

## Use of earthquake damage scenarios for cities of the 21st century

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**ABSTRACT:** Earthquake damage scenarios can play an important role in mitigating the social and economic consequences of future urban earthquakes.

The earthquake risk of large cities is outlined in the first three papers. By the year 2010, the majority of human population will be located in cities. These newer, larger cities will be more vulnerable to earthquakes than their predecessors. Through an accident of geography, much of the population of the developing world lives close to tectonic plate boundaries, where great earthquakes have occurred and will occur. Not only is the cost—in lives and dollars—proportionately greater in developing countries than in the industrialized world, but this higher relative cost is likely to increase in the future.

The techniques for making and using earthquake damage scenarios to mitigate earthquake hazards in Los Angeles and Tokyo are described next. The State of California has made earthquake damage scenarios for the most populated areas of the state. The City of Los Angeles used one such scenario in order to train emergency response officials and to promote planning, mitigation and preparedness measures. Motivated by the devastating earthquake of 1923, Japanese officials have repeated and refined exhaustive evaluations of the earthquake vulnerability of Tokyo since 1970.

The use of earthquake damage scenarios in meeting the needs of international disaster management agencies is discussed in the next three papers. The activities of the Office of the United Nations Disaster Relief Coordinator stress the relationship between earthquakes and development. A means of estimating the magnitude and distribution of expected losses in Mexico City due to future earthquakes has been developed since the 1985 earthquake. Earthquake damage scenarios also might be used to provide information immediately following a disaster. A damage and casualty model could incorporate updates on event parameters and generate priorities for search and rescue operations.

The final two papers summarize how earthquake damage scenarios could meet the needs of international insurance companies. The reasons for the insurance industry to develop earthquake hazard estimates are numerous and concern the very viability of the industry. Experience over the last decade has changed the scientific, economic and technical aspects of earthquake risk assessment. Currently available mathematical models are more advanced than the input data, suggesting the need for commonly accessible scientific data banks.

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### SESSION I. EARTHQUAKE RISK OF MEGACITIES

#### *Global urbanization*

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This paper examines the history and patterns of urbanization in different regions of the world. Understanding the reasons for changes in patterns of urbanization—primarily the rural-urban shift—in the

context of technological change and the corresponding economic structure help explain the increase in the vulnerability of cities to natural disaster. A knowledge of the effects of increased vulnerability on extractive industries, fabricative sectors, distributive sectors, and service sectors, and the responses of these sectors to such pressures can help policy makers formulate effective measures to mitigate the effects of natural disasters and to reduce

the vulnerability of cities to disasters. The paper examines the environmental effects of tremendous concentrations of people on a relatively small land area; it looks at the type of vulnerability urban areas face.

In two decades, most of the population of the world and most of its economic activities will be located in urban agglomerations for the first time in history. The urban population will be larger than the total population of the world in 1970. The structure of the world economy will have changed from rural agrarian to urban fabrication, trade, and services. Incomes will have risen as labor productivity increased. Vastly greater quantities of energy will be consumed. The enormous concentration of people and the structures that will have to be built to accommodate them and their activities will create urban environments of unprecedented magnitude. Simply building these environments is a heroic task. Making them habitable, healthy, safe, and invulnerable to natural hazards at acceptable levels seems beyond the accomplishable.

The implications are that the highest priority for all our efforts is to devote our attention, time, and resources to shaping the enormous urban environment that is emerging. Human and financial resources must be drastically reallocated from other tasks to cope with what will otherwise be overwhelming urban problems. Too much of our efforts to assist developing countries have for too long been focused on rural production and rural populations which are of ever diminishing relative magnitude and importance. Priorities must be revised.

*Earthquakes and megacities: present concern for future disaster*

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Through an accident of geography, much of the developing world's population resides close to plate boundaries where great earthquakes have occurred and will continue to recur. Three factors render this an observation of concern: a rapidly rising population in the developing nations, a migration from the countryside to cities which places unprecedented demands on the construction of dwelling units and urban infrastructure, and an unhealthy world economy favoring the construction of low cost housing unfettered by earthquake resistant building codes.

