USING GEOINFORMATION TECHNOLOGY TO DEVELOP A VULNERABILITY ASSESSMENT MODEL IN NATURAL DISASTER-PRONE AREAS

Md Mahbubur Rabb Meenar
Center for Sustainable Communities, Temple University, USA
meenar@temple.edu

Abstract—*Natural disasters are the consequences of natural hazards. The devastation of any natural disaster might get intensified by the unplanned rapid urbanization in the hazard-prone areas. Although natural hazards are inevitable, scientific knowledge and technology can be used to minimize or even control the damage. Geoinformation technology, which includes Geographic Information Systems, Global Positioning System, Satellite Communication, Remote Sensing, and World Wide Web, can be used in natural disaster assessment, prevention, and mitigation. The technology is usually applied in three temporal stages of disaster cycles: before, during, and after. The author discusses the geospatial data needs for various disaster analyses and presents a model to perform the vulnerability assessment in single- or multi-hazard prone areas.*

Keywords—*Disaster management, floodplain, geographic information systems, geoinformation technology, risk assessment.*

1. Natural Hazards and Natural Disasters

Catastrophic events or natural hazards are inevitable and may occur in the forms of flooding, hurricanes, Tsunamis, wildfires, earthquakes, landslides, cyclones, tornados, ice storms, volcanic eruptions, and droughts. Since the phenomenon occurs naturally, it is impossible either to prevent an earthquake or a hurricane, or fully recoup the damage caused by such hazard.

Natural disasters are the consequences of natural hazards that disrupt entire communities. When a disaster takes place anywhere in the world, people try to understand in depth what has happened and how, whether it is a hurricane flattening thousands of houses, or a flooding damaging hundreds of structures, or an earthquake severing highway arteries. In recent years, people have experienced a number of hazards that have turned into severe disasters, be it Hurricane Katrina (in USA, 2005), Kashmir Earthquake (in Pakistan, 2005), Tsunami (in South Asia, 2004), or Niigata Chuetsu Earthquake (in Japan, 2004).

The devastation of any natural disaster intensifies with the unplanned rapid urbanization in the hazard-prone areas, thus increasing the vulnerability of people who have migrated to those areas. For example, around 500 million people in the world are at risk of volcanic activity, a number far more than in previous centuries. This does not indicate an increase in volcanism, but an increase in population living near or on the flanks of active volcanoes [1]. Natural disaster not only causes substantial loss of human lives and properties, but also reduces the pace of sustained economic development [2].

However, scientific knowledge and technology can be used to minimize or even control the damage caused by these hazards and thus can prevent the transformation of these hazards into disasters. The accurate, relevant, understandable, and timely information can help reduce the loss of a natural disaster. With the help of latest Geoinformation technology we can better understand the geodynamic processes of disaster; increase the earthquake- or wind-resistance of buildings and bridges; restrict developments in flood-prone areas; install hurricane straps to reduce wind damage to roofs; issue early warnings on volcanic eruptions or tsunamis; organize community response to any disaster warning; and expedite the process of rehabilitation and post-disaster management [1, 3].

2. Use of Geoinformation Technology in Natural Disaster Management

Geoinformation, which is a shorter name of geographic information, can be created by manipulating spatial data in a computerized system using technology such as Geographic Information Systems (GIS), Remote Sensing (RS), Global Positioning System (GPS), and World Wide Web. GIS provides a powerful tool for storing, managing, analyzing, and displaying spatially distributed data that can be used in any engineering model. For example, data preparation and interpretation of hydraulic modeling are time consuming tasks that can be simplified using a GIS [4].

Disaster management should be targeted according to the expected duration of impact of a hazard and the time of forewarning. Some hazards may strike within a short notice and some may progress in such a slow pattern that people usually get enough time to take necessary steps to face those [5]. Any disaster management strategy should be addressed in the following three temporal stages of disaster cycles: before, during, and after.

2.1. Before Disaster: Planning, Identification, Mitigation, and Preparedness

A mix of disaster management planning and engineering practices, including hazard identification, disaster prevention and mitigation plans, and emergency preparedness, can reduce the risks and costs of disaster. With the help of GIS, the users can store, display, and analyze spatial data along with non-spatial information. In addition, GIS users can handle a large number of complex data sets stored in various formats and with enough precision to satisfy administrative requirements [6].

