# The Application of GIS in Earthquake Loss Estimation for the City of Lalitpur

## Introduction

The main objective of this research project is to develop a methodology for spatial information systems for municipalities, which will allow local authorities to evaluate the risk of natural disasters in their municipality, in order to implement strategies for vulnerability reduction. The project concentrates on medium-sized cities in developing countries, which do not yet utilize Geographic Information Systems in their urban planning, and which are threatened by natural hazards (such as earthquakes, flooding, landslides and volcanoes). The methodology concentrates on the application of methods for hazard assessment, elements at risk mapping, vulnerability assessment, risk assessment, and the development of GIS-based risk scenarios for varying hazard scenarios and vulnerability reduction options, using structural and/or non-structural measures. Although the methodology is primarily designed to assist municipalities in the decision-making regarding vulnerability reduction strategies, the resulting databases are designed in such a way that they can also be utilized for other municipal activities.

## Lalitpur Sub-Metropolitan City, Nepal

Within the project a number of case study cities have been identified. The Lalitpur Sub-Metropolitan City is located in the Kathmandu valley, on the Southern side of the capital of the Kingdom of Nepal, Kathmandu. Lalitpur has a population of 163,000, in 35,000 households, according to the 2001 census. The municipality is divided into 22 wards. Lalitpur, like its neighbouring cities of Kathmandu and Bhaktapur in the Kathmandu valley, are threatened by earthquakes. The last major earthquake took place in 1934, and less damaging earthquakes were reported in 1960 and 1988. The old core area is famous for its cultural heritage, and has a very dense structure, with a majority of buildings with load-bearing masonry, with mud mortar and adobe. Many houses are built in a courtyard pattern, with very narrow streets. In the fringe area, which was developed between the core area and the ring road, the majority of buildings are masonry with brick in cement and RCC. In the last years, also rapid construction takes place in the areas, on the outer side of the ring road, where the majority consists of RCC buildings (figure 1).

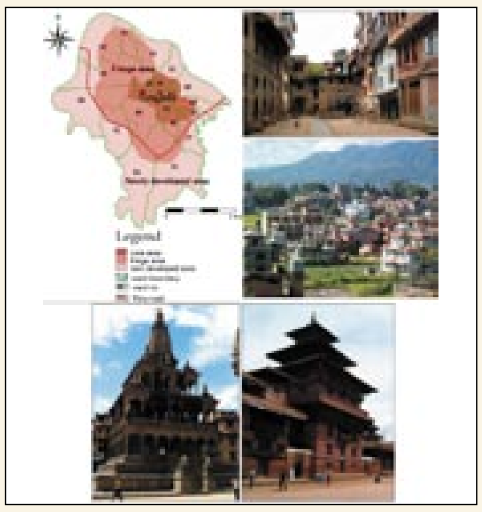

*Figure 1: Map of Lalitpur and some typical buildings. Upper right: Brick in mud buildings in courtyard. Middle right: RCC buildings in outer area. Below: Cultural heritage.*

## Generation of base dataset

A set of 1:2,000 topomaps was available in digital form (AutoCad), which were converted into a usable GIS database, consisting of separate layers for buildings, roads, contours and drainage. The building footprint map was prepared based on aerial photos of 1981 and 1992 and was updated in 1998. All the buildings constructed after this year as observed in the available IKONOS image from 2001 were digitized on screen to create the building data set for the year 2001. As also a CORONA image was available from 1967, this image was used to delete those buildings that were not yet present in 1967, and generate a building footprint map for that year. An example of the various building footprint maps for a part of the city is shown in figure 2.

