It also describes how the human/environment interaction influences the impacts of these significant events. The second section shifts the discussion to examine the nature and stages that encompass emergency management while also identifying some of the technological tools and data that are utilized in each stage. The final section provides further analysis of emergency management by examining some of the potential problems that are associated with using communication, spatial data, and spatial analysis during emergency management operations.

Hazard Effects

Every location throughout the world is potentially at risk of natural hazards (Table 1). However, when the hazard-causing events affect people they become disasters. The effects of these natural disasters can range from being minor incidents to catastrophic events. Some of the potential impacts include the destruction of large cities, significant loss of life, disturbance of local and global economies, and displacement of millions. These impacts can and sometimes do cause disruptions in local and global communication and transportation networks resulting in miscommunication, famine, and disease. For example, nearly 250,000 people lost their lives during the December 26, 2004 Indonesia tsunami that simultaneously also displaced and disrupted the lives of millions (UNEP, 2005, Szczucinski, et al., 2006). This event caused significant interruptions to communication and transportation networks in the affected areas resulting in a substantial delay in the distribution of vital resources to victims. Another event, Hurricane Katrina, occurring less than a year after the 2004 Indonesian tsunami, had approximately 1,700 deaths associated with it, small in comparison to the tsunami, but the losses incurred exceeded 80 billion (US) dollars (Farazmand, 2007). Like the tsunami event, the communication and transportation networks were interrupted resulting in a distribution delay of resources. The direct economic losses associated with just these two events exceed 100 billion (US) dollars while the indirect global economic losses remain immeasurable. These two events are anomalies when compared to other natural disasters, but studies have shown that humans are magnifying the impacts of natural hazards by modifying their environment and increasing population within areas of high risk.

Table 1. FEMA Defined Hazards.

Types of Hazards
• Chemical Release
• Dam Failure
• Earthquake
• Fire or Wildfire
• Flood
• Hazardous Material
• Heat
• Hurricane
• Landslide
• Nuclear Power Plant Emergency
• Terrorism
• Thunderstorm
• Tornado
• Tsunami
• Volcano
• Wildfire
• Winterstorm

It is a well accepted fact that there is a relationship between man and the environment and that through interaction both have altered and been altered by the other (Grossman, 1977).

Humans tend to influence their environment by modifying the soils, rivers, and virtually all aspects of the physical environment in order to provide food, housing, and sustenance. This has been done through a variety of mechanisms, such as damming rivers, clearing forests, and plowing fields (Goudie, 2006). But this relationship is not one way and the environment does in fact influence how humans form their cultures, ideals, and livelihoods. Unfortunately by altering the natural environment, natural hazard impacts have magnified. This, however, is but one reason why there has been an increase in the devastating impacts associated with these events.

People have populated locations that are more susceptible to natural hazards for several reasons. The first being because areas that are most appealing and offer a variety of vital resources tend to also be located in high risk locations. For instance, history has shown that people have settled along rivers and coastal regions because they offer fresh water, arable land, and a navigable waterway. These locations, however, have a history of annual floods which when left unpopulated have beneficial impacts instead of long-lasting, detrimental impacts to the environment. Once high risk areas become populated, the natural environment is altered in such a way that the disastrous effects of annual floods are magnified while the beneficial effects are diminished. Another reason people settle in high risk locations is the availability of limited settlement space, especially in alpine regions. In order to develop and extend, for example, touristic infrastructure in mountainous regions, an important part of local economies, people are forced to settle in locations at higher risk of natural hazard occurrence. Sidle et al. (2003) examined recent and historical records of natural hazards occurring throughout Austral-Asia finding evidence that by concentrating populations in a particular area, thereby extensively altering the natural environment to accommodate the growing population, has increased the incidence and severity of natural hazards. Another study by Huppert and Sparks (2006) found similar results but extended the finding to claim that human activities that alter the environment to counter natural hazards, specifically mitigation measures, are actually increasing the vulnerability to larger and more influential extreme events.

Emergency Management

No individual or environment is immune to the devastating impacts of natural hazards. These events are, however, manageable. They can be prepared for, responded to, recovered from, and to an extent have their impacts mitigated. The process directed at the management of disasters is emergency management.

Emergency management is a systematic process involving multifaceted effort in order to prepare, respond, recover, and mitigate the consequences of disaster events. Its primary objectives are to eliminate, reduce, and control disaster impacts inevitably minimizing and/or avoiding loss of life and property (Haddow, Bullock, & Coppola, 2008; Donahue & Joyce, 2001; Skinner & Mersham, 2002). Each of these objectives fall within one of the three stages associated with emergency management: planning, tactical, and recovery/mitigation. Although each stage can function independently, they are conceptually independent and often interact with one another as the constituents of one or multiple processes (Figure 1).

Figure 1. Stages of Emergency Management.

The initial stage of emergency management is planning for single or multiple events simultaneously. All preparatory and logistical operations and capabilities, which includes identifying the resources that EMOs are in possession of and ones that will be available should an event occur, are analyzed and created or modified so that an effective response plan can be formulated (Burngarner, 2008). In order to plan for a natural hazard event and analyze the capabilities of EMOs, the potential natural hazards and associated risks that may affect a particular locale must be determined. Once a list of potential hazards is realized, the next step is to determine which hazards will inevitably pose a threat to the environment and population as not all hazards are detrimental to the health and safety of the environment or population. It is vital at this stage to identify and estimate the populations at risk to a particular hazard or multiple hazards because it will assist emergency managers in allocating resources, establishing shelters, and identifying which populations to evacuate and warn in case of an impending hazard event.

In order to complete these tasks, emergency management personnel have a variety of methods, technologies, and data at their disposal. Historical, meteorological, and geological data can be an indicator to the type of hazard that has the potential to occur based on the assumption that what has happened in the past will eventually happen again in the future. A thorough examination of historical records is the most common mechanism for determining potential hazards but it is also vital to incorporate information from areas that are similar to the one being examined because low probability, high consequence events could occur even if they have yet to do so (State of Oklahoma Department of Emergency Management, 2007; State of Texas, 2007). Geographic data can be used to assist in the risk assessment process by providing information regarding a locale's physical and built characteristics. Finally, demographic data, which is inherently spatial, such as population censuses, can be used to identify which populations are at risk of natural hazards based on certain demographic characteristics and where those populations are located (National Research Council, 2007). Tools, such as spatial decision support systems (i.e. HAZUS-MH) and geographic information systems (GIS), offer a way to combine, manipulate, store, and view the variety of data available for assisting emergency management personnel to identify areas at greater risk (Gunes & Kovel, 2000; Cutter, 2003; ESRI, 2000; ESRI, 1999; ESRI, 2005; Federal Emergency Management Agency, 2004; Shneider, 2005; Laben, 2002).

