GIS Usage in Emergency Management –

An overview

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Contents:

Abstract:

Emergency management has been the hot topic in recent times. Emergency events imply all events that endanger normal functioning of services and companies, endanger lives or resources (living environment) as well as events that are threaten stability of state. All situations resulting from fires, explosions, technological and traffic accidents, terrorist attacks, transport of hazardous materials comprise hazardous events.

The purpose of this paper is to describe the different uses of Geographic Information Systems (GIS) in emergency management efforts for disaster preparedness, mitigation, and response. There have been multiple emergency scenarios around the World where GIS has been used to reduce risk or damage, for both pre and post emergency situations. We will also look at impediments in the application of GIS to such situations where time is critical, and how the technology can be streamlined and utilized in a less time consuming fashion so as to attain better efficiency and results.

Introduction

Emergency management can be defined as "the discipline and profession of applying science, technology, planning and management to deal with extreme events that can injure or kill large numbers of people, do extensive damage to property, and disrupt community life". (Drabek and Hoetmer 1991).

In dealing with such events, many of the critical problems that arise are spatial in nature. Analyzing the impact of a hazard as a precaution, or identifying the best route to be used during a disaster, or planning a rebuilding effort after a disaster has taken place, all of them have a high degree of spatial component in common. This is where GIS can be extremely handy and useful – It has been designed to support geographical inquiry and hence, spatial decision making.

Research Objective:

The focus of this paper is studying the role of GIS in managing sudden impact disasters which are caused naturally as well as man-made in nature, while taking a look ata few impediments which prevent GIS to be successfully implemented in such situations. This role can be demonstrated by a case study, which is a research done in the University of Redlands, in California, USA where the use of a GIS system which identifies population location and disaster situation location and integrates it with GIS can be helpful in evacuation scenarios.

Research Methodology:

The research methodology utilized in this paper is through extensive literature review of multiple papers which deal with the use of GIS in varied emergency situations.

General Types of emergencies

Natural Disasters - Unplanned events that occur as a result of natural processes such as earthquakes, tornadoes, tsunami, freezes, blizzards, extreme heat or cold, drought, or insect infestation are known as natural disasters.

Human Causes - Human-caused emergencies are those unplanned events or accidents that are a result of human activity or human developments. Some examples include chemical spills, nuclear radiation escapes, utility failures, epidemics, crashes, explosions, and urban fires.

Internal Disturbances - Events or activities planned by a group or individual to intentionally cause disruption is called internal disturbances. This includes riots, demonstrations, large-scale prison breaks, and violent strikes.

Energy and Material Shortages - Emergencies as a result of shortages include strikes, price wars, and resource scarcity.

Attack - This type of emergency includes acts of large-scale terrorism or war using nuclear, conventional, or biological agents.

In this paper I have divided all emergencies broadly into two types – Natural and Man-made.

Emergency Management

Emergency management is the generic name of an interdisciplinary field dealing with the strategic organizational management processes used to protect critical assets of an organization from hazard risks that can cause events like disasters or catastrophes and to ensure the continuance of the organization within their planned lifetime.

Phases of Emergency Management:

Emergency management activities can be grouped into five phases, which are related to each other through time and function to all emergency and disaster types. Each phase is related to another, and all of them require specific skills.

All phases of emergency management depend on data from a variety of sources. The appropriate data has to be gathered, organized, and displayed logically to determine the size and scope of emergency management programs. During an actual emergency it is critical to have the right data, at the right time, displayed logically, to respond and take appropriate action.

Most of the data requirements for emergency management are of a spatial nature and can be located on a map. The section below will illustrate how GIS can fulfill data requirement needs for planning and emergency operations and how GIS can become the backbone of emergency management.

Planning includes activities that are required to analyze and file the possibility of an emergency or disaster and the potential consequences or impacts on life, property, and the environment. This includes assessing the hazards, risks, their mitigation, preparedness for such problems, the response to them, and recovery needs.

Emergency management programs begin with locating and identifying potential emergency problems. Using a GIS, officials can pinpoint hazards and begin to evaluate the consequences of potential emergencies or disasters. When hazards (earthquake faults, fire hazard areas, flood zones, shoreline exposure, etc.) are viewed with other map data (streets, pipelines, buildings, residential areas, power lines, storage facilities, etc.), emergency management officials can begin to formulate mitigation, preparedness, response, and possible recovery needs. Lives, property, and environmental values at high risk from potential emergency or disaster become apparent. Public safety personnel can focus on where mitigation efforts will be necessary, where preparedness efforts must be focused, where response efforts must be strengthened, and the type of recovery efforts that may be necessary. Before an effective emergency management program can be implemented, thorough analysis and planning must be done. GIS facilitates this process by allowing planners to view the appropriate combinations of spatial data through computer-generated maps.

Mitigation includes activities that eliminate or reduce the chance of a disaster. It also includes long-term activities designed to reduce the effects of unavoidable disaster like land use management, or building restrictions in potential flood zones.

