A PROJECT TO STUDY URBAN EARTHQUAKE RISK WORLDWIDE

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SUMMARY

This paper describes the Understanding Urban Seismic Risk Around the World (UUSRAW) project undertaken by the Secretariat of the International Decade for Natural Disaster Reduction and GeoHazards International. The study aims to: (1) develop a systematic comparative assessment of the magnitude, causes, and ways to manage earthquake risk in cities worldwide, (2) identify cities around the world that are facing similar earthquake risk challenges and foster partnerships among them, and (3) provide a forum in which cities can share their earthquake and earthquake risk management experiences using a consistent, systematic framework for discussion.

The project has established a network of more than 70 seismically active cities worldwide, and in each one, identified a scientist to act as a local city representative. These city representatives have gathered the information necessary to develop a systematic comparison of the earthquake risk and risk management practices of the participating cities. Project participants have interacted through an internet forum (i.e., email discussion group) throughout the study. The Earthquake Disaster Risk Index (EDRI), a composite index that compares metropolitan areas according to the magnitude and nature of their earthquake disaster risk, has provided a framework for the UUSRAW project.

The project final report will include: (1) a comparative analysis of the earthquake risk and risk management practices in the participating cities, (2) a compilation of two-page city profiles that describe the key elements of a city's earthquake risk and risk management practices in a systematic way, and (3) a compilation of more than 60 risk management effort case studies from 27 cities. The project has also established a new worldwide network of earthquake professionals that can support continued work in comparative urban earthquake risk assessment.

INTRODUCTION

Earthquakes are infrequent, so no single city has endured many earthquake disasters. Every city, therefore, has much to gain if they all share their resources and experiences with earthquakes and earthquake risk management. To address the untapped potential of inter-city collaboration, in April 1998, the Secretariat of the International Decade for Natural Disaster Reduction (IDNDR) and GeoHazards International, a non-profit organization dedicated to reducing earthquake risk in the world's most vulnerable communities, launched the Understanding Urban Seismic Risk Around the World (UUSRAW) project. The UUSRAW study is being implemented as part of the Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters (RADIUS) initiative (http://www.geohaz.org/radius/understanding.html). The 18-month project was designed to help cities around the world recognize the ways in which they are similar (and different) with respect to the earthquake hazard, and to share their experiences and resources in working to reduce the impact of future earthquakes.

The study aims to achieve these goals in two ways: (1) by developing a systematic comparative assessment of the earthquake risk and risk management activities in cities around the world, and (2) by providing a forum in which those cities can share their experiences with earthquakes and earthquake risk management using a

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consistent, systematic framework for discussion. A network of more than 70 seismically active cities worldwide was established, and in each one, a scientist was identified to act as a local city representative. These city representatives have gathered the information necessary to develop a systematic comparison of the earthquake risk and risk management practices of the participating cities. Throughout the project, all project participants have interacted through an internet forum (i.e., email discussion group).

While earthquake risk assessments typically involve only estimating expected consequences of future earthquakes in a region, the UUSRAW project has placed equal emphasis on assessing the state of risk management practices in each city. It is crucial to collect this information because the project will be most effective in achieving its ultimate goal of reducing real earthquake risk if it not only defines the dimensions of the earthquake risk challenge, but also helps cities to address that challenge.

The UUSRAW project will produce a final report that includes: (1) a comparative analysis of the earthquake risk and risk management practices in the participating cities, (2) a compilation of two-page city profiles that describe the key elements of a city's earthquake risk and risk management practices in a systematic way, and (3) a compilation of more than 60 risk management effort case studies from 27 cities. The project has also established a worldwide network of earthquake professionals that can support continued work in comparative urban earthquake risk assessment. This paper describes the UUSRAW project, presents an overview of its results, and discusses some possible future work. At the present time, the project analysis is almost complete and the final report and city profiles are being written. The final report will be available by the time of the Twelfth World Conference on Earthquake Engineering (12WCEE).

