'Role Of Geographical Information System (GIS) In Managing Damages On Account Of Earthquakes'

Dr. Mrs Ashwini Atul Renavikar[1*], Mrs. Anjali Bapat (Deshpande)[2]

[1*]Associated with Symbiosis Skills Professional University and QA Professional at Shrisoft Pvt. Ltd. Pune
Contact det.: 9890247127 Email: ashwiinirenavikar@gmail.com
[2]Quality Management & Benchmarking (QMB), Symbiosis International (Deemed University), Pune.
Contact det.: 98347 48201 Email: hianjud18@gmail.com

***Corresponding Author:** Dr. Mrs Ashwini Atul Renavikar
*Associated with Symbiosis Skills Professional University and QA Professional at Shrisoft Pvt. Ltd. Pune
Contact det.: 9890247127 Email: ashwiinirenavikar@gmail.com

Abstract
The paper discusses different aspects of **Geographical Information System (GIS)** such as the technology requirement, array of GIS softwares available and methodology for capturing data through GIS software and some facets of GIS with respecte to the data capturing errors and manageing the same.
Many application areas such as real estate, public health, crime mapping, national defense, sustainable development, natural resources, transportation and logistics can benefit from GIS.
Though, the list of application areas for GIS is unending, the paper under consideration includes some facts and figures along with case studies as to how GIS can help managing the damages on account of natural disasters, in specific, earthquake, which is one of the inevitable and devastating natural hazards that causes lots of damages and problems to the economy, environment and the whole life of people. In comparison to other areas of application, less work has been done in the area of use of GIS in natural disaster management, for the obvious reason, these disasters being a very infrequent phenomenon. But, considering the past 5 years (2000-2005) record of natural disasters, such as earthquake, tsunamis, cyclones, volcano eruptions and land slides, the research in the area of GIS for natural disaster management has a lot of scope.

Introduction:
What is GIS: Geographical Information System (GIS) is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. Practitioners also define a GIS as including the procedures, operating personnel, and spatial data that go into the system.
The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship. Most of the information we have about our world contains a location reference, placing that information at some point on the globe. A GIS can also convert existing digital information, which may not yet be in map form, into forms it can recognize and use.

Why GIS: It was somewhere in late 19th century, the need was felt to store the data in image form. Only two-dimensional storage was possible till then. Technology did not provide any option to store the details along with data. The need for storing data in 3- dimensional format was the need of time. GIS helps in building a holistic view of geographical and spatial structures.

Objective of this paper: To highlight on some basic aspects of GIS such as the technology, data capturing, error refinement along with a specific angle of studying role played by GIS, in managing damages on account of earthquakes, in India and abroad with reference to prediction, loss assessment and relief activities.

Methodology: The work is based on secondary data, the source for which is mentioned in references and bibliography. The study is based on specific cases of earthquake in past, for which sufficient data was available in a published form.

Storing and refining data for GIS:

Spatial Objects and Data Models: The real world is too complex for our immediate and direct understanding. So, we create "models" of reality that are intended to have some similarity with selected aspects of the real world. Databases are created from these "models" as a fundamental step in analyzing, managing and understanding the world Spatial database is a collection of spatially referenced data that acts as a model of reality It is a model of reality since it represents a selected set or approximation, these selected phenomena are deemed important enough to represent in digital form

Fundamental database elements in GIS are elements of reality modeled in a GIS database have two identities:

1. the element in reality - entity
2. the element as it is represented in the database - object

A third identity important in cartographic applications is the symbol, which is used to depict the object/entity as a feature on a map or other graphic display.

Spatial object type classes can be classified into three main types - 0-D - an object that has a position in space, but no length - point ,- 1-D - an object having a length – line composed of two or more 0-D objects.

Figure 1: Three-dimensional image of the San Francisco Bay created to assess the potential of land and underwater avalanches.

Data in GIS ca be categorized in 3 major types i.e. 0-Dimensional spatial object types (point ,node),1-Dimensional spatial object types (line, line segment ,string , arc , link ,directed link , chain) and 2-Dimensional spatial object types(area, interior area ,simple polygon , complex polygon , pixel , grid cell)

Object classes is a set of objects which represent a set of entities of one type e.g., the set of points representing the set of wells.

Attributes are the characteristic of an entity which has been selected for representation, usually, non-spatial. Data model is a conceptual description of a database defining entity types and associated attributes. Each entity type is represented by specific spatial objects. The data model is a view of the database which the system can present to the user. It need not be related directly to the way the data are actually stored in the database e.g., census zones may be defined as being represented by polygons, but the program may actually represent the polygon as a series of line segments.

