Developing Spatial Data Infrastructure to Facilitate Disaster Management

***Abbas Rajabifard*[1], *Ali Mansourian*[2], *Mohammad Javad Valadan Zoej*[3], *Ian Williamson*[4]**

[1]abbas.r@unimelb.edu.au, [2]alimansourian@yahoo.com,
[3]valadanzouj@kntu.ac.ir, [4]ianpw@unimelb.edu.au
1,4: Centre for SDIs and Land Administration
Department of Geomatics, The University of Melbourne, Victoria 3010, Australia
2,3: Faculty of Geodesy and Geomatics Eng., K.N.Toosi University of Technology

ABSTRACT

The role of spatial information and related technologies in disaster management has been well-known worldwide. One of the challenges concerned with such a role is access to and usage of reliable, accurate and up-to-date spatial information for disaster management. This is a very important aspect to disaster response as timely, up-to-date and accurate spatial information describing the current situation is paramount to successfully responding to an emergency. This includes information about available resources, access to roads and damaged areas, required resources, required responding operations, etc., and should be available and accessible for use in a short period of time. Sharing information between involved parties in order to facilitate coordinated disaster response operations is another challenge in disaster management.

This paper aims to address the role of Spatial Data Infrastructures (SDI) as a framework for facilitating disaster management. It is argued that the design and implementation of an SDI model as a framework and consideration of SDI development factors and issues can assist the disaster management agencies in such a way that they improve the quality of their decision-makings and increase their efficiencies and effectiveness in all level of disaster management activities. The paper is based on an ongoing research project in Iran regarding the development of an SDI Model for disaster management. This includes the development of a prototype web-based system which can facilitate sharing, access and use of data in disaster management and especially disaster response.

INTRODUCTION

Disaster management is a cycle of activities (Figure 1) beginning with *mitigating* the vulnerability and negative impacts of disasters, *preparedness* in responding to operations, *responding* and providing relief in emergency situations such as search and rescue, fire fighting, etc., and aiding in *recovery* which can includes physical reconstruction and the ability to return quality of life to a community after a disaster. The employment of recent advances in spatial data management and Geomatic engineering technologies in disaster management, including Information Communication and Technology (ICT), Geographical Information Systems (GIS), Remote Sensing (RS), and Global Positioning System (GPS), has considerably improved disaster management through facilitating data capture, integration and analysis. The integration of such technologies with each other and with other technologies such as decision support systems (DSS), the world-wide-web and simulators has created more effective disaster management.

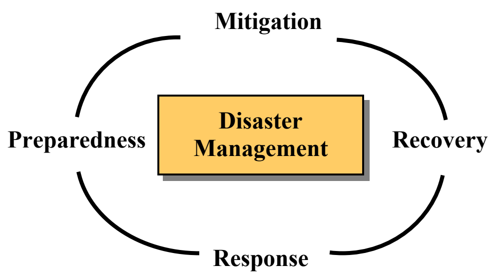

Figure 1: Disaster Management Activities Cycle

Spatial data and GIS have proven crucial in preparing for, mitigating, detecting, responding to, and recovering from natural and technological disasters (Amdahel, 2002). Without spatial data one cannot expect effective and efficient disaster management, as spatial data are the initial input for GIS and Emergency Response Modeling and Simulation Systems (ERMSSs). On the other hand studies have revealed that there are substantial problems in the way in which disaster-related spatial data are gathered, displayed, accessed, and disseminated (SNDR, 2002).

The response to the September 11 emergency situation was an example of the wide utilisation of spatial information and related technologies in effective and efficient disaster response. It also highlighted different issues regarding access to spatial information as well as the applicability of available information in systems, as reported by Donohue (2002) and Letham (2001).

PROVIDING INFORMATION FOR DISASTER RESPONSE

The dynamic nature of an emergency situation calls for timely updating of a variety of required data/information from various organisations as no individual agency can produce and update all the required information (which calls for partnership, data sharing and data exchange).

