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IMPLEMENTATION OF FAST EARTHQUAKE SCENARIOS FOR RISK MANAGEMENT IN DEVELOPING COUNTRIES

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SUMMARY

Earthquake scenarios are used worldwide to describe the estimated damage from potential earthquakes. By informing communities about the impact of such disasters, earthquake scenarios can help communities identify necessary earthquake risk management programs. However, past experience indicates that the general characteristics and uses of earthquake scenarios should vary depending on whether they are prepared for cities in industrialized or less developed countries.

While scenarios should provide accurate estimations that authorities can use to develop precise risk mitigation measures in industrialized countries, this degree of preciseness may not be feasible in developing countries, where resources, organizations and experience are more limited. In addition to the fact that existing methodologies have been developed for use mostly in industrialized countries, issues of limited data, resources and experience in earthquake preparedness are also a reality in developing countries. Moreover, since earthquake risk mitigation measures have to compete with other social efforts for limited government and financial support, it is not ideal to spend the time, money and energy on the generation of a long list of measures, based on a very accurate damage estimation, that may never be implemented.

This paper proposes the use of fast earthquake scenarios to identify the main factors contributing to the earthquake risk of cities in developing countries. The application of this methodology in actual risk management projects for Kathmandu Valley, Nepal and nine case study cities under the RADIUS Project is presented to show that fast earthquake scenarios:

- Optimize time, efforts and resources spent on the estimation of potential earthquake damage
- Make the best possible use of existing information and local knowledge and experience
- Raise awareness about a city's earthquake risk by involving key representatives of the community's various sectors

Identify a few, manageable earthquake risk management measures, which could be implemented immediately after the project's completion.

INTRODUCTION

Seismic microzoning studies and earthquake scenarios are being used extensively in the process of designing programs to manage urban risk. Earthquake scenarios describe the results of detailed estimates of damage from potential earthquakes and help to communicate the impact of such disasters. Although most earthquake scenarios have been prepared for cities in industrialized countries (Borchardt 1992 and Katayama 1992), there have been a few examples of scenarios produced for cities in developing countries (GeoHazards International 1994 and Erdik 1994).

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Past experiences (Mattingly 1992, Kaneko 1994, Castro de Perez et al. 1994, Alva-Hurtado 1994 and Villacís et al. 1997) show, however, that the general characteristics and uses of earthquake scenarios should vary depending on whether they are prepared for cities in developed or developing countries. Cities in industrialized nations have the resources, organization and experience to implement the strategies and recommendations that result from earthquake scenario studies. Their primary need is an accurate quantification of the expected damage and a precise description of the actions that, if implemented, will mitigate the effects of a future earthquake event. With this information, as well as corresponding cost analyses, these cities can allocate available resources to the various activities included in rather comprehensive Risk Management Plans prepared using the results and analysis of earthquake scenarios. Thus, earthquake scenarios for cities in industrialized countries should be as accurate as possible and their main use is for the precise definition of all the activities that can reduce the cities' earthquake risk.

Cities in less developed countries, on the other hand, have very limited resources, data, and, in most cases, very short histories of earthquake disaster preparedness. Most importantly, earthquake risk management requires a long-term commitment to counter a low-probability event and must compete for political and economic capital with development efforts and social programs that have immediate and visible benefits. Given this situation, it is impossible for a city in a developing country to implement all the measures that are necessary to reduce its earthquake risk. A long list of recommendations contained in a detailed Risk Management Plan is not of practical use for a city that does not have the resources to implement it. Therefore, it is unnecessary and discouraging to spend time, energy and resources on a very precise estimation of the expected damage of a future earthquake and in the production of a list of recommendations that will never be realized. Thus, earthquake scenarios for cities in developing countries should be just sound enough to clearly identify the main problems that contribute to the earthquake risk of the city. The scenario's principal uses should be to 1) raise awareness and understanding among the various sectors of the community; 2) to identify a limited number of actions, that can be implemented under the city's limited resources, that will produce the maximum benefits; and 3) to help create the social and political context in which more precise technical analyses become meaningful.