Layers are spatial objects can be grouped into layers, also called overlays, coverages or themes. One layer may represent a single entity type or a group of conceptually related entity types e.g. a layer may have only stream segments or may have streams, lakes, coastline and swamps. It depends on the system as well as the database model. Some spatial databases combine all entities into one layer.

Objects and entities are the objects in a spatial database are representations of real-world entities with associated attributes. The power of a GIS comes from its ability to look at entities in their geographical context and examine relationships between entities,

thus, a GIS database is much more than a collection of objects and attributes.

Point entities in GIS may represent city, water or oil well, soil sample site , telephone , pole, house , benchmark. The coordinates of each point can be stored as two additional attributes. Information on a set of points can be viewed as an extended attribute table,

In which each row is a point and each column is an attribute, two of the columns are the coordinates. Each point is independent of every other point, represented as a separate row in the database model.
Line objects usually represent network entities such as airline networks with hubs and routes, transportation networks - highways, railroads, utility networks - gas, electric, telephone, water, where as natural networks include river channels, underground drainage systems etc.

Data Base design: The Geographical Information System (GIS) has two distinct utilizations capabilities - the first pertaining to querying and obtaining information and the second pertaining to integrated analytical modeling. However, both these capabilities depend upon the core of the GIS - the database that has been organized. Many a GIS utilization have been limited because of improper database organization. The importance of the GIS database stems from the fact that the data elements of the database are closely interrelated and thus need to be structured for easy integration and retrieval. The GIS database has also to cater to the different needs of applications. In general, a proper database organization needs to ensure the following:
a) a flexibility in the design to adapt to the needs of different users. b) a controlled and standardized approach to data input and updation. c) a system of validation checks to maintain the integrity and consistency of the data elements. d) a level of security for minimizing damage to the data. e) minimizing redundancy in data storage.
While the above is a general consideration for database organization, in a GIS domain the considerations are pertinent with the different types and nature of data that need to be organized and stored.

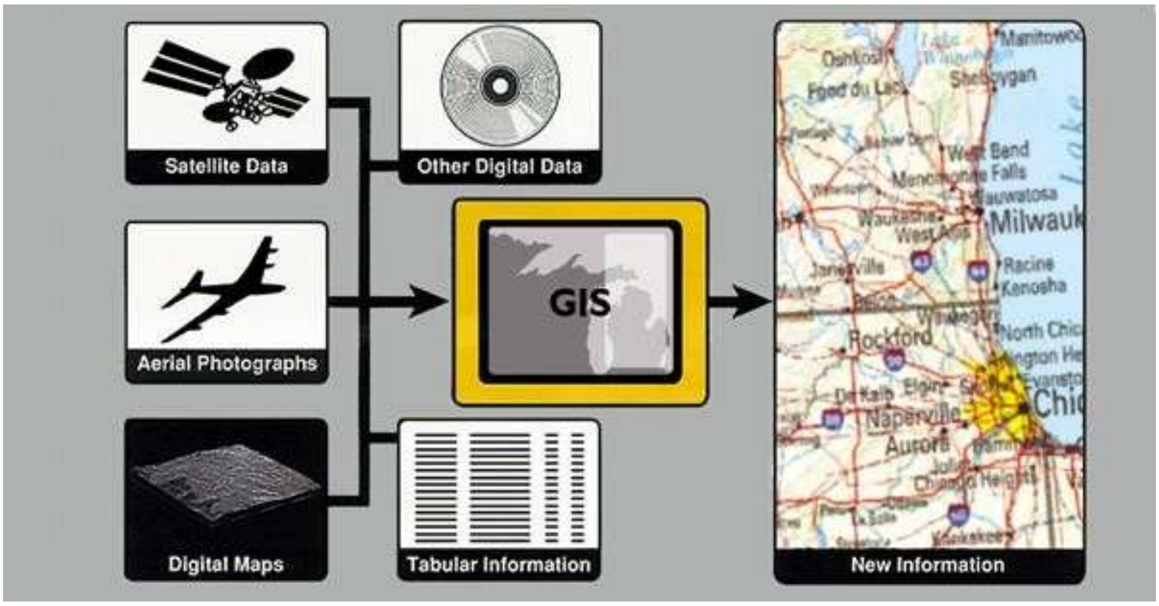

Figure 2: Data digitization Data In GIS:

Non-spatial data - attributes as complementary to the spatial data and describe what is at a point, along a line or in a polygon and as socio-economic characteristics from census and other sources. The attributes of a soil category could be the depth of soil, texture, erosion, drainage etc and for a geological category could be the rock type, its age, major composition etc. The socio-economic characteristics could be the demographic data, occupation data for a village or traffic volume data for roads in a city etc.