With the help of hazard information and historic disaster data, GIS and RS can be used to perform vulnerability assessments in order to identify the most hazard-prone areas, assess the risks, design disaster warning systems, and develop possible evacuation and response plans [7]. GIS is also used to design the emergency operation centres and shelters.

For example, the City of Wilson, North Carolina, USA used GIS to examine the relationship among the natural, anthropological, and administrative aspects of the disaster-prone areas. In preparation for the 2003 hurricane season, the city staff used GIS for pre-incident analysis of floodplain areas to prepare street closures, position resources, track feeder lines that lose power, and identify customers served by the feeder lines [8]. The city also conducted an analysis of historical flood events and designated flood hazard areas to quickly reveal areas and street sections that could become isolated during major flooding [8].

RS data, such as satellite images, can be collected or updated much faster than ground based observation and can be mapped to display the variability of terrain properties, such as vegetations, landcover, water, geology - both in space and time [5, 9]. Both GIS and RS technologies can also be used to implement a regional warning and dissemination system.

A GIS-based mitigation strategy can be used to restrict construction of homes and businesses in disaster-prone areas. Wherever such development is unavoidable, such as in the case of Dhaka or New Orleans, mitigation might require reinforcement for certain buildings by increasing setbacks and minimizing floor heights [6].

World Wide Web can provide an option for the rapid, automatic, and global dissemination of disaster information, including weather observation and forecasts [9]. Interactive web-based GIS tools can make people aware of the types and levels of risks in their communities and help them develop preparedness programmes, emergency plans, and reconstruction procedures. Based on the input data, such tools may generate different risk scenarios for different types of disasters. A similar project, known as Mexican Atlas of Risks, has been developed by the National Center for Disaster Prevention of Mexico [10].

2.2. During Disaster: Response

GIS and RS can help in responding to a natural disaster more effectively than any other technology. GIS-based spatial analyses, hazard simulation, and visualization can provide critical information to disaster managers, such as the size and direction of a wildfire perimeter or the location of a broken levee [6].

Interactive GIS-based on-line mapping applications can transmit real-time information to the emergency operating centres and thus enhance the decision-making process with the assessment of rapidly changing disaster conditions, such as hurricanes [6]. An example of internet-based mapping application is the Geospatial Multi-Agency Coordination Group or GeoMAC, which is designed for fire managers to access online maps of current fire locations, paths, perimeters, weather conditions, terrain, and natural obstacles for the entire USA. The application has used ArcIMS, ArcSDE and Oracle [1].

Satellite images help emergency responders detect the progress and flow path of any snow storm or hurricane during the time of occurrence. Orthophotographs with street sign labels can show disaster management personnel the full extent of damage as well as on-going debris removal condition from a perspective that is not visible from the ground level [6]. Light Detection and Ranging (LIDAR) data can even produce some detailed 3D images of buildings, debris, and other features after a disaster.

Wireless GIS services, embedded with mobile devices, handheld GPS, and wireless communication, have brought a revolution in the disaster response methods. Hand-held GPS receiver uses military Y-code radio signals transmitted by satellites to capture extremely accurate latitude and longitude information [1]. In a flood-prone area, for example, the assessment teams can go out in the flooded communities even before the rains have stopped in order to find out which communities have been hit and how hard [6]. Using mobile GIS technology, such teams can draw new floodwater boundaries directly in a GIS application right in the field.

For example, the South Florida Water Management District (USA) is able to make decisions to reduce the amount of floodwater by adjusting the network of flood canals, floodgates, and other mechanisms, based on the up-to-date information sent by the assessment teams from the field, using a wireless modem. The teams usually use GIS software ArcPad and a Personal Digital Assistant (PDA), in conjunction with GPS to get the positional accuracy [6].

2.3. After Disaster: Recovery

GIS is used to store and analyze data in the three phases of an after-disaster period: relief, rehabilitation, and re-construction. Many organizations use GIS to calculate the cleanup need and cost after any disaster. With the help of RS and GPS, planners can assess the actual damages, and thus provide and monitor relief efforts. GIS also helps in the establishment of long-term rehabilitation assistance centres that should be located in areas equally accessible to the greatest number of affected people [6].

