DESIGN AND IMPLEMENTATION OF A WEB-BASED GIS (IN RESPONSE PHASE) FOR EARTHQUAKE DISASTER MANAGEMENT IN TEHRAN CITY

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Commission PS WG VII/5

KEY WORDS: Earthquakes, Disaster, Management, GIS, Web based

ABSTRACT:

Natural hazards (i.e. earthquakes, floods) become disaster when they strike the man-made environment. To effectively reduce the impact of every disaster, governments prepare a complete strategy, called disaster management. Availability of data such as: buildings, lifeline systems, roads, hospitals and etc, will help the managers to better decision-making. The majority of this data is spatial and can be mapped. So a Geographical Information System (GIS) can support disaster management as a powerful tool for collecting, storing, analysis, modeling and displaying large amount of data. Many organizations which involve in disaster management, require to access to the right data in the right time to make the right decisions. So designing a GIS to distribute geospatial information on a network such as Web, gives a chance to the managers of organizations to easy access to the information about disaster any time and any where they are. This paper outlines different steps of developing a Web-based GIS to manage and response to earthquake in a central district of Tehran as a case study. Lack of a model to estimate the size and extend of damages immediately after earthquakes is one of the major problems in developing such a system. In this research a Building Damage Estimation Model (BDEM) has been developed to optimize the response time and cost against earthquake disaster.

1. INTRODUCTION

Earthquake, as the natural hazard, is the part of the world around human being. Its occurrence is inevitable. It destroys natural environment but the natural environment takes care of itself. So Earthquake becomes a disaster when it crosses paths with the man-made environment, such as buildings, roads, lifelines and crops. The man-made environment, in contrast to natural environment needs disaster management. Government of each country is responsible for disaster management at all levels (local, state, and regional). Disaster management can be divided into some phases: Planning, Mitigation and Preparedness are all pre-event phases, Response and Recovery are two during and post-event phases. These phases are related by time and function to all types of emergencies/disasters. Also, they are related to each other, and each involves different types of skills. As disasters (earthquakes, floods and hurricanes…) are usually spatial events therefore all phases of disaster management depend on data from a variety of sources. So, Geographical Information System (GIS) as a tool to collect, store, model, analyse and display large amount of spatially information layers, supports all aspects of disaster management. Tehran, as the capital city, the most populous and centre of political and economical activities of Iran, has a special situation against natural disasters. As the Greater Tehran Area is located at the foot slope area of the Alborz Mountains, which form part of the Alps-Himalayan Orogenic Zone and this zone is one of high seismic potential with many peculiar active faults, this city is threatened by earthquakes. Seismologists believe a strong earthquake will strike Tehran in the near future because the city has not experienced a disastrous earthquake since 1830.Although, Iranian government have been performing a lot of prevention plan in order to mitigate possible seismic damages in Tehran city, according to the expanse of Tehran and multiplicity of spatial features, still there are many features which are vulnerable against potential earthquakes. Therefore a sudden occurrence of such a potential earthquake may expose Tehran's population to the risk of death or injury and may damage or destroy private property and social infrastructure. So, it is urgently necessary to make a plan for response phase of earthquakes disaster management in order to reduce human losses and physical losses from damage. Gathering relevant data through all of governmental departments, organizations and input this data in a GIS as an appropriate tool to process and analyse it, can help managers to make a better decision during and just after of an earthquake. This paper describes design and development of a web-based GIS for disaster response. In order to test the system, a case study was conducted in one of the districts of Tehran, the capital of Iran.

2. EARTHQUAKE RESPONSE PHASE ACTIVITIES

Earthquake response phase includes activities take place during or just after an earthquake, which are designed to provide emergency assistance for victims. Just after the earthquake, repairing lifelines networks to stabilize the situation and reduce the probability of secondary damages (for example, gas network to prevent secondary damages or shutting off contaminated water supply sources…),search and rescue activities, transport and communication, evacuation are the priorities to operate. Quick rescue of people by search and rescue teams from collapsed buildings, after the impact of a destructive earthquake, can save considerable number of lives. Then, emergency sheltering should be managed and distribution of water, food and public services should be provided also, medical heath centres should be identified in order to give medical care to the casualties. Other activities in this phase include burying deaths immediately and damage assessment to speed recovery operations. As response phase includes variety of activities and skills, it urgently needs participating, cooperating and co-ordinating of a lot of organizations to manage it. Also it is necessary to establish a GIS to efficiently support such activities in this phase.