There have been several studies conducted that have examined how to conduct risk assessments and formulate emergency response plans, but few have examined specifically how risk assessment and plan formulation is currently being done within emergency management. One such study by Tissington and Flin (2005) examined a model of dynamic risk assessment of the fire hazard, which is taught to fire officials in the UK. They concluded that this model was not followed completely in a fire situation recognizing that the decisions made during a hazard fire event are mostly based on instinct rather than following a designated process. Therefore, it is vital to examine what information is used to make the instinctive decisions about risk regarding a fire event versus what are the data needs to support this type of ad-hoc decision process. By incorporating this information into the currently used model, there will be less reliance on instincts and more trust in the data so that better decisions can be made throughout EMO operations.

The second process in emergency management is the strategic/tactical stage. This is the stage that EMOs are most recognized for as it is when the hazard impacts are occurring and ongoing. In this stage of emergency management, EMOs sole objective is to reduce loss of life, property, and overall economic losses. The prepared emergency response plans are initiated, with hopes that they will enable EMOs to fulfill these objectives. Some of the methods used by EMOs during this stage include making evacuation orders, providing warnings and watches to populations at risk, placing sandbags in vulnerable locations to combat imminent flooding, initiating shelters, and allocating resources, i.e. food, water, and emergency personnel, such as police, fire, and ambulance.

There are many spatial technologies available that can assist EMOs in making decisions that will lessen the immediate impacts of natural disasters and reduce the amount of direct damages. One such technology is GIS. GIS can help to visualize where the impacts are occurring and link those to demographic and geographic data so that decision makers will be informed about where the impacts are occurring and who is impacted. This information can potentially assist decision makers in such tasks as allocating resources and placing evacuation orders. There have been several studies that have recommended the integration of GIS and spatial data, but none have examined the GIS technology is utilized within this stage by EMOs and if it has any impacts on how EMOs make their decisions.

The final stage of emergency management is the recovery/mitigation phase and begins promptly after the disaster impacts have ceased. As previously mentioned this stage is an agglomeration of what many studies have separated into two stages, but in this research it is treated as one because both stages build on one another in that proper disaster recovery should and many times does include adopting mitigation strategies. The objective for EMOs during this stage is to restore the community back to its original status prior to the event occurrence. One of the vital processes in accomplishing this objective is for EMOs to complete damage assessments of the affected area. Damage assessments can provide information related to the extent of devastation and can give an idea to decision makers for making community recovery time estimations. With this and additional information, i.e. visual reports of damage and debris outputs of spatial decision support systems such as HAZUS-MH, EMOs can begin rehabilitating their community by removing debris, restoring vital communication and transportation networks, and rebuilding. The information that is used to direct recovery can also provide insight into the type of mitigation strategies that should be implemented to reduce the overall impacts of a natural disaster. Some of these can be both extensive and relatively minor, but have positive influence on reducing the disaster impacts. These can include educating community members about their subsequent risk and vulnerability to disaster events; building infrastructures such as levees; creating building codes and zoning laws; and relocating and reallocating resources throughout the community.

Like the other stages of emergency management, there have been relatively few studies that have critically evaluated the fitness of spatial technology and data for specific tasks and have analyzed how EMOs use spatial data, and what the real processes occurring within EMOs are during the preparatory stage. There have, however, been multiple studies examining how best to evaluate and assess wildfire risk. For instance, in a 2008 study by Arroyo, Pascual, and Manzanera several different fire risk models utilized throughout the world were identified. Jaiswal, Mukherjee, Raju, and Saxena (2002) developed a method for identifying fire threat locations in India. These and other related have studies have developed a variety of methods using different tools and data to identify fire risk.

Emergency Management and Technology, Communication, and Data

Vital tools that emergency management relies on during the course of a hazard event are technology, communication, and information. The innovations associated with each of these tools have enabled emergency management to be more efficient and effective and has also contributed significantly to the development of the infrastructure (i.e. cellular and satellite telephones, computers, internet, and data management and hazard modeling software) that emergency management staff, policy makers, and the public use when preparing, managing, and recovering from natural disasters.

There are several obstacles associated with effectively and efficiently managing, responding, and recovering from a natural hazard. Studies have shown that people interpret information differently creating a significant obstacle for emergency managers. For instance, Garvin (2001) determined that there is a variety of paradigms which govern how different groups, i.e. policy makers, the public, and emergency management staff, understand the same data differently. Therefore, when communicating data between all stakeholders, it is vital that these communications are understood in the appropriate way so as not to create an adverse effect, such as panic or lack of reaction, during each stage of a disaster event (Garvin, 2001; Quarantelli, 2002; Zimmerman, 1987). Unfortunately there is no standard or system for which data is available and shared among all stake-holders perpetuating the misunderstandings that exist in emergency management.

Although there is an abundance of data available for use in emergency management operations, there are still obstacles associated with the implementation of data. For instance, data is produced in a variety of formats but many programs have format limitations making some data unusable or requiring additional software that may not be easily attainable. Data is also available in different spatial extents for several locations which in most instances provide enough resolution alternatives for emergency managers, but this data is not always easily manageable or available for all locales. Raw data is usually not in an understandable format and, therefore, requires processing or the addition of some basic information, such as the combination of remotely sensed imagery with a road map layer. The processing of this sort of data very often requires a substantial time investment which may not be acceptable when coping with a natural hazard. The demographic data that emergency managers rely on are readily available at a fine resolution in the United States and most developed countries, however, in many instances censuses are not taken frequently, especially in undeveloped or developing nations. There is also a delicate balance of having an adequate amount of data necessary for making informed decisions. The situation of having too much data available is a growing phenomenon referred to as information overload. This excess of information and data tends to accumulate and become incredibly confusing making it difficult for emergency management personnel to make well-informed decisions.

Information is a valuable resource to emergency management but there are gaps in the literature specifically describing which data is most useful and available for use in emergency management operations. It has been, however, hypothesized that current, spatially referenced census and survey data are heavily sought after by emergency managers, along with improved maps which to link this demographic data to, but it has yet to be realized if this data is available to emergency managers before a hazard event or if the available data is current enough to be deemed useful (National Research Council, 2007).