This paper proposes the implementation of fast earthquake scenarios for risk management in developing countries. The proposed methodology allows the preparation, in a very short time, of earthquake damage scenarios that make full use of the existing information and of the local experts' capabilities and familiarity with the particular characteristics of the city. The earthquake scenarios produced can be used to raise awareness within the local and international community of the earthquake risk in a given city, and to identify the most important problems that contribute to the earthquake risk of the community.

PROPOSAL OF A FAST EARTHQUAKE SCENARIO

A new methodology is proposed to prepare fast earthquake scenarios that better fit the needs of earthquake-threatened cities in developing countries. The main objectives of fast earthquake scenarios are to:

- Optimize the time and resources necessary to prepare damage estimates.
- Produce sound damage estimates that identify only the main factors that contribute to the earthquake risk of a city.
- Make the best possible use of already existing information as well as of the local scientists' expertise and their familiarity with the region.
- Incorporate representatives of the various sectors of the society in the preparation of a realistic, well-accepted description of potential damage to the city due to earthquakes.

Methodology

The process for the preparation of fast earthquake scenarios for a city includes the following steps:

- Selection of a recent past devastating earthquake, and collection of related information. A past devastating earthquake is used instead of several hypothetical earthquakes presuming it will be much more accurate to use observed distributions of ground shaking than to use those obtained from theoretical models based on incomplete data. Furthermore, it will be much easier for the members of the community, especially the general public, to identify themselves with an event that actually affected their city rather than with potential earthquakes that are not likely to occur exactly as they are hypothesized. This approach also saves a considerable amount of time, work, energy, and money because the distribution of intensities over the area is already known and, therefore, calculations are not required to determine it.

- Combination of the observed distribution of intensities in the past earthquake with the location of the existing structures and infrastructure of the city. This process couples the hazard and exposure elements of the risk and helps to show how the risk has increased since the actual earthquake took place. This facilitates the justification of the need for the project as well as the incorporation of decision-makers and representatives of the community. A preliminary estimation of the potential damage is then performed using theoretical vulnerability functions.

- Interviews with local experts and officers in charge of the city systems and services to estimate the possible effects of a recurrence of the past earthquake. This procedure incorporates the particular characteristics of the vulnerability of the local structures and infrastructure. This information, combined with the theoretical estimation of damage, allows for the preparation of a preliminary earthquake scenario.

- A workshop in which representatives of the key sectors of the city, informed by local and international technical experts, analyze the preliminary estimation of damage and collaboratively develop a disaster scenario which can be used both for planning and risk management purposes. This group then brainstorms options to reduce earthquake risk, and prioritize those options in terms of agreed-upon criteria for project effectiveness and implementability.

The use of GIS techniques for the analysis of available information and the presentation of results is extremely beneficial. A GIS allows not only for the use of many different formats of information (maps, tables, reports, and digital files) but also for calculations to be made in ways that would otherwise take a much longer time to execute. The graphic presentation of the results also helps to communicate the study results to non-technical people and to the general public. Depending on the specific circumstances of a city, desktop applications such as ArcView and MapInfo, which are less expensive than a more sophisticated GIS, could be used effectively for the study.

The preparation of a realistic earthquake scenario and its acceptance by the community requires the active collaboration of local experts and officers in charge of the city systems, as well as of representatives of the key sectors of the city, informed by local and technical experts. The process should also have the support and participation of the mass media in communicating the study results to the general public.

Expected Products

The presented methodology produces a sound estimation of potential damage from an earthquake. Depending on the characteristics of the study area, the estimation includes not only the damage due to ground shaking but also that caused by collateral hazards such as slope failure, liquefaction, tsunami, and fire. The inclusion of the knowledge of local scientists and system administrators, in addition to the theoretical calculations, produces a scenario that closely reflects the local conditions and characteristics of the local structures and infrastructure. The emergency response and recovery capabilities of the city are incorporated also.