3. DEVELOPING A WEB-BASED GIS TO MANAGE EARTHQUAKE RESPONSE PHASE

Developing a GIS to manage earthquake response phase is performing by a research team in K.N.T University of Iran. The main object of this team is to develop a GIS for managing earthquake response phase to better decision-making during and just after the earthquake. In this way, some steps have been mentioned. (See figure .1)

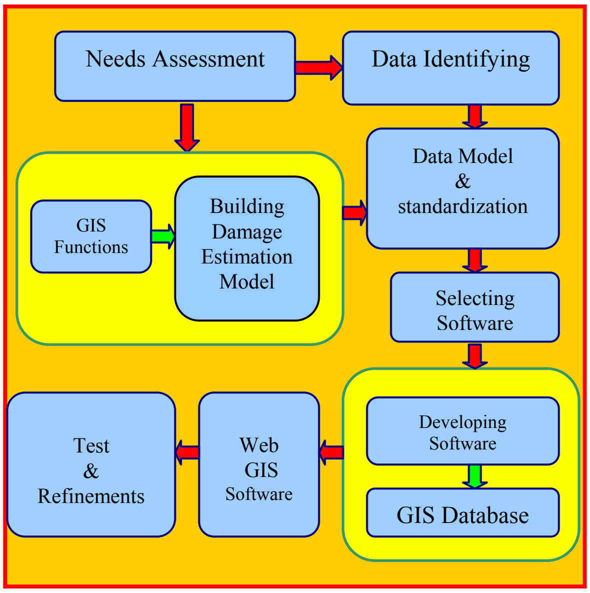

Figure 1. Steps of developing a GIS for earthquake disaster management

3.1 Needs assessment

Needs assessment is the first step in implementing a successful GIS within any government. Needs assessment is a systematic look at how departments function and the spatial data is needed to do their work .In the case of earthquake disaster management the involving organizations were identified .Then needs assessment was performed through interviewing potential users in these organizations. As a result of needs assessment some critical pieces of information have been produced .Then certain tasks were identified that can be done more efficiently or effectively in a GIS to be utilized by involved organizations such as , displaying epicentre, displaying destructed buildings, displaying the safe buildings, determination of the nearest emergency centres to the affected area, displaying the locations for sheltering, estimating the majority of damages or losses immediately after earthquake, find the best route to dispatch emergency personnel to the affected area, showing the locations of interruption in pipelines in order to reduce the probability of secondary damages and so forth. According to each application identified, certain GIS functions will be required such as, query and display, identify and spatial analysis functions (routing ,…),advanced analysis(modelling) and programming. Each GIS application requires relevant spatial and non-spatial data, so a list of required data was provided.

3.2 Data needed in the GIS database

A list of required data for earthquake disaster management was identified and categorized. These categories include the data about buildings (residential or business), roads (freeways, highways, streets…), lifeline systems (water pipes, electric lines…), open areas to settle the homeless (parks, orchards, camping area…), public service stations (gas station…), some urban structures (bridges), some natural and urban conditions data (population, soil layers, faults).

3.3 Data model

In this step, once the required data for response phase of earthquake disaster management applications has been identified, the data model that identifies the entities and their relationship were designed and require standards were developed.

