The Use of GIS as Disaster Preparedness and Response Tool

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Abstract

Disaster Management is currently receiving attention, especially in developing countries, although the necessary tools required for an efficient and effective management is grossly lacking. The very large volume of disparate data required for its management is mostly lacking or available in format which does not lend itself to integrated analysis. Existing simulation models are narrow in scope although disaster (both natural and human-induced) and its effects are multi-disciplinary in nature. Its management also requires multi-disciplinary knowledge and collaborations.

Geographic information system (GIS) is a computer-based technology. It allows the integration of various data and databases into a single environment for a comprehensive simulation and analysis of natural and human-induced hazards. This paper explores the strategy for the use of GIS capabilities as a disaster preparedness and response tool. The process of integrating topographical, geological and hydrological data with infrastructural and socio-economic data to undertake risk assessment mapping, response rate simulation, and other disaster management requirements is discussed.

Introduction

Natural hazards have led to destruction of life and property from time immemorial. Despite technological development, their occurrence are still difficult to prevent; but their consequences can be mitigated through properly designed and coordinated disaster preparedness and response management plans. Through the study of the causes and effects of specific hazards e.g. hurricanes, earthquakes, landslides, floods, tsunamis, volcanic eruptions, data on entities that trigger the occurrences of these hazards can be collected and monitored. Similarly, data on resources that would be damaged once the hazards occurred can also be collected and assessed. These two types of data thus provide us with tools for developing mitigation plans in respect of each hazard. Simple as it may seem, the real challenge is the nature, volume, and format of the data required for such plans and the ability to integrate the data for specific applications. The data required for an effective evaluation or forecasting the occurrence of some hazards are grossly lacking or exist in formats that are not usable. Mitigation plans for landslide, for example, require climatic data, topographic data, land use data, vegetation data, and socio-economic data. These data categories normally exist (if at all) in different government agencies, in different formats, different levels of details, and are collected for different purposes. Such disparate data are difficult to use in an integrated analysis typical of disaster management and monitoring. In addition, the volume of data required to undertake meaningful analyses could be too large for the mostly manual methods of analysis.

Geographic information systems provide an environment which permits an integrated data collection and analysis for disaster management and monitoring. Spatial or geographic data can be collected primarily using conventional land surveying techniques, global positioning systems (GPS), photogrammetry, or remote sensing techniques; or by scanning or digitizing existing maps. These techniques will provide positional data for the different hazard parameters in formats which can be integrated into a GIS. Thus, making it possible to integrate for example wind data with building and population data. The key to such integration is the design and adoption of data structures and data standards for the entire jurisdiction; followed by the development of corporate databases. The corporate database is one which is not application dependent and as such is accessible to all legitimate users in the community. Once developed, the databases would provide the platform for the simulation of the cause and effect of hazards; response rate simulation; and other disaster mitigation initiatives.

Geographic Information Systems

Geographic information systems are computerized information systems that are designed to capture, edit, store, retrieve, process and disseminate spatial and attribute data which are referenced to some predefined geographic/geodetic referencing systems (Opadeyi, 1992). The superior data handling and data processing capabilities of GIS are responsible for the increasing adaptation of the system in varying fields of application. Its application to real-life phenomena is widely growing and it cuts across professional barriers. Almost all life phenomena that has spatial relationship can be conceived to benefit from GIS functionalities. As a technology, GIS consist of the following sub-systems (Figure 1) combined together to perform GIS functions: Hardware subsystem; Software subsystem; Data and database subsystem; Institutional subsystem.

The *hardware subsystem* is the combination of computer configurations, plotters, scanners, digitizers and networking configurations. The design and specification of the architecture of this sub-system range from one-site, stand-alone personal computer to multi-site, multi-user workstation computer environment, with local area network (LAN) facilities. Financial investment in this subsystem is high and varies, depending on the degree of sophistication desired.

