CHAPTER 9

INTEGRATION OF HAZARD MAP USING GIS

9.1 GENERAL

Seismic Hazard Analysis is a term which subdivides a region into smaller areas with types of different potential for hazardous earthquake effects, and defines their specific seismic behavior for engineering design and land-use planning. Usually it includes approaches for assessing local ground response, slope instability and liquefaction. In fact hazard studies involve experimental techniques together with theoretical approaches. In this chapter an integration of all the developed maps is attempted based on weights and ranks. A final hazard index map for Coimbatore corporation area is developed by using Analytic Hierarchy Process (AHP) on GIS platform. Application of GIS for seismic hazard analysis mapping be sufficiently established by a lot of researchers every one in excess of the world. Shankar Kumar Nath (2005), Anbrazahan (2009) used GIS as additional tool to map seismic ground motion danger for Sikkim Himalaya and Bangalore in India. In this study, similar approach of Shankar Kumar Nath (2005), Anbrazagan (2009) developed a hazard index map where in the seismic hazard parameters are integrated and coupled with ground information. The hazard index maps are prepared using deterministic approach.
9.2 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Geographical information systems provide ideal surroundings to accomplishing comprehensive regional information including seismic damage assessment. It has ability to amass, influence, examine and show a big quantity of necessary spatial and tabular information. Geographical Information System is a data analyses of together spatial (explicit) and tabular (non-graphic) data. The dealings for information psychoanalysis characteristically establish in the majority Geographical Information Systems programs are as follows:

- Map over lay analysis including arithmetic, weighted average, comparison and correlation function.
- Spatial connectivity deal with proximity functions, optimal route selection and network study.
- Spatial neighborhood information, for example slope, feature ratio, summary and clustering.
- Measurements of line and arc lengths, point-to-point distance, polygon perimeters, area in addition to volume.
- Statistical analysis, including histograms or frequency counts, regressions, correlation and cross-tabulation.
- Output making, including map, chart, graph, table and extra user-distinct in order.

The existing abundant application-specific functions in GIS platforms are used for the analysis of geotechnical data and hazard mapping. The majority of the computer programming may not provide inbuilt capability to perform multidisciplinary macro language. The GIS macro language is
very simplified but it does not handle with computational features such as recursion, numerous simulations, subscripted variables, graphical features and subroutines. The above said feature provides input facilities for the external analysis and modeling of graphical and non-graphical data. The output of various formats from external programs such as spreadsheet, word processing, graphics modeling and mathematical modeling may be given as input for GIS to sequent analysis and interpretation of data. Hence, in this study GIS is used to integrate all themes (Sitharam and Anbazhagan 2009).

9.3 EARTHQUAKE HAZARD PARAMETERS

Seismic hazard analysis region is subdivided into smaller areas with different potential of earthquake effects. The earthquake effects depend on ground geomorphological attributes consisting of geological, geomorphology and geotechnical information. The parameters of geology and geomorphology, soil coverage/thickness, and rock outcrop or depth are nothing but geomorphological attributes. Other attributes are the earthquake parameters, which are estimated by hazard analysis and effects of local soil for a hazard. The Peak Ground Acceleration amplification or site response, predominant frequency due to earthquakes are some of the important seismological attributes in consequence of the earthquake. Weight of the attributes depends on the region and decision maker, flat terrain has weight of “0” value for population, PGA and spectral amplification has highest weight for site response.

9.3.1 Seismological Attributes

The south central part and south eastern part have largest overburden thickness in comparison with other areas. An average Coimbatore corporation has overburden thickness of less than 1m on North east side and about 15m in rest of the places which is obtained from boreholes does not
represent thickness of soil from the true engineering rock (shear wave velocity is 700 m/s) level. They correspond to thickness of overburden above the weathered rock. Hence the overburden thickness of Coimbatore corporation is represented in the form of engineering rock level using SPT results, which varies from 3.7 m to 80 m, engineering rock of shallow depth on the western part, moderate depth on the central part and deeper depth on the south east to north east. An average engineering rock depth which is found from the original ground level is 5m.