3.4 Modeling

The results of needs assessment show that, one of the major problems of involved organizations in earthquake disaster response of Tehran, is lack of any prediction on extend and size of damages for the urban features and human losses after the earthquake.So having a prediction about damages of earthquake provides a lot of benefits for managers before and just after the earthquake. Prediction of results before the occurrence of earthquake by assumption some earthquake scenarios and asking some "what if" type questions makes it possible to evaluate alternate solutions for pre-event managing of the earthquake which this subject is not concerned here. Estimation of the results of an earthquake just after the earthquake helps the emergency personnel to rapidly response to the affected area. In this respect spatial modeling is the most demanding use of a GIS and provides the greatest benefit to predict the results expected or estimate the results of an earthquake. Extend of damage to the urban structures depends on a lot of parameters such as structure resistance against earthquake, the intensity of earthquake, distance of urban structures to epicentre, soil type, materials used to build the structures and so forth. Since destroying of buildings causes the main physical damages and losses of human, a Building Damage Estimation Model (BDEM) has been developed to estimate extend and size of the damages of buildings, just after the earthquake. The model is based on some mathematical equations and needs data input such as environmental data, building property data and some real earthquake property data which will import to BDEM just after the occurrence of earthquake to estimate the situation of every building. As a result BDEM divides the situation of the buildings after the earthquake into three categories: buildings which stay safe (Safe buildings), buildings which are not destroy but because of some disastrous crack they should be evacuated (Evacuated buildings) and destructed buildings (Destructed buildings) (see figure.2).Categorizing buildings and displaying results help managers to realize about extend and size of the area which is affected by the earthquake and density and distribution of the buildings in every category. It also helps the managers to know about the situation of their recourses (business buildings) then decide about the priorities to dispatch their emergency's personnel from their safe resources to the residential affected areas with respect to density of destructed

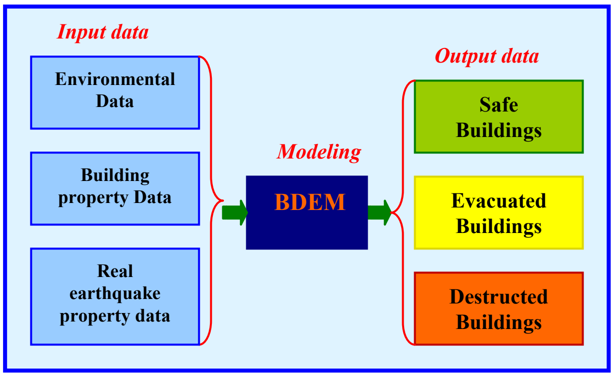

Figure 2. Building Damage Estimation Model (BDEM) process

buildings and transfer the causalities to the safe health centres. Also the number of Destructed and Evacuate buildings will be known which helps to estimate the number of human losses and number of citizens who need sheltering. Financial losses can be estimated as well. Displaying the results of BDEM, decrease the costs of gathering data from affected area and minimize the response time to the earthquake. Although BDEM has a lot of advantages, it has some difficulties such as dependence on a lot of environmental and building parameters as well as some pre-event spatial input data and post-event spatial input data to process BDEM .So one of the challenges of using this model is the availability and accessibility of required data as input for BDEM. In this respect, Spatial Data Infrastructure (SDI) is an appropriate framework for availability and access to required data.Currently, research team of K.N.T University of Iran is working on developing of an SDI conceptual model for disaster management which can facilitate collection, access, usage and management of spatial data. This SDI conceptual model creates an appropriate framework, in which all involved organizations in disaster response can access to their required spatial data for disaster response, through partnership effort in data collection and sharing, before and during disaster. (Mansourian et al, 2004a) (Mansourian et al., 2004b).Regards to the most spatial modeling tasks are very difficult to perform by hand , they are not usually done unless a computerized system, such as a GIS, is available. In order to implemente BDEM, designing appropriate GIS software is essential.