PROJECT OBJECTIVES

The objectives of the UUSARW project are to:

- Develop a systematic comparative assessment of the magnitude, causes, and ways to manage earthquake risk in cities worldwide
- Identify cities around the world facing similar earthquake risk challenges and foster partnerships among them
- Provide a forum in which cities can share their earthquake and earthquake risk management experiences using a consistent, systematic framework for discussion

PROJECT PARTICIPANTS

The United Nations IDNDR Secretariat invited seismically active cities around the world to participate in the UUSRAW project. More than 70 city governments from 50 countries expressed interest in participating (Fig. 1). Each government then designated a city representative for the project. The representative, usually a scientist or engineer, was selected to be someone who would have access to the variety of information needed to contribute to this project. Twenty of the 74 cities participated actively, collecting the requested information and participating in the internet forum discussion. Together these twenty cities represent a diverse group with respect to their size, seismicity, collateral hazard potential, structural types, economic and political situations, and social and cultural characteristics. The cities are:

Algiers, Algeria	Gilgit, Pakistan	Pimpri, India	Santiago, Chile
Bogota, Colombia	Guadalajara, Mexico	Quito, Ecuador	Skopje, Macedonia
Bucharest, Romania	Gyumri, Armenia	Rome, Italy	Sofia, Bulgaria
Dehra Dun, India	Kampala, Uganda	San Juan, Argentina	Tehran, Iran
Dhaka, Bangladesh	Kathmandu, Nepal	San Salvador, El Salvador	Ulaanbaatar, Mongolia

The authors of this paper have served as project coordinators, developing worksheets to gather information from the designated city representatives, compiling and analyzing the requested information for each participating city, moderating an internet forum for the city representatives and invited international advisors, keeping participants informed of the project's status, and writing the project final report and city profiles.

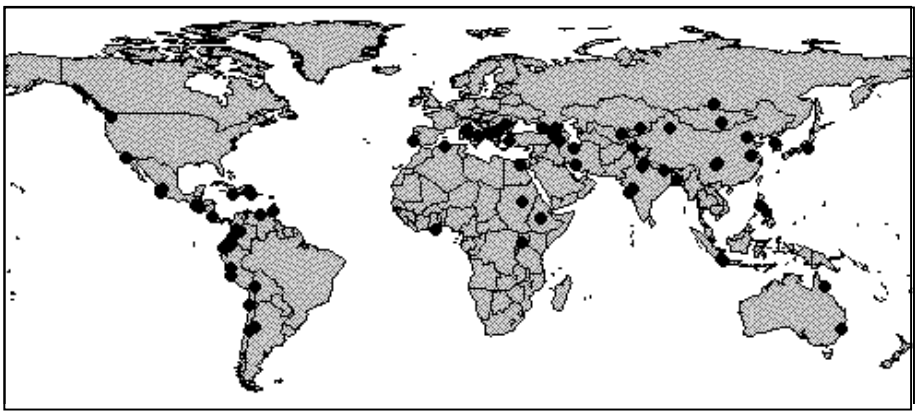

Figure 1: Map of the 74 cities that applied to the UUSRAW project

BACKGROUND: THE EARTHQUAKE DISASTER RISK INDEX

The Earthquake Disaster Risk Index (EDRI) provided a framework for the UUSRAW project's worldwide comparative urban earthquake risk assessment. Introduced in 1997, the EDRI is a composite index that compares metropolitan areas according to the magnitude and nature of their earthquake disaster risk [Davidson 1997, 1998]. The index aims to allow direct comparison of the relative earthquake disaster risk of different cities, and to describe the relative contributions of various factors (e.g., hazard, vulnerability, emergency response and recovery capability) to that risk. The EDRI is analogous to the Human Development Index and the Consumer Price Index, but instead of assessing relative levels of development in various countries or relative price levels in different years, it assesses relative levels of earthquake disaster risk in various metropolitan areas. It may demonstrate, for example, that the earthquake disaster risk in Mexico City is about the same as the risk in Jakarta, but significantly less than the risk in Tokyo. Examining the components of the EDRI could indicate that while the risk in one city is mostly the result of the vulnerability of the infrastructure and insufficient emergency response and recovery capability, the risk in a second city is due primarily to the high frequency of earthquakes, and the risk in a third city is driven by the number of people and structures exposed.