The GIS users can utilize the available data to assess and evaluate different response strategies by modeling their likely outcomes in given situations, an analysis that can be invaluable when making planning and policy decisions [7].

In the aftermath of a disaster, a community should be able to precisely document where the money is most needed and for whom. Although it seems not a common function of GIS, this technology helps identify those people in need without the need for paperwork [6].

2.4. Data Integration - Thinking Outside the Box

Since the dissemination of scientific knowledge plays an important role in disaster preparedness, it is important to develop collaborative relationships among all disaster management agencies that might be involved well before any emergency occurs. All the disaster based data, whether in GIS, GPS or some other format, should be brought together into a nation-wide data repository. In the short term this would enable users to share, import, integrate, and synchronize datasets into operational databases for emergency operation centres so that they can respond to any urgent needs. In the long term users can focus on recovery and re-construction efforts as well as disaster preparedness [11]. The USA has implemented a similar pilot database, known as “GIS for the Gulf”, for Hurricane Katrina and Rita affected areas. Another example of such database is the Composite Risk Atlas, developed by Gujarat State Management Authority of India.

After the Niigata Chuetsu Earthquake, the Disaster Prevention Research Institute of Kyoto University, Japan, helped develop a GIS portal web site that gathered various organizations from the national, local, educational, and private domains to build an interactive GIS based online framework to share data in real time [12].

3. Developing a Vulnerability Assessment Model

According to [13], predictive and operational models should be developed in disaster-prone areas in order to assess and mitigate risks to human life and property as well as to respond to emergency needs effectively. The key components of a GIS-based vulnerability assessment model are discussed in this section.

3.1. Spatial Data Acquisition and Integration

Spatial data might be available from a number of sources; but the myriad data sources require time and energy for preliminary conversion work before they become usable [6]. The following list of hazards is not all inclusive, but includes some of the most common natural hazards. The type of spatial datasets and maps required to assess those hazards are also discussed.

Flooding: Flooding may occur as a result of some other hazards, such as landslide, excessive rainfall, or hurricane. Satellite images can help identify flood inundated areas. GIS and orthophotography can be used to delineate flood zones or floodplains with high degree of accuracy. Flooding hazard maps may include orthophotos, floodplains, parcels, building footprints, streams, transportation networks, zoning, and landuse. The following data layers are needed to delineate new floodplains in a watershed: a digital terrain model (DTM), preferably in the form of a Triangulated Irregular Network (TIN), stream centrelines, water flow, banks, cross sections, hydraulic structures or obstructions (bridges, culverts and weirs), and other data representing the extent of the area [4].

Landslide/ Mudslide: The landslide hazard map typically includes the areas of potential slides (slumps and transitional slides), earth flows (flows of clayey earth), debris flows (rapidly moving slides), topography, steep slopes, hillshades, transportation networks, hydrography, floodplains, drainage, Digital Elevation Models (DEM), vegetation types, mapped distribution of slides and earth flows, rainfall thresholds for debris flows, and likely debris flow areas [1, 13].

Hurricane: The hurricane disaster maps show the locations of landslides, floods, damage to roads, bridges, and other infrastructure, precipitation values, and impacts on agricultural lands [13]. One example of such an application is the Consequences Assessment Tool Set (CATS), developed in the USA.

Drought: Satellite data can be used to target potential ground water sites or to evaluate areas subject to desertification [9]. In addition, GIS can be used to map the agricultural activities that have caused an area's aquifer to drop below the depth of homeowner water wells [1].

Tornado: Tornado maps can use GIS to identify locations of damage reports and the actual damaged properties.

Ice Storm: GIS-based databases for analyzing ice storms may include the location of sanding trucks, accidents, downed power lines, fallen trees, temperature shifts, and microclimates [1].

Tsunami: Although it is difficult to predict, the inundation zones of a Tsunami along the coastline can be mapped using GIS. Such maps are essential to assess Tsunami hazards and identify areas of potential Tsunami flooding [13].

Earthquake: GIS and RS technology can be used to prepare seismic hazard maps to show the areas falling in high seismic zones [9]. The maps can show amplified shaking hazard zones, which are known as areas where historic amplified ground shaking has occurred or where local geological and geotechnical conditions indicate a potential for ground shaking [13]. The maps also display past or potential liquefaction or ground displacement as well as earthquake-induced landslides, especially in the higher urbanized areas [13].