Measurement of geographical data: The data in a GIS is generally having a geographical connotation and thus it carries the normal characteristics of geographical data. The measurement of the data pertains to the description of what the data represents - a naming or legending or classification function and the calculation of their quantity - a counting or scaling or measurement function. Thus, scaling of the data is important while organizing a GIS database.

a) Nominal, where the data is principally classified into mutually exclusive sets or levels based on relevant characteristics. The landuse information on a map representing the different categories of landuses is a nominal representation of data. The nominal scale is the commonly used measure for spatial data.

b) Ordinal, which is a more sophisticated measurement as the classes are placed into some form of rank order based on a logical property of magnitude. A Ground water prospect map showing different classes of prospects and categorized from "high prospect" to "low prospect" is an ordinal scale measurement.

c) Interval, which is continuous scale of measurement and is crude representation of numeric data on a scale. Here, the class definition is a rank order where the differences between the ranks are quantified. The representation of population density in rank order is an example of interval data.

d) Ratio, which is also a continuous scale where the original of the scale is real and not imaginary. Further ratio interval represents the scaling between individual observation in the dataset and not just between datasets. An example

of the ratio scale is when each value is normalized against a reference - generally an average or maxima or minima.
The above four scales have been defined as an hierarchy and thus the ratio scale exhibits all the defining operations while those further down the hierarchy possess fewer. Thus, a ratio scale may be re-expressed as an interval, ordinal or nominal data but nominal data cannot be expressed as ratios. Further, the nominal and ordinal scale are used to define categorical data - which is the method of representing maps or spatial data and the interval and ratio data are used to define continuous data.

GIS Database Design: Just as in any normal database activity, the GIS database also needs to be designed so as to cater to the needs of the application that proposes to utilize it. Apart from this the design would also:

a) Provide a comprehensive framework of the database.

b) Allow the database to be viewed in its entirety so that interaction and linkages between elements can be defined and evaluated.

c) Permit identification of potential bottlenecks and problem areas so that design alternatives can be considered.

d) Identify the essential and correct data and filter out irrelevant data

e) Define updation procedures so that newer data can be incorporated in future.

The design of the GIS database will include three major elements

a) Conceptual design, basically laying down the application requirements and specifying the end- utilization of the database. The conceptual design is independent of hardware and software and could be a wish-list of utilization goals.

b) Logical design, which is the specification of the database vis-a-vis a particular GIS package. This design sets out the logical structure of the database elements determined by the GIS package.

c) Physical design, which pertains to the hardware and software characteristics and requires consideration of file structure, memory and disk space, access and speed etc. Each stage is interrelated to the next stage of the design and impacts the organization in a major way. For example, if the concepts are clearly defined, the logical design is easier done and if the logical design is clear the physical design is also easy. The success or failure of a GIS project is determined by the strength of the design and a good deal of time must be allocated to the design activity.

GIS – Core of the database: The Geographical Information system (GIS) package is the core of the GIS database as both spatial and non-spatial databases have to be handled. The GIS package offers efficient utilities for handling both these datasets and also allows for the spatial database organization; non-spatial datasets organization - mainly as attributes of the spatial elements; analysis and transformation for obtaining the required information; obtaining information in specific format (cartographic quality outputs and reports); organization of a user-friendly Query-system. Different types of GIS packages are available and the GIS database organization depends on the GIS package that is to beutilized. Apart from the basic functionality of a GIS package, some of the crucial aspects that impact the GIS database organization are as follows:

a) Data structure of the GIS package : Most GIS packages adopt either a raster or vector structure, or their variants, internally to organize spatial data and represent real world features.

b) Attribute data management: Most of the GIS packages have embedded linkage to a Data Base Management System (DBMS) to manage the attribute data as tables.

c) A tiled concept of spatial data handling: Is fundamental to the way maps are represented in real world. For example, 16 SOI 1:50,000 map sheets make up 1 1: 250,000 sheet and 16 1:250,000 sheet make 1 1:1,000,000 sheet. This map tile graticule could also be represented in a GIS and some GIS package allows tile-data handling.

GIS database-conceptual design: The Conceptual Design (CD) of a GIS database defines the application needs and the end objective of the database. Generally, this is a statement of end needs and is defined fuzzily. However, it crystallizes and evolves as the GIS database progresses but within the framework of the broad statement of intentions. However, the clearer and well defined the CD the easier it is for the logical designing of the GIS database. Some of the key issues that merit consideration for the CD are:

a) Specifying the ultimate use of the GIS database as a single statement. Some examples could be GIS DATABASE FOR URBAN PLANNING AT MICRO-LEVEL; GIS DATABASE FOR WATER SUPPLY MANAGEMENT; GIS DATABASE FOR WILDLIFE HABITAT MANAGEMENT. The important aspect here is the management of a particular resource, facility etc and thus the statement would generally include the management activity.

b) Level or detail of GIS database which indicates the scale or level of the data contents of the database. A database designed for MICRO-LEVEL would require far more details than one designed for MACRO-LEVEL applications.

c) Spatial elements of GIS database, which depends upon the end use and defines the spatial data sets that will populate the database. The spatial element is application specific and is mainly made of maps obtained from different sources.