As potential emergency situations are identified, mitigation needs can be determined and prioritized. In the case of an earthquake, developments within the primary impact zone of earthquake faults could be identified. Based on the expected magnitude of an earthquake, characteristics of soils, and other geologic data, occurring damage could be studied. Areas where facilities require reinforced construction or relocation is required can be identified. High hazard areas like bridges, primary roads, hospitals, dangerous material storage areas can be highlighted. Mitigation may include implementing legislation that limits building in earthquake or flood zones. Other mitigation may target fire-safe roofing materials in wild land fire hazard areas. Values at risk can be displayed quickly and efficiently through a GIS. Utilizing existing databases linked to geographic features in GIS makes this possible. Fire hazard zones can be identified. A GIS can identify specific slope categories in combination with certain species of flammable vegetation near homes that could be threatened by wildfire. A GIS can identify certain soil types inland adjacent to earthquake impact zones where bridges or overpasses are at risk. A GIS can identify the likely path of a flood based on topographic features or the spread of coastal oil spill based on currents and wind. More importantly, human life and other values (property, habitat, wildlife, etc.) at risk from these emergencies can be quickly identified and targeted for protective action.

Preparedness involves activities necessary to the extent that mitigation measures have not, or cannot, prevent disasters is included in preparedness. In this phase, governments, organizations, and individuals develop plans to save lives and minimize disaster damage by compiling state resource inventories, mounting training exercises, installing early warning systems, or preparing predetermined emergency response forces. Preparedness measures also seek to enhance disaster response operations (for example, by stockpiling vital food and medical supplies, through training exercises, and by mobilizing emergency response personnel on standby).

Preparedness also can be defined as those activities that prepare for actual emergencies. GIS can provide answers to questions such as where should fire stations be located if a five minute response time is expected, or how many paramedic units are required and where their location should be. Shelter facilities at evacuation times can be analyzed. GIS can display real-time monitoring for emergency early warning. Remote weather stations can provide current weather indexes based on location and surrounding areas.

Wind direction, temperature, and relative humidity can be displayed by the reporting weather station. Wind information is vital in predicting the movement of a chemical cloud release or anticipating the direction of wildfire spread upon early report. Earth movements (earthquake), reservoir level at dam sights, radiation monitors, and so forth, can all be monitored and displayed by location in GIS. It is now possible to deliver this type of information and geographic display over the Internet for public information or the Intranet for organizational information delivery.

Response includes all activities immediately or developed over a period of time following an emergency or disaster. These activities are designed to provide emergency assistance for victims (for example, search and rescue, emergency shelter, medical care, and mass feeding). They also seek to stabilize the situation and reduce the probability of secondary damage (for example, shutting off contaminated water supply sources, and securing and patrolling areas prone to looting) and to speed recovery operations (for example, damage assessment).

GIS can provide one of the primary components for computer-aided dispatch (CAD) systems. Emergency response units based at fixed locations can be selected and routed for emergency response. The closest (quickest) response units can be selected, routed, and dispatched to an emergency once the location is known. Depending on the emergency, a GIS can provide detailed information before the first units arrive. For example, during a commercial building fire, it is possible to identify the closest hydrants, electrical panels, hazardous materials, and floor plan of the building while en route to the emergency. For hazardous spills or chemical cloud release, the direction and speed of movement can be modeled to determine evacuation zones and containment needs.

Advanced vehicle locating (AVL) can be incorporated to track (in real time) the location of incoming emergency units. AVL can also assist in determining the closest mobile units (law enforcement) to be dispatched to an emergency, as they are located on the map through global positioning system (GPS) transponders.

During multiple emergencies (numerous wildfires, mud slides, earthquake damage) in different locations, a GIS can display the current emergency unit locations and assigned responsibilities to maintain overall situation status. If the emergency becomes a disaster and emergency response units arrive from outside the local area, they can be added and displayed.

Finally, **Recovery** activities are the ones necessary to return all systems to normal or better that they were before. They include two sets of activities: (1) short-term recovery activities which return vital life support systems to minimum operating standards (for example, cleanup, temporary housing, and access to food and water), and (2) long-term recovery activities which may continue for a number of years after a disaster. Their purpose is to return life to normal or improved levels (for example, re-development loans, legal assistance, and community planning).

Short-Term Recovery restores vital services and systems. This may include temporary food, water, and shelter to citizens who have lost homes in a hurricane or large wildfire, assuring injured persons have medical care, and/or restoring electrical services through emergency generators, and so forth. A GIS can play an important role in short-term recovery efforts. One of the most difficult jobs in a disaster is damage assessment. A GIS can work in concert with GPS to locate each damaged facility, identify the type and amount of damage, and begin to establish priorities for action (triage). Laptop computers can update the primary database from remote locations through a variety of methods. GIS can display (through the primary database) overall current damage assessment as it is conducted. Emergency distribution centers' supplies (medical, food, water, clothing, etc.) can be assigned in appropriate amounts to shelters based on the amount and type of damage in each area. GIS can display the number of shelters needed and where they should be located for reasonable access. A GIS can display areas where services have been restored in order to quickly reallocate recovery work to priority tasks. Action plans with maps can be printed, outlining work for each specific area. Shelters can update inventory databases allowing the primary command center to consolidate supply orders for all shelters. The immediate recovery efforts can be visually displayed and quickly updated until short-term recovery is complete. This visual status map can be accessed and viewed from remote locations. This is particularly helpful for large emergencies or disasters where work is ongoing in different locations.