9.3.2 Peak Ground Acceleration for MCE from DSHA (PGA)

From deterministic seismic hazard analysis presented in chapter 5, maximum credible earthquake for Coimbatore corporation is Mw of 5.4. For MCE considering the Cauvery fault (L10) as the source. The rock level at 173 borehole locations using rock depth information has been obtained from geotechnical data. The peak ground acceleration at each borehole locations obtained (Iyengar and Raghukanth 2009). PGA at rock level from ground motions using DSHA is as shown in Figure 9.1.

Figure 9.1 Peak ground acceleration map
9.3.3 Amplification factor (AF)

Amplification factor is defined to be the ratio of peak horizontal acceleration at the ground surface to peak horizontal acceleration at bed rock. These values are calculated using the correlation given by Iyengar and Raghukanth (2005). The characteristic of amplification factor is influenced by the soil property of the region. The Amplification factors vary as of 2.12 to 2.9 and can be divided into four zones. The amplification factor for soft and medium dense soil will vary with the rock level PGA values. The method adopted for evaluation of amplification factor ($F_s$) values considers this effect and the value of $F_s$ varies with the rock level PGA values. The values assigned to each zone are given in the Figure 9.2.

![Figure 9.2 Amplification factor map](image)
9.3.4 Soil Thickness (ST)

Another important theme is overburden thickness of soil, which can be as rock depth from surface or soil thickness. The soil thickness map is shown in the figure 9.3. The overburden thickness of study area is estimated by using drilled boreholes information at selected 148 locations data and geophysical investigations at 25 locations. The soil thickness from the borehole data and geophysical investigation is well matched with each other. The soft computing technique ANN also used to predict the soil thickness for unknown locations. The geotechnical attributes presented in the soil map are based on a large number of geotechnical data and experiments.

![Figure 9.3 Soil thickness map](image-url)
9.3.5 Shear Wave Velocity of Soil (SS)

Seismic response analyses require the mechanical and geometrical parameters of the overburden soil above the engineering rock depth. Mechanical and geometrical parameters are nothing but properties of overburden soil, which is generally represented in term of geology, average shear wave velocity of the normal and standard penetration test “N” values. The site is characterized for site response behavior based on the above two parameters. During the process of site characterization, it becomes necessary to determine the variations in soil stratification and engineering properties of soil and rock layers encountered at the site preferably based on in-situ tests. Initially by considering the possible variations in each unit, the site classification is measured based on characteristics of geologic units.

It is needed to justify the geological use for assessing the effects of local soil conditions (Ansal 2004). Seismic hazard study at Silivri, Turkey has demonstrated that the existing geological unit’s not homogenous and significant changes in their properties could be observed from one point to another, even in the same formation. Therefore, considering the geological units as the only criteria in seismic hazard analysis is not appropriate (Ansal 2004). But the geology map provides the basic information to plan the detailed site investigations and to control the reliability of the results obtained by site characterizations and site response analyses. Equivalent (average) shear wave velocity became most accepted criterion for site characterization. Equivalent (average) shear wave velocity is defined as the weighted average of shear wave velocities of soil and rock layers in the top 30 meters. For the purpose of evaluating the design earthquake individuality on top of the earth face, equivalent shear wave velocities are being used in earthquake codes (Borchert 1994).
Equivalent (standard) shear wave velocity of the study area is calculated based on in-situ measured shear wave velocity using SPT. In the study area, hard rock is found within 15m; hence the site classification is attempted to considered soil overburden velocity in addition to $V_s^{30}$. It is observed that the average of 30m velocity shows the major part of the study area can be classified as Site Class D. The average shear wave rate of soil has been calculated based on engineering rock depth which is obtained from SPT testing. The average shear wave velocity intended for soil overburden in the study area is shown in Figure 9.4. It shows that whole study area has a medium to dense soil with an average velocity range of 180m/s to 310.477m/s falling in to Site Class D as per NEHRP classification.

Figure 9.4 Shear wave velocity map
9.3.6 Predominant Frequency (PF)

Predominant frequency map of our study area for 30m soil column prepared using the simple relation flanked by means of the shear wave velocity (β) of the sediment of column 30m, viz. f= β/4H, (Kandpal et al 2007). For each bore hole location predominant frequency was calculated and predominant frequency map prepared using GIS software. The predominant frequency map is revealed that the predominant frequency of 30m soil column vary between 1.59 to 3.07 Hz is shown in the Figure 9.5. Rock PGA were calculated for each bore hole location considering the hypocentral distance calculate used for each one bore to tears log to the lineament used as input for the corresponding borehole for site response study.