3.5 Web-based GIS software

The prime concern during any disaster management is the availability of the right spatial information in the right time and the dissemination of this information to all concerned to make right decisions. In this way, distributing geospatial information on a network of information gives a chance to the managers of organizations to easy access to the information about earthquake disaster management, any time and any where they are .So a stand-alone GIS can't be useful in this respect and earthquake disaster management needs a network-based GIS with accessing to online data. Therefore a Web-based GIS has been considered for managing response phase of earthquake disaster management. Web-based GIS applications involve a user (the client) who contacts a server for some information. Commonly two strategies have been used for Web-based GIS applications .In the first extreme the server passes data and mapping applications (usually Java applets) to the client means that server supplies the data and the programs, but all GIS functions are carried out on the client side (client-side strategy). In the second strategy, the client indicates the type of map of functions that wishes to execute, and the server passes back the map the client request (server-side strategy). Several factors influence the strategy of Web-based GIS .In client-side strategy; server passes data and Java applets to the client, so it is functional and easy to use, but this strategy has some drawbacks for example, client-side strategy is not useful for transmitting huge data, because it takes a long of time, also it needs enough disk space and/or RAM to store in client-side. It doesn't concern about data security as well, because people can download raw data and may be there is some sensitive data which it shouldn't be download by them. Server-side strategy hasn't these kinds of difficulties. However, it is not without its drawbacks. For example, if site receives a lot of traffic, the server is going to be very busy processing for each user's request for a map so, this strategy is not suitable if server overloaded. As a lot of data gathered from variety of organizations in GIS database of earthquake disaster management and it is necessary to access to the right data for disaster managers, so data security is an important aspect in this respect. Therefore a server-side strategy has been chosen for developing the Web-based GIS system. (See figure.3)

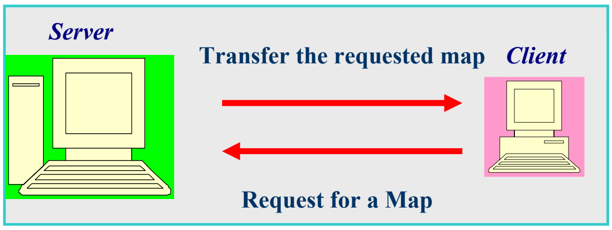

Figure 3. Server-side strategy

While the purpose of designed earthquake disaster management system is to provide the managers and potential users requests, the Web-based GIS become useless for the others users. With this assumption, the problem of overloading of the server-side strategy will be faded. Selecting suitable software is an important step in a successful implementation. For the purpose of managing response phase of earthquake disaster a Web-based Earthquake Disaster Management GIS software (EDM) has been developed by using GISengine and programming languages such as visual basic, HTML and Java script (See figure.4).

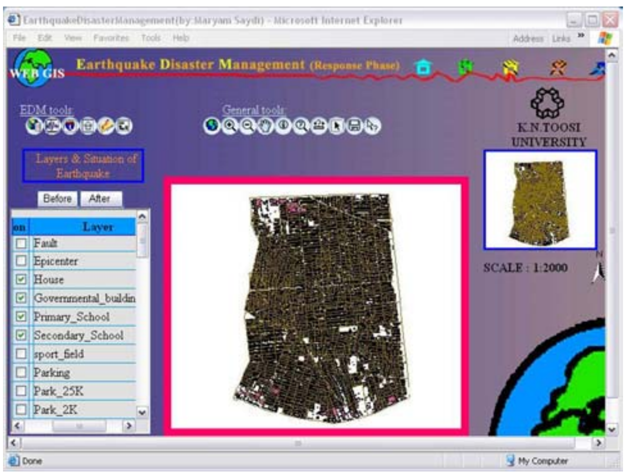

Figure 4. EDM interface

EDM includes a small and large extent display, some buttons for general GIS functions such as, pan, zoom, select, identify…, and some buttons for specific GIS functions .Also it includes a column of layers, to enable or disable showing the layers. In the case of specific GIS functions, there are some buttons: a button which allows the managers or potential users to access to the database in order to create ,edit or delete the data from the GIS database, a button to routing ,a button to import post-event data from another on-line earthquake site .As soon as this post-event data imports in EDM , it allows the next button which is about estimation situation of buildings after the earthquake ,to be enabled .Then, BDEM begins to process the post-event data with pre-event data . Results of this processing will be shown by clicking 'After' button. In this way, managers immediately can see a primary estimation of extend and size of earthquake and its effects on the buildings on-line. Utilizing relevant GIS functions makes managers to decide rapidly. The system is now testing and setting up at K.N.T University and is going to be completed specially on database and modelling using more parameters.

4. CONCLUSIONS

A Web-based GIS and a Building Damage Estimation Model (BDEM) has been developed for supporting earthquake disaster management of Tehran. This system helps to estimate the extent and size of damages, just after the earthquake. It also, helps the managers to rapidly response to earthquake disaster. This takes a lot of advantages to the managers by decreasing the cost and response time to make better decision during and just after the earthquake.

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