

Suitable Site Selection for Seismic Microzonation By Applying GIS Technology

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Abstract

The ability to undertake seismic microzonation can be improved through current advances in GIS technology. Undertaking seismic microzonation for large areas is very expensive, hence it is imperative to identify the areas, which are most susceptible to natural hazards.

This paper highlights the use of ESRI technology to create an application, which can help Seismologists identify the most suitable areas for seismic microzonation from various related parameters, which include geological/geotechnical parameters-base rock motion, soil amplification, liquefaction, slope failure, building vulnerability and Social Parameters-Socioeconomic characters. The tool was created using Avenue programming with ArcView software at the background

The application does an overlay operation and creates separate social and natural hazard maps, along with creating an integrated map of the input parameters and finally divides the area into multiple Seismic zones. Users have the option to increase or decrease the weightage for any of the input parameters.

Introduction

The frequent occurrence of earthquakes in the recent past, causing extensive human and property losses has made it important for bureaucrats to create a risk based seismic zonation. Such seismic microzonation basically involves mapping of geology-related seismic hazards, such as earthquake sources, deep underground structures and site-specific conditions such as seismicity, seismo-tectonics, deep geological features, amplification of seismic motion through subsurface geology, underlying soil strata and their physical properties, groundwater table, and topography or geomorphology of the land surface. Seismic microzonation maps are prepared to identify the significant possibility of severe vibration and ground disturbances during a seismic event such as landslides and liquefaction of soil amongst others. If the earthquake sources are in

the sea, tsunamis should be additionally considered. However, to create a useful and effective seismic zonation, the above stated hazard parameters need to be analyzed in relation to the corresponding socioeconomic conditions.

GIS can be an effective tool in devising disaster management strategies by planning evacuation routes, design centers for emergency operations, and integrating satellite data with other relevant available information. The strength of GIS lies in its ability to truly represent the real world situations with layers of maps that can be combined in a predetermined manner to identify the impact of natural hazards.

The paper discusses an application that can create microzonation maps using the above parameters. The application does an overlay operation and creates separate social and natural hazard maps, along with creating an integrated map of the input parameters. Users have the option to increase or decrease the weightage for any of the input parameters and visualize the affect of that in the overall microzonation map.

History

The seismic microzonation started during 1970's in two major earthquake prone areas - Japan and United States. The first International seismic microzonation conference was held in 1972 at Seattle, USA. Since then a lot of research is being done in this field. During the initial stages, outputs of the seismic microzonation were mainly related to seismic intensity, building damage and deaths caused by the target/scenario earthquakes.

Later people started developing earthquake scenarios for possible earthquakes for each area and started undertaking comprehensive studies for active fault activities for the probability of earthquake generation. They also investigated the seismic hazards & vulnerability of earthquake prone areas.

Natural hazards turn into disasters when they affect the social factors. The degree of damage is dependent on the population density and infrastructure available. To understand the impact of different disasters, it is imperative to understand the interactions and inter-relationships among these diverse and complex entities subjected to a given magnitude of the hazardous event.

Microzonation Feasibility

Earthquake disasters are the outcome of many complex geological and geophysical characteristics and the related social circumstances that are subject to hazard. All these events are location dependent in the sense that a hazard is provoked by the geological, topographical and landuse/landcover at the location of the hazard. To evaluate the feasibility of microzonation the following parameters need to be considered- vibration, liquefaction, landslides, as well as several socio economic parameters like, building vulnerability, demographic condition and economic condition such as industrial development of the area.

Methodology

To evaluate the most suitable areas for the seismic microzonation, the following natural and social hazard factors were considered:

A) Natural Hazard Factors: The four key natural hazard factors include

1. Base Rock Motion
2. Soil Amplification
3. Liquefaction Potential
4. Slope Failure Potential

B) Social Hazard Factors: The three key social hazard factors include

1. Building Vulnerability
2. Demographic Condition
3. Economical Condition

1. **Base Rock Motion** – For calculating the base rock motion all the faults that have the probability to cause an earthquake were taken into consideration to choose the high seismic hazard regions within the area. The magnitude of each fault was estimated from the fault length using empirical formula given by Wells & Coppersmith (1994). These factors were given grades ranging from one to five depending on the PGA at base rock.

$$M = 5.08 + 1.16 \cdot \log L \text{ (for all slip type)}$$

M= moment magnitude

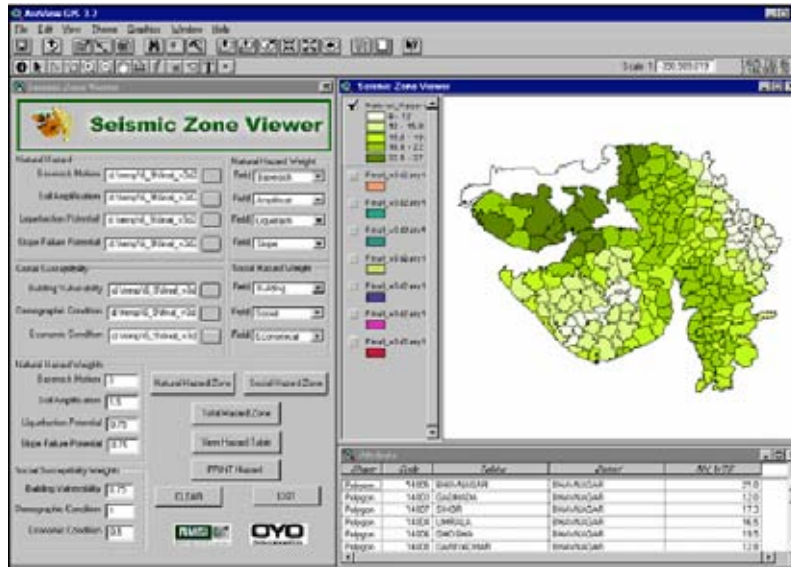
L = fault length (km).