Populations at risk from future great earthquakes in the developing nations live near convergent and transform plate boundaries in the Middle and Far East, Indonesia, and Central and western South America. The populations at greatest risk are those in cities with populations greater than 2 million, so called supercities, many of which have grown to this size in the past decade. Many of these same cities

and others, especially those in the developing world, will double in size in the next several decades. The pressure to provide shelter in these supercities is relentless and is often undertaken within local economies that favor cost-cutting construction methods.

The recurrence time of great earthquakes at plate boundaries varies from several decades to several centuries, time periods that are long compared to a human lifetime. It follows that residents of plate boundaries are complacent about earthquake risk. However, the lifetime of a building is comparable to the recurrence time of great earthquakes, and many of the buildings that will threaten life in future earthquakes are currently in the planning stage.

The urban planners of today are responsible for safety in the cities of their descendants. However, unless given a clear signal by seismologists, urban planners are likely to share the complacency of their fellow residents, and to bend to economic pressures that may ignore considerations of earthquake risk. Clearly, seismologists of this decade must make a considerable effort to characterize future seismic hazard in unequivocal terms. Unless they make this effort they must be prepared to share the burden of responsibility for future disasters.

*Socioeconomic consequences of past earthquakes in Latin America and some considerations about their future impact*

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Earthquakes cause proportionately greater casualties and losses in developing countries than in the industrialized world. This is mainly due to a) the characteristics of human settlements, and b) the extraordinary pace assumed by the process of urbanization. The combination of both factors results in a higher proportion of the population living in more vulnerable conditions with respect to the occurrence of geological phenomena in the countries of the Third World.

It is highly probable that this comparatively greater negative socioeconomic impact of earthquakes in developing countries will increase in the future. A number of factors, including the nature of the technological changes likely to take place and the mutations likely to occur in the patterns and sources of energy utilized, seem likely to exacerbate this difference in coming years. Existing records indicate that, between 1846 and 1978, 34 major natural disasters occurred in Latin America and the Caribbean which caused the death of approximately 1.2 million persons.

A comparison of losses related to the gross national product (GNP) that give an idea of the relative impact of earthquakes in Latin America shows that earthquakes typically exceeded 5% of the total GNP in the year they occurred. It was also

observed that the weaker economic position of the country, the greater the relative impact of the damages on the national economy. For instance, the losses caused by the earthquake that struck the

capital of Mexico in 1985 represented only 2.8% of the GNP, whereas the one which occurred in Managua, Nicaragua in 1972 produced losses that exceeded 75% of Nicaragua's GNP.

## SESSION II. EARTHQUAKE DAMAGE SCENARIOS OF LOS ANGELES AND TOKYO

### *Techniques of making earthquake scenarios in California*

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Since 1982, the State of California has been developing and publishing earthquake scenarios that include the hypothetical effects of earthquakes in the most populated areas of the state. Designed to give a realistic image of the anticipated disaster, scenarios teach us an important scientific lesson about the affected resources: some will be usable and some will be unusable. By pinpointing the areas where extensive damage is likely, scenarios highlight occasions where search and rescue will be needed and where alternative lifeline facilities need to be developed for that effort.

Through historic and paleoseismologic analysis we have determined which urban areas of the state are likely to suffer major earthquakes in the next few decades. Five earthquake planning scenarios have already been prepared and two more are in preparation. Each of these documents has become the centerpiece of planning for earthquake recovery in its respective region. Although the scenarios are hypothetical, they are founded on the latest scientific and engineering information.