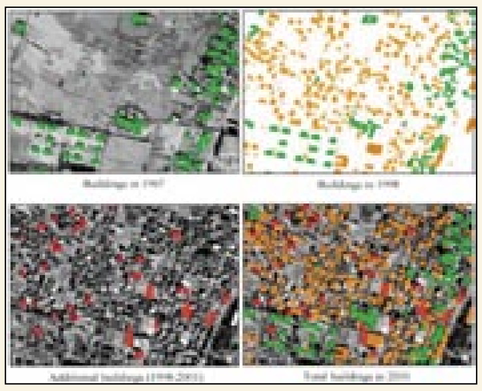

*Figure 2 Illustration of the use of multi-temporal imagery for the generation of building footprint maps for different periods for a part of the city of Lalitpur.*

Homogeneous units were mapped as groups of buildings with more or less similar characteristics that can be delineated from high-resolution satellite imagery, and that can be described in the field. The map was combined with the building footprint map in order to calculate the percentage built-up area and the number of buildings per unit (see figure 3). In the field mobile GIS was used to characterize the buildings within each unit according to age, occupancy class, landuse type and building type, which was a combination of construction material and number of floors. Also population data was collected and population distribution was modeled for different times of the day.

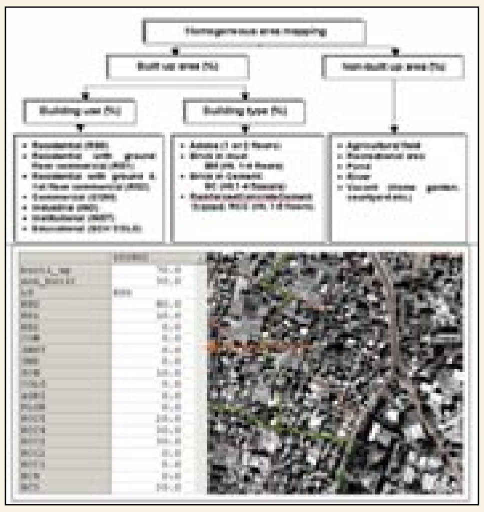

*Figure 3: Above: Schematic overview of homogeneous unit mapping approach. Below: example of the resulting database.*

Seismic amplification and liquefaction potential

A geological database was made for storing the information for 185 deep boreholes, and 328 shallow boreholes All boreholes were divided into 4 main stratigraphical units, for which the depth was determined and used in GIS for subsequent layer modeling. The depth of each of the layer boundaries, including the surface elevation was used in GIS and Digital Elevation Models of each of these surfaces was obtained through point interpolation. The results are shown in figure 4. The GIS layer models were used for one-dimensional calculations of the ground response, with SHAKE2000, using strong motion records for three earthquake scenarios. Each of the sampling points was transformed into a soilprofile which was entered in the SHAKE2000 program. The results were calculated as Peak Ground Acceleration (PGA) as well as spectral acceleration for frequencies of 5, 3 2 and 1 Herz. These values were later linked back to the sampling points and a map was obtained through point interpolation. An overview of the method is shown in figure 5.

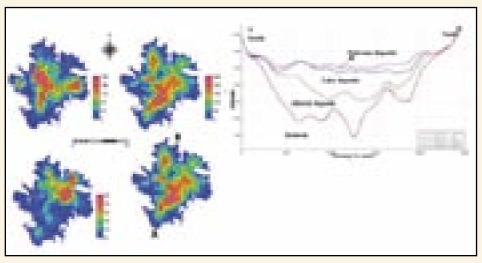

*Figure 4: Left: Thickness maps of the three main material types in the Kathmandu valley. Right: Cross section based on the layer thickness maps.*

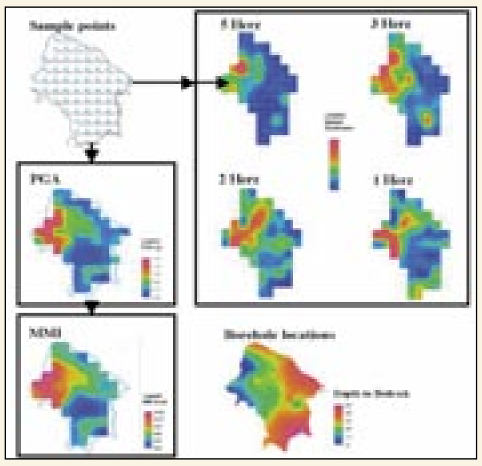


*Figure 5: Schematic representation of the two methods used for soil response analysis. One resulting in PGA and MMI maps, and one resulting in spectral acceleration maps.*