The development of the EDRI required three steps: (1) creating a conceptual framework of all the factors that contribute to earthquake disaster risk—geological, engineering, economic, social, political, and cultural factors; (2) identifying measurable, scalar indicators to represent each of the factors in the framework (e.g., population, per capita Gross Domestic Product, percentage of the urbanized area that is soft soil); and (3) defining a mathematical model to combine the indicators into the composite EDRI that best represents the concept of earthquake disaster risk. In its current form, the conceptual framework suggests that five main factors contribute to a city's earthquake disaster risk: Hazard, Exposure, Vulnerability, External Context, and Emergency Response and Recovery Capability. The mathematical combination involves scaling each indicator with respect to the mean and standard deviation for the sample of cities, using a weighted linear combination to combine them into indexes that represent each of the five main factors, then combining the five factor indexes into the EDRI. Davidson (1997 and 1998) describe the mechanics of the EDRI and its development in more detail.

A few key features of the EDRI have implications for the UUSRAW study. First, it attempts to measure the risk of an urban earthquake disaster. This is a broader concept than just the expected frequency of future earthquakes, or even their expected impact in terms of number of deaths, injuries, or damaged buildings. An earthquake disaster is considered to be a function of not only the expected physical impact of future earthquakes, but also the capacity of the affected city to sustain that impact, and the implications of that impact to the city and to world affairs. Second, EDRI analysis results are valid only for the greater metropolitan areas as they are defined by the boundaries established at the outset of the analysis. Third, EDRI results can be interpreted only in terms of the mean and standard deviation of the sample of cities in the analysis. As a result, the index conveys a city's risk only as it is understood relative to the mean risk for a specified sample of cities, not on an absolute scale.

In the UUSRAW project, the EDRI methodology has offered a helpful structure with which to conduct a systematic, easily accessible discussion of earthquake risk that includes issues related to all disciplines, to academicians and practitioners, and to all regions of the world.

WORK PLAN

The project design has two principal components. First, each city representative gathers the information required to develop an earthquake risk profile and to gain a better understanding of his city's earthquake risk and risk management practices. Second, throughout the project's duration, city representatives share their experiences in gathering the requested information and their thoughts on the form and usefulness of the EDRI and the project.

Data Collection

The project coordinators created worksheets requesting: (1) the earthquake risk information necessary to determine the cities' EDRI values, (2) information about earthquake risk management efforts that have been undertaken in each city, and (3) feedback on the experience of gathering the requested data, the form and usefulness of the EDRI, and the project design and management. The requested risk information included the EDRI indicator values, associated estimates of uncertainty, and some important background information (e.g., a list of key developments in the city's seismic building code). The risk management information worksheet requested: (1) responses to an overview survey that aimed to determine, of all possible risk management efforts, which efforts a city has made, and (2) detailed descriptions of five specific risk management efforts that have been undertaken to reduce the earthquake risk in the representative's city. The worksheets were distributed to the city representatives who then completed and returned them.

Data Compilation, Analysis, and Review

The project coordinators compiled the requested earthquake risk information into a Microsoft Excel database that organizes the information, automatically computes the EDRI and five factor values for each city, and presents the results in tabular and graphical form. Using a computer program written for the purpose, a sensitivity analysis was performed to assess the robustness of the EDRI analysis results, given the uncertainty in the input data. Estimates of data uncertainty were supplied by city representatives. The earthquake risk database and the results of the sensitivity analysis were distributed to the participating city representatives to give them an opportunity to review the input data and results, and to experiment with the EDRI methodology by investigating how changes in input values, weights, or other parameters affect the EDRI results.

