The Role of Geospatıal Tools in Dısaster Management Life Cycle

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SUMMARY

Geospatial tools have a great potential in disaster management life cycle for saving lives, limiting damages, and reducing the costs. Disaster managers, especially, would like to know where the incidents are, where their impacts are greatest, where critical information is needed to respond. Because of the chaotic nature of disasters, disaster managers need geospatial data and tools that are collected and distributed in the form of useful products to allow effective response without any confusion. The term of geospatial includes interdependent resources such as maps, data sets, tools, and procedures. Geospatial tools can consist of several forms including paper maps, in-car navigation systems, internet sites, software and databases; and analytical, mapping, and visualization tools that support decision-making in emergency management. Remote sensing, Geographic Information Systems (GIS), Spatial Decision Support Systems (SDSS); and clearinghouses, geolibraries, archives, geoportals, and geobrowsers can be taken into consideration as the types of geospatial tools in disaster management activities. GIS are able to integrate information from different sources, scales, accuracies, and formats into a single source; and they could facilitate modeling, mapping and spatial decision support. These systems can be used for training in the preparedness phase, or in responding to actual emergencies. Recent developments in real-time GIS, remote sensing, interoperable GIS, and the Internet have greatly influenced emergency management activities. GIS can be a powerful tool for analysis purposes because each phase in the emergency management life cycle is geographically and spatially related to each other. In this paper, the role of geospatial tools in disaster management life cycle (Preparedness, Response, Recovery, and Mitigation phases) is taken into consideration.

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1. INTRODUCTION

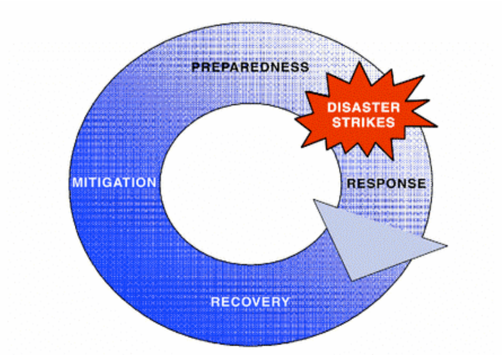
Disasters are now beginning to affect many people's lives and property everyday; and a better understanding of disasters are more crucial today. Researchers are developing new aspects for responding to them by using computer and communication technologies. They are also using analysis and modeling techniques such as operations research, risk analysis, simulation, spatial decision support systems (SDSS), artificial intelligence-expert systems, and geographic information systems (GIS) to manage disasters via developing new approaches (Tufekci and Wallace, 1998).

In the practitioner community, disaster managers have learned and stated that accurate and timely information is as crucial as is rapid and coherent coordination among the responding organizations. Effective geospatial tools that provide timely access to comprehensive, relevant, and reliable information are critical. The faster emergency responders are able to collect, analyze, disseminate and act on key information, the more effective and timely will be their response, the better needs will be met and the greater the benefit to the affected populations. (De Valle and Turoff, 2007).

2. DISASTER MANAGEMENT LIFE CYCLE

US National Governor's Association developed an all-hazard or comprehensive disaster management model in the early 1970s. With this approach, disaster management activities divided into four functional classes: mitigation, preparedness, response, and recovery (See in Figure 1.). While mitigation and preparedness are pre-emergency activities, response and recovery are considered during and post-emergency activities, respectively. Mitigation deals with disasters to prevent or reduce losses. Preparedness is planning and enhancing response activities for managing disasters. Response begins immediately following an event and examples include mass evacuation, providing medical care, search and rescue, firefighting, containing the hazard, and protecting property and the environment. Recovery continues after the event to restore lifelines (Waugh, 2000).

Figure 1. Emergency Management Life Cycle (NRC, 2007)



3. DEFINITIONS OF GEOSPATIAL TOOLS IN TERMS OF DISASTER MANAGEMENT

Disaster is a sudden, unpredictable event that poses a substantial threat to life or property. Disaster management is the organization and management of resources and responsibilities for dealing with all aspects of disasters. Disaster management activities are effective in all phases in diasaster management life cycle. Disaster management involves plans, structures, and arrangements established to manage the disasters in a comprehensive and coordinated way (NRC, 2007).

