USE OF GEOSPATIAL TOOLS IN EMERGENCY MANAGEMENT

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Abstract

Geospatial tools have a great potential in emergency management life cycle for saving lives, limiting damages, and reducing the costs. Emergency 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 emergencies, emergency 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 emergency 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 use of geospatial tools in emergency management is taken into consideration. And a few applications from Turkey are given in this context.

INTRODUCTION

The major emergencies in the world have shown the importance of emergency management activities. Emergencies that people have endured taught costly lessons. From hurricanes to wildfires, each can be deadly; hovewer, preparation and good planning may reduce their damages. One of the specific difficulties in responding to such emergencies is lack of response coordination. Another difficulty is delivery of the goods to incident areas. These

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difficulties may be overcome by using integrated information and communication systems, and geospatial data and tools.

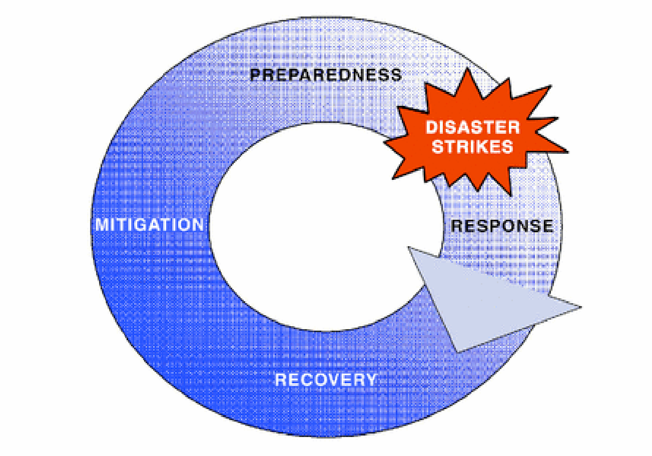
Emergencies are now beginning to affect many people's lives and property everyday; and a better understanding of emergencies are more crucial today. Researchers are developing new aspects for responding to emergencies by using computer and communication technologies. They are also using analysis and 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, emergency 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).

Emergency Management Framework

US National Governor's Association developed an all-hazard or comprehensive emergency management model in the early 1970s. With this approach, emergency 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 emergencies to prevent or reduce losses. Preparedness is planning and enhancing response activities in an emergency. 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)



Terms and Definitions

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

(NRC, 2003) says ‘much of the information that underspins emergency preparedness, response, recovery, and mitigation is geospatial nature’. All emergencies 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.

The Role of Maps in Emergency Management

Mapping is one of the main geospatial tool in emergency 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 emergency response teams is 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 emergency 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 emergency; 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 emergency management. By producing crisis maps, emergency managers able to document the details of spatial relationships and the changing elements of the emergencies to control and mitigate the effects of the emergencies. Crisis mapping should be recognized as a critical part of emergency management that needs to be integrated into emergency planning.

The role of mapping for emergency 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 will show the areas having different degrees of vulnerability and prone to multiple disasters (Mishra, 2002). Maps underpin the GIS activities by facilitating simulation models that can be useful at various stages in emergency 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 emergency managers.

Another use of maps in emergency 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 emergency 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.

The Role of Geospatial Tools in Emergency Management Life Cycle

Preparedness Phase

Preparedness involves activities undertaken in the short term before emergency 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 stadards 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 emergency 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.

Response Phase

Response activities are undertaken immediately following an emergency to provide assistance to victims. Geospatial information and analysis are critical inputs to emergency 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.

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).

Mitigation Phase

Mitigation includes those activities undertaken in the long term after one emergency and before another strikes. They are designed to prevent emergencies 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.

GIS and SDSS in Emergency 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 emergencies. 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 an emergency in response and recovery activities; there is a growing interest that emergency management is much more complex and comprehensive than traditionally perceived. Because of the fact that emergency management is a national concern, county emergency management agencies have the responsibility to deal with emergencies. These agencies should develop emergency 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 emergency 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).

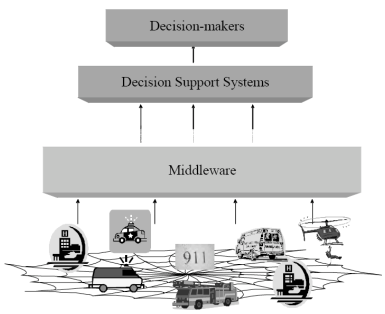
Sometimes, a decision maker, for instance, might use the basic functionality of a GIS to find the optimal route from the fire station to the incident area. For this analysis, the analyst might require the locations of the fire stations, the road networks, the barrier information, etc. This information 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.

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.