After incorporating the city representatives' feedback, the results of the EDRI and sensitivity analyses were finalized to provide a foundation for the comparative assessments of earthquake risk in the participating cities. Project coordinators also compiled databases of the requested earthquake *risk management* information and the feedback on the EDRI methodology and the project. The risk assessment analysis, risk management information, and feedback are now being incorporated into the project's final report and the compilation of city profiles that describe the key elements of each city's risk and risk management efforts in a consistent, systematic way.

Local Participation

The project centers on local participation for several reasons. The integral involvement of local professionals improves the quality of the final comparative urban risk assessment because local professionals have access to information that is unavailable to outside researchers, a valuable intuitive understanding of their own cities, and insight into the ways in which the risk assessment results can be used to reduce future losses in their cities. Moreover, local participation improves the chances that the assessment will lead to real risk management activities, and benefits the participants in several ways. Through their participation, city representatives gain a better understanding of their city's risk and risk management practices, and how they compare to those in other cities. Through the project's internet forum, local representatives are able to voice their ideas and concerns, and learn from the comments of others. They establish valuable connections with other earthquake professionals worldwide, and are able to participate in the analysis of the information collected.

Use of the Internet

The study relies on the internet as a vehicle for implementation. Worksheets were distributed and collected as email attachments. Email has facilitated administrative communication between the project coordinators and participants. Most importantly, an internet forum lasting the duration of the project has provided a way for all participants to discuss the project methodology and how to develop and present the earthquake risk information so that it is most understandable and useful to the public, government officials and other stakeholders. Using the internet has reduced project costs significantly by virtually eliminating the need for travel, and has enabled implementation of a truly global project that included participants from around the world. While the experience

has highlighted a few logistical difficulties associated with coordinating a large group of geographically dispersed participants (e.g., inter-regional differences in computer capabilities and language), the success of the project suggests that the internet is a valuable tool for enabling future global endeavors.

Final In-Person Meeting

Although the internet forum provided city representatives with a valuable means to communicate and discuss issues related to the project and urban earthquake risk, many city representatives have expressed their desire to have an in-person meeting that will allow them to review the project results, attempt to reach consensus on some of the issues that have been raised in the internet forum, and develop a plan for possible future projects to outlast the end of UUSRAW. Since an in-person meeting will complement the internet forum by allowing an intensity of discussion that is difficult to achieve via email, a session is being planned to take place during the RADIUS Symposium in Tijuana, Mexico in October 1999. The most actively participating city representatives will be invited, and their attendance will be sponsored by the United Nations.

PROJECT FINAL REPORT

The UUSRAW project will produce a final report that includes five main components: (1) description of the project design, (2) summary of the assessments of earthquake risk and risk management in the participating cities, (3) discussion of the city representatives' feedback, (4) compilation of the city profiles, and (5) compilation of specific risk management efforts undertaken in the participating cities. Each is discussed in turn below. More results will be provided in the presentation at the 12WCEE. The final report will be published and disseminated by the United Nations.

Project Description

To provide a context in which the results can be understood, the report will describe the rationale for the project, relevant background, its objectives, how it was implemented, and participant information.

Assessments Summary

The report will provide comparative assessments of the earthquake risk, the relative contributions of its contributing factors (e.g., hazard, vulnerability, emergency response and recovery capability), and the state of risk management in the participating cities. The assessments will be based on the EDRI and sensitivity analyses, and the databases of locally provided information. Because the information for each city was gathered using the same worksheets, it will be possible to provide descriptions of the key elements of a city's risk and risk management efforts in a consistent, systematic way.

For example, the analysis suggests that Tehran and Dhaka both have high earthquake disaster risk *relative to the other cities participating in the project*. By examining the components of the risk, it appears that Tehran's relatively high risk is primarily due to its large exposure. It is the most populous city in the sample, with 10 million residents, and it has the second highest per capita Gross Domestic Product behind Rome. Dhaka's risk, on the other hand, seems to be driven by its Vulnerability (because of its high density, fast development, and low income), its Exposure (it is the second largest city in the sample, with 7.3 million residents), and its limited Emergency Response and Recovery capability. As another example, Exposure also plays a significant role in creating Santiago's risk. Unlike Dhaka and Tehran, however, Hazard is the factor that contributes most to the relative earthquake disaster risk in Santiago. Santiago has significant long-term seismicity relative to the other cities in the sample, with a 500-year return period peak ground acceleration of 0.82g.