In addition, a higher level of earthquake risk awareness among the local and international communities is obtained. Through the communication of the potential threat and devastating impacts a significant earthquake event can cause, both the public and private sectors of the city can begin to understand a realistic danger exists and what should be done to mitigate it. The active participation in the study is expected to create a feeling of ownership among the local participants that can motivate them to continue the efforts in the future and implement the recommendations produced by the study.

Another important product is the creation of multi-disciplinary working groups through the involvement and cooperation in the study of various sectors of the community. This creation of working relationships will hopefully outlast the duration of the project and prove beneficial to the city in many ways.

Potential generation of local funding for these activities is also a product of the earthquake scenarios. Once the local people have participated in the identification of the city's main problems and in proposing solutions, there exists a better understanding of what is at risk in the city as well as measures that are helpful in the mitigation of this risk. This can motivate them to allocate resources for the implementation of the measures.

Finally, the fast earthquake scenario is expected to produce a few, but manageable, earthquake risk management measures whose implementation could start immediately after the project's completion. Due to time and budget constraints in developing countries, as well as differing priorities, not all of the measures traditionally proposed to reduce earthquake risk are feasible ones. Only those that the community deems most important and feasible should be considered.

KATHMANDU VALLEY - A CASE STUDY

The Kathmandu Valley Earthquake Risk Management Project (KVERMP) is an 18-month project that started on Sept. 1, 1997. The project is being implemented by the National Society for Earthquake Technology – Nepal (NSET-Nepal) and GeoHazards International (GHI), and is part of the Asian Urban Disaster Mitigation Project (AUDMP).

KVERMP has four objectives: to 1) evaluate Kathmandu Valley's earthquake risk and prescribe an action plan for managing that risk; 2) reduce the public schools' earthquake vulnerability; 3) raise awareness among the public, government officials, the international community resident in Kathmandu Valley, and international organizations about Kathmandu Valley's earthquake risk; and 4) build local institutions that can sustain the work launched in this project. Project activities pertaining to the use of fast earthquake scenarios are described below.

Kathmandu Valley's Earthquake Risk

Kathmandu Valley, located in Nepal, has a long history of destructive earthquakes. Most recently, a 1934 earthquake produced intensities of IX-X MMI in Kathmandu Valley, and destroyed 20% and damaged 40% of the valley's building stock. Three earthquakes produced intensities of IX-X in Kathmandu Valley in the 19th Century: in 1810, 1833, and 1866. The seismic record of the region extends back to 1255, and indicates that such major earthquakes affect the valley approximately twice a century.

Like many urban areas in developing countries, the risk of Kathmandu Valley has increased significantly since the last major earthquake. The Valley has a burgeoning population of almost 1 1/2 million people, uncontrolled development, and a construction practice that has actually degraded over this century. Nepal is among the poorest and least developed countries in the world with a per capita GDP of US$ 145. Approximately 14% of the GDP (US$ 400 million) is derived from foreign development aid. A weak economy and abundant poverty result in a lack of government funds to support earthquake hazard mitigation programs (including ratification of a building code), inexpensive and poorly constructed dwellings that often fail even in the absence of earthquakes, and a tendency in the general population to ignore the earthquake hazard because of more immediate needs. Kathmandu Valley has an urban growth rate of 6.5% and one of the highest urban densities in the world.

Despite this threat, there is no institution within Kathmandu Valley to assess earthquake hazards or promote an earthquake risk management program. The technical information about earthquake risk in Kathmandu Valley is incomplete and scattered among several governmental agencies. However, a more important contributor to the region's lack of earthquake preparedness is that the technical information that is available has not been synthesized, has not been applied to the infrastructure of modern day Kathmandu Valley, and has not been presented in a form that the public and government officials can digest.