The spatial elements could be categorized into primary elements, which are the ones that are digitized or entered into the database and derived elements, those that are derived from the primary elements based on a GIS operation. For example, the contours/elevation points could be primary elements but the slope that is derived from the contours/elevation points is a derived element. This distinction of the primary and secondary element is useful in estimating the database creation load and also in scheduling GIS operations.

d) Non-spatial elements of GIS database which are the non-spatial datasets that would populate the GIS database. The actual definition of the non-spatial elements would depend upon the end use and is application specific. For example, non-spatial data for forest applications would include data on tree species, age, production etc and non-spatial data for urban applications would include ward-wise population, services and facilities data and so on. Much of the non-spatial data comes from sources like the Census department, municipalities, resource survey agencies etc.

e) Source of spatial and non-spatial data is an important design issue as it brings about the details of the data collection activity and also helps identify the need for data generation. Most of the spatial data or thematic maps are available from the central and state survey agencies and non-spatial data is available as Census records or from the survey departments.

f) Age of data is an important design issue as it, in turn, defines the age of the database - making it either useful or useless for a particular end application. For example, if the application is to study the impact of pollution in an urban area, then the pollution data needs to be current and the use of past data would render the impact analysis ineffective.

g) Spatial data domain, pertaining to the basic framework of the spatial datasets. Most of the spatial data sets in India follow the Survey of India (SOI) latitude-longitude coordinate system (as is given in the SOI maps) and thus, the spatial data base needs to follow the standards of the SOI map sheets.

GIS database - logical design: The Logical Design of the GIS database pertains to the logical definition of the database and is a more detailed organization activity in a GIS. Most of the design issues are specific to GIS and thus the scope varies with the type and kind of GIS package to be utilized. However, in an overall manner most of these issues are common over the different GIS packages. Some of the key issues are:

a) Coordinate system for database, which determines the way coordinates are to be stored in the GIS packages. Most GIS package offer a range of coordinate systems depending on what projection systems are employed. The coordinate system for the GIS database needs to be in appropriate units that represent the geographic features in their true shape and sizes. The coordinate system would generally get defined by the spatial domain of the GIS database.

b) Defining attribute data dictionary: The data dictionary is an organized collection of attribute data records containing information on the feature attribute codes and names used for the spatial database. The dictionary consists descriptions of the attribute code for each spatial data element.

c) Spatial data normalization is akin to the Normalization of relations and pertains to finding the simplest structure of the spatial data and identifying the dependency between spatial elements. Normalization avoids general information and also reduces redundancy. A process of normalization of the spatial data is also essential to identify master templates and component templates. This normalization process ensures that the coincident component features of the various elements are coordinate coincident - thus limiting overlay sliver problems. This also ensures the redundancy in digitization process as master templates are digitized only once and form a part of all elements) Tolerances definitions are an important aspect of the GIS database design. The tolerances specify the error-level associated with each spatial element.

d) Spatial and non-spatial data linkage where the interlinkages of the spatial and non- spatial data are defined. These linkages and interrelationships are an important element of the GIS database organization as they define the user relations or use reviews that can be created.

GIS database physical design: The Physical Design (PD) pertains to the assessment of the load, disk space requirement, memory requirement, access and speed requirements etc for the GIS. Much of these pertain to the hardware platform on which the GIS will operate. There are no standards on PD aspects available and much of the design has to be based on experience. However, some of the key issues are as follows:

a) Disk space requirement is a major concern for GIS database designers. The paradigm THERE IS NO END TO A GIS DATABASE sums it up all as most GIS databases have realized how fast their disk space estimates have gone awry.

b) Load of database is also difficult to determine as there is no way of estimating the number of points, line, polygons in each spatial element. However, broad guidelines could be evolved and estimates can be made.

c) Access and speed requirements are more oriented towards the ability to handle large and dense maps rather that the time involved in processing. The GIS applications are not real-time applications and thus the access time or speed becomes a secondary aspect.

d) File and data organization in GIS is an activity which is taken care of by the GIS package itself and no design aspects need be considered for the physical organization of files. Each GIS package has its own file system organization which could be either a single file or a set of files and are transparent to the user.

Defining relations between spatial and non-spatial data: The GIS allows for the spatial data and the non-spatial features to be related or linked based upon a defined relationship. The relation in the GIS is a method of relating the same spatial entity to different non-spatial entities based on a linkkey.

