Earthquake Disaster Information Management System (E-DIMS)

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Abstract

E-DIMS facilitates evaluation of Regional seismicity, development of a procedure allowing City personnel to evaluate earthquake severity and potential impact on the facilities, and suggested associated levels of post-earthquake monitoring response for different magnitude earthquakes occurring within certain distances from the facilities. E-DIMS is a GIS-based (Geographical Information System) earthquake risk analysis application for the use of decision-makers, planners, and engineers alike. No prior knowledge in the fields of Earthquake Engineering and Risk Management is assumed, although it would help much. The Analysis are grouped into three main modules: (1) Hazard, (2) Risk, and (3) Exposure Analysis. The Hazard module looks at where the sources of seismic hazard (faults) are, where earthquakes have occurred in the past, how severe would the ground shake for different earthquake scenarios with reference to Indian sub-continent. The Risk module addresses questions like what would happen if a magnitude 7 earthquake were to occur on the “x” Fault, how much would be the exposure in terms of man-made and natural resources for any geographical region/area. The Exposure module looks at the geographic and temporal distribution/variation of population and estimated building property value. Population and building stock at microzone level are used as sample portfolios for analysis. This has an extension facility to plan and monitor services for relief and rehabilitation. In the Planning for Relief and Rehabilitation sub-module, the quake-hit areas are compared with available general services such as hospitals, police stations, fire stations, and trucks to arrive at decisions to facilitate their services, to find the shortest path and to monitor the services at use.

Key words: Natural Disaster Management, Earthquakes, Seismic hazard maps, Vulnerability assessment; Risk Analysis; ArcGIS customization.

1. Introduction

In order to maintain regional sustainability and develop environmentally preventive measures, the fundamental focus of the effort is to facilitate people-centered, community driven development processes. The developmental and planning efforts have become more significant especially when dealing with the natural calamities like landslides, earthquakes, floods and tsunamis. Mapping and monitoring the dynamic urban land-use changes including urban expansion in Indian cities have become increasingly complex due to its dense pre-colonial urban core and haphazard sprawling into rural fringes. Several attempts have been made to estimate land-use changes, urban sprawling as well as urban simulation models to predict growth patterns using the latest Geospatial technology driven tools both in developed and developing world (Pathan et al 1991, Raghvswamy et al, 1991) Some of the recent attempts deal with identification of potential risk zones to natural hazards in city environment at micro level to macro-level mapping and zoning of disaster prone zones (Jothimani, 1997, GSI 2000, Bhandari 2002) as well as mapping of environmental
Earthquake Disaster Information Management System (E-DIMS)  

Table 1. Benefits from Disaster Management Systems.

<table>
<thead>
<tr>
<th>Description</th>
<th>Output</th>
<th>Scale</th>
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<tbody>
<tr>
<td>Maps of seismic hazards</td>
<td>Information on seismic features, seismic zones etc., Intensities of</td>
<td>1:250,000</td>
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<tr>
<td></td>
<td>ground shaking for each census tract</td>
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<td></td>
<td>Contour maps of intensities of ground shaking</td>
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<tr>
<td>Land sliding probability*</td>
<td>Characterization of damage to general building stock</td>
<td>1:8000</td>
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<td>Structural and nonstructural damage probabilities by census tract,</td>
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<td></td>
<td>building type and occupancy class.</td>
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<td>Transportation and utility lifelines</td>
<td>Damage probabilities for occurrence of earthquake For all pipeline</td>
<td>1:4000</td>
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<td>systems: the estimated Number of leaks and breaks For potable water</td>
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<td></td>
<td>and electric power Systems: estimate of service outages</td>
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<tr>
<td>Essential facilities</td>
<td>Damage probabilities; Probability of functionality Loss of beds in</td>
<td>1:4000</td>
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<tr>
<td></td>
<td>hospitals</td>
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<tr>
<td>High potential loss</td>
<td>Locations of dams</td>
<td>State level</td>
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<td></td>
<td>Locations of other identified sites</td>
<td>1:50,000</td>
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<tr>
<td>Fire following earthquake</td>
<td>Number of ignitions by census tract Percentage of burned area by</td>
<td>1:12500,</td>
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<tr>
<td></td>
<td>census Tract</td>
<td>1:2500</td>
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<tr>
<td>Inundated areas</td>
<td>Exposed population and exposed Value of general building stock</td>
<td>1:300000</td>
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<tr>
<td>Debris</td>
<td>Total debris generated by weight and type of materials</td>
<td>1:2500</td>
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<tr>
<td>Social losses</td>
<td>Number of displaced households Number of people</td>
<td>1:2500</td>
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<td></td>
<td>requiring temporary shelter Casualties in four categories of Severity</td>
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<td></td>
<td>based on three different times of day</td>
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<tr>
<td>Losses associated with Buildings</td>
<td>Structural and nonstructural cost of repair or replacement</td>
<td>1:2500</td>
</tr>
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<td></td>
<td>Loss of contents, Business inventory loss Relocation costs, Business</td>
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<td></td>
<td>income loss Employee wage loss, Loss of rental income</td>
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fragile zones within urban regions in India as well with specific case studies (Jothimani 2002/2003, Kaur et al 2004). Assessment of risk and vulnerability in urban areas or city regions to natural hazards have been perceived with contrasting perspectives and even regarded as ill-structured problem (Tarek and Weeks, 2003) Nationwide Disaster information management has also gained attention recently (Rego, 2001). In India realizing the compulsory circumstances Disaster Management Bill and Act was passed in Parliament in 2005. Recent Disaster Management Congress debated on various issues in disaster mitigation and management including major emphasize on the public private participation and its role (Swati Mitra, 2006.) Although we have made long strides in improving the performance of structures exposed to natural hazards on a micro level, our risk has actually risen due to three main factors: (1) our exposure has increased as we build closer and closer to hazards (closer to faults in earthquake prone areas), (2) our infrastructure has grown increasingly complex and interdependent making them more vulnerable at a macro level, and (3) lessons learnt from disasters seem to take much longer to implement in the design and construction practices than before.