The first phase of the work, involving the preparation of a seismic intensity distribution (SID) map, includes: 1) selection of the scenario earthquake, including its epicenter, magnitude, extent of rupture, and amount of ground displacement, 2) computer generation of a seismic contour map showing the reduction in bedrock shaking intensity as a function of distance, 3) superimposition of the contour map on a suitable geological map for calculation of the amplification effects expected from soft bedrock and alluvium, and 4) delineation of areas of potential ground failure due to fault rupture, soil liquefaction, and landslide. **The resulting SID map predicts the Modified Mercalli isoseismal distribution and the areas of ground failure.**

The second phase of the work, involving preparation of maps showing the likely effects of the disaster on the most important lifelines, includes: 1) superimposition of the SID map upon a map of the lifeline to be analyzed, 2) assessment of the damage expected at critical points along the lifeline, and 3) the degree of repair expected within the first three days after the earthquake. The assessment relies on data from similar lifelines that were subjected to

similar levels of shaking or ground failure during previous earthquakes. These assessments are reviewed by structural engineers and officials in charge of each lifeline. New site-specific information brought to light in this way is added to each assessment.

Although no scenario has been fully tested, the Loma Prieta M 7.1 event of 1989 produced damage that was predicted in 1982. Preparation techniques are being continually updated to include the inevitable surprises and new developments in predicting shaking intensity and ground failure.

### *The use of earthquake damage scenarios by the City of Los Angeles*

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Large cities like Los Angeles face special earthquake risks due to the vast numbers of people and amount of both public and private investment at risk. The interdependencies in their socioeconomic systems and physical infrastructure and lifelines are complex. Moreover, these cities often have both uncontrolled urban sprawl and older, more densely populated sectors characterized by seismically vulnerable structures. Local officials in these urban population centers constantly face public policy decisions which directly impact their cities' vulnerability to disaster, but all too often they are handicapped in making appropriate risk management decisions by a lack of sound risk assessment data. If vulnerability is to be reduced, if localities are to adopt hazard reduction programs, good hazard and risk assessment information must be available and accessible to decision makers.

The seismic risk faced by Los Angeles, known for generations, is only in recent years becoming well understood. Earthquake scenarios, beginning with the publication in 1982 of the California Division of Mines and Geology (CDMG) Special Publication 60, gave substance to the earthquake threat and made the risk and the potential impacts real and convincing. They provided a realistic basis for training and exercises, and better data for decision making, thus serving as a marketing tool helping the City promote planning, mitigation and preparedness measures. Also, they paved the way for further needs-based research.

The City has responded to these scenarios with a variety of actions. Armed with insight into actual

expected patterns of damage to our lifeline systems, we formulated new planning partnerships with utilities, the business community, and other governmental agencies whose cooperation would be needed in responding to and recovering from destructive events such as those described in the scenarios. A business-government coalition named the Business and Industry Council for Emergency Planning and Preparedness, or BICEPP, was formed, and it continues to thrive.

Response plans and exercises to test them were developed based on the scenario's damage projections. Public awareness events and media campaigns were initiated by the City and adopted by the State so that now each month of April is Earthquake Preparedness Month throughout California, featuring drills in schools, businesses, and government and a media blitz of public information. The sound scientific basis for the scenarios helped convince City policy makers to dedicate resources annually for enhancing response readiness and capacity for recovery. They also served as the source of data on which to base policy setting for recovery and reconstruction from earthquakes and other destructive events. The scenarios have been effectively used in Los Angeles for ten years.

*From macro scenario to micro scenario—damage assessment for Tokyo jurisdictions and residents*

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Tokyo has been the most earthquake-conscious city in Japan. This is understandable if you remember the disaster we had in 1923 which killed about 140,000 people in and around Tokyo. In addition, the south Kanto area is located in a zone of extremely high seismic hazards, where three tectonic plates interact with each other in a very complex manner.

The Metropolitan Government of Tokyo began seriously conducting seismic vulnerability studies in the early 1960's and the work accelerated after the 1964 Niigata earthquake. A systematic investigation began around 1970 on the assessment of seismic damage in the Tokyo metropolitan area, where about 8,650,000 people lived on 580 square km of land, by assuming a recurrence of the 1923 Kanto earthquake. The final report was published in June 1978, the month in which the Miyagi-ken-oki earthquake inflicted substantial damage on the lifelines of Sendai, population 640,000. The report was the first comprehensive damage assessment of a large urban area. An earthquake of magnitude 7.9 was assumed about 100 km from Tokyo. Though it is difficult to say how many years it took to complete the study because there had been a considerable period of preparatory investigations, I should say that about 15 years were spent.