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



Emergency Management Applications in TURKEY

TABIS (Turkish Disaster Information System)

The high probability of Istanbul Earthquake has initiated important agreements about disaster management activities between Turkey and United States of America. The first agreement that named "A Cooperative Hazard Impact-reduction Effort via Education- ACHIEVE" was signed with Federal Emergency Management Agency (FEMA-USA) and Istanbul Technical University (ITU) in 2000. The second agreement was signed between ITU and Ministry of Interior of Turkey in 2001. Turkey Disaster Information System (TABIS) is one of the projects signed between ITU and Ministry of Interior of Turkey. The exact name of this project is "Development of a National Database Using GIS and Remote Sensing System and Standards for a Disaster Management Decision Support System" (Karaman and Sahin, 2004).

Istanbul Disaster Information System

Aim of this study is to apply the proposed GIS-based information and management support system standards model for a selected pilot region in Istanbul in order to set an example for the succeeding applications in the country to be implemented in the future. The system, using modern satellite technologies and information systems, will be used especially for planning and applying emergency preparations, disaster management and loss assessment activities in case of a disaster and will also function as a decision support system for central or local authorities (ministries, governorships, municipalities, etc.) at other times. As a result of the study, an information system model is planned to be built that will support the authorities on their decisions by assisting the harmony and coordination in disaster planning between Istanbul, local municipalities and neighboring cities and by improving the TABIS standards (Unen, et al, 2007).

HAZTURK (Hazards Turkey- Development of an Earthquake Loss Estimation Tool for Turkey)

The other disaster management activity for Turkey is to design HAZTURK (Hazards Turkey) program nationwide to mitigate the long term effects of the natural disasters on human life at social and economic areas. The designing HAZTURK program will help on natural risk management, program development, development of the current lifelines of Turkey according to the seismic hazards, and designing more stable economy in addition to development and testing of methods for hazard characterization. The key objectives for the HAZTURK are to: develop an earthquake hazard characterization model for Turkey based on HAZUS; create a comprehensive Turkish inventory database for loss estimation; develop vulnerability functions for infrastructure at risk to supplement those in HAZUS; develop parameters for casualties, shelter needs and economic loss that reflect conditions in Turkey; provide improved near real time loss assessment capability based on Turkish information resources; provide software that takes full advantage of state-of-the-art GIS platforms and internet capability; provide user-friendly computer interface and support materials suitable for a wide variety of users in Turkey including emergency managers, scientific investigators and decision makers (Şahin and Karaman, 2006).

More Applications in Emergency Management in TURKEY

Another project based on TABIS is Rize ABMES-KBS which is "Installation of Disaster Management and Meteorological Early Warning System in Rize Province and Urban Information System" in Rize City in Turkey. In this study, a new system will be established using Geographic information systems, remote sensing and meteorological early warning system in order to minimize the impact, loss of life, and loss of property against the disasters that will affect Rize city and provincial area. (Şahin et al, 2006).

There are some projects about GIS-based seismic risk mitigation in Turkey. One of these projects is ISMEP which is "Istanbul Seismic Risk Mitigation & Emergency Preparedness Project". The specific objective of the project is to improve the city of Istanbul's preparedness for a potential earthquake through enhancing the institutional and technical capacity for disaster management and emergency response, strengthening critical public facilities for earthquake resistance, and supporting measures for better enforcement of building codes and land use plans (Şahin, 2006).

The other project is "The Study on a Disaster Prevention/Mitigation Basic Plan in Istanbul Including Seismic Microzonation in the Republic of Turkey". In the main report of this project, existing social and physical conditions of the study area are described and seismic damage analysis was carried out based on the potential big earthquakes. Necessary recommendations for the seismic disaster prevention and mitigation were also made. The Study Team developed a comprehensive geographic database (GIS) to support data analysis and presentation of the study results. (JICA and IMM, 2002).

There is also one more project related to e-government and disaster management in Turkey. This project is "System Design of Disaster Management Information System in Turkey as a Part of e-Government". The consultancy of this project has been given to Yıldız Technical University in Istanbul. The Disaster Information Management System (AFAYBIS) which based on GIS consists of two components namely data and process design and communication design (Eraslan et al, 2004).

Conclusion

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

In the World there are numerous geospatial based applications to deal with emergencies at local, regional or global level. The countries including developing World such as Turkey are trying to become an Information Society member and trying to use geospatial information for decision making process in effective emergency management.

The experiences of recent emergencies have shown that the geospatial tools are extremely important means that must be integrated effectively into emergency planning and management activities. Emergency 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, emergencies will be better targeted and managed, and additional lives may be saved.

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