![Figure 9.5 Predominant frequency map](image-url)
9.3.7 Population (PP)

Coimbatore corporation is our study area which lies between $10^\circ53'58''$ N to $11^\circ05'08''$ N latitude and $76^\circ53'56''$ E to $77^\circ05'20''$ E longitudes. According to the 2011 census it is the third largest city in the state of Tamil Nadu. The population in Coimbatore is spread over an area 105.4sq.kms with a population density of 8815 persons per sq.km as shown in Figure 9.6.

![Population map of the study area](image)

Figure 9.6 Population map of the study area

9.3.8 Land use / Land cover (LL)

Review of the land use pattern of Coimbatore for an area of 105.4sq.km, indicates that approximately 76 % of land is put to development use where as approximately 23 % of the land is still being put to agricultural use, water bodies, vacant areas and heritage sites. In the developed land use plan for 2001, it is noted that the city is predominantly expected to develop in residential area and in industrial area. The existing and proposed land use
pattern for 1993 and 2001 respectively is indicated in Coimbatore master plan.

Review of the land use pattern of Coimbatore for an area of 105.60sq.km is indicated in Coimbatore master plan 1993, indicates that approximately 76 % of land is put to residential and industrial use. In the proposed land use plan 2001, it is noted that the city is predominantly expected to develop in residential area and in industrial area. Satellite imageries are used for locating favorable ground water potential areas. Landuse, geomorphological and lineament maps are prepared with the help of satellite imageries. The satellite data was acquired at the date of 14th march 2008 from the satellite of IRS-ID, LISS-4 sensor. This data have a resolution of 5.2m. The data source is obtained from the National Remote Sensing Centre (NRSC), Hyderabad. Satellite imageries of landuse / landcover were measured by means of Earth Resource Data Analysis System (ERDAS) sources as shown in Figure 9.7.

Figure 9.7 Land use / land cover map of the study area
9.3.9 Elevation Level (EL)

The average mean sea level of Coimbatore corporation is 432m. The elevation ranges as 445m on Northwest to 385m on Southeast and contour at 10 m interval as shown in Figure 9.8. The study area is bounded on the north and west by steeply rising mountains of Western Ghats. The Nilgiris on the North West and Palghat on the west side, besides these Western Ghats ranges, the other hills such as Vellingiri and Boluvampatti hills run western and northwest respectively very close to the study area. The most of the study area consists of undulating plain sloping gradually from west to east. The Noyyil River has its origin in the Boluvampatty valley of the Vellingiri hills and called the Swamy mudiyar. Further south, it joins with Periyar and Chinnar. Then it takes east-northwest courses and forms the boundary of Coimbatore and Avinasi taluk. The Noyyil River is dry for the major part of the year.

Figure 9.8 Elevation map of the study area
9.3.10 Drainage Pattern (DR)

The city has a natural topography, sloping from north towards south and west towards east. The natural drains in Coimbatore such as Sanganur Pallam, Velangurichi-Singanallure drain, Ganapathy-Singanallur drain, Karperayan coil drain, Koilmedu drain, and railway feeder road side drain, and Tiruchy-Singanallur check drain. There are eight major water bodies within the corporation limits. Most of the tanks are used for irrigation purposes.

Majority of the tanks encouraged with poor people and drainage subjected to road side encroachments. The other important parameters of drainage pattern (DR) and elevation level (EL) are considered as separate themes based on the recent available information. Figure 9.9 shows the drainage pattern of study area with water bodies.

Figure 9.9 Drainage map of the study area
9.3.11 Geomorphological Attributes

The geomorphological attributes called as themes and considered in this study are Geology and Geomorphology (GG), Soil thickness (ST), Population (PP), land use/landcover (LL), Drainage pattern (DR) and Elevation Level (EL).