City Representative Feedback

The report will summarize the feedback that city representatives have provided throughout the project. The input will be compiled from responses to a worksheet designed especially to solicit feedback, the discussion on the internet forum, and the in-person meeting at the RADIUS Symposium. The feedback relates to the EDRI methodology, the project design, potential uses and users of the study's results, global earthquake risk assessment in general, and the potential for conducting related work in the future.

For example, some city representatives suggested including indicators in the EDRI to represent the landslide hazard and induced hazards, e.g., dam failure. Others discussed issues particular to those cities with large informal or squatter settlements, or large seasonal tourist populations. Many city representatives felt the use of

the internet was an effective way to implement the project, and most thought that a risk-based ranking of cities would be an effective way to help raise awareness and prompt government risk reduction actions.

City Profiles

For each of the participating cities, project coordinators are developing a two-page profile of the city's earthquake risk, its causes, and efforts that have been undertaken to reduce it. Each city profile includes a map of the greater metropolitan area, basic information about the city, significant historical developments in the seismic building code, a graph of the city's historical population growth, a list of significant historical earthquakes, a comparative analysis that describes the city's earthquake risk in relation to other cities worldwide, a list of agencies involved in earthquake risk management in the city, and examples of efforts undertaken to reduce the city's earthquake risk. Figure 2 presents an example of a city profile for Algiers, Algeria.