The *software subsystem* is the combination of automated computer programs. Software modules are assembled to handle data collection, storage, processing, retrieval functions of the GIS. The suite of software is desirable to be integrated, and this is becoming necessary with the direct down-loading and processing of GPS and photogrammetric stereo plotters data within GIS software environment. This subsystem is the driving force behind the sales of GIS. GIS vendors concentrate on the functionalities of GIS software and thus become the first contact point of most GIS practitioners.

The *Data and Database subsystem* is the backbone of a full fledged GIS. Without data in its usable form, GIS functionalities cannot be accomplished. Data and database management are known to account for almost 75% of the total investment in GIS. Data acquisition and preparation are the first real undertaken of new GIS projects.

The *Institutional subsystem* is a people related sub-system. It deals with human resource management and especially the relationship between GIS developer, users and the financing agencies. Procedure, training, copyright, data access, authorization and authentication are the major components of this sub-system.

Functional Components of GIS and Disaster Management

There are five functional components of GIS (Figure 2): data collection and acquisition, data preparation; data integration; data management; data analysis and application. These are activities that produce tangible benefits to GIS investments (Opadeyi, 1992). *Data collection and acquisition* under a GIS environment provide for flexibility in the nature and format of the data required. Tabular data currently existing in digital format; graphical data in hard copy map format; photographs, remote sensing data and analogue field data can all be incorporated into a single GIS environment for a comprehensive data collection and data acquisition programme of an agency. *Data preparation* components is the process of extracting, spatial coding and conversion of field sample data and related data in a form which will provide for easy referencing and the ability to cross-reference the data with other data. Monitoring stations can be spatially referenced using either the geographic or Cartesian coordinate systems. Such coordinate systems provide for spatial uniqueness in the identification of the points.