In order to process and organize spatial data, a variety of technology platforms are available but their effective use requires specific technical skills and substantial financial investments. For instance, one commonly used GIS program is ESRI's ArcMAP. Proficient use of this program requires a significant financial and temporal investment by EMOs in order to either hire expert users of ArcGIS software or provide technical training to current EMO personnel. Another technology that can be useful by EMOs and requires virtually equal investments as the previously mentioned platform is remote sensing software. Some available remote sensing platforms are ERDAS Imagine, ENVI, and IDRISI. Web-GIS applications and Web Mapping Services are another important technology utilized by EMOs. These can provide experts within and of different organizations access to comprehensive spatial data sources (Paulus, et al., 2004). These applications can also be used for communication purposes with the public. One example would be the insurance sponsored HORA- application which provides the public access to flood risk maps for every location in Austria.

Technology, communication, and data are vital components of emergency management, but there have been no studies that have identified which types of spatial data and technology are currently being utilized by EMOs. Most of these studies have only developed mechanisms for utilizing these technologies and have not examined whether or not they are in fact being used to any extent by EMOs. This research should fill this apparent gap within the literature by examining what spatial data and tools are being utilized and how spatial technologies are being used to create products that will aid in the decision making process.

METHODOLOGY

The overarching goal of this research is to create a model that will improve EMOs preparatory activities, which in turn should improve their management of natural disaster events. In order to accomplish this goal, this research examined two EMOs concentrating on analyzing and identifying the (1) spatial data and tools that are available, the (2) extent to which the spatial data and tools are used within these organizations, the (3) laws and regulations that govern emergency preparedness and planning, the (4) applications of risk management, and the (5) information, technological, and overall gaps that occur during the preparatory phase of emergency management.

This research project is divided into three stages. The first stage of the project is an examination of both EMOs processes focusing on identifying the specific bottlenecks or information gaps that are occurring before a hazard event by obtaining information in the five categories listed above. The second stage consisted of compiling, interpreting, and organizing the knowledge acquired during the initial stage of this research relying solely on qualitative comparative techniques. Within this stage it may be realized that there are gaps within the previously acquired knowledge, which will necessitate a return to the previous research stage. The final stage involved developing a suggested framework that will improve EMO management and effectiveness by determining where improvements within the preparatory processes can be made ultimately removing some of the bottlenecks occurring.

Study Sites

Natural hazards occur at nearly every location throughout the world; however, the events that threaten urban areas and/or vital economic locales are occurring more frequently and thus necessitate efficient management in order to reduce and control their devastating impacts. The study locations for this research are both very familiar with these destructive hazard events.

In fall 2007, San Diego County, located in southern California, had one of the most destructive and costly series of fires within all of the United States. Approximately 13% of the county's total area was destroyed by this single fire event. Unfortunately, much of the directly impacted locations were either densely populated or vital agricultural, economic areas making this fire event particularly devastating. Although these fires directly impacted about 13% of the county, all of San Diego county residents were either directly or indirectly affected in some way by these fires. Overall, over 6,000 homes were threatened, 450 homes destroyed or damaged, 515,000 residents evacuated, and 369,000 acres destroyed (URS Corp, 2004). These statistics are staggering, however, thousands of homes, residents, and acres of land were spared the direct devastating impacts of this fire event because of EMOs management. Even though EMOs consider the management of this event successful, there were some areas within their operations that even EMO personnel recognized as still requiring improvement, which is why this location is ideal for study.

Emergency management operations throughout the United States, regardless of the scale of responsibility the EMO has, are very similar in how they conduct their preparatory activities of hazard events between EMOs. Therefore, to obtain a new perspective and a comparable study area to San Diego County, this research examined another location in a different developed country, which has different laws, regulations, policies, tools, and data available for use in their EMOs preparatory activities in order to answer the research questions previously stated.

Carinthia, Austria is an ideal study location for several reasons. First and most importantly, it is located within a developed country and is also susceptible to multiple natural hazards. Some of these hazards include avalanche, landslide, and flood. This is comparable to San Diego, CA, because as in Carinthia, San Diego County is also susceptible to floods and landslides. Secondly, like all EMOs located throughout the United States, the EMO organizations within Carinthia also have some deficiencies that warrant improvement when dealing with natural hazards. Although the populations between the two study areas are not quite comparable in actual population size, with San Diego County having a population of 3.1 million and Carinthia only having a population of 600,000, they are comparable in sheer size as both are approximately 400,000 square miles with similar geographical regions. Finally, the climate throughout the world is changing each year and both study areas have begun experiencing some of these alterations. For instance in San Diego, the winters are warming and becoming less wet whereas in Carinthia the summers are warming and less snowfall is accumulating in the winter leaving dryer conditions throughout the region. These changes have also altered the natural hazards that both are susceptible to, thus it is necessary that both locations undergo a revision of their preparatory emergency management activities to reduce losses from natural hazard events.

Knowledge Acquisition

In order to obtain the necessary knowledge to answer the research questions and achieve the goals of this study, information was collected from each EMO by examining and recording information from government reports, documents, and publications and if necessary via interviews with local officials and EMO personnel to supplement and fill any gaps within the previously acquired knowledge. A list of specific tasks to be performed for the preparatory stage of emergency management and a list of map products that are utilized based on some that are created in San Diego to make decisions during this stage was used to assist in initiating discussions with the interviewees regarding the processes EMOs utilize during the preparatory stage of emergency management. These lists also helped to formulate some of the interview questions asked. The interview questions concentrated on determining how the specific spatial data and tools are utilized, what data products are produced, how the data outputs are communicated, what the laws and regulations govern EMO operations, and what applications and risk reductions strategies do the outputs contribute to. These interview question responses helped to determine the bottlenecks that are occurring within each EMO. These interviews were conducted with the assistance of Dr. Gernot Paulus of the Carinthia University of Applied Sciences in Villach, Austria, who is familiar with Carinthia EMO's and hazards in Carinthia and also fluent in the German language.

Data Analysis

A variety of qualitative data was collected and the optimal method to organize these findings was to code the data to discern the specific themes apparent within the data. In order to code the data, the findings were first separated between the two study areas, San Diego County and Carinthia. Once these data have been organized and collected for both EMOs, it was further divided and coded according to the following subcategories: (1) data, which refers to the type and potential uses, resolution, scale, accuracy, presence of metadata, accessibility, and frequency of updates for each data type; (2) products developed, which include information related to the purpose of the created product, who the intended audience is for the product, how the product contributes to the decision making, whether or not the product is efficient and successful, and how the product is communicated and distributed; (3) governance, which refers to the particular laws, regulations, policies, codes and standards, and accountability that regulate EMOs and are altered or developed based on the outputs of their activities; and (4) deficiencies present.