Wildfire: Fire hazards have both spatial and temporal movements and can be determined on the basis of steep slope, current and antecedent weather, vegetation types, landcover, level of service, fuel loading, fuel types, and state of live and dead fuel moisture [1, 13]. GIS plays important role in mapping and documenting wildfires, predicting its future course, analyzing alternate fire fighting strategies, and directing tactics and strategies in the field [13]. Some fire modeling software packages that run on GIS platform are BEHAVE, FBPS and FARSITE [6, 13].

Volcano: GIS is modestly used in volcanic hazard studies, especially with mass movement, such as landslides and debris flows, in the form of distributed computing, visualization, and interactive modeling [13].

3.2. Risk Assessment and Identification of Hazardous Lands

Hazard risk assessment can be performed using GIS-based suitability modeling techniques. The model rasterizes all the input datasets following a specific cell size; reclassifies the cells according to a scale ranging from 1 to 5 or more; weighs all the input data layers; and finally assigns values to all the cells using a raster calculator. The output values show which cells have the least risk and which cells have the highest?

Choosing an appropriate cell size depends on the geographic scale of the study and selecting appropriate input datasets depends on the type of disaster to be analyzed. For example, the assessment of wildfire risk of any particular cell should consider whether the air type is dry or moist, or whether there is presence of tree canopies that keep soil and vegetation moist and shield the area from wind. Other input layers may include accessibility to fire stations, residential density, population density, likely speed, size and intensity of fire, vegetation type, distance from roads, steep and direction of slope, also known as aspect [6]. Again, assessment of values for some of these criteria depends on the geographic location. For example, in Northern Hemisphere south aspects tend to burn faster compared to the north ones.

Risk assessment helps identify hazardous lands that represent the coastal zones, floodplains, fault zones, unstable slopes and fire-prone areas. Software is available in the market that performs complex calculations of hazard risk and probability for a variety of disaster events, and then returns extremely accurate estimates of human casualties, building damage, infrastructure loss, and other consequences [6]. For example, the US Federal Emergency Management Agency (FEMA) has developed HAZUS, a free GIS-based hazard identification and risk assessment software, to estimate losses occurred by earthquakes, flooding, and fire [6, 14]. The programme predicts the losses by incorporating building inventories that include the classification systems for buildings and their lifelines, as well as other data such as local geology, utilities, and transportation systems. It also can predict any possible future scenario, such as a dam failure or tsunami, and thus refine the results [14].

Another example is the free GIS-based assessment tool, known as CATS, that can estimate damage and probable casualty figures for a broad range of natural and man-made disasters, using real-time climatic conditions [6].