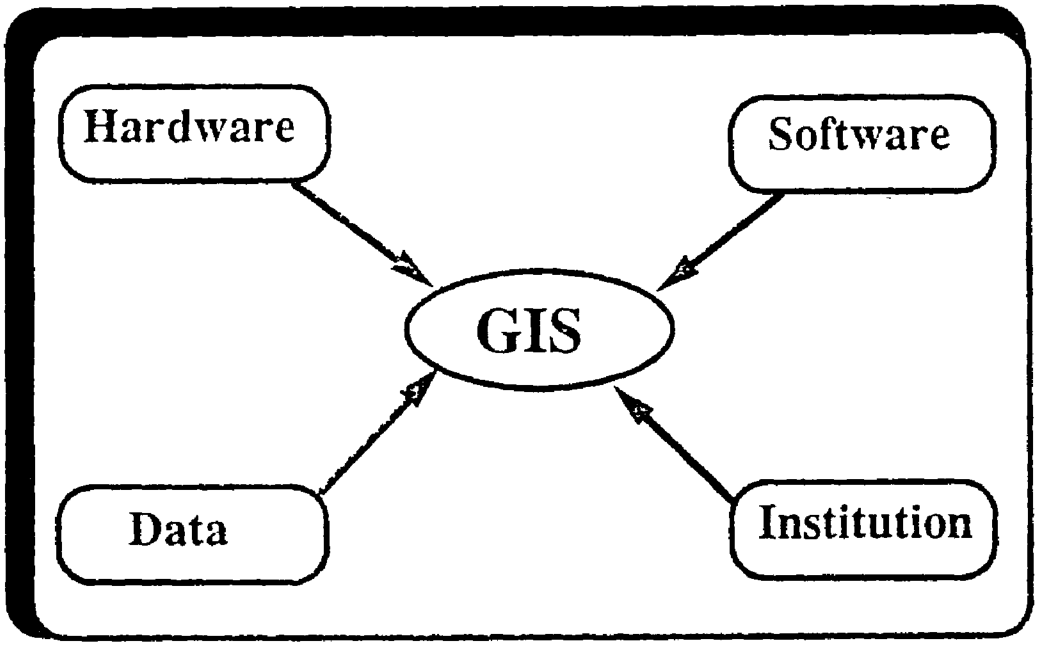

Figure 1: The Sub-systems of a GIS

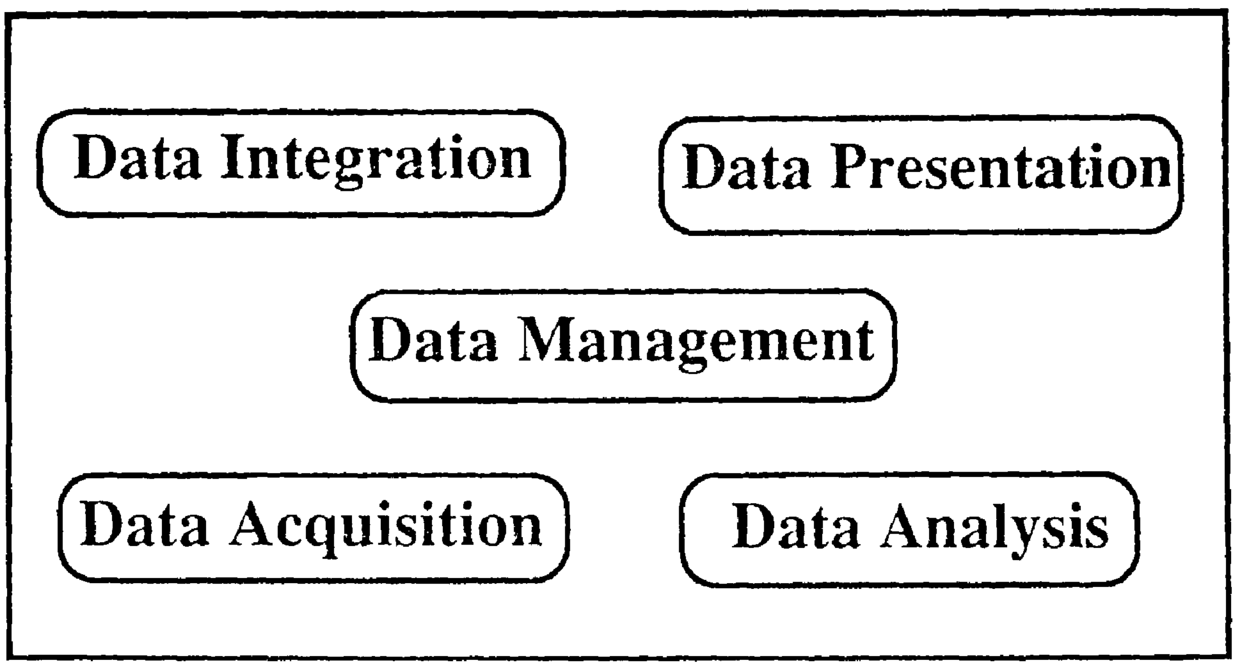

Figure 2: The Function Components of a GIS

Data integration functionality provides the unique advantage of being able to link spatial data to attribute data and the ability to add any other form of data within the GIS environment. This functionality is used in the generation of thematic maps e.g. landslide susceptibility map over an entire region. *Data management* functionality in the computer environment provides the infrastructure for the storage, retrieval, merger and generalization of different data categories required for disaster management. Such an infrastructure provides efficiency for disaster monitoring programmes through improved usability of the data collected. *Data analysis and application* functionalities are the main functions or end-products for the use of GIS in disaster monitoring. The major challenges to the implementation of analysis and application functionalities are the availability of data and the knowledge of the appropriate theoretical concepts (Opadeyi, 1993).