Data capturing and refining techniques: GIS data is stored in a very different way than paper map data, the relationships between map scale, data accuracy, resolution, and density are very different between GIS and paper maps.

1	1	1	1	1	1	1	3	3	3
1	1	1	1	1	1	1	3	3	3
1	1	1	1	1	1	3	3	3	3
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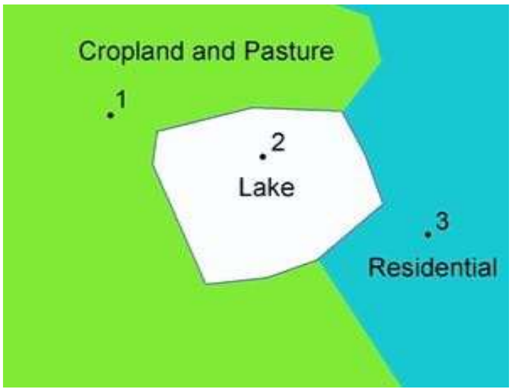


Figure 3 : Example of the structure of raster data file and structure of a vector data file.

Map scale : Map scale specifies the amount of reduction between the real world and its graphic representation (usually a paper map). It is usually expressed as a ratio (eg 1:20,000), or equivalence (e.g.1 mm = 20 m). Since a paper map is always the same size, its scale is fixed when it is printed, and cannot change.
However, a map in a GIS can be shrunk or enlarged at will on the screen or on paper. One can zoom in until the screen displays a square meter or less, or zoom out until the screen displays all of BC. This means that geographic data in a GIS doesn't really have a 'map scale'.

Display scale: The display scale of a map is the scale at which it 'looks right'. Because a paper map is created at certain scale, its 'map scale' and 'display scale' are the same.
The display scale influences two things about a map:
• The amount of detail. The map must not be overwhelmed with detail, and become too crowded.
• The size and placement of text and symbols. These must be sized to be readable at the display scale, and placed so that they do not overlap each other.
If we put a 1:20,000 scale paper map on a reducing photocopier, you can make it into a 1:100,000 map (i.e. reduce it by a factor of 5). However, probably areas of detail will be merged into big black blobs, and most of the text on the map will be too small to read.
A GIS map's annotation (i.e. text and symbols) must be designed with a display scale, just like a paper map. There is a range of scale in which it will 'look right', even though it is possible to display it at other scales with the GIS software.

Data accuracy and uncertainty: Data accuracy is an statement of how closely a bit of data represents the real world. It applies to geographical information in all these ways:
• What features have been omitted?
• What non-existent features are represented?
• How correct is their classification?
• How current is the data?
• How far away is a map feature from its actual location in the world?
This last, or 'locational' accuracy is of interest here, and is generally stated in terms of uncertainty. Locational accuracy includes:
• absolute accuracy: How close is the location on the map or data representation to its real location on the earth? For example, '95% of the well locations are within 50 meters of their surveyed locations'.
• relative accuracy: How similar is a shape on the map or data representation to the shape of the object on the earth. For example, 'cutblock boundaries do not vary by more than 10 meters from their actual shape'.
These are separated because a map object may have a very accurate shape, but not be registered (located) correctly.
A rigorous statement of accuracy will include statistical measures of uncertainty and variation, as well as how and when the information was collected. Spatial data accuracy is independent of map scale and display scale, and should be stated in ground measurement units.

Data precision: Data precision is the smallest difference between adjacent positions That can be recorded and stored. Most GIS store locations in ground units (e.g. UTM coordinates, or Longitude/Latitude) with a precision of a meter, centimeter or less. This precision is far greater than the resolution of any of MSRM's data, except for some cadastral data. See MSRM GIS Storage Precision for a detailed discussion.

Data resolution: Resolution is the degree to which closely related entities can be discriminated. Since a paper map is always the same size, its data resolution is tied to its scale. Resolution also limits the minimum size of feature that can

be stored.
Generally, a line cannot be drawn much narrower than about 1/2 a millimeter. Therefore, on a 1:20,000 scale paper map, the minimum distance which can be represented (resolution) is about 10 meters. On a 1:250,000 scale paper map, the resolution is 125 meters.
Usually, it is desirable to specify the resolution of a dataset as a minimum feature size. For example, 'no lakes of less than 5 hectares surface area should be captured'. In a GIS, this is the most important reason for having the same data represented at different 'scales'.

Raster data resolution: Raster data is stored as (usually square) pixels, which form a grid or mesh over an area of the earth. The size of these pixels determines the resolution of the raster, because it is impossible to store anything which falls 'between' the pixels. A GIS allows raster pixels to be any size, although they should not be smaller than the uncertainty of the data.
If a raster coverage is derived from vector linework, its pixels should not be smaller than the uncertainty in the linework. If it comes from an air-photo or satellite image, its pixels should not be smaller than the resolution of the camera that recorded it.