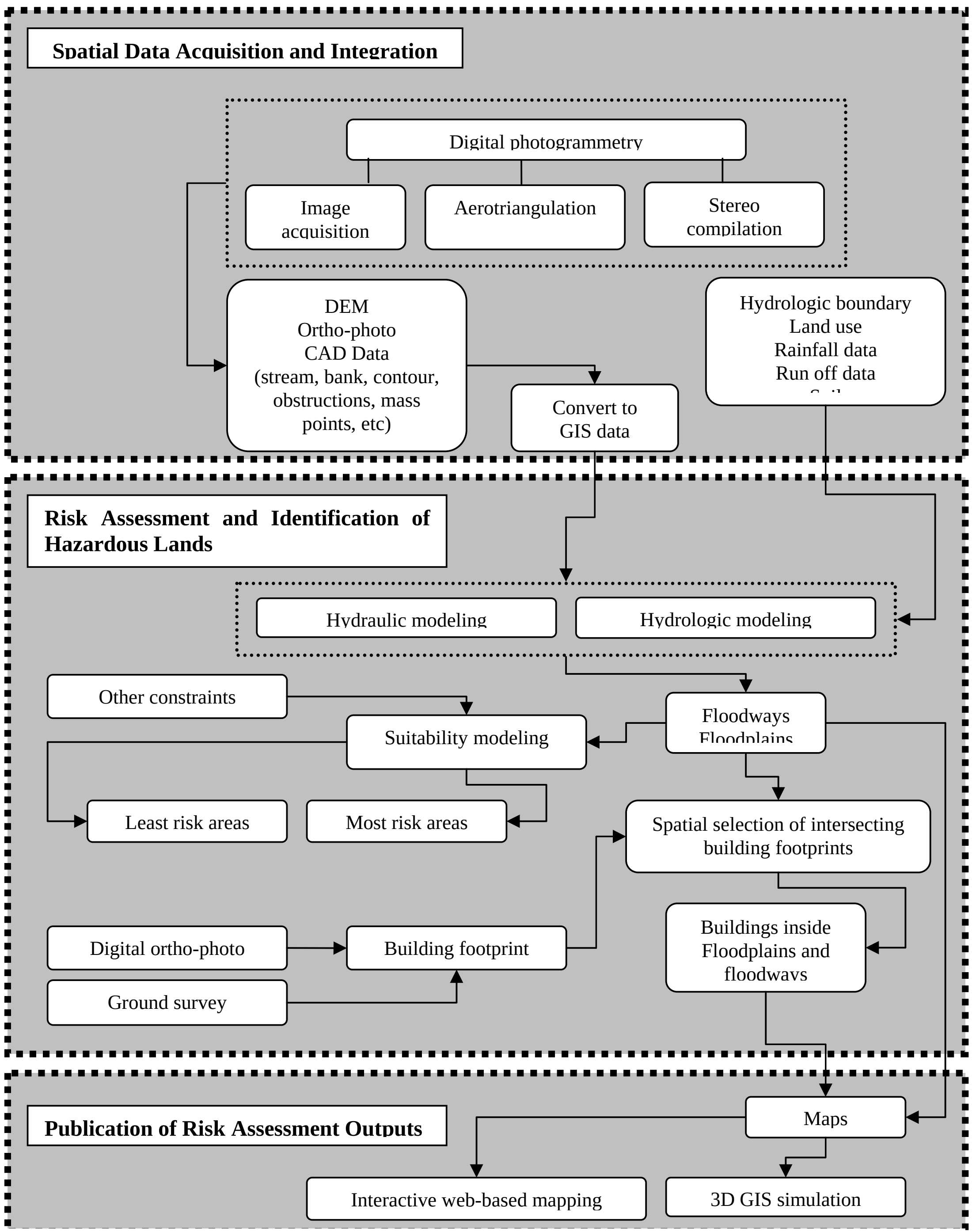

Figure 1: An application of the vulnerability assessment model in flood-prone areas.

3.3. Publication of Risk Assessment Outputs

3.3.1. Maps: Risk assessment maps encompass geographic analysis of any potential disaster threat and measure the probability that the threat will cause significant damage or high dollar-value losses [6]. In general, the GIS-based hazard mapping has the following purposes:

(a) Mapping the history of hazards in a particular area, such as floodplains, location of known active earthquake faults, or El Nino conditions at a certain time of year [6];

(b) Assessing assets by displaying the structures overlaid with floodplains or earthquake faults, and mapping emergency centres and their service areas;

(c) Identifying vulnerable structures by creating a database of unsafe structures that are not able to withstand a major hazard, such as an earthquake or a tornado; and

(d) Calculating emergency shelter requirements based on the socio-economic condition of any particular area.

3.3.2. 3D GIS simulation: 3D GIS can present multiple aspects of an emergency situation in a visual and comprehensible way. This technique is helpful to persuade people of the dangers of a disaster [7]. Using the spatial analysis and 3D analysis tools available in a GIS software, sophisticated 3D hazard simulation can be generated that allows public safety officials, scientists, and general population to understand the effect of the disaster event and to design appropriate mitigation plans [6].

3.3.3. Real-time assessment and interactive mapping: Internet can be used to present real-time assessment of disasters and thus disseminate information to the public. An informed population will be better able to embrace mitigation, respond and even participate in an emergency situation, and recover from disaster [6].

4. Sample Application of the Model

The vulnerability assessment model has been applied for assessing the flooding risks in the

Figure 2: A 3D GIS simulation showing differences between the existing (shown as outline) and new (shown as solid areas) floodplain boundaries.

Pennypack Creek Watershed, a 148 sq km area located in south-eastern Pennsylvania, USA. The project was initiated by a group of interdisciplinary researchers of the Center for Sustainable Communities (CSC) at Temple University. The flow process of different phases and components of the model is shown in figure 1.