Long-Term Recovery restores all services to normal or better. Long-term recovery (replacement of homes, water systems, streets, hospitals, bridges, schools, etc.) can take several years. Long-term plans and progress can be displayed and tracked utilizing a GIS. Prioritization for major restoration investments can be made with the assistance of GIS. As long-term restoration is completed, it can be identified and visually tracked through GIS. Accounting for disaster costs can be complicated. As funds are allocated for repairs, accounting information can be recorded and linked to each location. Long-term recovery costs can be in the millions (or more) for large disasters. Accounting for how and where funds are allocated is demanding. A GIS can ease the burden of this task.

GIS usage in Emergencies

GIS and related technologies have already contributed in many areas related to this paper. There are many examples of ongoing projects to predict hazards, assess the risk to human life and property, assist help during emergencies, recover from damage, and manage ongoing hazardous conditions, plan and mitigate for future hazards, and impact policy and decision making. We need to study to understand how this is done, and also realize the future challenges that lay ahead in this application area.

We will begin with natural disasters and then move on to human inflicted disasters.

Natural Emergencies

Earthquakes

Major earthquakes of the past include Turkey 1998/1999, Taiwan 1999, and California 1999 etc. Earthquakes can affect any area within a broad zone and can pose great risk to life and infrastructure. Since the turn of the century, earthquakes have been steadily increasing in frequency around the World, and this calls for a need for GIS to be more readily available to the situation. Earthquakes cannot be predicted as in the case of volcanoes or hurricanes, but an idea can be gauged from mapping the area of fault lines around the globe.

Some of the examples of GIS usage in the field of earthquakes are:

1. California Department of Conservation, Division of Mines and Geology (DOC/DMG) – This office has mapped seismic hazard zones and identified areas of risk that are subject to potential ground failure. The maps help cities and counties regulate their growth in hazardous areas. These maps show amplified shaking hazard zones, or ground displacements that have happened in the past, or past and potential earthquake induced landslide areas. These maps are focused on urban areas, and plans are underway to release the maps on PDF versions, such that they are usable on GIS software.
2. United States Geological Survey (USGS) has produced National Seismic Hazard Maps which were available in 1996. These maps cover US and depict probabilistic ground motions and response for future movements of 500, 1000, and 2500 years. This has been utilized in California after the Northridge 1994 earthquake, which provided unexpected efficiency to providing relief to victims of the natural disaster.
3. Association of Bay Area Government (ABAG), with the help of USGS and National Science Foundation, has been using GIS for a long time now to produce seismic area maps for the Bay Area in San Francisco. They show faulty areas, ground shaking intensity fault traces, and tsunami inundation zones. These maps are combined with population maps provided by Census bureau and boundary planners to understand land use decision and mitigation planning.

Volcanoes

Hazardous volcanic phenomena range from passive gas emission and slow effusion of lava to dense descending currents of incandescent volcanic ash and rock that race at high speeds along the surface away from the volcano. During the past two decades, about tens of thousands of deaths have been caused due to these phenomena.

The management of hazards related to volcanoes in the United States is administered by the USGS. The use of GIS in volcanic hazards studies is unfortunately very modest. However, volcanoes are appropriate for GIS tracking as they are in a known source area of threat. The last decade of the twentieth century witnessed the development of several forms of computerized models for volcanic eruptions and their associated hazards. Unfortunately, these have not often been linked to interactive GIS systems. In general, posters, still images, or video scenes of events at other volcanoes were the main methods used to explain the phenomena to the public safety officials. Only in a few cases were advanced technologies or computer models used in the development of volcanic hazard maps. Sophisticated themes, such as distributed computing, visualization, use of large data sets, and interactive modeling and analysis, are lacking in paper that have been published to date.

Tsunamis

Tsunamis like earthquakes are hard to predict but their inundation zone along coastlines can be mapped easily and hence early warnings can be sent. A National Tsunami Hazard Mitigation Program was initiated in July 1994 when the Senate Appropriations Committee directed the National Oceanic and Atmospheric Administration (NOAA) to formulate a plan for reducing the tsunami risks to coastal residents. The program is designed to reduce the impact of tsunamis through hazard assessment, warning guidance, and mitigation. The first step in producing Tsunami Inundation Maps is essential to assess the tsunami hazard. The Center for Tsunami Inundation Mapping Efforts (TIME) within the Pacific Marine Environmental Laboratory of NOAA (NOAA R/PMEL) (Bobbitt, 1999) was created for the purpose of development, maintenance, and upgrade of maps that identify areas of potential tsunami flooding.

The Pacific Marine Environmental Laboratory maintains large databases related to the research and exploration of hydrothermal vent processes and applies GIS to integrating multidisciplinary data sets to create both a map gallery and an Internet site (Trudeau, 1998).