Once all findings have been organized into the categorization tables, the underlying themes were identifiable. The three themes are risk identification, governance, and risk management applications. Each theme was populated with tasks and/or mechanisms that were deemed necessary for emergency management preparatory activities according to the United Nations International Strategy for Disaster Reduction 2004 publication, *Living with Risk*. By distinguishing activities within each of the themes for both EMOs, a comparative qualitative analysis of the differences and similarities between the EMOs was conducted. This analysis yielded results that will answer the major research questions that were previously identified. The analysis contributed to the creation of a framework that will identify some of the deficiencies occurring within EMOs for multiple hazard events. Because it is believed that there are different bottlenecks or gaps that occur between each EMO, some of these gaps may have already been addressed in one EMO and, therefore, their solution can be applied to the other to correct those deficiencies. The bottlenecks that were found to occur within both EMOs will require further examination of the current, relevant literature. This secondary analysis identified studies that suggest methods that address the specific bottlenecks identified in both EMOs. The methods chosen will be presented as suggestions within the final framework and can be replicated easily using the data and tools available to these EMOs.

RESULTS & DISCUSSION

Risk Identification

A thorough understanding of the potential risk a location has is a vital and necessary preparatory activity within EMOs and one of the prevalent themes of this research. Risk identification allows EMOs to properly prepare for and initiate a variety of mitigation activities that may in fact reduce the losses that could incur from a natural hazard event. By conducting a risk assessment, which includes activities such as identification of hazards, estimation of possible losses, and vulnerability assessments, EMOs can enhance public awareness, create a decision tool, and facilitate intergovernmental agency cooperation and coordination among other things. Risk identification activities are present within both of the study locations; however, the extent and thoroughness of which San Diego County and Carinthia, Austria are participating in such activities varies. Table 1 below provides a summarization of the research results showing the extent to which both EMOs are involved in risk identification. An assignment of ‘fully’ implies that a particular task is being conducted to the full extent, where as ‘minimal’ implies that only minimum or no emphasis is being placed on completing the task. Designations with an asterisk imply that improvements can be made within a task ultimately identifying the bottlenecks that are occurring.

Table 2. Risk Identification Summarization Table.

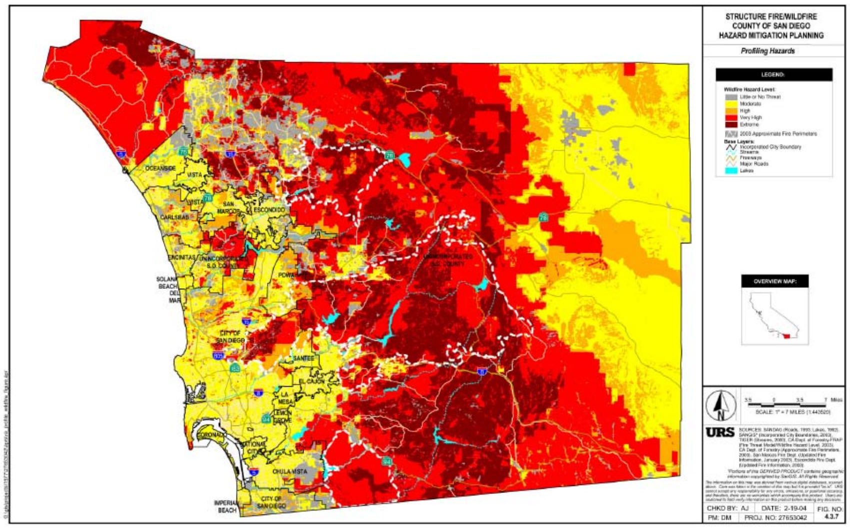
THEME 1: RISK IDENTIFICATION ***Tasks***	**San Diego County, CA USA**	**Carinthia, Austria**
Identify Hazards	Fully	*To Some Extent
Profile Hazard - Probability - Magnitude/Severity - Frequency - Duration	*Fully	*Fully
Evaluate Risk (Extent of Hazard) - Create Risk Maps	Fully	*Fully
Assess Vulnerability - Identify & Assess Assets - Assess Exposure - Estimate Damages - Estimate Losses - Assess Resiliency	Fully	*Fully
Creation of Hypothetical Scenarios	*To Some Extent	*To Some Extent
Data Quality - Accuracy - Scale/Resolution - Frequency of Updates	*Fully	*Fully
Establish Hazard Priority	To Some Extent	To Some Extent

* indicates areas that can be improved upon

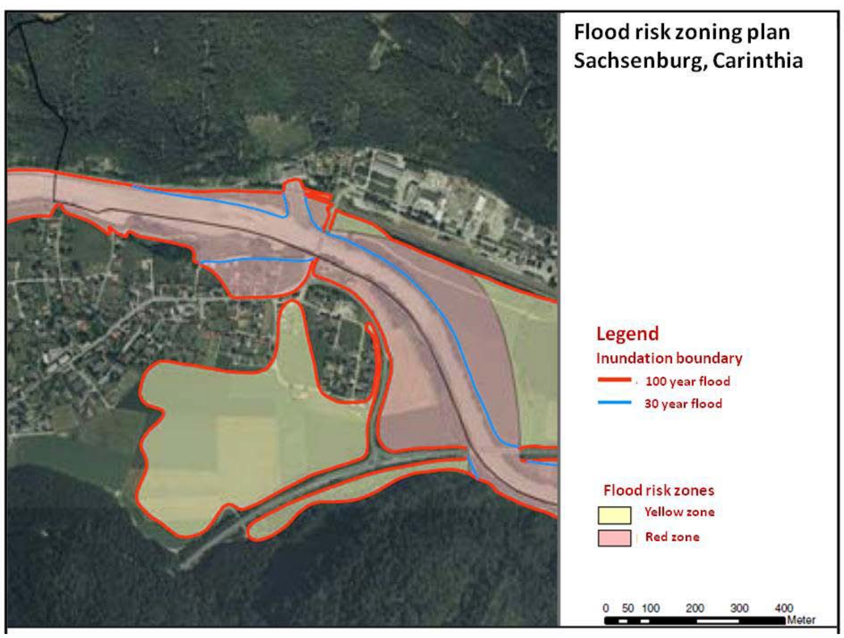
No location throughout the world is immune to the impacts of a natural hazard and in most locations there is a high probability of more than one type of natural hazard occurring at any given time. Therefore, current trends within emergency management are moving towards a multi-hazard approach. EMOs within the United States are currently adopting a multi-hazard approach, but EMOs within other developing countries are only beginning to engage in this approach which is confirmed by this research.