In an emergency situation, different organisations become involved in disaster response. Agencies such as fire-fighters, red-cross, medical emergency departments and police departments undertake emergency response within their everyday activities. Other organisations like utility companies however are only called upon in certain emergency situations. These agencies, organisations and departments must be prepared to provide training and other required resources such as spatial data when the need arises.

These organisations are logically the producer and updater of datasets during their everyday business and during an emergency situation. If the results of such data production and updating efforts are physically recorded in appropriate databases, the required data/information for disaster response is always available to the producer. If this information is shared and exchanged, then datasets are accessible to the wider emergency management community. In order for this data exchange to occur however, appropriate data standards and interoperability models need to be implemented by stakeholders so that information can be utilised within different systems. This brings the concept of partnerships in spatial data production and sharing to the fore.

Therefore through a partnership effort, it is possible to have the required spatial data for disaster management always available and accessible for use. To achieve this aim, required information for disaster management should be recognised and an information framework established. The responsibility of maintaining information should be shared between different organisations based on:

- appropriate and accepted policies;
- appropriate standards for the production of data;
- the training of people to work with these datasets;
- the establishment of appropriate network and software tools for exchanging and sharing information/data; and
- appropriate policies for accessing and using data/information

Figure 2, describes the required components as discussed above for having spatial information ready for access and use. These components can aid and contribute to the development of a proper disaster response environment.

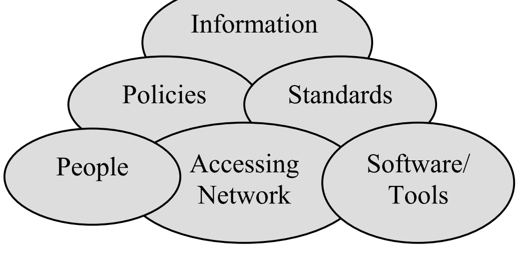

Figure 2: Required Components for Proper Disaster Response

There is a need for an appropriate framework which recognizes the relationships between each component including the effect that the components have on each other, external factors affecting each component, as well as the internal elements of each component. For example regarding policies, it is necessary to understand what policies are required, who the policy makers are, what internal or external factors affect policy making, the effect that the polices have on the other components, etc.

ROLE OF SDI IN DISASTER MANAGEMENT

The growing need to organise data across different disciplines and organisations and also the need to create multi-participant, decision-supported environments has resulted in the concept of spatial data infrastructure (SDI). SDI is an initiative intended to create an environment that will enable a wide variety of users to access, retrieve and disseminate spatial data and information in an easy and secure way. In principle, SDIs allow the sharing of data, which is extremely useful, as it enables users to save resources, time and effort when trying to acquire new datasets by avoiding duplication of expenses associated with generation and maintenance of data and their integration with other datasets. SDI is also an integrated, multi-leveled hierarchy of interconnected SDIs based on collaboration and partnerships among different stakeholders. With this in mind, many countries are developing SDIs to better manage and utilise their spatial data assets by taking a perspective that starts at a local level and proceeds through state, national and regional levels to the global level. These activities have resulted in different models being suggested for facilitating SDI development.

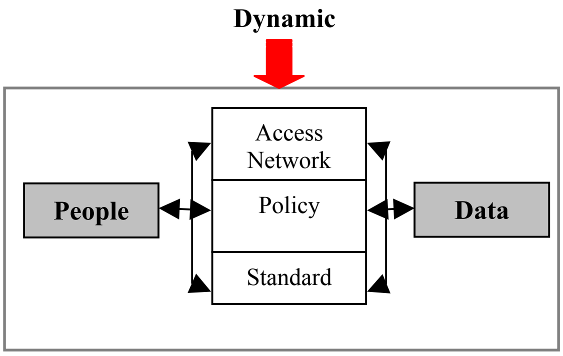

Figure 3: SDI Components (Rajabifard *et al*, 2002)

As illustrated in Figure 3, an SDI encompasses the policies, access networks and data handling facilities (based on the available technologies), standards, and human resources necessary for the effective collection, management, access, delivery and utilisation of spatial data for a specific jurisdiction or community.