Conceptual data Model for Disaster Monitoring and Management

Fundamental to the successful development of GIS to support disaster monitoring and management is the development of digital natural hazard databases for the entire management area. The databases would provide support for the qualitative and quantitative analyses of queries. A conceptual data model can be developed, as shown in Figure 3, that integrates in a distributed environment, all the basic data categories required for disaster monitoring and management. The following are the basic spatial databases and applications required (OAS, 1991):

Topographic Database
- Contours/Elevations
- Slopes/Aspects
- Vegetation
- Soils
- Bathymetry

Geologic Database
- Bedrock geology
- Fault lines
- Epicentre (earthquake)
- Plate Boundaries

Hydrologic Database
- Rainfall
- Air temperature
- Net radiation
- Wind speed/direction
- Evaporation rate
- Rivers/Watersheds

Infrastructural Database
- Telecommunication
- Transportation
- Overhead utilities
- Undergound utilities
- Police/Fire stations
- Emergency offices

Socio-Economic Database
- Schools/Churches
- Medical Centres
- Industrial sites
- Commercial sites
- Residential sites
- Agicultural sites

Occurrence Database
- Type of disaster
- Date & time of occurrence
- Location
- Magnitude/Severity
- Impact/Damage
- Others

Basic Map Layers Relevant to Applications Development
- Fault maps
- Epicentre maps
- Flash flood maps
- Flood plain maps
- Landslide occurrence maps