Simplified Scenario and Action Plan

A simplified earthquake scenario was developed describing the consequences of a repeat of the 1934 earthquake in modern day Kathmandu Valley (Fig. 1). Although the next major earthquake to affect Kathmandu Valley will not be identical to the 1934 event, this approach is assumed to be valid for planning purposes because the soft soil geology in Kathmandu Valley should dominate the shaking pattern produced by all distant earthquakes, which traditionally produce the most damage to the valley. The effects of the earthquake on Kathmandu Valley's infrastructure was estimated by interviewing operators of critical facilities, incorporating existing studies, and conducting a workshop in which the interrelations of Kathmandu Valley's lifelines were examined (Fig. 2).

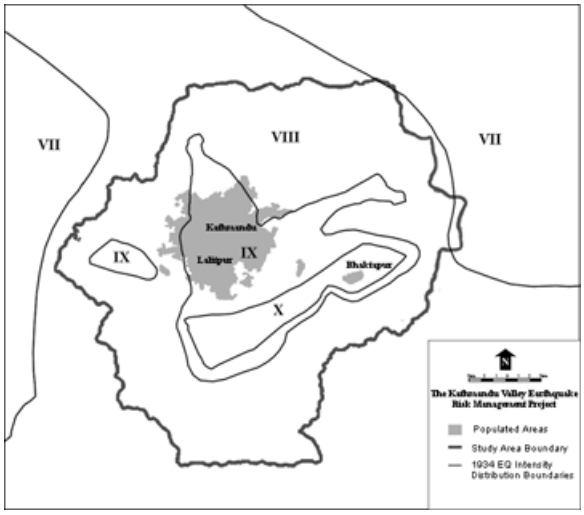

Figure 1. Seismic intensities observed during the 1934 earthquake superimposed on presently populated areas (darker areas).

The prepared scenario was used as the basis for the creation of an action plan of mitigation activities. This risk management plan was officially released by the Prime Minister of Nepal on January 16, 1999 (the actual date of the Great 1934 Earthquake in Nepal) during Kathmandu's First Annual Earthquake Safety Day (established by the King of Nepal based on a recommendation from KVERMP), which also served to raise public awareness through various presentations, a shake table demonstration, and a march for earthquake safety that involved hundreds of Nepali students, professionals and citizens (Figs. 3, 4). The plan included 10 initiatives that are politically, financially, and technically feasible and that NSET-Nepal will actively aid and promote the implementation of. Furthermore, NSET-Nepal will annually review the progress that has been made towards the goals of the action plan, assess the reasons when progress has not met expectations, and write a report for the public.

Remarks on the Kathmandu Valley Risk Management Project

KVERMP aimed to develop sound earthquake management policies for Kathmandu Valley and to begin the process of implementing them. The experiences gained in this project should be useful for other earthquake-threatened cities in developing countries, and should establish NSET-Nepal as a self-sustaining organization that can carry on the work of this project even after its completion.

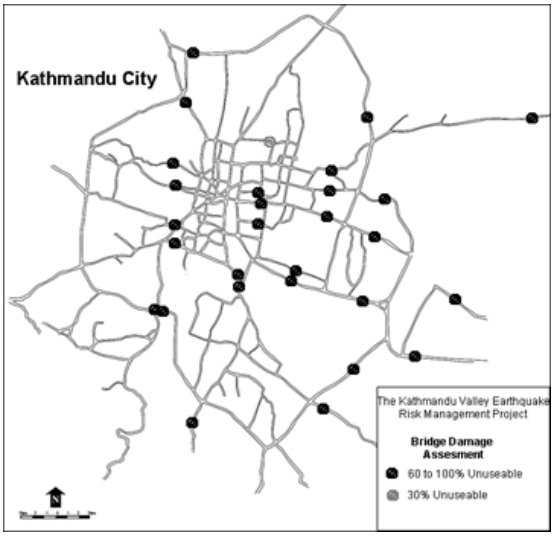

Figure 2. Estimated potential damage to bridges in Kathmandu City.