Landslides

Landslides can destroy human infrastructure and potentially be deadly. However, their impact is generally localized and predictable. The USGS has been extremely active in mapping landslide hazards and in developing new methods and models for assessing and analyzing these hazards. In anticipation of the heavy El Niño rains in 1997–98, scientists from the USGS San Francisco Bay Landslide Team (SFBLT) created landslide hazard maps of the Bay region. Following the rains, the San Francisco Bay Area Region Project and their Landslide Hazards Program, both of the USGS conducted inventories of landslides in the Bay Area, which were then used to develop digital landslide distribution databases, computer landslide models, and landslide hazard maps. The SFBLT created digital maps that depict areas of potential slides (slumps and translational slides), earth flows (flows of clayey earth), and debris flows (rapidly moving slides). The map layers include topography in shaded relief, road networks, hydrograph, mapped distributions of slides and earth flows, rainfall thresholds for debris flows, and likely debris flow areas. Most of the data is mapped at 1:125,000 scale (for local emergency planning) and 1:275,000 scale (for regional planning). These maps are part of an overall strategy to help planners mitigate and respond to disasters (Pikei, 1997).

Additionally, the California Department of Conservation (1999) DOC/DMG has been active in mapping landslide hazards in the State. They produce six types of maps that depict landslide hazards. Among them are Landslide Hazard Identification Maps, 1:24,000-scale maps showing landslide features, landslide susceptibility, and debris flow susceptibility. They were produced from 1986 to 1995 under the now-repealed Landslide Hazard Mapping Act. Watershed Maps are 1:24,000-scale maps that include landslide features to assist in timber harvest planning and water quality protection. They were produced in concert with the California Department of Forestry. Four categories of active and dormant landslides are depicted.

Fires

A fire hazard exists to a greater or lesser extent across the North American continent, but nowhere in the United States is the hazard greater than in California. The Mediterranean climate, the rugged topography, a shifting urban wild-land interface, and the recent practice of fire suppression all collaborate to create catastrophic conditions. In the hills east of the San Francisco Bay alone, 5,298 structures have been lost in dozens of fires since 1920, with the majority of them occurring in the last decade (Radke, 1995).

Geographic information science plays a critical role in mapping and documenting fire, then subsequently predicting its course, analyzing alternative fire-fighting strategies, and directing tactics and strategies in the field. The California Department of Forestry (CDF) began an intensive program of mapping fire in response to legislation in the early 1980s. This legislation required CDF to map different classifications of fire hazards with State Responsibility Areas (SRAs), or areas of State fire prevention responsibility (i.e., outside of large, incorporated cities). As a result of the catastrophic Oakland Hills fire, the Bates Bill (AB 337) was passed in the California legislature in 1992. This bill required the CDF to work with local fire authorities to map fire hazard severity zones within Local Responsibility Areas (LRAs), generally referring to areas subject to wildfire hazard that are within incorporated city boundaries. These maps are intended for purposes of enforcing roofing and vegetative clearance requirements. For both types of maps, fire hazard is determined on the basis of fuel loading, fire weather, and slope, among other criteria. Vectorized fire hazard zones were overlaid on USGS topographic maps at 1:24,000, 1:62500, and 1:100,000 scales (Irby, 1997).

At the local or neighborhood scale, mapping and modeling topography and fuel load based on vegetation and structures is gaining in popularity due to advances in geographic information technology.

The 1991 Oakland Hills fire resulted in a local study integrating fire models and data inputs within a GIS to map potential firestorm risk (Radke, 1995).

Floods

Flood zones can be mapped and floods can be predicted with some degree of accuracy. The widest-scale and most systematic mapping of flood hazards come from the Federal Emergency Management Agency (FEMA). FEMA produces flood insurance rate maps (FIRMs) for the purposes of determining whether properties lie within the floodway of a river system or the 100-year floodplain. These maps form the basis of FEMA's policy under the 1969 National Flood Insurance Act (and later amendments). FEMA has worked in recent years to make these maps digitally available.

Another very different application of flood mapping technology was used to help emergency managers in North Carolina to evacuate flood-prone areas prior to Hurricane Fran in 1996. Before this hurricane, the North Carolina Center for Geographic Information an Analysis had used the Sea, Lake, and Overland Surges from Hurricane (SLOSH) model to prepare several Hurricane Storm Surge Inundation Area Maps for coastal areas of the State, showing the historic extent of hurricane storm surge inundation. The model was used to produce maps showing flood extent under conditions of slow- and fast-velocity hurricanes. These flood extents were then overlaid on 1; 24,000-scale USGS topographic maps. Based on the SLOSH model, Hurricane Evacuation Restudy Maps were prepared that were used to guide the evacuation of residents from low-lying and coastal areas. These maps were also used by other agencies, such as the Division of Forest Resources, that performed overlays of these maps with forest cover layers to predict the amount of forest damage (Dymon, 1999).

A methodology to understand flood hazard by incorporating GIS and distributed hydrological modeling has also been proposed (Lanza and Siccardi 1995).

Tornadoes

Tornadoes are one of nature's most violent storms. In an average year, 800 tornadoes are reported across the United States, resulting in eighty deaths and over 1,500 injuries, which is the most severe of any country in the world. Although GIS is employed to map and summarize the events of tornadoes, in a growing number of communities it is used in real time on the front line. On the evening of May 3, 1999, the National Weather Service (NWS) issued a tornado warning for southeastern Sedgwick County, Kansas (DeYoe, 1999).

For cyclone risk management, Johnson and Smith (1994) have provided a comprehensive example in their paper, using 100 year old maps and taking cues from US National weather service.