2. Natural Disasters and Earthquakes

The effective utilization of such realistic emergency management emphasize the need for integrated approach, reliable updated data sets, validity and its robustness at micro-level information. Maintaining sustainable regional environment provides effective mechanisms in a disaster management scenario. Efficient city/regional planning and related establishment and operational workflow within life-line utilities is the backbone for restoring normal living environment in disaster prone areas. Infact rescuing, rehabilitating and resettlement issues concerned with sustainable local environment needs very effective administrative and techno- scientific coordination at all levels (Refer.Table. 1 Benefits from Disaster Management Systems)

Despite all the technological, we still have a hard time understanding the risks posed by what we often like to call "natural" disasters. While natural hazards may not have changed much in frequency and severity over time, the risks have actually increased sharply. It is always not nature that we are bracing against, it is rather the human's misguided intervention with nature disregards the repercussions. We continue to build weak structures right on the frontlines of extreme hazards. Although we have made long strides in improving the performance of structures exposed to natural hazards on a micro level, our risk has actually risen due to three main factors: (1) our exposure has increased as we build closer and closer to hazards (closer to faults in earthquake prone areas), (2) our infrastructure has grown increasingly complex and interdependent making them more vulnerable at a macro level, and (3) lessons learnt from disasters seem to take much longer to implement in the design and construction practices than before. Earthquakes, unlike hurricanes, tornadoes and flood, are unique in two
respects. They are less frequent (for comparable severity) and less predictable, which makes it very difficult for the public, and therefore policy makers, to constantly bear that risk in mind. Predicting earthquakes is still in its infancy. Seismologists can only tell us something like there is a 90% chance. Given our prediction inaccuracies and hazards’ unpredictability, we have to augment that effort by building better structures and infrastructures that can withstand the elements of nature.

What is Earthquake Disaster Information Management System (e-DIMS)

E-DIMS is a GIS-based (Geographical Information System) earthquake risk analysis application for the use of decision-makers, planners, and engineers alike. E-DIMS facilitates evaluation of Regional seismicity, development of a procedure allowing City personnel to evaluate earthquake severity and potential impact on the facilities, and suggested associated levels of post-earthquake monitoring response for different magnitude earthquakes occurring within certain distances from the facilities. An estimate of losses from future earthquakes is essential to preparing for a disaster and facilitating good decision making at the local, regional, state, and national levels of government. A map-based analysis of the potential intensity of ground shaking from a postulated earthquake that identifies those parts of the community that will experience the most violent shaking and the buildings at greatest risk of damage. Such a map would be a useful tool in land use planning and facility siting decisions. An estimate of building damage that provides the basis for establishing programs to mitigate or strengthen buildings that may collapse in earthquakes. Estimates of damage and life loss will help in setting priorities for retrofit or abatement programs. An estimate of damage to buildings and utilities and of casualties, which provides the basis for emergency response and contingency planning at the local, regional, and state level. An estimate of casualties and homelessness, providing a basis for medical and relief agency preparedness and response.