San Diego County, CA, USA, EMOs identify 13 hazards (coastal storms, erosion, and tsunami; dam failure; earthquake; floods; hazardous materials release; landslide; liquefaction; nuclear materials release; terrorism; wildfire/structural fire) that pose a threat to the county by examining past historical records, disaster declarations, newspapers, and operating under the assumption that if a particular hazard has occurred in the past, regardless of how long ago, that hazard has the potential to recur (URS Corp, 2004). In Carinthia, Austria, EMOs perceive that they are susceptible to multiple hazards, but concentrate only on the hazards which have a high probability of occurring in alpine regions, i.e. floods, avalanche, and landslide/rockfall (Paulus, et al., 2004). They do not examine any other natural hazards, i.e. earthquakes or liquefaction, which may have occurred in the past but are unlikely to recur in the immediate future.

By profiling each natural hazard, an EMO can begin to understand what the actual risk is to their particular locale for that hazard. The San Diego County EMOs create a detailed profile of every hazard that they identify as posing a threat. The profiles include information relating to the magnitude, duration, frequency, probability, and extent of that natural hazard. However, these profiles do not make note of the cascading potential of additional natural disaster events that could occur during the event of the profiled hazard. EMOs in Carinthia create profiles very similarly to that of the San Diego County EMOs, but like San Diego County, Carinthia also does not include information relating to the cascading potential of a natural hazard. Once each hazard is profiled, both EMOs create a map (Figure 2a) assigning different levels of risk, high, medium, and low in San Diego County and high and low for Carinthia (Figure 2b), to each profiled hazard for their respective locales.



a) San Diego Fire Threat Map (URS Corp, 2004)



b) Carinthia Flood Zoning Plan (Piechl, 2005)

***Figure 2*.** Hazard Risk Map Examples

In conjunction with evaluating risk, it is necessary for EMOs to also examine their locales vulnerability. A vulnerability analysis assesses the exposure potential of the population and assets for each hazard event, estimates potential losses and damages, and examines the resiliency of the population and assets (i.e. critical facilities, emergency response units, schools, road infrastructures, etc.). By creating such assessments, potential weaknesses within a locale can be realized providing governments an opportunity to rectify the situation and ultimately reduce vulnerability and become better prepared for a disaster event. Both San Diego County and Carinthia conduct vulnerability analyses for their respective locales for each of the identified hazards, however, San Diego County EMOs utilized a more extensive array of software and data. For instance, in San Diego County EMOs utilize such tools as HAZUS-MH, GIS, FEMA FIRM VE, and inundation modeling software overlaid with digital census and detailed building data to map the assets and vulnerable populations whereas in Carinthia, EMOs utilize primarily GIS and inundation modeling software overlaid with a general asset catalog to assess vulnerability. Within both EMOs, each hazard creates an extensive vulnerability assessment that is utilized by decision-makers to formulate appropriate suggestions for possible mitigation measures to reduce risk and vulnerability.

It is debated throughout the world whether or not natural hazards are increasing in frequency, but it is apparent that they are increasing in magnitude of devastation as in the case of the 2004 Hurricane Katrina and the 2004 Indonesian Tsunami. Therefore, with the changing dynamics of natural hazards, it is important that EMOs prepare for the unexpected event. One method that can assist EMOs in preparing for these unanticipated events is to create hypothetical scenarios of hazards that pose a threat and assess how a variety of events change their locales particular risk and vulnerability. San Diego County utilizes HAZUS-MH to model multiple hypothetical flood and earthquake scenarios, but does not create scenarios for other hazard types. Although the EMOs in Carinthia do not develop hypothetical scenarios, they do conduct comprehensive hydrologic simulations for floods based on the 30, 100, and 300 year flood record. For the hazards avalanches and torrent floods, similar simulation models are also created, but a methodology for simulating landslides/rockfall is not currently being utilized but is being developed and investigated.

To obtain the most credible risk understanding, it is necessary to use quality spatial data and tools to create risk and vulnerability assessments. Unfortunately due to financial, technical, and personnel resources it may not be achievable to obtain the highest quality data and tools available. Within both San Diego and Carinthia the EMOs utilize the most up-to-date data and software that are attainable. However, as technology is improving and decreasing in costs it is becoming easier for EMOs to attain such data and therefore necessary for both to continuously reassess their risk with updated data sets and tools.

One of the final tasks of understanding risk to natural hazards is to prioritize each hazard. By prioritizing hazards, funds can be allocated according to priority giving decision makers additional information regarding each hazard. Although the hazards themselves are not prioritized within either study area, the mitigation measures proposed for each hazard are prioritized in an extensive cost/benefit analysis.

Both EMOs were found to have particular areas that necessitate improvement. The bottlenecks within the risk identification activities for both EMOs were centered on data quality. Although both EMOs are utilizing the best data and tools available there is room for improvement in data quality and data coverage which could subsequently improve their preparatory activities. Another bottleneck occurring in both EMOs was related to the task of hypothetical scenario creation. As hazards are characterized as having several unknown variables and no single hazard event is the same, it is necessary for both EMOs to create hypothetical scenarios for multiple hazards and to prepare for unanticipated events. It will also be vital that EMOs in Carinthia expand their analysis beyond hazards that pose an immediate threat to examining any hazard that could potential occur, regardless of frequency, as history has continuously shown that natural hazards tend to recur in locations where they have taken place in the past.

Governance

A vital, but commonly overlooked, theme within emergency management research is governance. How an EMO is governed dictates the ways in which the emergency management operations are conducted and how effective EMO operations can be. Specific laws and regulations have been initiated within governments throughout the world to ensure that preparation and mitigation activities with the intent to reduce hazard impacts are implemented. Other factors which influence how an EMO operates relate to how the EMO is organized within the government structure, if there are mechanisms in place to facilitate intergovernmental cooperation and coordination, and how the laws, regulations, and codes/standards are enforced. Table 2 below provides a matrix summarizing the results of interviews and an examination of government documents related to San Diego County and Carinthia EMOs organization and legal support. As in Table 1, an assignment of 'fully' implies that there are specific mechanisms in place to support EMOs in San Diego County and Carinthia. The assignment of 'minimal' implies that there is little to no support present for facilitating that mechanism. The bottlenecks or gaps that are occurring are symbolized with an asterisk.

Table 3. Governance Summarization Table.