Hurricanes

Hurricanes can destroy human infrastructure and habitat, killing and impacting large populations across vast territory. We only have to refer to a few—Agnes (1972), Hugo (1989), Andrew (1992), and Floyd (1999)—to illustrate the damage and loss to society.

After the devastation of Hurricane Andrew, FEMA upgraded its pre- and post disaster planning and response capabilities. The GIS-based system, called the Consequences Assessment Tool Set (CATS), developed by Science Applications International Corporation (SAIC), enables FEMA to predict the effect of impending disasters, such as hurricanes, and quickly mobilize a well-coordinated an directed response (Corbley, 1999). This allows FEMA to pinpoint critical evacuation areas as well as make accurate damage predictions for phenomena such as storm surge and wind damage that facilitates a quick recovery (Trudeau, 1998).

As disaster strikes, CATS, using combined government, business, and demographic databases, produces reports and graphics that provide emergency managers and the national media with timely information.

Known damage is reported along with mapped estimates of the extent of damage and affected population. Suitable mobilization sites are identified along with nearby airstrips, empty warehouse space, and information about federal and local sources for disaster relief. When Hurricane Eduardo (1996) was threatening to endanger the U.S. coastline, FEMA identified areas of potential water contamination and quickly moved freshwater supplies to those sites ahead of the storm.

Manmade emergencies

Unlike many natural hazards, most human-induced hazards could be prevented, reducing or even eliminating loss of life and damage to property. With a better understanding of the underlying forces that induce disasters, we can work toward mitigation and possibly elimination of some of them.

Health Related Epidemics

Epidemiologists use maps to log locations, encode associations, and study the spread of disease (Clarke et al., 1999). Using geographic information tools and integrating them with spatial analysis, a technology that is well suited to track disease can be created.

GIS was used to identify and locate environmental risk factors associated with Lyme disease in Baltimore County, Maryland. Watershed, land use, soil type, geology, and forest distribution data was collected at the residences of Lyme disease patients and combined with data collected at randomly selected addresses to fuel a model detecting the most probable locations where Lyme disease might occur.

At a national level, GIS has been used to help design a surveillance system for the monitoring and control of malaria in Israel (Wood et al., 1994). The GIS-based surveillance system located breeding sites of Anopheles mosquitoes, imported malaria cases, and population centers in an effort to better respond in the cases of outbreaks. On a global scale, the National Aeronautics and Space Administration (NASA) established the Global Monitoring and Disease Prediction Program at Ames Research Center to identify environmental factors that affect the patterns of disease risk and transmission (Ahearn and De Rooy, 1996). The program developed predictive models of vector population dynamics and disease transmission risk using remotely sensed data and GIS technologies and applied them to malaria surveillance and control (Beck et al., 1994).

For ground-water pollution risk assessment, Cavallin and Floris (1995) described a raster-based GIS.

Social Unrest – War

Although one could argue that war is a good candidate for a health-related epidemic via germ warfare, the use of geographic information technologies by the military has been more proactive than simply monitoring and surveillance.

The National Imagery and Mapping Agency (NIMA) (NIMA, 1999b), a major combat support agency of the Department of Defense and a member of the intelligence community, was established in 1996 to provide accurate imagery, imagery intelligence, and geospatial information in support of the nation.

GIS is also used as a tracking tool for troops in training and combat, and as a planning and negotiation tool for peacemakers. The military will use it to plan and rehearse missions, improve weapon accuracy, and for modeling and simulation purposes. Geographic information technology is also being used for environmental monitoring and cleanup at several Navy installations as part of the Navy's comprehensive, long-term environmental action (CLEAN) program and at the Rocky Flats Nuclear Weapons Complex (Bromley, 1995).

Toxic Spills, Explosions and Fires

Man-made crises are extreme events that can be accidental, such as toxic spills, or premeditated such as bombings by terrorists. No matter what their origin, many of these human-induced disasters could be lessened or even prevented by integrating geographic information technologies. For example, in a case of toxic release, population data, residential locations, wind speed, and direction could populate a model to map the extent of the disaster and suggest evacuation strategies. All crises require an immediate and well-coordinated response where data handling and system interoperability are critical. Besides the political and technical challenges of fusing data from mixed sources, proprietary data formats often impede interoperability.

During a crisis, such as the Oklahoma City bombing, data access speed is paramount for rescue workers, and advances in robust indexing mechanisms, such as geographic footprints (Goodchild, 1996), will prove invaluable. Although many successful initiatives are already underway at both the local and national levels, they could greatly benefit from advances in geographic information science. The City of Winston–Salem, North Carolina, built an Integrated Network Fire Operations (I.N.F.O.) system that is designed to reduce the time it takes for firefighters to respond to emergency (911) calls and to provide information about the address of an incident to aid firefighters in making better informed decisions and plan the fire-fighting effort while en route (Chakraborty and Armstrong, 1996).

In Cova and Church's study, they described the use of an Emergency Planning Zone (EPZ) because "…it serves as a formal agreement among emergency planners regarding the definition of a likely evacuation. This allows analysts to move directly to issues related to estimating and reducing the time it may take to clear a zone."

De Silva, Pidd and Eglese (1993) suggested a Spatial Decision Support System than can integrate simulation models and GIS software to provide evacuation routes for radiological disasters.