4.1. Background

The existing floodplain maps available for the watershed were developed by FEMA in the early 1970s. According to FEMA, "Flood hazard conditions are dynamic, and many maps may not reflect recent development and/or natural changes in the environment" [15]. Since the eleven watershed communities have experienced significant urban growth since the 1970s, there was a critical need to update the existing maps. The major focus of this study was the delineation of new floodplain boundaries that result from two hypothetical (design) storms: 100-year and 500-year storms.

4.2. Spatial Data Acquisition and Integration

Using digital photogrammetry technology, the CSC has developed a GIS-based inventory of the watershed, including 2 ft resolution DEM and TIN, 2 ft contours, updated stream network, flow-paths, bridges and culverts, and dams [16]. The CSC has collected, created, and edited a number of GIS data layers from different sources. These data layers include political and hydrologic boundaries, streets, parcels, building footprints, geology, baseflow, soil, land use, and parks and open spaces. The CSC has also converted a number of paper maps to GIS data layers, such as the zoning maps. A complete list of data layers used in this project is available from [16].

Research has indicated that the precipitation values (from U.S. Weather Bureau's Technical Paper 40, which was published in 1961) widely used throughout the USA are no longer valid. These values were used in the floodplain delineation for the existing Flood Insurance Rate Maps (FIRM). The CSC researchers believe that it has been well established that TP-40 systematically underestimated the extreme precipitation events. This was due to a number of factors: the short average duration of the precipitation records analyzed; the relatively small number of weather stations; and the statistical distribution used to analyze the data [17]. The CSC researchers have received permission from FEMA to use more recent NOAA Atlas 14. This higher rainfall volume along with the new land use data resulted in runoff peak values and volumes that are significantly larger than those predicted in prior studies in the watershed [17].

4.3. Spatial Data Acquisition and Integration

GIS-based hydraulic and hydrologic modelings were run to assess the flood risks and to identify the new floodplain boundaries. The Pennypack hydrologic model was calibrated to twelve historic storms that occurred over the watershed area. The calibration required the input of land use, rainfall, and runoff data. The latest land use data and high resolution (1 km x 1 km) radar rainfall data were incorporated as well. Nine storms were used to estimate the hydrologic parameters' values. The results indicated that these values are capable of accurately predicting the runoff occurring in the remaining three storms. For this reason, the estimated parameters' values were used to predict the runoff resulting from the 100-year storm.

The research team provided field data on constrictions in the watershed to support the hydrologic modeling and mapping. As constrictions can significantly divert flood flows locally, this step was necessary to fine tune the modeling and floodplain maps.

4.4. Publication of Risk Assessment Outputs

The first draft of the floodways and 100- and 500-year floodplain maps have been completed and delivered to the township managers and engineers before submission to the FEMA. A database of all parcels and buildings within the new floodplains has been created to help municipalities identify high risk structures for buy-outs and residents eligible for flood insurance.

Figure 2 shows the 3D simulation of 100-year floodplains with building footprints. A project web site has been created to showcase the floodplain maps and other outputs.

5. Conclusion

Although natural disasters are dynamic phenomenon, GIS is not traditionally designed to analyze, assess, or respond to the dynamic nature of this kind of phenomenon. In future more research should be focused on temporal GIS, representation of risk and human vulnerability, visualizing alternative scenarios for uncertain hazards as well as multiple hazards, and 3D visualization and animation of various phenomena.

Natural disasters do not recognize political or administrative boundaries. Based on the lessons learned from the Asian Tsunami and Hurricane

Katrina, the disaster-prone countries should build a nation-wide integrated data sharing model so that all the agencies at different levels of the government (local, regional, or national) can collaborate more effectively and facilitate more easily by sharing their datasets without any protective passwords or any other barriers. More investments are needed in satellite, radar, and surface observing networks for modern information processing. A global disaster information network is needed to predict severe disasters that spread across the continents.

The capability of technology is increasing day by day. However, successful disaster mitigation can be only possible if researchers can provide accurate and detail data to be used by the technology. It is very crucial to identify the character, frequency or magnitude a probable hazard might have way before its occurrence.

Although natural hazards may happen anywhere in the world, the hazards occur as disasters mostly in the developing countries where there is no or few allocation of resources in information technology, especially in the field of Geoinformation. It is important to increase such allocation of resources, the awareness amongst public and government, and training in modern technology.