Theme 2: Governance ***Mechanisms in Place***	**San Diego County, CA USA**	**Carinthia, Austria**
Policy & Planning - Create Hazard Mitigation Plan	Fully	Fully
Laws	Fully	Fully
Regulations	Fully	Fully
Codes/Standards	Fully	Fully
Accountability - Mechanism to Measure Compliance - Enforcement	*To Some Extent	*To Some Extent
Intergovernmental Cooperation	Fully	*To Some Extent

* indicates areas that can be improved upon

The overall style of governance between San Diego County and Carinthia is quite different and has influenced how each EMO organization is structured within the government. In San Diego County there is a hierarchy in place. At various levels of this hierarchy preparatory activities are conducted with each level reporting information to the level above or dictating information below. For instance, at the lowest hierarchical level are jurisdictions. Each jurisdiction has an opportunity to conduct a risk assessment for their particular locale. Once completed the jurisdiction reports their findings to the county who then can include or omit the jurisdictional report within the risk assessment that they complete and so forth. It is important to note, however, that the activities that each jurisdiction are responsible for are not hazard specific and follow a multi-hazard approach although there are a few hazard specific entities within the overall structure at the state level of government.

The EMOs in Austria are organized quite differently. Instead of each jurisdiction having an EMO and/or emergency manager, there are overall entities, i.e. Federal Water Engineering Administration and Austrian Hydrographic Service, which have jurisdiction over large areas within the state of Carinthia. These entities are hazard specific and do not examine multiple hazards. This type of organization can be detrimental to adopting a multiple hazard approach or examining additional hazards as there is not a mechanism in place to facilitate interagency coordination and cooperation as each agency or EMO is hazard specific. However, in response to the emergency management trend to addressing multiple hazards, there are organizations that span multiple countries within the EU that are conducting some preparatory activities to multiple natural hazards.

Within both EMOs it was discovered that there are specific rules, regulations, and codes/standards in place that are influenced by the created risk and vulnerability assessments. For instance, in both Carinthia and San Diego, zoning plans are developed based on the created risk maps and are enforced by limiting building permit approval to locations outside of a risk area. The vulnerability and risk maps also influenced the building codes, most specifically within the San Diego County study area. These are enforced by the granting or denial of building permits based on how well the proposed building schematics are in compliance with the building codes.

Several laws are also in place to direct the actions and operations of EMOs. These laws can be either hazard specific or are related to multiple hazards. In the United States there are both types of laws, but in Austria the laws tend to be hazard specific. In 2000, for example, the United States passed the Disaster Mitigation Act which mandated that in order for a state to receive federal disaster aid, preparatory activities must include the creation of risk identification assessments for multiple hazards, a FEMA approved multi-hazard mitigation plan, and a mechanism to facilitate interagency coordination and communication. Because of the passage of the Disaster Mitigation Act, states passed similar laws for counties. The entity that was granted responsibility for ensuring that a county is in compliance with the law was EMOs and therefore, the San Diego County EMOs examine risk and vulnerability and create mitigation plans. Although the laws that influence the actions of the EMOs in Carinthia are not multi-hazard, there are laws in place that demand similar things as the Disaster Mitigation Act for each hazard. For instance, the Law on Hydrography requires that the EMOS within the state of Carinthia create risk and vulnerability assessments for the hazard flood (Federal Water Engineering Administration, 2007). Both EMOs have also developed plans of action to facilitate intergovernmental and interagency communication and coordination. In San Diego County the Unified Disaster Council, San Diego County Emergency Services Organization, and Office of Emergency Services was developed to organize a communication and coordination mechanism for all emergency service agencies within the county. This research did not yield a plan, law, or mechanism to facilitate communication and coordination of emergency service personnel in Carinthia, Austria, but it was found that each agency openly communicates and coordinates with one another.

The most prevalent problems occurring within this theme were discovered in how legal regulations and rules were enforced. Measuring law compliance is a difficult task for both EMOs. The most difficult of which is the monitoring of building codes in which many of the older structures are not in compliance as they were constructed prior to the current building codes being in place and there is little assistance available to bring the structure up to code. Another identified gap lied within Carinthia EMOs. The Carinthia EMOs have an open communication between emergency agencies at the current time but if the lines of communication are interrupted for any reason the state emergency service agencies will be less successful at preparing, coping, and recovering from a natural hazard event. By creating a documented and mandated plan of communication and coordination, these vital lines could not be ceased for any reason.

Risk Management Applications

The third theme is the applications of risk management. These include activities resulting from the risk identification phase and include developing mitigation strategies in response to the risk and vulnerability assessments, creating a disaster response plan, effectively communicating a locales risk to all stakeholders, allocating resources to reduce a locales risk and vulnerability and/or to increase resiliency, and conducting a cost/benefit analysis of different mitigation strategies. By examining government documents and reports, determining the extent to which the activities were conducted within each EMO was possible and the extent to which each is fulfilling that activity is summarized below in Table 3. If a task is being completed optimally, implying that the EMO is completing a task with positive results, the EMO was assigned a designation of ‘fully’. If a task is either not being completed or only minimally being completed, the EMO was assigned ‘minimal’ and if any substantial effort had been made to accomplish the task the EMO was assigned ‘to some extent’.

Table 4. Summarization of Risk Management Applications Theme.

THEME 3: RISK MANAGEMENT APPLICATIONS ***Tasks***	**San Diego County, CA USA**	**Carinthia, Austria**
Mitigation Strategies	Fully	Fully
Disaster Response Plan	Fully	*Fully
Communicate Risk	*Fully	*To Some Extent
Examine/Reallocate Resources - Personnel - Financial	Fully	To Some Extent
Cost/Benefit Analysis	Fully	Fully

* indicates areas that can be improved upon

The technique of employing mitigation strategies to prepare for and reduce the effects of natural hazards has been used throughout the world. However, the effectiveness of mitigation strategies is highly dependent on the strategy set within society and/or location of the infrastructures that are constructed. The best method of determining the optimal mitigation strategy and/or location of mitigation infrastructure is by conducting thorough risk and vulnerability assessments along with comprehensive cost/benefit analyses of each proposed mitigation strategy. The EMOs in both San Diego County and Carinthia are creating comprehensive risk and vulnerability assessments, as described previously, and cost/benefit analyses thereby allowing them to propose, create, select, and implement the most appropriate mitigation strategies. They do however, complete them slightly differently. For example, each of the 35 jurisdictions within San Diego County undergoes a capability assessment. The capability assessment determines how capable they, each jurisdiction, are at achieving the mitigation goals, which aim to reduce the impacts of all hazards, of that jurisdiction by examining their available resources, laws and regulations, and technical ability. Once completed, each jurisdiction creates a set of alternative mitigation strategies and examines the social, technical, administrative, legal, economic, and environmental constraints and opportunities of each mitigation strategy to select only realistic and reasonable strategies (URS Corp, 2004). Whereas in Carinthia, the EMOs conduct a compulsory cost/benefit analysis for only floods and avalanches. The analysis is, however, very similar to the analysis of San Diego County EMOs examining similar variables. Both EMOs cost/benefit analysis examine the available resources and, if necessary, reallocate them appropriately to reduce risk.