The DYNamicEVacuation (DYNEV) model of traffic evacuation has been designed for people living within 10 miles of a nuclear power plant, as described by MItrani and Newsom (1993).

Challenges for GIS Implementation

Impediments to implementation of GIS can be analyzed on the basis of long term planning for a situation that might occur in the near as well as distant future; but this type of planning is quite different from the usage of GIS in real time disaster management. We will look at long term planning hurdles now. Some of them as mentioned are:

Data Gathering

Data acquisition and integration may be the single-largest contribution area needed for emergency preparedness and response. Although models can be developed for handling disasters, making them operational on a day-to-day basis means huge investments in data acquisition and integration.

Distributed Computing

Modern computer simulations of complex natural phenomena, such as rapid forest firegrowth or development of a volcanic plume, require supercomputer facilities with distributed simultaneous computing on many processors. Linked to geographic information systems, these models for pre-disaster planning, crisis management, and post-disaster recovery could become extremely valuable mitigation and response tools. Although this level of analysis is not possible today, during a crisis such a system could be highly useful. It is important that any new data systems be developed on a platform that is widely compatible with those of existing data users. It is also important that these systems be designed to run on thin clients, as in an emergency it is likely portable, wireless computers will be the communication tool in the field.

Extensions to Geographic Phenomena

A key area to pursue is the dynamic representation of physical and human processes inemergency preparedness and response. Geographic information systems have not traditionally been designed to represent dynamic phenomena, but this is critical in assessing and responding to emergencies. The computational representation of human vulnerability has lagged behind the theoretical advancements in this area. Risk and human vulnerability are much more dynamic than the representations that are now being used in GIS. There is a need to be able to rapidly model and summarize alternative scenarios, especially when the future is uncertain. i.e. There should be a link between the representation of GIS imagery and land reality, such that emergencies can be easily taken care of. For this, up to date representations of imagery should be present.

Interoperability of Geographic Information

Software used for emergencies is no use if it cannot be used by one and all – Hence it is necessary such that there is interoperability between different softwares to read each other's data such that the positive influence brought about by GIS can be used by anyone in the case of a emergency situation.

Scale

Detail required for emergencies needs to be at a comprehensive level, and hence this might lead to file sizes which might run into gigabytes. Current risk simulation codes work on small areas with large grids and are slow. Future codes should operate on fine grids of data sets that include the entire area of risk surrounding, for example, a volcano.

Secondly, impediments to Real time disaster management using a GIS example are:

1. GIS was unable to answer questions asked of it in real time due to technical constraints that included limited computer processing power, and the size of building database. The building database size especially did not provide answers for spatial questions in the required short time.

2. Emergency managers were more pressed to make evacuation and decision making concerns, than those with which GIS has been designed to address.
3. Inexperience of emergency managers with GIS precluded them using it to aid decision-making to its full potential.
4. Difficulties in sharing information via a single computer terminal to multiple users.

Case Study – University of Redlands

The University of Redlands is a private liberal arts and sciences university located in Redlands, California, United States. To assist the University, a customized GIS application was developed enabling a temporal based analysis of a disaster occurrence integrated with concentrations of campus populations identified down to the room level. The GIS Emergency Management System (GEMS) application is an interactive system to be utilized in the Emergency Operation Center to support the direction of the response. If a disaster were to occur, the response and recovery efforts could be initially focused to the most critical areas with the largest concentrations of people.

Threats facing University of Redlands

Threats to public safety at the UoR are from many sources. Human-caused threats are those unintended events or accidents resulting from human activity. Examples include chemical spills, utility failures, airborne illness, plane crashes, truck crashes, explosions, and fires. In addition, other human caused disasters can be events or activities planned to intentionally cause disruption to a population. Although the UoR may never be a direct target, the University's close proximity to larger metropolitan areas and military bases poses a serious threat. A second type of threat facing the UoR is from natural causes. The UoR location in near proximity to the San Andres fault makes it particularly vulnerable to earthquakes and their many secondary effects including building structural failure, pipeline breaks, release of hazardous chemicals, fire, and down electrical power lines. Another natural hazard facing the UoR is wild fires; the dry climate of the region increases the likelihood of danger and disruption caused by uncontrolled fires. Although the Redlands' area is dry most of the year, there is potential for excessive rain and the resulting floods during certain seasons. For example, the Seven Oaks Dam was completed to help mitigate flood damages; however, with the University being located 8 miles southwest of the dam, it is potentially in harm's way if the dam was to experience a structural failure.

GEMS Overview

For the initial implementation of a GIS emergency management system at the University of Redlands, there are several key functional components being delivered. The first component, Population Locator, includes the capability for spatially locating concentrations of people throughout the day on campus. The second component, Disaster Occurrence, provides the capability to record disasters with a threat range or modeled plume into the database. The final Query and Analysis component enables the campus population to be analyzed with the threat areas for a given date and time query.