(NRC, 2003) says ‘much of the information that underspins disaster preparedness, response, recovery, and mitigation is geospatial nature’. All disasters have a temporal and geographic nature that identifies the duration of impact. The term *geospatial* is used to refer to interdependent resources such as imagery, maps, data sets, tools, and procedures.
Remote sensing describes the collection of data from a wide range of automated systems, including satellites and aircraft with imaging sensors, and groud-based surveillance cameras. Geographic information systems are software systems used to capture, store, manage, analyze, and display geospatial data sources. GIS are among the most important and widely used of geospatial tools, and their functions allow emergency managers to integrate geospatial data, create maps, produce statistical summaries, and perform other essential functions. Spatial decision support systems (SDSS) are designed to provide the essential information needed by decision makers when decisions involve location. A SDSS might be used design evacuation routes, to select optimum locations for response teams, or to allocate evacuees to shelters (NRC, 2007). SDSS includes following tools and techniques: modeling and simulation capabilites; data visualization and integration tools; advanced data mining and core sampling applications; rapid damage assessment tools; logistics planning tools; collaboration technologies supporting real-time dissemination in distributed environments; enabling technologies and methodologies supporting virtual expert forums (GDIN, 1997).

Many web sites provide access to large collections of geospatial data sets, which developed and assessed by remotely located users and service providers. Clearinghouses, geolibraries, archives, and geoportals are taken into account such services. *Geospatial tools* are software and hardware systems that perform specific operations on geospatial data. They include GIS and SDSS; furthermore, more limited tools and equipment designed for such functions are taken into consideration as analysing and processing images, acquisition and reformatting data.

4. THE ROLE OF MAPS IN DISASTER MANAGEMENT

Mapping is one of the main geospatial tool in disaster management activities. It is a key element for disaster response personnel to become oriented during a response. Especially in this phase, displaying the location of available resources on a base map such as schools, hospitals, and airports is clearly useful. Mapping the location of disaster response teams is very important in coordinating response, and mapping is also essential to the interpretation of the data in response activities (Walker, 1997).

Maps also provide spatial organization of the critical movements in a hazardous event. They are indispensable tools to coordinate the efforts of disaster teams and services; to provide a guide for possible action by the public; to aid the flow of resources and services before, during, and after an disaster; to serve as the quickest method for locating all the elements in a specific geographic area without having to read large volumes of information; to determine the physical constrains of the incident site and to make the optimal decision for action; and to serve as educational devices or public relations means (Dymon, 1990; Mishra, 2002).

Detailed maps take a role in disaster management. By producing crisis maps, disaster managers able to document the details of spatial relationships and the changing elements of the disasters to control and mitigate the effects of the disasters. Crisis mapping should be recognized as a critical part of disaster management that needs to be integrated into it.
The role of mapping for disaster management can be analyzed in the following phases: hazard assessment and vulnerability analysis; mitigation and preparedness; pre-disaster phase; response; loss and damage assessment; and rehabilitation and reconstruction. In hazard assessment and vulnerability analysis phase, vulnerable and risky areas need to be identified and mapped. Maps show the areas having different degrees of vulnerability and prone to multiple disasters (Mishra, 2002).

From disaster management perspective, maps enable the location-specific assessment of hazard, risk, vulnerability, and damage. They are required with different levels of geographic detail in terms of disaster management life cycle, from the moment an incident occurs through long-term recovery and into mitigation (NRC, 2007).

Maps underpin the GIS activities by facilitating simulation models that can be useful at various stages in disaster management life cycle. Based on such analysis, one can assess the likelihood of such phenomena at different locations over time; and mitigation measures shold be taken effectively in hazard prone areas. During the pre-disaster phase, with the help of maps, scenarios can be analyzed and response operations can be planned and also evacuation routes can be determined for use of disaster managers.

Another use of maps in disaster management is “ShakeMaps” developed by U.S Geological Survey, which can be prepared in a few minutes after an earthquake and sent to the response agency. The results are rapidly available via the Web through a variety of map formats, including GIS coverages. These maps have become a valuable tool for disaster response, public information, loss estimation, earthquake planning, and post-earthquake engineering and scientific analyses (USGS, 2009).

Mapping is essential even during relief, rehabilitation and recovery phases after an emergency occurs. In the event of a major emergency affecting a large population, it is necessary to plan relief and recovery activities with the help of the maps. Maps of earthquake affected areas showing population, deaths and injuries, houses damages, health centers, and all of other facilities such potable waters provide valuable data for planning relief and recovery works.