Data density: Data density is a measure of how many features per area are stored, and may imply a minimum feature size. Greater density implies more features in a given area, and therefore the features may be smaller.
The density of paper map's data is limited by its scale (and therefore its resolution). Areas (polygons) cannot be shown if they are smaller than the lines which draw them. For example, a polygon less than 250 meters wide cannot be drawn on a 1:250,000 scale map.
This minimum size also limits the number of polygons that can be represented in a given area of a paper map.
A GIS stores its data digitally, so the minimum size of a feature is limited only by the precision, which is effectively infinitesimal. Where the degree of detail in a coverage is arbitrary (e.g. soil polygons), a data definition or convention should specify the minimum size of features, and therefore their density, or resolution. Without this, different parts of the same coverage may have widely varying degrees of detail, influencing analysis results.

Figure 4: Examples of finished maps that can be generated using a GIS, showing landforms and geology (left) and human-built and physical features (right).

Data detail: Data detail is a measure of how much information is stored for each feature. A GIS stores lines (e.g. a lake shoreline) as a sequence of point locations, and draws it with the edges that join them. There is no limit to how many points can be stored, or how close together they may be.
The amount of detail on line features should be limited just like data density. It does not make sense to store points at intervals which are shorter than the accuracy of their locations.

GIS analysis: In a GIS, analysis is done at the precision of the data, not at any display scale. For example, the area of a habitat polygon is calculated to the nearest square centimeter. The GIS will carry much more precision through its calculations than are justified by the data's accuracy. The results of these calculations should be rounded to a value appropriate to the uncertainty of the data for reporting.
Some operations may result in features which are smaller than the data uncertainty. For example, overlaying rivers and forest polygons may create 'slivers' along the riverbanks which are 10 meters wide, when the uncertainty of the data is 20 meters. These slivers should be ignored, or included with their neighbors before the results of the overlay are used for further analysis.

Separation of data and annotation: In a GIS, it is common to display the same data (e.g. wildlife management unit boundaries) at several different scales for different purposes. It is also possible to create symbols and text that 'look right' at several different scales, and store them apart from the data they label.
For example, management unit boundaries could be stored in one provincial coverage, and annotation layers could be

developed for labeling them at display scales of 1:20,000, 1:250,000, and 1:2,000,000.
If done carefully, this avoids duplication of the same data for display at different scales. **Generalization:** In a GIS, it is possible to create a new coverage by reducing the amount of detail in existing coverage. This 'generalizing' may or may not reduce the number of objects in the coverage.
For example, a detailed forest cover map may be generalized by combining polygons with similar characteristics. This reduces the number of objects in the coverage.
Conversely, a detailed ecosystem classification map may be generalized by reducing the amount of detail in the boundaries between regions, without reducing the number of regions.

Generalizing a raster image usually reduces both the number of objects, and the amount of detail.
Map series: It is convenient to identify a series of paper maps by their scale (the 1:50,000 water atlas), or the amount of earth they cover (e.g. NTS 2-degree letter blocks). Neither of these are well-suited to GIS data. GIS data can be displayed at any scale, and can be manipulated as a seamless coverage for either analysis or display.
A GIS coverage should be identified by its accuracy (or uncertainty) and data resolution or density (or minimum feature size).

GIS Software packages available:
There is an array of GIS vendors selling a series of softwares. To mention a few with good selling record are mentioned below:
- ESRI
- Intergraph
- Autodesk
- Bentley
- Mapinfo

Each software has its own pros and cons along with different hardware and software requirements. GIS packages are available mainly in three forms, Desktop/personal and web-enabled.

Managing damages on account of earthquakes - Some case studies: Earthquake is one of the unavoidable and most devastating natural disaster. It is impossible managing an earthquake, but an attempt can be made to manage the losses on account of earthquakes. This includes prevention, damage assessment and post-incidence relief disbursement. For using GIS for managing the losses on account of earthquake, or any natural disaster for that matter, it is necessary to have some few thing ready in advance. This, in fact acts as a prerequisite for GIS application in the above-mentioned area.