## Building loss estimation

For analyzing seismic vulnerability, the buildings in Kathmandu valley have been divided into the a number of classes, for which vulnerability curves were used in the GIS analysis (from NSET Nepal). This resulted in figure 6 showing the total number of vulnerable buildings in different damage grades and in the four earthquake-intensities used ranging from VI to IX. In a next step specific damage estimations were made for three earthquake For each of these scenarios the ranges of partially and heavily damaged buildings have been estimated, with and without the effect of liquefaction.

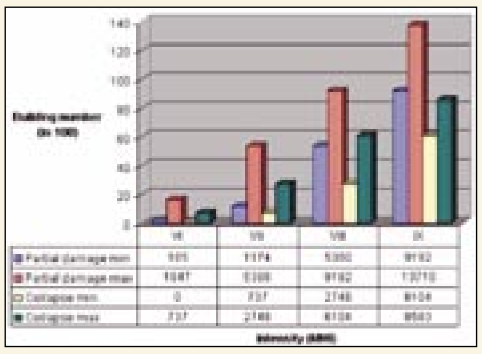

*Figure 6: Total number of damaged buildings in different damage grades in four earthquake intensities.*

## Population loss estimation

The number of human casualties was estimated at homogeneous unit level for the three different earthquake scenarios. The data used for this calculation were the population distribution for different periods of the day and within different occupancy classes, the building loss estimation discussed in the previous section and vulnerability and casualty ratios with respect to building damage, derived from HAZUS. Preliminary results are shown in Figure 7.

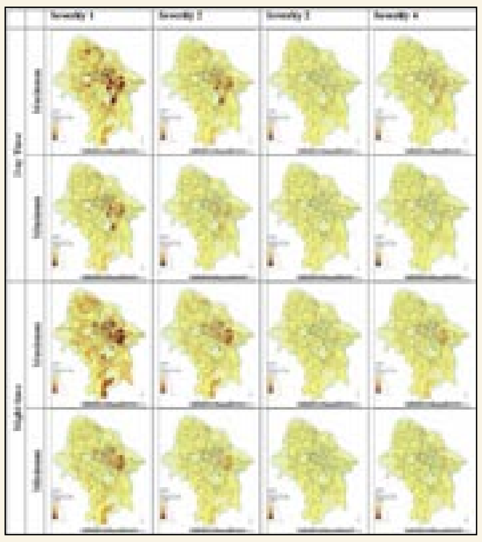

*Figure 7: Various casualty level for Mid Nepal earthquake scenario*

## Conclusions

The example from Lalitpur Sub-Metropolitan City in Nepal illustrates the direction of the SLARIM research project, in supporting local authorities with methods to collect and manage information used for risk estimation, analysis, assessment and finally management. What has become clear in the case study with the Lalitpur Sub-Metropolitan City so far is that specific GIS based Decision Support Systems for Disaster Management at municipal level can only be implemented if a municipality has experience with GIS and has developed a municipal database. Even then, such a system would be less useful for disaster prevention, as vulnerability reduction measures should be an integrated part of all common municipal activities, than for disaster preparedness.

### For more information:


**Cees Van Westen, Mark Brussel M., Siefko Slob, Birendra Kumar Piya, Umut Destegul, Jeewan Guragain.**

International Institute for Geoinformation Science and Earth Observation, ITC, Hengelosestraat 99, P.O. Box 6, 7500 AA Enschede, The Netherlands, E-mail: westen@itc.nl


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