The contents of the study may be summarized as follows:

Table 1. Contents of Tokyo Earthquake Study

- Ground motion severity and liquefaction
- Damage to wooden houses
- Failures of slopes and retaining walls
- Collapses of highway bridges
- Effects of fallen objects from buildings
- Damage to buried water and gas pipes
- Spread of toxic gases
- Conflagration following the earthquake
- Tsunami and earthquake-induced flooding
- Panic and loss of life

From the list of the contents, we see that the 1978 assessment placed emphasis on the primary, or structural, damage following the earthquake.

Table 2. Some statistics from 1978 assessment.

Collapsed wooden houses	62,000	(4.3%)
Burnt-down houses	473,000	(33.0%)
Failures of major distr. pipes (water)	220	
(gas)	670	
Death casualties	35,700	(0.41%)
Affected families	1,240,000	

In the conflagration assessment, a total of 300 fire breakouts was assumed, and the velocity and direction of the wind were also assumed. The final number of houses burnt down corresponds to the situation 24 hours after the occurrence of the earthquake.

Several years later, a similar assessment was made for the suburban area of Tokyo, where a population of 3,350,000 lived on 1,160 square kilometers, which was published as a report in 1985. The damages estimated were lighter than those estimated for the metropolitan area. Total death casualties were estimated at 1,660 (0.05%), and the death rate was 1/8 of that calculated for the metropolitan area. This difference had been expected because the population density of the suburban area was 2,900/sq. km, while that in the metropolitan area was 14,900/sq. km, both on average.

In this study, a network analysis of water lifelines was performed, and the effects of primary damages on the people in the affected areas were qualitatively investigated. For this study, a total of 10 years was required.

The study for the revised, second version of damage assessment was initiated in 1986 and the final report published in September 1991. This time, the metropolitan, suburban and island areas were all considered. The study was executed under the following nine subcommittees; ground motion and

soil, buildings, transportation facilities, lifelines, hazardous materials, fire, casualties, socioeconomic problems and damage on islands.

The study took five years, 500 million Yen (approximately 4 million US dollars) and about 100 people—including researchers from universities, practicing engineers from consulting firms and the Metropolitan Government of Tokyo—to complete. It is interesting to note that 15, 10 and 5 years were spent for the three assessment studies in chronological order. An annual progress report was made for each subcommittee and the total number of the pages of the progress reports for each year was approximately 2,000.

Table 3. Some Statistics from Recent Assessments

Total population (night)	11,800,000	
Total population (day)	14,000,000	
Total number of houses and bldg.	2,400,000	
Collapsed houses/buildings: (Wood)	133,000	
	(RC) 14,000	
	(Steel) 8,600	
Houses and buildings burnt down (first 48 hours)	633,000	26%
Conflagration area (metropolitan area alone)		23%
Impairment immediately following event:	(water)	8%
	(gas)	87%
	(power)	33%
	(phone)	28%
Number of deaths	9,400	
Number of families without houses	1,236,000	
Number of people without houses	3,200,000	

Some notes of clarification and background for the above-mentioned numbers:

### SESSION III. EARTHQUAKE DAMAGE SCENARIOS FOR MEETING THE NEEDS OF INTERNATIONAL DISASTER MANAGERMENTS AGENCIES

#### *DHA-UNDRO earthquake disaster mitigation activities*

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#### A. Earthquake disasters and development

For a long time, the close linkage between earthquakes and social and economic development was ignored, and development programs were not assessed with regard to seismic disasters. Neither the potential impact of disasters on development programs nor whether a given development strategy was likely to increase the severity of a given disaster's effects was considered. Earthquakes were seen in the context of emergency response, and not as part of long-term development planning.