Organized GIS database
- Critical infrastructure data
- Up-to-date image data bank
- Metadata
- Data interoperability
- Predefined emergency response database model
- Data sharing with media

Prevention by prediction: Three countries, China, Japan and Indonesia are in the process of developing a GIS based system, that can help in predicting the earthquakes. Chinese scientists, working on this project, believe, by closely monitoring electromagnetic disturbances in the ground and in the ionosphere the layer of the atmosphere at an altitude of more than 80 kilometers, which many scientists expect, may herald earthquakes, the experimental satellite is expected to detect precursor signals and make more reliable forecasts.
The main objective of earthquake preventive measures should be to develop and promote knowledge, practices and policies that reduce fatalities, injuries and other economic losses from earthquake. Providing Geoscientific information to the masses can well minimize these losses. Formulation of preventive measures includes:
- Compiling digital surfacial geological maps to find out area more prone to crustal movement.
- Preparation of ground shaking amplification maps to demarcate area susceptible to high amount of destruction.
- Preparation of liquefaction and lateral spreading susceptibility maps
- Preparation of landslide susceptibility maps mainly in high relief region to delineate area highly susceptible to landslide
- Compilation of GIS databases of existing data on active earthquake source zones and make these databases easily accessible to user groups
- Modification of palaeoseismological maps
- Geoscientific modeling of the shallow crust using seismic, geodetic and geological data for earthquake hazard evaluation.

Identification & Planning: Using Shadowing mechanism
1. Identifying the physical damages caused to buildings: using shadow imaging techniques.

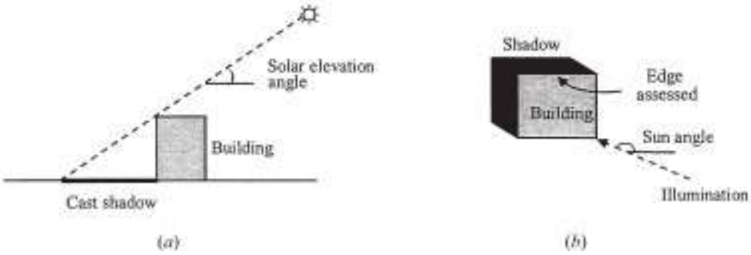
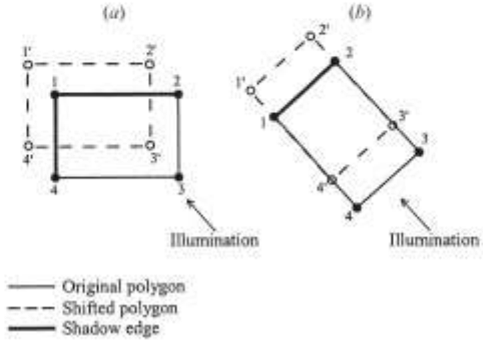


Illustration of a cast shadow, where an uncollapsed building blocks direct solar illumination from reaching the ground. (b) Sun orientation, shadow area and the shadow casting edges.



Shadow casting edges:

Illustration identifying the shadow casting edges: (a) shadow-casting edges are incident to node 1 which falls within the shifted polygon; and (b) shadow-casting edge connects nodes 1 and 2. Ref (M. TURKER* and B. T. SAN Middle East Technical University, Graduate School of Natural and Applied Sciences, Geodetic and Geographic Information Technologies, 06531 Ankara) **Assessment of losses** - Bhuj (2001) :

The benefits of using this technology in damage assessment include the development of:

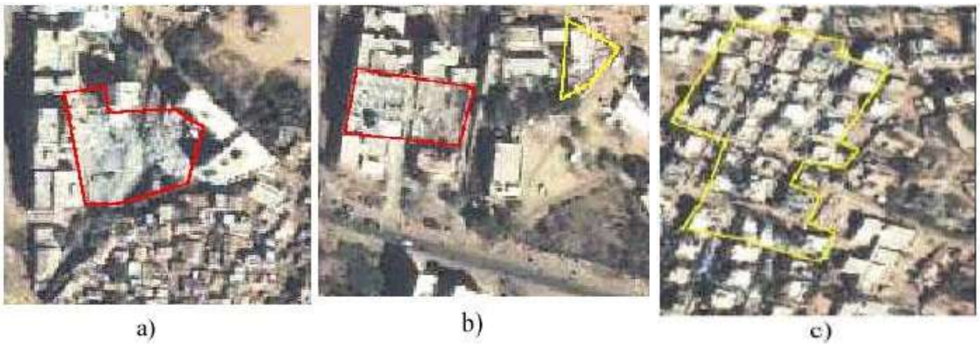
- Innovative procedures for assessing the seismic hazard potential of large urban regions
- Alternative approaches for developing regional damage or vulnerability models for buildings and lifelines
- Cost-effective procedures for creating building and lifeline inventories
- Rapid loss estimation and model calibration methodologies for post-earthquake damage assessment.