5. THE ROLE OF GEOSPATIAL TOOLS IN DISASTER MANAGEMENT

5.1. Preparedness phase

Preparedness involves activities undertaken in the short term before disaster strikes that enhance the readiness of organizations and communities to respond effectively. From the geospatial perspective, preparedness works include identifying data requirements, developing data sets, and sharing data across agencies. This includes activities such as developing foundation data on infrastructure, hazards and risks, location of assets for use for response and recovery, determining common standards of data, making potentially difficult decisions about attributes, and compiling necessary metadata (NRC, 2007).

In this phase, geospatial tools can be used to display the distribution of hazards and risks which exist now or will be potentially existed in the future scenarios. This enables local and regional planners to work with disaster managers to plan the future through mitigation of higher-risk alternatives. For example, evacuation routes can be planned based on demographics, capacity of existing roads, and traffic volume as a function of day and time.

5.2. Response phase

Response activities are undertaken immediately following a disaster to provide assistance to victims. Geospatial information and analysis are critical inputs to disaster management and tactical decision making. Activities during this period include image acquisition, processing, analysis, distribution, and conversion to information products. Other geospatial data should also be collected, summarized, and converted into maps, reports, and other products.

During the response phase following an event, geospatial tools can be used to provide damage estimates. Alternatively, real-time data from in situ monitoring can be used with geospatial models to determine conditions during an event. Use of dynamic models can guide and improve response activities; for example, the wildfire community makes extensive use of real-time geospatial modeling of wildfire behavior for logistical support. Display functions in geospatial tools remain important by showing the location of damage to specific infrastructure components as well as showing severity of damage. Accomplishing all of these tasks is quite hard to undertake in this phase because demands are urgent and requests are voluminous. With poor products, response operations can not be managed in an efficient way. Geospatial professionals must be trained to perform well in this environment.

5.3. Recovery phase

Recovery includes short and long-term activities undertaken after an emergency that are designed to return people and property in an affected community to at least their pre-emergency condition. Geospatial activities during recovery include the use of geospatial information and analysis to help managers direct the recovery process, including the urban search-and-rescue grid and status, tracking the progress of repairs, locating populations, identifying sites for temporary housing and services, and showing the operational status of hospitals and clinics (NRC, 2007).

5.4. Mitigation phase

Mitigation includes those activities undertaken in the long term after disaster and before another strikes. They are designed to prevent disasters and to reduce the damage resulting from those that occur. They include identifying and modifying hazards, assessing and reducing vulnerability to risks.

Geospatial assets can inform mitigation planning in important ways, most importantly the opportunity to visualize and measure the effects of alternative mitigation plans. Simulation models can help planners make effective decisions in this phase. Geospatial analysis can support benefit-cost analysis by comparing the cost of changes. Geospatial tools have particular benefit due to their ability to permit the evaluation of multiple alternatives rapidly.

6. GIS AND SDSS IN DISASTER MANAGEMENT

GIS are able to integrate information from different sources, scales, accuracies, and formats into a single source; and they could facilitate modeling, mapping and spatial decision support. These systems can be used for training in the preparedness phase, or in responding to actual disasters. Recent developments in real-time GIS, remote sensing, interoperable GIS, and the Internet have greatly influenced disaster response activities (Cova, 1999).

Although emergency management has historically focused on urgent aspects of disaster in response and recovery activities; there is a growing interest that disaster management is much more complex and comprehensive than traditionally perceived. Because of the fact that disaster management is a national concern, county disaster management agencies have the responsibility to deal with disasters. These agencies should develop disaster action plans and be equipped with tools that help them overcome the resource shortfall. These tools can be used for reaching proper information as well as determine , visualize, and analyse the ranges of disasters. Such tools can be developed to act as a decision support systems for disaster management agencies via using geographic information systems (GIS) capabilities (Gunes and Kovel, 2000).

GIS can be a powerful tool for analysis purposes because each phase in the disaster management life cycle is geographically and spatially related to each other. According to Thomas et al (2003), geo-technologies are at the center of the disaster management life cycle and GIS support the decision-making process by providing people with a tool for assessing and analyzing the geographic nature. After the September 11th disaster in New York City, geo-technologies were implemented for this reason.