Viewing the core components of SDIs, Rajabifard *et al.* (2002) suggested that different categories of components can be formed based on the different nature of their interactions within the SDI framework. Considering the important and fundamental role between people and data as one category, a second category can be considered consisting of the main technological components: the access networks, policy and standards. The nature of these two categories are very dynamic due to the changes occurring in communities (people) and their needs, as well as their ongoing requirement for different sets of data. Additionally, with the rapidity with which technology develops, the need for the mediation of rights, restrictions and responsibilities between people and data are also constantly subject to change. This suggests an integrated SDI cannot be composed of spatial data, value-added services and end-users alone, but instead involves other important issues regarding interoperability, policies and networks. According to this view, anyone (data users through producers) wishing to access datasets must utilise the technological components.

The five core components of SDIs (along with software/tools) are also the components that have been found to most adequately address proper disaster management. Moreover, the relations between each of the SDI components, particularly between people and data through the technological components are the relationships that need to be defined in order to have a better and proper disaster response environment.

Therefore, it is proposed that SDI as an information infrastructure can be an appropriate framework in bringing the disaster response components together and facilitating decision-making for disaster management as illustrated in Figure 4. By designing an SDI model for a disaster management community, and by utilizing relevant information and communication technologies (ICT) in disaster management, it is possible to have better decision-making and increase the efficiencies and effectiveness of all level of disaster management activities from mitigation to preparedness, response and recovery phases. The result of such quality decision-making then can directly contribute to the sustainable development of the jurisdiction or community in terms of social, economical and environmental development (Figure 4).

Within this framework, it should be also noted that, the challenge of designing, building, implementing, and maintaining an SDI draws on many different disciplines and requires examination of different factors and issues relating to the conceptual, technical, socio-technical, political, institutional and financial perspectives. Therefore, it is essential that the decision-makers in disaster management community understand the significance of these factors and also the importance of human and societal issues, which contribute to the success of SDI developments. It is note-worthy that these factors and issues should be considered in the long-term in order to achieve sustainable and ongoing development of SDIs for disaster management environment.

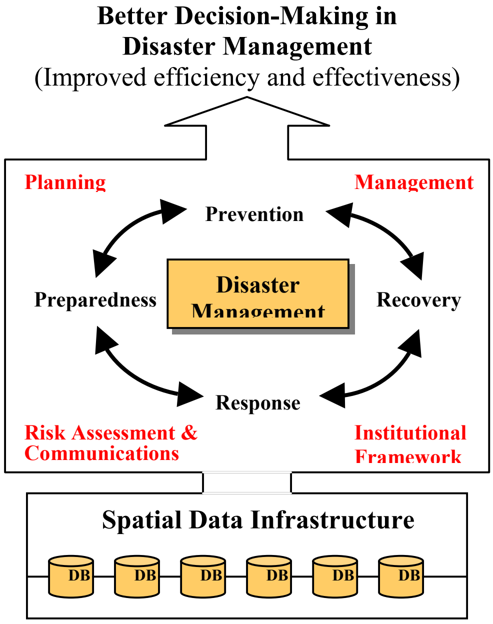

Figure 4: SDI to Facilitate Disaster Management

PROTOTYPE SYSTEM FOR FACILITATING DISASTER MANAGEMENT

With respect to the above-mentioned environment, a research study in Iran has been designed and conducted with an aim to develop a system based on SDI through which access to and usage of data/information and consequently disaster response/management can be facilitated. Two important outputs through this research are:

- a conceptual SDI model to facilitate the development of an infrastructure for disaster management; and
- a web-based disaster management system for data sharing, data exchange and data analysis using an SDI model.

Considering the six components of proper disaster response environment, the first output is to facilitate the interaction between all disaster management activities and particularly disaster response components, and the second output is refers to the required software and tools discussed above for the disaster response environment.

To date a prototype web-based system that facilitates disaster response based on data/information sharing and analysis for decision-making, coordination, command and control has been developed. Also, initial standards and guides describing data standards, identifying organisations for data production and updating, data production methods, and updating processes within and outside of an emergency situation have been developed.