- Seismotectonic maps
- Storm surge maps

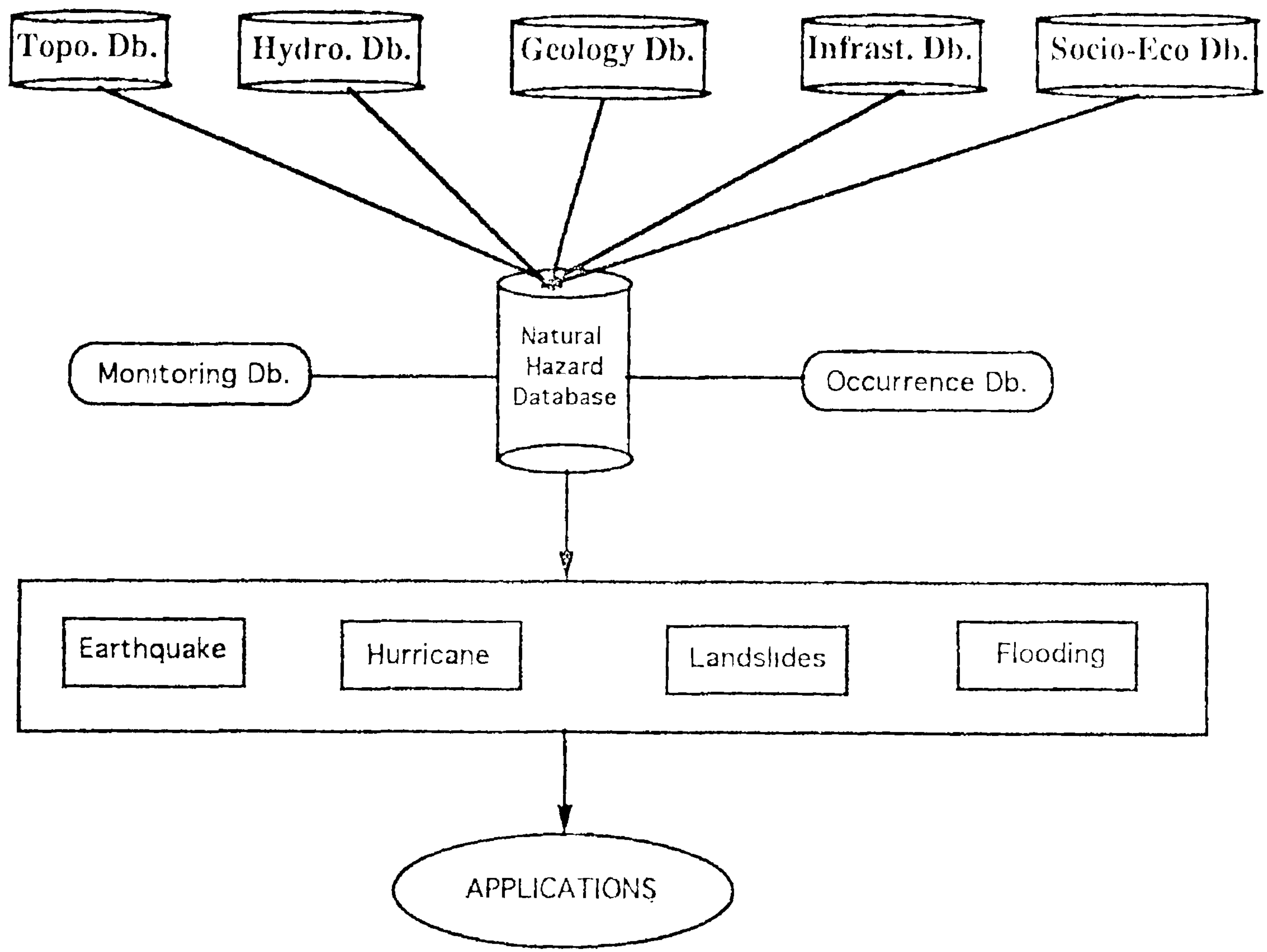

Figure 3: Conceptual Data Model of for Disaster Management

Examples of Applications
Natural hazard prediction
Response rate simulation
Cause-effect analysis
Zone/degree of severity map
Degree of vulnerability map
Storm runoff prediction from urban watersheds
Land use planning and management within a river basin
Calculation of the spatial variations of rates of evapo-transpiration
Simulation of environmental impact assessment
Site suitability screening for hazardous waste facilities
Groundwater contamination monitoring

GIS provides a platform for undertaking the following analyses which are peculiar to disaster monitoring and management:

Temporal analysis of natural hazard parameters
Trend analysis of the occurrence of disasters
Spatial analysis of the effect of disaster over a geographic region
Three dimensional analysis of the effect of natural hazards
Multivariable analysis

Conclusions

The use and development of GIS for disaster management has moved from the conceptual stage to the implementation stage. Due to the many benefits, developing countries should be incorporating GIS concepts and technology into their daily operations especially for the various planning requirements. With the decreasing costs of hardware and software, GIS technology is now affordable; and its use should be adopted as a matter of urgency.

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Risk Mitigation Strategies: The Case of the Costa Oriental Oil Fields in Western Venezuela

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Abstract

Oil production in the famed Costa Bolivar (now Costa Oriental) oil fields started in the late 1920s and has continued uninterruptedly since then. The oilfields extend along the eastern coast of Lake Maracaibo in Western Venezuela from Cabimas in the north to Mene Grande in the South.

Reservoir compaction is the main production mechanism in these shallow (100 to 1000 m), unconsolidated reservoirs, causing considerable ground subsidence, up to 5.3 m in areas of intensive oil production.

Coastal dykes had to be built to protect life and oil industry installations from lake waters. The gradual character of subsidence has allowed for the staged construction of the coastal dykes, as well as for the construction of inner (diversion) dykes and an elaborate drainage system. Three polders, coinciding with the oil fields of Tia Juana, Lagunillas, and Bachaquero, have evolved as a result.

These works are collectively known as the Costa Oriental Protection System and have been constructed on the basis of the latest technical knowhow. Recent studies have shown the liquefaction potential of some layers of the dyke foundation soils under appropriate earthquake shaking in this region of moderate seismicity.

Soil liquefaction could bring about a non-controllable dyke failure which would lead to the flooding of the protected areas below lake level with the resulting human and material losses.

In view of the above, Petróleos de Venezuela, the national oil company, through its fully owned operating companies Lagoven and Maraven, has implemented a risk reduction programme consisting of preventative and mitigative measures as well as a contingency plan.

This contingency plan is known as PLAN COLM (COLM being the acronym of Costa Oriental del Lago de Maracaibo). Its preparation has been coordinated by Maraven. Local, state and central government officials, as well as Lagoven staff, have actively participated in these activities. Venezuelan and international consultants have also taken part in the preparation of the PLAN COLM.

The final paper will describe in detail the contingency plan, the problems encountered and the solutions adopted and will also summarize future activities to be performed.