3. Objectives

The main objective of the e-DIMS is to develop a GIS based analysis tool for seismic data visualization and data mining so as to support strategic planning and mitigation of earthquake disasters, to facilitate post earthquake disaster relief planning and rehabilitation. E-DIMS is designed for a wide range of audiences, people, companies, institutions and governments at all levels who have a direct or indirect stake (at earthquake risk). That includes, property and real estate owners/managers/agents the insurance industry, mortgage lenders, investors, city planners, emergency managers, relief organizations.

4. Methodology and User-Friendly Customization

- Data collection / data validation / data updating
- Establish standards for accuracy of maps and data
- Modular design in application development catering to wide range of user groups
- To facilitate analysis at various geographic extents from broad seismicity analysis to micro zone loss analysis
- Develop easy-to-use interface to run sophisticated Analysis with minimum inputs
- Security & locking for user levels to handle and analyze client-sensitive data
- To derive Micro zone loss analysis in terms of direct losses to population, direct losses to building property
- Ground Motion Analysis as per past earthquake scenario with seismic parameters
- Access to modules through a customized user interface
- Building code regulation for new and existing buildings

5. Design and Development of Modules

5.1 Seismic Hazard Identification Module

Hazard Analysis is an essential part of risk assessment. Earthquake hazard identification refers to: (1) how frequent and severe have earthquakes happened in the past, (2) where are the active zones in respect to population centers, (3) what is the relative seismicity.

5.2 Seismicity Maps

Seismicity Maps are part of the Hazard Analysis Module. E-DIMS uses India earthquake catalogs that were downloaded from the Indian Meteorological Department Website. The catalogs include earthquakes that occurred since 1800. The map annotations show the date (GMT), time (GMT), longitude/latitude, magnitude (scale), reference catalog and any other attached notes.

5.3 Potential Risk Zones Module

Fault Maps are part of the Potential Risk Zones Module (shown for the region of Gujarat). The fault data originally includes the fault zones, fault classification, lengths, rupture mechanism, slip rates, rank, magnitude recurrence model, maximum and minimum magnitudes, moment rates, characteristic rates & return intervals for maximum magnitudes, down dip width, depths of top and bottom fault plane edges, rake, dip angle, azimuth, number of points, polyline longitude/latitude coordinates and notes for the faults). The map annotations list only a small subset of those parameters. The fault polylines shown on the fault maps are the top edges of the faults’ 3D planes. Faults are superimposed
on Kerala's administrative map for orientation.

- The Management System which would use the above maps and databases shall be used by the state / district / local administration not only for the risk analysis and vulnerability assessment, but also for organizing response operations.

- The system would have a great functional value for the resource and development planning of the district.

- Designed as an accessible information base to be used by all the government agencies, with proper networking and updating facilities within.

- Should be a valuable asset to provide information on hazards, monitoring facilities, regulatory regimes, countermeasures.

This would also aide in the mitigation strategy and plan with focus on the long-term planning for disaster reduction. It shall also deal with the issues of continued hazard identification and risk assessment. With additional data on disaster legislation, mitigation regulation this module could be effectively used for land use management, building codes, traffic standards, health standards, etc.

5.4 Vulnerability Analysis

The Risk Analysis and Vulnerability Assessment depict the present picture for disaster- exposure, loss of life, property damage, etc. Exposure Analysis is broken down into two main analysis modules; namely, the Population and Property Analysis Modules. Both allow you to look at the geographic distribution of population and estimated building property value, aggregated at various geographic resolutions (village, city, and zonal territories).

5.5 Population Analysis

Population Analysis is part of the Exposure Analysis. It is a preface to the Injury and Casualty Loss Analysis that could be added to the E-DIMS. Currently the Loss Analysis Module models earthquake losses to the building stock. This analysis module looks at a region's population (along with other demographics like the number of households and housing units) aggregated at various geographic resolutions (zones and villages). Population data is based on census data from R.K.SWAMY's BBTU.

5.6 Building Inventory (Property) Analysis

Property Analysis is part of the Exposure Analysis and a preface to the Loss Analysis Module. Property value refers to estimate building property values in Indian Rupees. It does not include the infrastructure and non-building structures like highways, railroad, bridges, etc. It includes buildings' structural, non-structural and content values combined, but exclude land. For homes (dwellings), relevant structures are included in the property value.

- The Module deals with nearly all aspects of the built environment, and with a wide range of different types of losses (structural & non-structural, population, infrastructure etc.).

- The technology to execute this would be ESRI's GIS software ArcView to provide easy-to-use Graphical User Interface.

6. Query Shell Development

The design and standardization of query shell is an integral part of GIS development. This would enable access level controls, user friendly menus & interfaces. This takes into consideration the privileges given for personnel at various levels of management and day-to-day operations and at the time of disasters. The interface shall be designed to reflect the existing processes, which the disaster management staff is accustomed to. This would enhance smooth transition from the current system of works to data automation.