Figure 5, illustrates the overall structure of the designed system. As the figure shows, each of the involved organisations has a database containing their required datasets for everyday business as well as disaster response. There is also a database in an Emergency Operation Center (EOC) where the representatives of involved organisations can gather to coordinate disaster response. The EOC Database contains base maps as well as fundamental required datasets for disaster management. Each of the involved organisations is responsible for producing and updating one or more datasets within the EOC database before and after a disaster. Each organisation can then utilise required datasets from the EOC database for their own use. This demonstrates the important concept of partnerships in producing and updating datasets, as well as the concept of sharing datasets, which allows each organisation to work on a common data base. Based on Figure 5, all of the organisations are connected to the EOC database through the inter- and intranets. It is through such a network that organisations can share and access their required datasets.

As Figure 5 also shows, the ability of all parties to have access to information that describes a current emergency situation through the development of the EOC, will enable a more coordinated response to disasters. The figure illustrates that the process of producing, updating, accessing and using spatial data is carried out based on an SDI framework. This framework defines standards, policies (partnership, accessing rules, funding, etc.), people (training, cultures etc.), access network and data/information framework.

The structural system developed needs to be tested with feedback used to design and develop a functioning system. This will also aid in presenting the overall advantages of utilizing the SDI concept within disaster management. A pilot project developed to respond to an assumed earthquake and was held with the collaboration of 12 organisations within Iran. A software and database model was developed based on the concept of an Emergency Operations Centre as shown in Figure 5. The 12 organisations managed the emergency situation by dealing and updating their own datasets and sharing them with other involved parties. The objectives of this pilot project were to:

- develop a conceptual SDI model;
- test the system and gain feedback for the design and development of a real functioning system;
- present the overall structure, concept and advantages of developing such a system; and
- present the advantages of utilizing the SDI model in developing a disaster response system.

The results of the pilot project showed how useful such a system can be for effective and efficient disaster response management. At the present time the research team is working on the refinement of the SDI conceptual model for disaster management and designing the principles and concepts for the web-based system, based on the results and the lessons learned through the pilot-project and the prototype.