On Jan 26th 2001, at approximately 8:46 a.m. local time, a 7.9 (on Richter scale) earthquake occurred in western India, where around 20 million people live and work. While the earthquake was felt as far as Nepal and in Pakistan, its most heavy destruction was in the state of Gujarat. The death toll stands at over 20,000 and about 167,000 people have been injured. It is estimated that nearly one million homes were damaged or destroyed. Some cities were completely destroyed, like Anjar or Bachau. The city of Bhuj, located at around 20 km from the epicenter, suffered important losses.There are two possibilities to detect damages using photo interpretation analysis: a mono temporal technique based on a post event image, and a multi temporal approach, where a before event scene is compared with an after-event scene. The mono temporal procedure consists in the visual recognition of the damaged elements, and it is directly related with the image resolution. With a medium resolution (around 10 meters) only larges zones completely destroyed can be observed. The 1-meter resolution allows the detection of damaged buildings one by one, the building size being considerably greater than the pixel size. In this study it was applied a classical mono temporal photo interpretation method, the damage being detectable by a visual analysis. In the south part of the town, the recognition of destruction was facilitated by the regular distribution of buildings (Figures 1 and 2).

FIGURE 1. A total collapse of a building, in the red circle, is detected by a mono temporal photo interpretation

FIGURE 2. Collapse of a few buildings, in the modern side of the city

Damage states are generally not recognizable by remote sensing, only buildings completely destroyed being detectable. However, a distinction was made between two levels of destructions: extensive damage and complete damage (Fig. 3 a, b and c). The extensive damage is considered when a building or an entire zone is damaged, but the building(s) is not totally collapsed (partial failure of the structure). The complete damage corresponds to a totally collapsed building (total failure of the structure).



Recent developments: Traditional Internet GIS applications and Web-based mapping tools always suffer from the slow response and the lack of high resolution images because of the limitation of image data sizes and the client/server communications. The two new technologies (AJAX and image tiling) can improve the performance and repose times of Internet GIS application significantly.

Another fast-growing domain is the wireless location-based services (LBS) on mobile devices, such as PDAs, PocketPCs, or mobile phones. Many GIS vendors and Internet GIServices providers started to focus on this market in 2005 and created many interesting applications, such as "Google Mobile Local Search".

With the progress of wireless technology, including Wi-Fi, WiMAX, and 4G cellular phone systems, people can access on-line maps and Internet GIS from anywhere via portable devices. 2005 is a boost point for the new types of mobile GIS applications.

Conclusion: GIS has been helping in managing damages on account of earthquakes. The recent developments show that it can take this further to really be of help to predict, loss assessment and relief distribution. Natural disasters like earthquakes, floods, tsunamis and land slides have been a real problem to mankind. But, with GIS, the damages can be better managed and prevented, with suitable technology and of course sufficient preparation to support.

EBSCO refereed journals:

1. Detection of collapsed buildings caused by the 1999 Izmit, Turkey earthquake through digital analysis of post-event aerial photographs. By Turker, M.,San, B. T.,International Journal of Remote Sensing; 11/10/2004, Vol. 25 Issue 21, p4701-4714, 14p
2. Neotectonic study of Ganga and Yamuna tear faults, NW Himalaya, using remote sensing and GIS. By Sahoo, Pradeep K. Kumar, Sandeep Singh, Ramesh P.,International Journal of Remote Sensing; 02/15/2000, Vol. 21 Issue 3, p499-518, 20p, 1 chart, 4 diagrams, 12 maps
3. Automated Systems for Disaster Response: Three Case Studies. By: Suchyta, Gene; Marquardt, Otto; Crooks, Vinny. Geospatial Solutions, Apr2006, Vol. 16 Issue 4, p26-29, 4p; (AN 20544721)
4. Lessons in GIS & Emergency Management. By: Gauthier, Susan. Geospatial Solutions, Feb2004, Vol. 14 Issue 2, p38-41, 4p; (AN 12215532)

Other references:

1. Cell phone can warn of earthquake – 18^{th} Oct 05 by Dr Arun Bapat – Research seismologist SEISMICITY, Some lessons from 1900 by ARUN BAPAT
2. Volume 18 - Issue 19, Sep. 15 - 28, 2001, India's National Magazine from the publishers of THE HINDU
3. Application of GPS in crustal deformation studies: Some case studies C.D. Reddy, Indian Institute of Geomagnetism, Colaba "GIS Basics". London: Taylor & Francis, Wise, S. 2002.
4. Worboys, Michael, and Matt Duckham. 2004. GIS: a computing perspective. Boca Raton: CRC Press
5. Wheatley, David and Gillings, Mark, 2002. Spatial Technology and Archaeology. The Archaeological Application of GIS. London, New York, Taylor & Francis.
6. Earthquake loss estimation using high resolution satellite imagery by L. Chiroiu, G. André, F. Bahoken Paris University
7. hamoli earthquake and its impact assessment using high resolution IRS 1C/ 1D data
8. M. M. Kimothi, J. K. Garg, V. Joshi and A. K. Naithani, Space Applications Centre, ISRO, Ahmedabad
9. Recent developments in Internet GIS by Ming-Hsiang Tsou , Department of Geography, San Diego State University