

GIS & Risk Assessment

Introduction

GIS technology is increasingly being used in spatial decision support systems. In the past few years, GIS has emerged as a powerful risk assessment tool and is being put to use to assess risk to property and life stemming from natural hazards such as earthquakes, hurricanes, cyclones, and floods.

Manipulation, analysis, and graphic presentation of the risk and hazard data can be done within a GIS system, and because these data have associated location information which is also stored within the GIS, their spatial inter-relationships can be determined and used in computer-based risk assessment models.

This assessment is used by insurance companies to help them make decisions on their insurance policy rates, by land developers to make decisions on the feasibility of project sites, and by government planners for better disaster preparedness.

Risk Assessment

A fundamental principle of Risk Assessment is that risk due to natural catastrophes such as earthquakes, hurricanes and flood, is location-dependent, and that it can be assessed within an acceptable range of uncertainty if reliable historical and location-specific data is available.

Risk assessment of natural catastrophes has two components - hazard and vulnerability. The hazard is a measure of the physical intensity of the peril (earthquake, wind, surge, etc.) at a particular location and the associated probabilities of these intensities. Hazard is location dependent. For example, a location which is surrounded by seismic faults and has weak surface geology has a higher hazard potential than a location far away from faults and with strong surface geology. Similarly, hurricane hazard at a location near the coast and with a flat, bare terrain is far higher than at a location which is inland and has a rugged terrain.

Vulnerability is a measure of the damage that the peril can cause to the built environment (houses, buildings, infrastructure and utilities) at that location. Man-made structures respond to different perils in different ways, depending on the design of their structural systems and methods of construction.

GIS as a tool in Risk Assessment

GIS in conjunction with remote sensing and photogrammetry, can be used to identify hazards. Seismic faults and flood prone areas can be identified by scientists using GIS to analyse satellite images, aerial photos and field survey data.

Once the hazards have been identified, their representation can be stored conveniently in GIS databases. The information required for earthquake risk assessment includes the location and properties of seismic faults, surface geology, terrain slope, water table levels and inventories of epicentres and landslide occurrences. For hurricane risk, information on land use, land cover, coast line and distance from coast are important. Similarly, topology data is required for flood assessment and storm surge analysis.

In addition, new hazard layers can be generated within a GIS by combining hazard layers. For example, a landslide hazard layer can be generated by overlaying elevation; surface geology, water table level and landslide inventory data, and liquefaction hazard can be generated in a GIS by overlaying geology with water table level data.

Inventory data can also be stored easily in a GIS database. Data on building stock, lifelines, utilities, etc. can be aggregated into manageable geographic regions such as census wards, pin codes, or larger administrative regions such as villages, talukas and even districts. Using statistical functions available in GIS systems, the average value of various properties of different building classes can be computed (e.g. average monetary value of residential dwellings in a particular village) and stored with their corresponding geographic regions in the GIS database.

The information retrieved by querying the GIS database serves as inputs for the risk assessment models. These risk assessment models can run both deterministic as well as probabilistic risk assessment. Deterministic risk assessment involves defining a disaster event and computing the damage associated with that event, whereas probabilistic risk assessment computes damages for different events, accounting for the probability of each event. Deterministic events could be defined using a GIS front-end system.

The resulting loss patterns over regions and their associated uncertainties that are computed through this risk assessment can be mapped and again used for querying information through GIS applications. GIS technology provides a powerful tool for displaying outputs and permits users to “see” the geographic distribution of impacts from different peril scenarios and assumptions and allows the user to perform a quick graphical sensitivity analysis of the factors affecting the risk potential. A GIS-based software system creates the ideal framework to integrate the various components of the model.

Examples of GIS applications in the field of risk assessment

Hazard Mapping

A very common use of GIS in risk assessment is in the preparation of hazard maps. Hazard maps could be created to show earthquake hazard, landslide hazard, flood hazard or fire hazard. These maps could be created for cities, districts or even for the entire country.

GIS can be used for the analysis to determine hazard zones in the map, as well as in the output and printing of such maps. These hazard maps serve as risk zone identifiers for the general population since they are easy to understand and interpret, but they are also of use to planners, developers and insurance companies, since they serve as a quick identifier of risk prone areas.

Threat Maps

Tropical cyclone threat maps are used by meteorological departments to improve the quality of their tropical storms warning services. The purpose of these maps is to quickly communicate the risks to the people likely to get affected by the cyclones. GIS is used effectively to display the position and likely movement of the winds and the vulnerability for the identified zones. These maps are very helpful for

administrative agencies involved in risk assessment and disaster mitigation. The threat maps can be suitably overlapped with population and land use maps to arrive at meaningful conclusions. These maps can also be provided to the media for effective communication. Considering the quick turn-around time for generation of these maps, threat maps can be used for real time simulation of wind velocities, cyclone tracks and identification of potential high-risk zones.

Insurance Underwriting

GIS is now being used on "Geographic Underwriting Stations" (GUS). Insurance underwriters can access data on demographics, property values, crime rates, locations of fire hydrants, police stations and fire stations, as well as locations of hazardous facilities, all available on their desktops, delivered through GIS. Risk indexes for areas can be created by the GIS in conjunction with risk assessment programs - e.g. a very high "risk index" can be assigned to an area with dense population, high crime rate and high frequency of earthquake events. Using the GUS, underwriters can make real-time yet informed decisions on whether to underwrite any particular property for fire, burglary, or natural hazards, and what premium to charge for insurance. GIS can also be used as a tool for segmenting the market for an insurer, in terms of income potential, policy requirements and buying trends.

Government planning for disaster management

Regional planners require sophisticated risk assessment tools in order to plan for disaster mitigation as well as disaster monitoring and rescue in the event of a disaster. GIS can deliver not only data on hazards in the region, information on buildings, lifelines, and critical facilities, but can also contain built-in risk assessment programs that allow the planner to simulate disaster scenarios and graphically view the potential damages and affected areas as well as plan rescue operations. The Indian government has also launched an initiative called National Resource Information System (NRIS) through the Department of Space, in an effort to create a nation-wide GIS database of national resources that could be used for better disaster management.

Conclusions

This paper has attempted to describe the various ways in which GIS can be used in risk assessment. GIS can be used in the very beginning of the risk assessment process, in the identification of hazards itself. It can also be used to determine new hazards through overlay of hazard data sets. Hazard and vulnerability data which is both spatial and non-spatial in nature can be stored in GIS databases. Risk assessment programs can be called within the GIS to access this data and evaluate potential damages and risks. Finally, by displaying the potential damages that can be caused by natural hazards, GIS helps planners and insurers to take preventive actions. GIS thus plays an almost indispensable role in the process of risk assessment.