Figure 3. Nepal Prime Ministers at the Inaugural Ceremony of the 1st annual Kathmandu Earthquake Safety Day.

Figure 4. School children marching along the streets of Kathmandu during Earthquake Safety Day.

RADIUS - NINE CASE STUDIES WORLDWIDE

Currently, the methodology for fast earthquake scenarios is being utilized by the Risk Assessment Tools for the Diagnosis of Urban Seismic Risk (RADIUS) Project (http://www.geohaz.org/radius). RADIUS is being implemented by the United Nations in nine cities around the world under the International Decade for Natural Disaster Reduction (IDNDR) initiative. The nine cities selected for the RADIUS case studies among 58 applicants worldwide were the following: Addis Ababa (Ethiopia), Antofagasta (Chile), Bandung (Indonesia), Guayaquil (Ecuador), Izmir (Turkey), Skopje (TFYR Macedonia), Tashkent (Uzbekistan), Tijuana (Mexico), Zigong (China).

This initiative has three concrete objectives:

- Development of seismic damage scenarios and earthquake risk management plans for nine selected cities worldwide
- Development of a practical manual for seismic damage assessment in urban areas
- Raise awareness on seismic risk in the communities where the project was implemented

Since several other papers on the RADIUS Project are being presented at this conference, the authors of this paper will not present the project's details here. However, it is important to note that the case study cities implement the fast earthquake scenario methodology.

As was the case in KVERMP, the RADIUS case studies were implemented over an 18-month period. Therefore, necessary efforts and resources to carry out the project needed to be optimized. The evaluation of the risk of each case study city was efficiently achieved by carrying out a damage assessment involving both local data collection and interviews with local system managers. As in Kathmandu, this interview process complemented the collected data by contributing specific information characteristic to each system and known only by the people who manage it. Figure 4 shows an example of a building damage map which was developed for Guayaquil, Ecuador. The damage assessment made in the evaluation phase of the project was used to produce an earthquake scenario that was then presented to the entire community during the Earthquake Scenario Workshop. Besides the involvement of the interviewed system managers and representatives of the various city sectors in this workshop, abundant media coverage helped to raise awareness locally, nationally and internationally.

Next, based on the results of the damage assessment, actions were proposed that, if implemented, would help mitigate each city's earthquake risk. These proposed action items were elaborated on by the institutions proposing them and included in a preliminary action plan, which was presented during a second workshop called the Action Plan Workshop. Currently, the communities of the case study cities are working to finalize their city's risk management plans by selecting and prioritizing the action plan items agreed upon by the entire community during the Action Plan Workshop.

Figure 5. Newspaper Clipping on RADIUS from Tijuana, Mexico and Antofagasta, Chile.

Finally, since no evaluation or plan is of any use if the resulting recommendations are ignored, the implementation process is currently being discussed in each city. Awareness continues to be raised with the help of the mass media (Fig. 5), and the institutional, financial, and legal framework necessary to continue these efforts on a long-term basis are being set up.

CONCLUSIONS

Fast earthquake scenarios have been proposed in this paper to identify the main factors that contribute to the earthquake risk of cities in developing countries. The methodology was described and its application to actual risk management projects for Kathmandu Valley, Nepal as well as the nine case study cities under the RADIUS Project was presented to show that fast earthquake scenarios:

- Optimize the time, efforts and resources spent on the estimation of potential damage due to earthquakes
- Make the best possible use of the existing information and of the knowledge and experience of local experts and city-services administrators
- Raise awareness among the local and international community about the earthquake risk of a city through the active participation in the project of key representatives of the various community sectors
- Identify a few, but manageable, earthquake risk management measures whose implementation could start immediately after the project's completion. The identification of these measures and their acceptance by key representatives of the city could result in the generation of local funding to implement them.

The methodology described in this paper, as well as the experience gained in projects such as KVERMP and RADIUS, should be useful for other earthquake-threatened cities in developing countries.

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