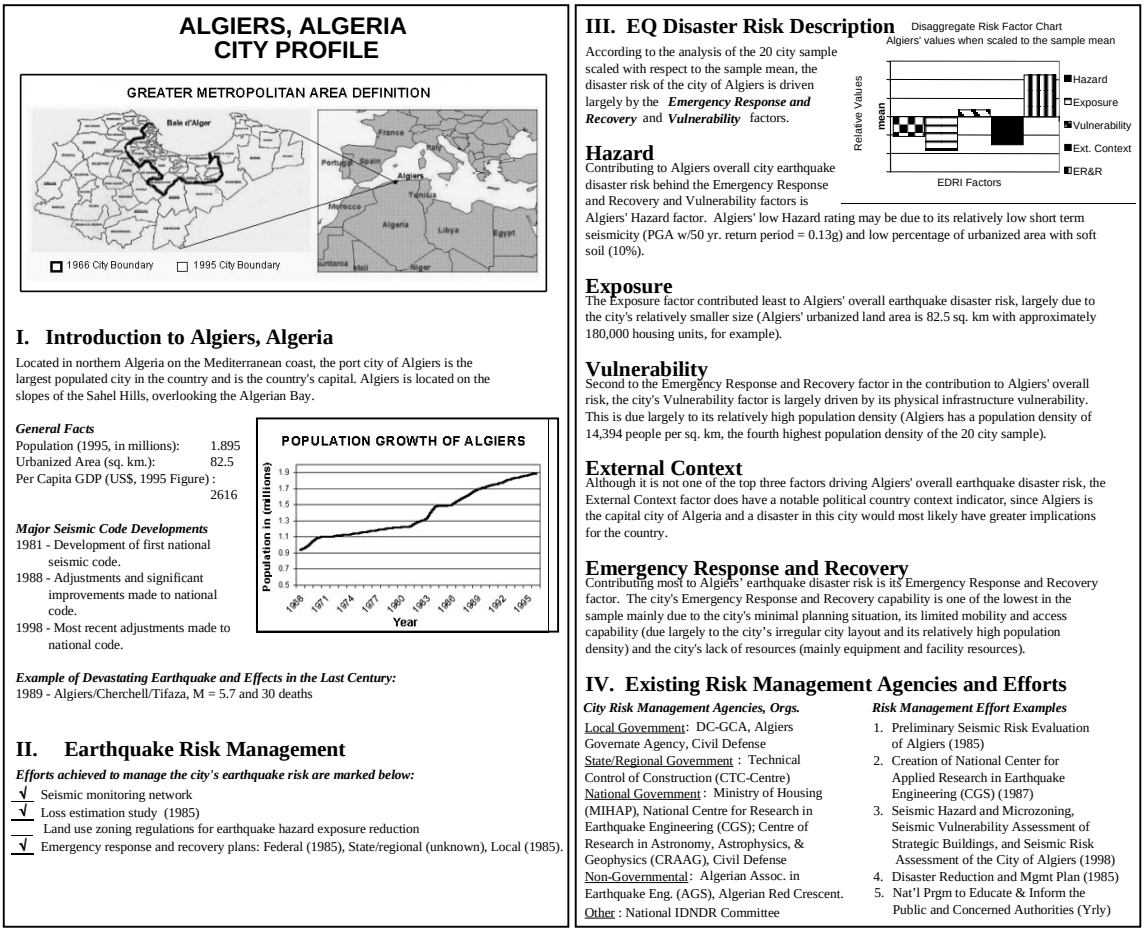

Figure 2: Example of a city profile for Algiers, Algeria

Risk Management Effort Case Studies

The final report also includes a compilation of more than 60 risk management effort case studies from 27 cities. Together they cover a variety of types of efforts. They were implemented by different groups (e.g., local government agencies, private sector), target different groups (e.g., schools, transportation network, small businesses), target different needs (e.g., emergency response planning, infrastructure strengthening, public education), use different forms of implementation (e.g., establishing an organization, developing a new technology, passing legislation), and they cover different areas (e.g., local, state, national).

While the EDRI focuses on the magnitude and causes of a city's earthquake risk, in order to achieve the UUSRAW study's ultimate goal of reducing real earthquake risk, this portion of the UUSRAW study highlights what has been done to address that risk by not only defining the dimensions of the earthquake risk challenge, but

also helping cities to address that challenge. Specifically, the risk management case studies were gathered to serve two main purposes. First, the compilation, which can be expanded and updated over time, can provide city representatives with specific risk management ideas and contact information should they wish to obtain more information. It will help facilitate the general sharing of risk management experiences among cities. Second, the compilation may be used to help determine which cities are making significant earthquake risk management efforts, so that those cities can be recognized publicly as positive examples for others to follow. A future effort to publicize these "best practices" might be a way to motivate future risk management efforts.

While city representatives were given total freedom in deciding which five risk management activities to highlight, they were asked to describe them using a common format, again to facilitate comparison among them. Figure 3 illustrates the format used for one effort undertaken by Kathmandu, Nepal. Four other case study efforts are described briefly below.

Name of Project: Disaster preparedness training for Kathmandu Metropolitan City officers
Description: Officers of KMC government departments (e.g., Public Works, Security, Communication & Information, Urban Development Planning, Public Health, Solid Waste, Law and Litigation) were taught how to train their respective departments in disaster preparedness. A training community representing each responsible department was formed to provide emergency organization and to help identify earthquake prone areas.
Effort maker: Disaster Management unit of Social Welfare Department, in collaboration with Lutheran World Service, an International Organization working for Disaster mitigation & preparedness and professional organization.
Targeted recipients: Officers of the different faculty of Kathmandu Metropolitan City.
Targeted needs: Emergency response planning, infrastructure vulnerability, public education.
Form of implementation: 1) Initiation of a program, 2) establishment of an organization
Level of implementation: Community as well as city.
Evaluation of success: Benefits include the following:

- Production of resource people and skilled manpower within the authorized level for proper planning and preparedness.
- Handle community level training independently through the organizational level.
- Organizational capacity building of Metropolitan City in Disaster Management.