Another vital task for applications of risk management is to effectively and efficiently communicate the potential risk of an area to all stakeholders (public, policy-makers, and emergency service organizations). It is understood that the best way to communicate risk is to educate stakeholders about natural hazards (United Nations International Strategy for Disaster Reduction, 2004). Unfortunately this is a very difficult task to undertake due to the multitude of variables about the stakeholders, i.e. education, income, personal experience, and accessibility to communication mediums (internet, television, or newspapers), that must be taken into account. San Diego County EMOs present several opportunities for stakeholders to become informed regarding their specific risk, such as distributing mailings, conducting town hall meetings, and utilizing the Internet, Web-GIS, and television. Within the EMOs of Carinthia few opportunities to educate the stakeholders regarding their risk are presented. The most common mechanism is to hold a public presentation of the risk maps for flood, avalanche, and landslide/rockfall at the local mayor’s office. During this time all stakeholders can voice their concerns in writing and/or learn about the hazards which they may be susceptible to. This method can lead to many stakeholders being uniformed as it is not well publicized when these risk maps are available for viewing.

A final mechanism that is helpful in reducing risk and increasing resiliency within a location is the development of a disaster response plan. This plan establishes a hierarchy of responsibilities of each emergency response organization (EMOs, fire, police, and ambulance). It also determines how to distribute these resources throughout the area. The San Diego County EMOs have adopted a disaster response plan which outlines and explains the tasks of each response agency for any hazard event. To improve response action further, San Diego has also created an internal WebEOC (Web Emergency Operations Center), for communicating information among and between the different agencies during and after an event, a Geographic Information System Standards of Operation, which outlines a universal structure for naming maps and selecting colors to represent particular infrastructure and phenomenon. Although the EMOs in Carinthia have not established a communication tool or specific operation standards, the fire brigades of Carinthia have developed a general disaster response plan addressing hazards of different severity.

Like all other aspects of emergency management, there are ways in which EMOs can be improved upon. The bottlenecks that are occurring within these tasks are concentrated around communicating risk. This is an ongoing battle that EMOs throughout the world are dealing with and the EMOs of Carinthia and San Diego County are no exception. Another bottleneck mildly problematic is the extent to which a disaster response plan is formulated. In Carinthia the EMOs are only prepared for the hazards which are assessed for risk and thus if another type of hazard occurs, the disaster plan can be ineffective.

Wildfire Risk Analysis

Wildfires are hazards that plague regions throughout the world. Fortunately, Carinthia, Austria has yet to endure the devastation that a severe wildfire can inflict. However, in a study funded by the European Union examining climate change trends in the Alps and the consequences of these changes, it was predicted that the risk of wildfires will dramatically increase in the foreseeable future in the Austrian Alps thus making it necessary for EMOS in Carinthia to monitor and prevent the hazard wildfire (EURAC Research and AlpenforschungsInstitut, 2008).

Currently, EMOs in Carinthia do not have a mechanism of monitoring fire risk and thus are magnifying their vulnerability. Unfortunately these events cannot be predicted, but locations that are highly susceptible to fire can be identified. Thus it is vital that EMOs conduct thorough risk analyses identifying areas that are susceptible to wildfire. It is also vital to reevaluate risk after a fire hazard event because with every fire occurrence the risk changes due to fire impacts upon an environment. Unfortunately San Diego County's environment and climate creates the optimal conditions for fires, but as such they have adopted sophisticated methods for identifying fire threat and thus it would be beneficial to EMOs in Carinthia to adopt similar mechanisms for identifying their fire threat.

EMOs in San Diego County utilize the California Department of Forestry and Fire Protections Fire and Resource Assessment Program (CDF-FRAP) Fire Threat Model to determine the counties fire risk (URS Corp, 2004). The model has two primary parameters, fire rotation and potential fire behavior. Fire rotation relates to the likelihood and frequency of a given area burning by examining past fire events and comparing the pre-burned locations characteristics to current location characteristics to determine how susceptible the study area is to wildfires. Potential fire behavior concentrates on examining the topography and vegetation of the assessment area. CDF-FRAP Fire Threat Model and a variety of input data are integrated into a GIS which calculates fire threat and outputs maps that rank fire risk on a scale from 2-6 where six encompasses areas at most threat to wildfires.

Applying a model such as this is difficult for Carinthia EMOs because Carinthia has no record of severe past wildfire events and, therefore, one of the primary components of the CDF-FRAP Fire Threat Model, fire rotation, will have no input data. However, the other primary component, potential fire behavior, is useful. Carinthia EMOs have access to extensive topography and vegetation data. Although the data inputs are somewhat different in detail to that of San Diego County EMOs, a mechanism resembling the CDF-FRAP model is possible to recreate for Carinthia EMOs.

To develop a framework for Carinthia EMOs to identify fire threat it is necessary to integrate topographical and vegetation parameters as in the CDF-FRAP model but to also include the parameter proximity to road. This additional parameter will be useful in determining fire threat in the Carinthia area because there is an extensive mountain road network that many tourists and locals utilize and the cause of most wildfires is either deliberate or accidental by humans who are not aware of the fire threat.

Table 5. Table of fire sensitivity rating of variables and classes.

Variable	Classes	Fire Sensitivity Rating
Vegetation Type* (35%)	0 – Spruce	Low
	1 – Green Alder	High
	3 – 10-25% Coniferous Forest	High
	4 – 26-50% Coniferous Forest	Moderate
	4 – 51-74% Coniferous Forest	Low
	5 – 75-80% Coniferous Forest	Low
	6 – Larch 60-90%	Low
	7 – Larch 30-60%	Moderate
	8 – 0-10% Coniferous Forest	High
	9 – Mountain Pine	Moderate
	10 – Larch 10-30%	Moderate
	11 – Larch > 90%	Low
Slope (25%)	1 – 0-5%	Low
	2 – 5-15%	Moderate
	3 – 15-25%	High
	4 - >25%	Very High
Canopy Cover* (15%)	0 – 81-100%	Very High
	1 – 61-80%	Very High
	2 – 51-60%	High
	3 – 31-50%	Moderate
	4 - <30%	Low
Growth Stage* (15%)	0 – Mature – Large Tree	Low
	1 – Adult – Medium Tree	Low
	2 – Pole Wood	Medium
	3 – Sapling	High
	4 – Beginning Reforestation	Very High
	5 – Clear Cut	Very High
Proximity to Road (10%)	0 – > 400m	Low
	1 – 300-400m	Low
	2 – 200-300m	Moderate
	3 – 100-200m	High
	4 – 0-100m	High