9.3.12 Geology and Geomorphology (GG)

As the study area is full of buildings, it is very difficult to get the detailed geomorphological or geological datas which is shown in Figure 9.10 and 9.11. The geomorphological features cover major part of the study area by shallow pediments. Several parts are covered by deep pediments, moderate pediments and dissected or undissected pediments. Only two types of geological features exist in the study area. The major part is sand and silt which covers the western part where as the remaining part Gneiss covers the eastern part.

Figure 9.10 Geomorphology of the study area
9.4 INTEGRATION OF THEMATIC MAPS

For seismic hazard delineation, the different themes as presented in the map, considering both geomorphological and seismological are integrated to generate seismic hazard maps. Usually hazard map gives an account of the Hazard Index (HI) based on hazard calculation and site conditions. Hazard index is an integrated factor, and it depends on weights and ranks of the seismological and geomorphologic themes. Theme weight can be assigned based on their contribution to the seismic hazard. Rank can be assigned with in theme against on their values closer to hazards. Usually higher rank will be assigned to values, which are more hazards in nature, for example larger PGA will have the higher rank. The contributing themes and their weights are listed below in Table 9.1, once the identical weights are assigned.
Then normalized weights can be calculated upon the pair-wise comparison matrix. Some of the attributes has two values for the same theme, hence both are given same weights. The normalized weights are calculated by means of Saaty's Investigative pecking order Process (Nath, 2004). Here this technique, a matrix of pair wise comparisons (ratio) flanked by the factors are built, which is second-hand to develop the human being normalize weights of each one factor. The pair-wise comparison is made by calculating the principal eigen vector of the matrix with the element of the medium are in the variety of 0 to 1 summing to '1' in each one column. The weights meant for each one theme can be calculate through averaging the value in each one line of the matrix. These weights will also sum to '1' and can be used in deriving the weighted sum of rating or scores of each region of cells or polygon of the mapped layers. Since the values within each thematic map/layer vary significantly, those are classified into various ranges known as the features of a layer.

**Table 9.1 Themes and weights for various layers for GIS integration**

<table>
<thead>
<tr>
<th>Index</th>
<th>Themes</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGA</td>
<td>Peak ground acceleration</td>
<td>10</td>
</tr>
<tr>
<td>AF</td>
<td>Amplification factor</td>
<td>9</td>
</tr>
<tr>
<td>ST</td>
<td>Soil thickness</td>
<td>8</td>
</tr>
<tr>
<td>SS</td>
<td>Shear wave velocity</td>
<td>7</td>
</tr>
<tr>
<td>PF</td>
<td>Predominant frequency</td>
<td>6</td>
</tr>
<tr>
<td>PP</td>
<td>Population</td>
<td>5</td>
</tr>
<tr>
<td>LL</td>
<td>Land uses and Land covers</td>
<td>4</td>
</tr>
<tr>
<td>EL</td>
<td>Elevation levels</td>
<td>3</td>
</tr>
<tr>
<td>DR</td>
<td>Drainage patterns</td>
<td>2</td>
</tr>
<tr>
<td>GG</td>
<td>Geology and geomorphology</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 9.2 shows the pair-wise comparison matrix of themes and the calculated of normalized weights. Within individual theme a grouping has been made according to their respective values. Afterward rank is assigned
based on the values. Usually these ranks vary from 1 to 10; highest rank is assigned for values more hazard in nature. This position is normalizing to 0-1. Consign ranks with normalized values are given in Table 9.2. Based on above attributes, the hazard index map is generated.