In terms of responding to the catastrophic incidents, Thomas et al (2003) provide an overview of how geo-technologies were used in the aftermath of the September 11th disaster. In their paper, they discuss how to use geo-technologies in support of disaster response operations. The September 11th disaster provided opportunities to evaluate the use of geo-technologies in response to a catastrophic event. Immediately after September 11th, many maps and imageries appeared in the media showing the damages and depicting the level of disaster response operations. Moreover, Thomas et al (2003) discuss the geo-technologies as a decision-support tool. Improving disaster responders ability in effective response is the main objective of using geo-technologies. Creating useful tools for improved decision making is an essential task in the face of any disaster.

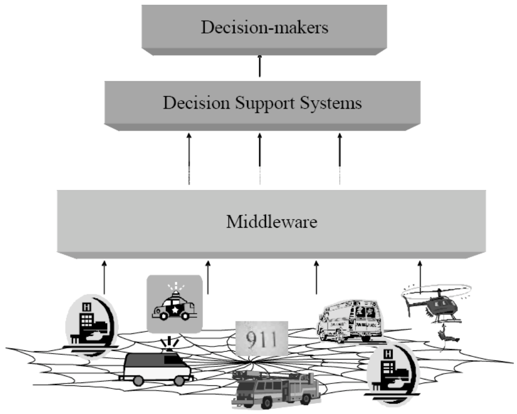
SDSS provide the essential information for decision makers when decisions involve location. For example, a SDSS can be used for determining the evacuation routes, choosing the optimal location of response teams, or allocating evacuees to shelters. SDSS are designed to assist decision makers in evaluating comparions between many possible alternatives. They allow the decision maker to summarize, model, and transform data to support such tasks as analytical reporting, visualization, and trend analysis (NRC, 2007).

Sometimes, a decision maker, for instance, might use the basic functionality of a GIS to find the optimal route from the fire station to the incident area. For this analysis, the analyst might require the locations of the fire stations, the road networks, the barrier information, etc. This information could be the main input for disaster response decision; and GIS could act as a SDSS in this analysis. Some analysts also want to analyse the existing location of fire stations and want to find the optimal location of them. Some would like to determine the service areas on existing fire stations to help evaluate accessibility. In addition to this, some analysts use service areas to identify how many people, how much property, or anything else that is within the neighborhood. If these types of analyses and decisions were frequently made, it would be useful to code a macro for making spatial operations easy. Such a system would use a database, spatial models, and suitable interface and might be considered a DSS in terms of traditional definitions (Keenan, 2003).

Occasionally, quite complex modeling techniques can be required, such as, evacuation planning or routing applications and the spatial tools of GIS can assist for these types of analysis. In this case, additional modeling software is needed and integrated with GIS. Disaster evacuation is an important example of being integrated with simulation software and GIS (Cova and Church, 1997; de Silva and Eglese, 2000).

Thompson et al (2006) discuss the relationship between disaster response efforts and decision support systems and they establish a link between disaster response problems and strategies. In their paper, the term ‘decision support technology’ can be covered with a broad range of systems, hardware, and communication technologies; and information technology can be used to aid in the decision-making process with associated tools that can be considered as a decision support system. As illustrated by figure 2, a DSS provides support to decision-makers by transfering, analysing, filtering, and processing the appropriate data. The concept of middleware can also be seen in the figure 2. According to Thompson et al (2006), middleware is a software application that is designed to perform the data exchange between two different systems.

Figure 2. A Decision Support System (Thompson et al, 2006)



SDSS provide help to explore, structure and solve complex spatial problems such as the evacuation process in disaster response. To support decision making, quantitative approaches can be used with geographic information within a GIS. The GIS provides analyses of critical information related to a disaster on maps/imageries/digital terrains. de Silva (2001) defines two extremes: one where various components of GIS can be employed into the modeling process, the other where modeling can be embedded in GIS. Disaster response support can be enhanced to provide dynamism and flexibility with the integration of simulation models with GIS.

7. CONCLUSION

In this paper, disaster management framework, the role of maps, geospatial tools, GIS and SDSS in emergency management taken into consideration. Disaster management needs accurate and quick information for dealing with a disaster in a timely and safe manner. Because all phases in disaster management are graphically and spatially related to each other, geospatial tools in disaster management have a greater role in these activities.

The experiences of recent disasters have shown that the geospatial tools are extremely important means that must be integrated effectively into disaster planning and management activities. Disaster management personnel must practice the use of geospatial data and tools under a range of scenarios and must be fully familiar with the kinds of problems they can confront. In this case, disasters will be better targeted and managed, and additional lives may be saved.

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