Population Locator Component

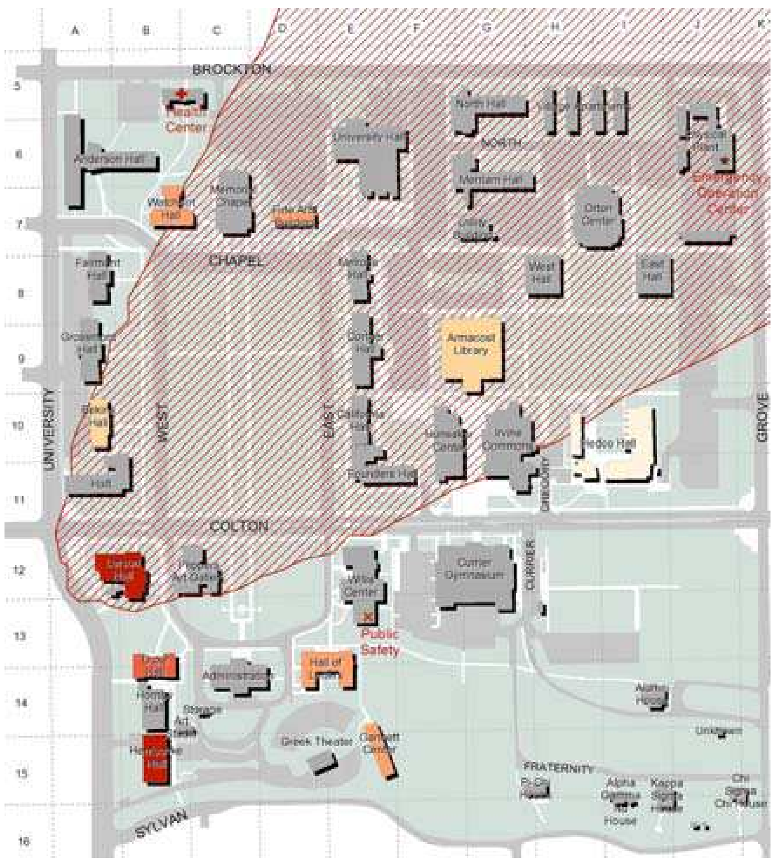
The first component developed for GEMS is the function to locate the concentration of people throughout the day for classes located on the main UoR campus. This integrates several data sources from the UoR Registrar's office into the GEMS database. The first record set from the Registrar's office is the classroom location schedule which includes the day and the time frame for each class in the semester. The second record set is the aggregated student class data to be able to determine the number of students in each class. Records can be updated on an as needed basis throughout a semester with inputs provided the Office of the Registrar. As an updated record set is provided, the corresponding semester records in the database will be overwritten.

Additionally, to accommodate for known population concentrations outside of classes, such as dining hall crowds or football game crowds, population estimations can be recorded directly into a table in the GEMS database.

To improve the granularity of data analysis, the floor plans for the classroom buildings at the University have been added to this application.