6. Acknowledgements

The author gratefully acknowledges the comments and recommendations provided by Jeffrey Featherstone and Shirley Loveless. The research reported in this article was supported by grants from the Federal Emergency Management Agency and William Penn Foundation to the Center for Sustainable Communities. The views expressed in this paper do not necessarily reflect those of the Agency, the Foundation, or the Center.

7. References

[1] G. Amdahl, *Disaster Response: GIS for Public Safety*, Redlands, California: ESRI Press, 2001, pp. 2-3.

[2] K.V. Venkatacharya, B. Manikiam, and S.K. Srivastava, "Harnessing Information and Technology for Disaster Management", *Proceedings of the India-United States Conference on Space Science, Applications and Commerce*, Bangalore, India, 2004.

[3] UNESCO Earth Science Programme, "About Natural Disasters", Published in the http://www.unesco.org, accessed on March 11, 2006.

[4] D. Djokic, *Hydrologic and hydraulic Modeling Support with Geographic Information Systems*. Redlands, California: ESRI Press, 2000, pp. 145-176.

[5] S.K. Banger, "Remote Sensing and Geographical Information System for Natural Disaster Management", Published in http://gisdevelopment.net, Accessed on February 27, 2006.

[6] R.W. Greene, *Confronting Catastrophe – a GIS Handbook*, Redlands, California: ESRI Press 2002.

[7] D. Briggs, P. Forer, L. Järup, R. Stern, eds., *GIS for Emergency Preparedness and Health Risk Reduction*, Dordrecht, The Netherlands: Kluwer Academic Publishers, 2002, pp. 5, 102, 116.

[8] C. Thomas and O. Milton. *Measuring Up: The Business Case for GIS*. Redlands, California: ESRI Press, 2004, pp. 22.

[9] A. Gupta, "Information Technology and Natural Disaster Management in India", Published in http://gisdevelopment.net, Accessed on February 27, 2006.

[10] O. Zepeda, "Mexico's National Center for Disaster Prevention Delivers Natural and Human-Made Risk Information to the Web via GIS", *ArcNews*, Vol. 27, No. 4, 2006, pp. 33.

[11] H. Garie and P. Bottenberg, "USGS, NGA, and DHS Collaborate to Build "GIS for the Gulf"", *ArcNews*, Vol. 27, No. 4, 2006, pp. 30.

[12] P. Yoshitomi, "GIS Portal Helps to Quickly Share Disaster Data", *ArcNews*, Vol. 27, No. 4, 2006, pp. 31.

[13] J. Radke, T. Cova, M. Sheridan, A. Troy, L. Mu, and R. Johnson, "Challenges for GIS in Emergency Preparedness and Response", ESRI White Paper, Redlands, California: ESRI, 2000.

[14] US Geological Survey (USGS) web site, http://www.usgs.gov/, Accessed on March 11, 2006.

[15] US Federal Emergency Management Agency (FEMA) web site, http://www.fema.gov, Accessed on March 22, 2006.

[16] M. Meenar, A. Bari and K. Paulsen. "Developing a Watershed Inventory for Vulnerability Assessment Using ArcGIS", *ArcUser*, Vol. 9 No. 1, 2006, California: ESRI Press, pp. 20-23.

[17] M. Meenar, J. Duffy and A. Bari. "Life on the Floodplain: Remapping Watersheds, Neighborhoods, and Lives", *Planning*, Vol. 72, No. 7, 2006, Illinois: American Planning Association, pp. 30-33.

Md Mahbubur Rabb Meenar has received a master's degree in urban and regional planning in 2002 from the State University of New York at Buffalo, USA, and a bachelor's degree in architecture in 1997 from Bangladesh University of Engineering & Technology.

He works as a Senior GIS Design Specialist at the Center for Sustainable Communities and as an adjunct assistant professor in the Department of Community and Regional Planning at Temple University, USA. Prior to his current positions, he has worked as a research assistant at the Institute for Local Governance and Regional Growth and the Center for Urban Studies at Buffalo, USA. His research interests include

environmental modeling, neighborhood revitalization, disaster management planning, sustainable development, and three-dimensional GIS simulations.

Mr. Meenar is a member of American Planning Association, Urban and Regional Information Systems Association, Urban Affairs Association, and Institute of Architects Bangladesh.