Table 9.2  Pair-wise comparison matrix of themes and their normalized weights

<table>
<thead>
<tr>
<th>Theme</th>
<th>PGA</th>
<th>AF</th>
<th>ST</th>
<th>SS</th>
<th>PF</th>
<th>PP</th>
<th>LL</th>
<th>EL</th>
<th>DR</th>
<th>GG</th>
<th>Weight</th>
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</thead>
<tbody>
<tr>
<td>PGA</td>
<td>1/1</td>
<td>10/9</td>
<td>10/8</td>
<td>10/7</td>
<td>10/6</td>
<td>10/5</td>
<td>10/4</td>
<td>10/3</td>
<td>10/2</td>
<td>10/1</td>
<td>0.182</td>
</tr>
<tr>
<td>AF</td>
<td>9/10</td>
<td>1/1</td>
<td>9/8</td>
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<td>9/6</td>
<td>9/5</td>
<td>9/4</td>
<td>9/3</td>
<td>9/2</td>
<td>9/1</td>
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</tr>
<tr>
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<td>8/9</td>
<td>1/1</td>
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<td>8/6</td>
<td>8/5</td>
<td>8/4</td>
<td>8/3</td>
<td>8/2</td>
<td>8/1</td>
<td>0.145</td>
</tr>
<tr>
<td>SS</td>
<td>7/10</td>
<td>7/9</td>
<td>7/8</td>
<td>1/1</td>
<td>7/6</td>
<td>7/5</td>
<td>7/4</td>
<td>7/3</td>
<td>7/2</td>
<td>7/1</td>
<td>0.127</td>
</tr>
<tr>
<td>PF</td>
<td>6/10</td>
<td>6/9</td>
<td>6/8</td>
<td>6/7</td>
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<td>6/5</td>
<td>6/4</td>
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<td>5/9</td>
<td>5/8</td>
<td>5/7</td>
<td>5/6</td>
<td>1/1</td>
<td>5/4</td>
<td>5/3</td>
<td>5/2</td>
<td>5/1</td>
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<td>4/8</td>
<td>4/7</td>
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<td>1/1</td>
<td>4/3</td>
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<td>4/1</td>
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<td>3/5</td>
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<td>3/1</td>
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</tr>
<tr>
<td>DR</td>
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<td>2/8</td>
<td>2/7</td>
<td>2/6</td>
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<td>1/9</td>
<td>1/8</td>
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<td>1/3</td>
<td>1/2</td>
<td>1/1</td>
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</tr>
</tbody>
</table>

Deterministic seismic hazard map is hazard index map for worst scenario earthquake. The importance factor 10 assigned for peak ground acceleration (PGA) at bed rock level from scenario earthquake.

\[
DSM = \frac{PGA \times DPGA + DAF \times DAF_r + DST \times DST_r + DSS \times DSS_r + DPF \times DPF_r + DPP \times DPP_r + DLL \times DLL_r + DEL \times DEL_r + DDR \times DDR + DGG \times DGG_r}{\sum w}
\]  

From equation 9.1 HI values are obtained using the assigned ranks and normalized weights and given in Table 9.3 and seismic hazard index map of the study area is shown in Figure 9.13.
### Table 9.3 Themes and its weights for GIS integration

<table>
<thead>
<tr>
<th>Themes</th>
<th>Values</th>
<th>Weight</th>
<th>Ranks</th>
<th>Normalize Rank</th>
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<td>0.13 to 0.14</td>
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<tr>
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<td>ST (m)</td>
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<td>1</td>
</tr>
<tr>
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<td>0.66</td>
</tr>
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<td></td>
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<td>4</td>
<td>1</td>
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<td>Low slope</td>
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<td>Flat ground</td>
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</tr>
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<tr>
<td></td>
<td>Drainage area</td>
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<tr>
<td></td>
<td>Flat area</td>
<td></td>
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<td>0</td>
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<tr>
<td>GG</td>
<td>Granitic intrusion</td>
<td>0.018</td>
<td>4</td>
<td>1</td>
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<tr>
<td></td>
<td>Magnetic instruction</td>
<td></td>
<td>3</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>Swarms</td>
<td></td>
<td>2</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Granitic rock</td>
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9.5 CONCLUSION

Base map of Coimbatore on a scale of 1:50000 with about 10 layers of theme rank such as Peak Ground acceleration map, Amplification factor map, Soil thickness map, Shear wave velocity map, Predominant frequency map, Population map, Land use / Land cover map, Elevation map, Drainage map and Geology and Geomorphology map are prepared and presented.

Seismic hazard maps are prepared by using GIS based upon Fuzzy logic sets method adopted by the Analytic Hierarchy Process (AHP). Seismic hazard maps have been generated, based geological and seismological attributes. Maximum hazard expected at western part of city in deterministic seismic approach and it may be recognized as a seismic source (Cauvery fault L10) which contribute large PGA in that area and takes population concentration upon growing population. Seismic hazard index value is calculated.