Analysis through user-friendly queries

Results from an analysis using only default inventory can be improved greatly with a minimum amount of locally developed input. This is generally the intended level of implementation. However, there could be no standard analysis with user-supplied data and hence, no minimum or standard amount of input. Such an effort might involve

- Development of maps of soil conditions affecting ground shaking, liquefaction and land sliding potential. These maps would be used for evaluation of the effects of these local conditions upon damage and losses.

- Preparation of a detailed inventory for all essential facilities.

- Collection of detailed inventory and cost data to improve evaluation of losses and lack of function in various transportation and utility lifelines.

- Collections of data, such as number of fire trucks, for evaluation of the probable extent of areas affected by fires.

- Gathering of information concerning high potential loss facilities and facilities housing hazardous materials.

Various "Avenue" based interface / programs were created to enable easy-to-use interface and for the flexible access of the database. Certain assumptions have been made for calculations of Vulnerability, Loss estimation and planning relief in order to highlight the features of e-DIMS. The modules developed as sub-systems and its assumptions and with its typical content is shown as an example in Figure. 1
7. Demonstration of System with Content and Modules

7.1 System - Contents

The System developed using Arc View along with its extension modules like Arc View Spatial Analysts, Network Analyst are shown below in separate slides for relevant knowledge and understanding of the readers to give an insight into the presentation and its efficacy in spatial data integration, analysis and visualization.

**E-DIMS**

- GIS-based earthquake risk analysis application s/w package
- A support tool to civil service personnel to give real time information reports as operational maps
- Prepare scenarios relevant to the interested territorial zones
- Enables faster decision making process
- Facilitates spatial data visualization & analysis

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![Figure 1: Information Needs, Integration and Assessment in customization.](image)

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7.2 System - Demonstration - Sample Views

1) Menu Interface for toggling between main Themes (By using this Interface User can select the Area of Interest i.e., for viewing India or Gujarat or Ahmedabad. If the User Clicked the I Radio button to view India then another dialog pops to view the India Natural hazards map)

2) Hazard mapping Menu Interface for Highlighting Epicenters based on their magnitude
User can select the Range of the magnitude by the combo control provided in this dialog. The ranges are based on the past earthquakes that occurred before Jan 26, 2001. Canceling this dialog would take one to Gujarat Vulnerability Analysis interface

3) Potential Risk Zones Menu Interface for the Earthquake Scenario

User can View the past events or define an earthquake scenario in this Gujarat Vulnerability Analysis interface. To create a scenario, select a Fault and pick a magnitude that would open a window showing the scenario results Alternatively, user can locate the epicenter by using Latitude and Longitude values to simulate a scenario. In the absence of scientific data on earthquakes, ground shake and ground motion parameters related to a particular magnitude or fault, we assumed a standard to simulate the scenario (demonstration purposes only). For a particular fault and its length, it has been assumed that a "X" magnitude would create a ground shake covering a distance of "Y" Kilometers. This simulation is created through buffer analysis and results of buffer are used to derive the vulnerability in terms of people, infrastructure data etc. by overlay / union operations.

8. Emergency Management

The Emergency Management for immediate post-quake phase has two parts: loss estimation, planning relief operations. The loss estimation in an urban region for affected parts. To begin with, the affected sites/areas has to be recorded. In our case we have assumed 3 areas as seriously affected and a series of network & spatial analysis are done to derive the population loss and building units loss of the 3 areas. The data for population and building index have been appended to the urban land use from which the statistics are arrived at. The planning relief operations aims at finding out closest service facilities (hospital, fire station, police station, school, hotel) to the affected sites; best / alternate route to the sites. The closest facilities are identified by defining certain minimum distance to reach the site (in this case it is 3 kms). After finalizing on the facilities, the shortest paths to reach the site are found through network analysis. Considering that there may be affected roads or other hindrances to the regular routes, a facility have been given to update the road data thereby one can derive alternate route to the affected sites. The facilities and affected areas are both assumed but similar exercises could be demonstrated for real data.

9. Conclusion

This E-DIMS system is attempted as a tool to assist the planners, decision-makers and administrators in disaster preparedness. Actual demonstration and feedback from the audience have shown us that even-though more scientific and technical inputs are required for in-depth analysis as well as micro-level categorization, this self-starter demo tool can be of use to aid the disaster preparedness using GIS and Satellite Remote Sensing technology. More appropriate and relevant modules facilitating Disaster Alert, Warning and Communication, Rehabilitation and Resettlement could be added based on the requirements for enabling efficient decision-making.

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