Contact information: Social Welfare Department, Kathmandu Metropolitan City, P.O. Box No. 13512, Fax: 977-1-229242, E-mail: kmc@social.mos.com.np
Year of implementation: 1998

Figure 3: Example of risk management effort case study submitted by the city of Kathmandu, Nepal

Gyumri, Armenia described the creation, in 1997, of the Gyumri Branch of For Sustainable Human Development (FSHD). FSHD is a public, non-political, non-governmental, non-profit Armenian organization that seeks to develop seismic hazard and risk assessments, minimize disaster consequences, and improve emergency response and recovery. The organization was founded through partnerships among an interdisciplinary group of private individuals, government officials, and professionals.

Pimpri, India described a 1997 effort in which the Pimpri Chinchwad Municipal Corporation incorporated Geographic Information Systems (GIS) software into the operations of all city departments (e.g., Development Planning, Water and Drainage, Electricity, and Traffic and Roads Departments) for use as a decision making tool in the event of a disaster situation and at other times. The GIS system can be used, for example, to identify the locations of hazardous areas, hospitals, and fire stations, and to illustrate the fastest routes to hospitals.

In Tehran, Iran, the Ministry of Housing and Building and the Tehran Municipality have worked since 1985 to improve and better enforce regulations for structural design and construction. Two pieces of legislation were passed to update the earthquake resistant design codes, and to implement more stringent technical supervision and quality control in applying them.

Santiago, Chile described the Integral Plan for the Safety of Schools. Led by the Regional Office of Emergency and the Ministry of Education, the program establishes a standard process for the development of specific safety plans in each school and its surroundings. The process involves authorities, teachers, parents and students, with the support of the police and fire departments and health sector.

WORLDWIDE NETWORK OF EARTHQUAKE PROFESSIONALS

The project's second main contribution is less tangible than the final report, but equally important—the development of a new network of earthquake professionals that spans more than 70 cities, and 50 countries of the world. The professionals represent a variety of disciplines, and cities with diverse earthquake risk and risk management situations. In particular, twenty of the individuals are active, interested participants who have already established a basis of common understanding through this project, have gained experience collaborating via email, and most of whom, will meet together at the RADIUS October 1999 Symposium.

This network will be an important resource for formal projects, either following up the UUSRAW project in particular, or for similar future work. It will also provide valuable contacts for informal interaction, particularly for representatives of cities that do not have a great deal of internal earthquake risk resources.

FUTURE WORK

The UUSRAW project represents a significant step in helping cities share experiences and learn from each other more effectively, but challenges remain (1) to improve, expand, and apply the UUSRAW risk assessment methodology, and (2) to capitalize on the network of earthquake professionals that has been established.

First, there is still work to be done in developing a technically sound, widely accepted assessment of the earthquake risk and risk management practices of cities worldwide. Future efforts to improve the project's methodology should include more thorough validation, incorporation of the local input gathered in the UUSRAW project, and more comprehensive review by the worldwide community of natural disaster risk experts. The UUSRAW study should be expanded to include coverage of more cities and more hazards (e.g., tropical cyclone, flood). Finally, efforts must be undertaken to actually use the global comparative risk assessment to try to raise public awareness, motivate mitigation efforts among government officials, and help international development organizations improve the efficiency of their strategic planning and resource allocation. The authors of this paper are continuing work towards these objectives. In addition, city representatives from San Salvador have already used the results of this study to raise awareness and prompt a discussion among representatives of the city's various sectors. They hosted a meeting attended by more than 20 people, in which the UUSRAW project was presented and used as a framework for discussion about earthquake risk and risk management in San Salvador. The event was covered in the city's major newspapers and on national television.

Second, the worldwide network of earthquake professionals that has been established in this project represents a valuable resource that should not be wasted. The participating city representatives have expressed interest in continuing to foster the development of partnerships with each other by participating in follow-up projects. Suggestions for follow-up studies are being collected from city representatives now, to be presented and discussed at the October 1999 RADIUS Symposium meeting.

ACKNOWLEDGEMENTS

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