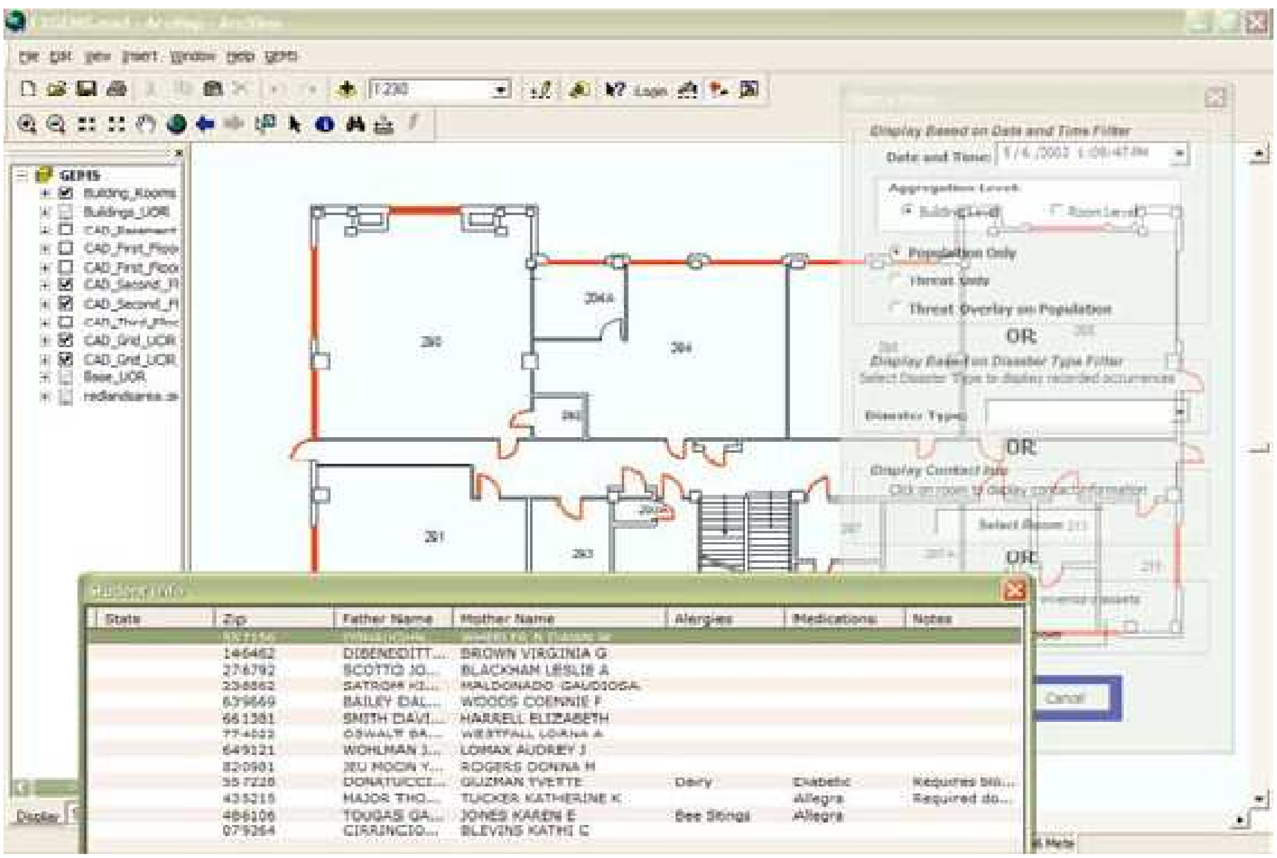
Disaster Occurrence Component

It is important to document and track disaster occurrences to support the phases in a disaster management plan, a component implemented with GEMS. Once a disaster occurs, it can be recorded into the application through a graphical user interface. As events unfold, the user can document the location, the disaster or threat area, time frame, hazard type, and detailed description of the disaster. Two types of disaster or threat areas can be defined. The first is a circular threat or disaster range suitable for occurrences such as a bomb threat. This only requires a source location and threat radius to create the area. The second is for areal hazards as complex plume areas can be modeled with the Environmental Protection Agency's (EPA) Areal Locations of Hazardous Atmospheres (ALOHA) model and utilized within GEMS. ALOHA estimates air dispersions to evaluate hazardous chemical release scenarios and predict dispersion scenarios.



Query and Analysis Component

With the population concentrations and disaster or threat areas incorporated into GEMS, the final component developed is for querying and analyzing the data. Concentrations of the population can be isolated for a specific date/time through a query. For the initial implementation of this application the results are displayed on the map at the building level, but an output table can be generated to identify populations at the room level. A look-up table creates the relation between the registrar attribute data and the building spatial data based on the query. As queries are generated in the application, the results are displayed as map layers with a population field. In addition, a Hypertext Markup Language (HTML) report is created with the location of population concentrations displayed to the room level. With the threats previously entered into the system, a threat query based on time can be displayed on the map. This will allow analysis with the threat area defined and displayed on the map interface. Additionally, the population concentrations can be identified within the threat ranges for a given time, identifying the specific population concentrations in harms way. Another query capability is to zoom down to the room level of the buildings. By selecting a date/time and clicking on a room will display the contact information for the students registered for that class and any special medical conditions are pertinent to the safety of a student. This may be particularly useful in lock down situations to inform the contacts for each student, as shown in Figure 2.



The results of the other queries are a generated html report with tabular data and a map. This can be printed out easily, used interactively in the EOC, or quickly and easily copied to a web server to share information across the internet. Figure 3 is a sample HTML report generated by the GEMS application.

Note: Critical buildings containing populations within a threat zone are labeled

The following buildings have populations and are located within the threat zone

Building (Student Count)
Armacost Library (13)
Currier Gymnasium (26)
Duke Hall (78)
Gannett Center (42)
Hall of Letters (186)
Hedco Hall (45)
Hornby Hall (38)
Peppers Art Gallery (17)

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GEMS Design Considerations

The overall goal of the GEMS application is to develop, promote, and implement location based data and GIS technology in support of emergency management at the UoR. The GEMS approach is to integrate sources of geographic and attribute data from the UoR with threat or disaster occurrences in a GIS application to analyze, support, record and track the different phases of emergency response management.

GEMS is built on ArcGIS 8.x, a customizable commercial off the shelf (COTS) GIS software package. The software is developed and distributed by Environmental Services Research Inc. (ESRI) of Redlands; CA. GEMS is developed in compliance with the UoR campus wide software license for ESRI products. The emphasis for the GEMS application is a focus on a simple interface with the key functionality readily available for the purpose of avoiding additional stress on the user when employing GEMS in response to a disaster. The data for the system is stored in the ArcGIS personal geo-database, which uses Microsoft Access technology.

Conclusion:

GIS is well suited for disaster management because of varied reasons – It can produce information quickly which is a vital ingredient in time constraint situations like emergencies; it can produce maps with structured data and hence the information is well organized; and GIS information is easy to update and maintain current files.

However, the knowledge of the above is not all. Efficient management of potential risks can only be accomplished if emergency managers are aware of the extent of the possible effects of disasters. Tools can be developed to act as a decision support system for emergency management agencies, through the use of a geographic information system (GIS). Because each cyclic phase in emergency management is related to where people, places, and things are spatially located, GIS can be a valuable tool for analysis purposes throughout each cycle. Disasters can affect us anytime, and even if the window to predict their happening is open, nature can take its course without an alarm and hence it should be our priority to be aware of the dangers that such disasters may inflict. Usage of GIS in natural as well as man-made emergencies is a requirement that all governments need to take seriously. Although there are obstacles to the implementation of GIS in every disaster affected area, effective planning can be used to reduce the number of people, places and the extent of disaster that is affected by the calamity.

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