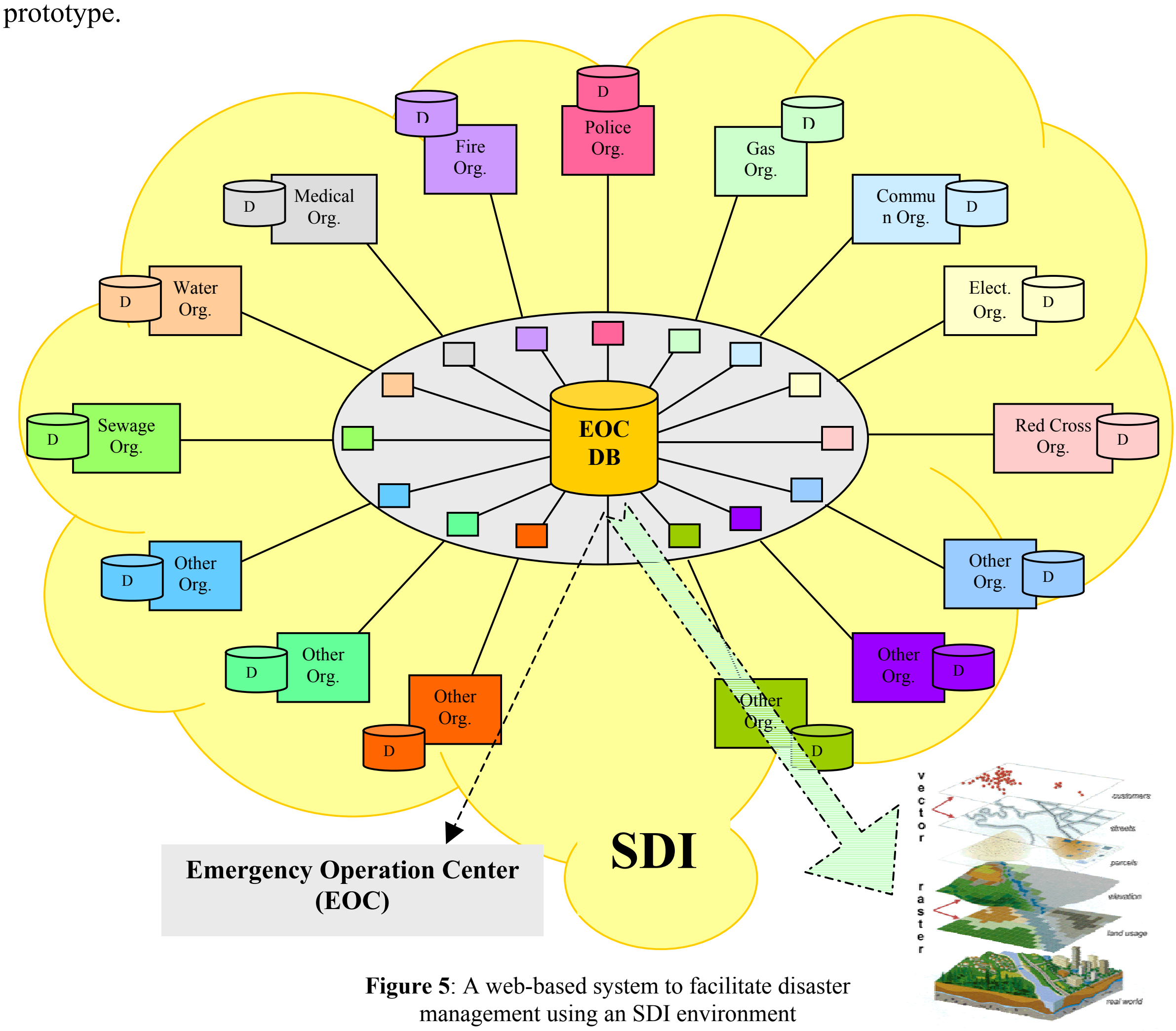

Figure 5: A web-based system to facilitate disaster management using an SDI environment

CONCLUSION

Spatial information and information communication technologies are the important elements in disaster management which has been well-known worldwide. With this in mind, the paper first addressed the role of SDI as a framework for facilitating disaster management. The paper then presented the results of an ongoing research project in developing of an SDI Model for disaster management in Iran. This includes the development of a prototype web-based system which facilitates sharing, accessing and use of data in disaster management and particularly disaster response.

It is argued that the design and implementation of an SDI model as a framework and consideration of SDI development factors and issues can assist the disaster management agencies in such a way that they improve the quality of their decision-makings and increase their effectiveness as well as efficiencies in all level of disaster management activities from mitigation to preparedness, response and recovery phases. The result of such quality decision-making in disaster management then can directly contribute to the sustainable development of the jurisdiction/community in terms of social, economical and environmental development.

ACKNOWLEDGMENTS

The author would like to acknowledge the support of the University of Melbourne, K.N.Toosi University, and the member of the Centre for Spatial Data Infrastructures and Land Administration at the Department of Geomatics, the University of Melbourne, in the preparation of this paper and the associated research. However, the views expressed in the paper are those of the author and do not necessarily reflect the views of these groups.

REFERENCES

Amdahl, G. (2002). Disaster response: GIS for public safety, Published by ESRI, Redlands California. http://www.esri.com/news/arcnews/winter0102articles/gis-homeland.html - (visited on October 2002).

Donohue, K. (2002). Using GIS for all-hazard emergency management, http://www.edc.uri.edu/nrs/classes/nr5409/509-2002/donahue.pdf - (visited on February 2004).

Letham, G. (2001). GIS database development for New York WTC recovery efforts, http://spatialnews.geocomm.com/features/wtc/ - (visited on February 2004).

Rajabifard, A., Feeney, M., and Williamson I.P. (2002). Future Directions for the Development of Spatial Data Infrastructure, Journal of the International Institute for Aerospace Survey and Earth Sciences, ITC, Vol. 4, No. 1, The Netherlands, PP 11-22.

SNDR (2002). A national hazards information strategy: reducing disaster losses through better information, National Science and Technology Council, Committee on the Environment and Natural Resources, Subcommittee on Natural Disaster Reduction (SNDR), Washington, DC, April 2002.