2. **Surface Amplification** – The relation between the geology/geomorphology and the surface amplification were analyzed based on the comparison of the baserock motion and the surface motion at the site. A relation between geomorphology and soil amplification was created and were grouped into five grades.
3. **Liquefaction Potential** – This was calculated from the geomorphological unit, as liquefaction has higher correlation with the geomorphologic unit. The geomorphological maps along with ground water table map were used to calculate the liquefaction potential of the area. For example, the liquefaction potential/susceptibility of natural levee and abandoned river channel is high because of relatively low ground water condition.
4. **Slope Failure Potential** – Slope failure potential was calculated based on parameters like slope height, slope angle, soil type, rainfall, etc. Different slope parameters were derived from DEM (Digital Elevation Model) as well as from available spot heights.
5. **Building Vulnerability** – Building vulnerability was estimated from the structure of the buildings. A relationship established between MSK (Medvedev-Sponheuer-Karnik) scale and damage vulnerability of building derived by Prof. Arya (Recent developments toward earthquake risk reduction in India, Nov.2000) were used to classify the building material into 7 classes - earthen walls (mud, unburnt brick/blocks), stone walls, burned brick walls, concrete walls, wood and ekra wall, GI and other metal sheet, bamboo thatch leaves, etc. Further percentage occupancy of each of these wall materials was used to calculate the Building vulnerability of the area.
6. **Demographic Condition** – Whenever an earthquake occurs, there is a possibility that the high population/buildings density area will suffer more heavy damage especially if peoples are not aware of earthquakes. Population was classified into five grades depending upon the population density of the area, which were used to calibrate the demographic condition.
7. **Economical Condition** – When an earthquake occurs, it may cause significant economical problem, such as physical and monetary loss, functional loss of an urban facilities and stagnation in the economy and so on. Hence we have used several parameters like agricultural and commercial production, industrial development and production to calculate the economical condition of the area. These parameters were further grouped into five grades depending upon the importance of these individual layers.

Microzonation Viewer

GIS is used to manage large volumes of data needed for the hazard and risk assessment. As it is well known that the strength of GIS lies in the ability to represent the real world situation closely with layers of maps that can be combined in a predetermined manner to identify the impacts of a natural hazard through the introduction of hazard dimension. It has become necessary to create a viewer to get an idea of impact of each of the above mentioned hazard parameter on the geographic area.

RMSI developed an application named – “Seismic Zone Viewer” to create seismic hazard zone maps of an area. The application allows a user to modify the weightages as well as gives a facility to select or deselect any of the input layers to modify the hazard model for microzonation. The objective of this application was to create a user-friendly application to generate seismic hazard zone of any area. The output of the viewer is a map representing seismic hazard zone of the area based on the earthquake hazards and vulnerability factors of that area.



Software Used

ArcView 3.2, Avenue was used as a programming language for the application.

Input Data

The application does an overlay analysis and calculations for each input layers along with their respective weights. For getting the hazard zone at any administrative level, we need to have these datasets at that administrative level.

- a) Rank of Base Rock Motion,
- b) Rank of Soil Amplification
- c) Rank of Liquefaction Potential
- d) Rank of Slope Failure Potential
- e) Rank of Building Vulnerability
- f) Rank of Demographic Condition
- g) Rank of Economical Condition

All the input data should have similar boundary conditions. Each of the above mentioned input should contain the rank for each of these layers at the administrative boundary.

Viewing Facility

The advantage with this tool is visualization of each hazard layer as an individual, as well as in the combination of input layers. In this application a user can modify weightage of any map layer and can visualize the impact of that in an overall scenario. User has a facility to create the seismic zonation map using different combinations (only natural or only social parameters or a combinations of both). User can modify any one of these layers or add new map layers as per their requirement.

Analytical Facility

The application (Seismic Microzonation Viewer) can also perform spatial analysis on selected input layers. Weightages need to be defined for each of the input parameters depending on their importance in the overall calculation of the hazard. Based on a study undertaken by RMSI, it has been inferred that in normal Indian condition the weightages for each of these layers is as follows:

Factor	Item	Weight
Natural Hazard	1 Baserock Motion	3
	2 Soil Amplification	1.5
	3 Liquefaction Potential	0.75
	4 Slope Failure Potential	0.75
Social Factor	5 Building Vulnerability	0.75
	6 Demographic Condition	1
	7 Economical Condition	0.5

Advantages of the Application

1. This is a flexible tool that can be used for multiple applications other than microzonation by simply changing the parameters.
2. The tool is user friendly, and even a non-GIS user can run this tool (Arcview analysis are done on the back end).
3. The end user, normally a non-technical person can change the scenarios and analyze the impact at his ease by changing weightages.
4. The tool is effective for group discussions even among the people from different discipline such as engineer, scientist, socialist and government officers.

Limitations of the Application

1. This tool does not permit any intra thematic weightage adjustments
2. This tool requires Arcview on the background. However, this can be modified by using ArcObjects or MapObjects and VB as a programming language

Conclusion

The automations possible through using GIS can be directly used in microzonation, as the basic information fusion process involves comparison, indices and overlaying of different input layers in microzonation. Here users can do the vulnerability analysis (for the socio economic conditions) for even those areas where the regional hazard potential is equally distributed.

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