Table 5 above provides the classes within each of the data inputs and a suggestion for how to rank the fire sensitivity for each class. The fire sensitivity ranking suggestions were based on an examination of related fire fuel model literature (Anderson, 1982; Jaiswal, Mukherjee, Raju, & Saxena, 2002; Scott & Burgan, 2005; Butler, Anderson, & Catchpole, 2007; Arroyo, Pascual, & Manzanera, 2008; Hornby, 1935). Each variable was input into a GIS with the Spatial Analyst extension activated. Each input raster was projected, resampled, and reclassed using available tools. Because each variable contributes differently to potential fire threat, the variables were assigned weights which reflected the importance of each variable in the final calculation. The equation below was utilized to calculate the fire threat of an area using raster calculator in the Spatial Analyst Toolbar in ArcGIS.

$$\text{Fire Threat} = [0.35(VT)] + [0.25(S)] + [0.15(CC)] + [0.15(GS)] + [0.10(PtR)]$$

Where: VT – Vegetation Type
S – Slope
CC – Canopy Cover
GS – Growth Stage
PtR – Proximity to Road

The proposed framework was tested for a location in Upper Carinthia. It is important to note that this framework and resulting fire threat identification operates under the assumption that optimal conditions for fires exist. Some of the characteristics of such conditions are low relative humidity, high winds, high temperatures, and low fuel moistures. The resulting map output (Figure 3) identifies areas that are susceptible to wildfire and assigns a rank (low, moderate, high, very high) for the overall sensitivity of a particular area.

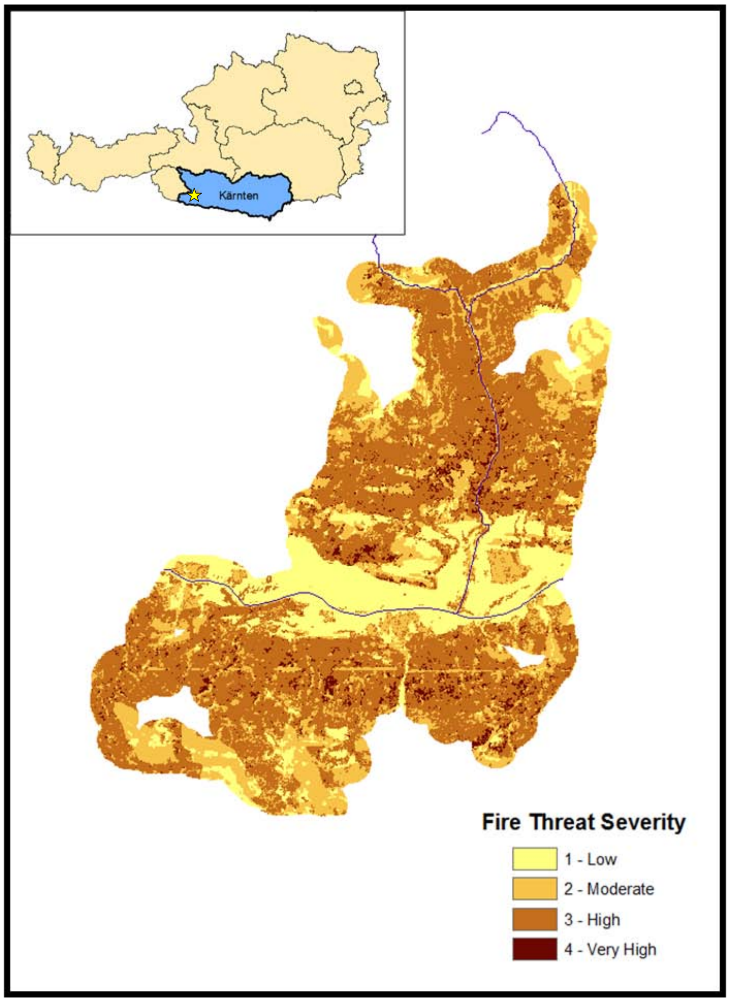


Figure 3. Fire severity threat identification map for Dellach, Austria, area.

Although the proposed framework is not precise and additional research is necessary, this framework can provide Carinthia EMOs with a simple mechanism for determining fire threat and creating risk maps for the hazard wildfire.

Proposed Framework

Natural disasters throughout the world are becoming more costly as populations concentrate in areas particularly vulnerable making it vital and necessary for EMOs to complete their hazard preparatory activities as effectively and efficiently as possible, thereby providing decision makers with the most useful information available to make informed decisions.

Through the progress of this research, several bottlenecks were discovered within both San Diego County and Carinthia EMOs, but perhaps by fully participating in each task of the matrixes, EMOs can provide useful information to the decision makers which will enable decision makers make more informed decisions.

It has been concluded that as the climate changes the environment also changes which in turn adjusts the dynamics and occurrence of natural hazards. With the environment becoming altered, different types of hazards may begin to occur in areas where these events have yet to impact or occur. Therefore, it is necessary to broaden the scope of hazards which Carinthia EMOs examine to prepare for a variety of natural hazards in the case that certain hazards may develop within their locale based on how the climate has altered the environment. Other suggestions to remove the bottlenecks of Carinthia EMOs include creating hypothetical scenarios; improving data quality; ensuring enforcement of all rules, codes, laws, and regulations; develop a disaster response plan; developing a plan of intergovernmental and interagency communication and coordination; and improve risk communication.

Although there are fewer bottlenecks that were identified during the course of this research in San Diego County than in Carinthia, Austria, bottlenecks still exist within EMOs of San Diego County and should be addressed. One such is the creation of hypothetical disaster scenarios for additional hazards. This will enable EMO personnel to become more familiar with natural hazards and how risk changes with every hazard occurrence. Other tasks that necessitate improvement in San Diego County EMOs, like Carinthia EMOs, are to improve accountability, data quality, and risk communication. Unfortunately, even with a variety of mediums for communicating risk available, there are a multitude of opportunities for misunderstandings and miscommunication to occur and thus it is necessary for EMOs to continually obtain information about their stakeholders and utilize as many mediums possible so that appropriate action can be taken during an event.

CONCLUSION

Natural hazard will continue to affect populations throughout the world. To reduce the losses that are incurred for hazard events, EMOs conduct a range of preparatory activities. This research has provided some insight into two EMOs in developed countries and how they conduct their preparatory operations while identifying bottlenecks that occur within each. The proposed framework can help to rectify some of these bottlenecks and improve emergency management operations. As technology and methods change, further research can extend the research results and propose additional methods in which to improve emergency management.

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