a) About 2.2 million people commute daily to Tokyo from surrounding jurisdictions. Tokyo is not a closed city, and although the city itself has a population of over 12 million, the total population including the surrounding jurisdictions reaches about 30 million.

b) Impairment rates of power (33%) and phone (28%) are strongly affected by the fire.

c) The high impairment rate of city gas is due to the service shutdown for precautionary purposes.

d) Conflagration estimates were made assuming time, weather, season, etc. The earthquake (M7.9) was assumed to occur at 6 o'clock on a winter evening with the wind velocity of 6 m/s. The total number of fire breakouts were estimated at 758, of which 580 occurred in the metropolitan area.

e) Evacuation simulation was also incorporated, and this apparently reduced the number of deaths. Note, however, that the numbers related to fire were obtained from the results of only one case study.

Table 4. Estimates of lifeline recovery.

Water	4 - 7 days
Gas	18 - 26 days
Power	4 - 6 days
Phone	16 - 20 days
Sewer	22 - 66 days

A 15-minute video was made for educational purposes.

Some additional topics:

a) Damage assessment on a microscopic scale—an assessment in which each house can be identified.

b) On-line estimates of ground motion severity and damage for a large lifeline system.

Earthquakes were not viewed as events to be planned for before they occurred, and shifting development schemes to promote longer-term development and better preparedness for future earthquake disasters was not considered. Only recently have earthquake managers begun to recognize the disaster/development relationship.

Decision makers who ignore the relationship between disasters and development do a disservice to the people who place their trust in them. Development projects should in the future be pursued with disaster mitigation and disaster recovery in mind and should reflect a long-term development perspective.

#### B. DHA-UNDRO earthquake mitigation activities

During its 25 years of existence, the Office of the

United Nations Disaster Relief Coordinator (UNDRO), which is now an integral part of the UN Department of Humanitarian Affairs (DHA), has prepared and implemented a large number of disaster mitigation projects. Projects were designed with a view to protecting people, property and the environment against the destructive effects of natural and man-made disasters that might significantly slow the economic and social progress of the disaster-prone countries.

Disaster mitigation programs generally include and seek to coordinate two principal elements: prevention and preparedness, on the one hand, and relief, rehabilitation and reconstruction, on the other.

Depending on the context in which the earthquake event occurs, either a regional, sub-regional or single-country approach to disaster mitigation may be deemed most appropriate.

#### C. Earthquake disaster mitigation in Colombia (DHA-UNDRO project)

This comprehensive program covers a wide spectrum of all major disasters likely to occur in Colombia, including earthquakes, tsunamis, landslides, volcanic eruptions, floods and industrial hazards. The program also covers training for search and rescue and general disaster management coaching. Scenarios for six different disaster events have been developed for areas where natural or man-made hazards are likely to take place in the future.

In order to mitigate the devastating impact of future earthquakes on Cali and Manizales, two seismically hazardous cities, the following sequence of activities is being implemented:

- hazard evaluation
- risk and vulnerability assessment
- monitoring system
- technology and know-how transfer
- emergency planning
- mitigation measures: engineering, spatial planning, economic, management, institution building, societal
- integration of disaster mitigation considerations into development planning
- public information, education, training.

*A description of one state-of-the-art GIS, which might serve as a model for international earthquake hazard assessment*

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Since the September 19, 1985 earthquake in Mexico City, which produced severe damage to buildings in

the city's lake-bed zone, a great effort has been made to better understand the nature of ground motions and the seismic behavior of structures. Results from this effort have now made it possible to combine several sources of information to produce detailed estimates of seismic hazard and risk that would be expected due to the occurrence of postulated earthquakes. In this paper, we describe a model to estimate a) expected ground motions; and b) expected damage, based on intensity damage data derived for 14 classes of buildings representative of Mexico City construction. This information, along with the geographic distribution of construction density, allows computation of expected losses during a given event and their spatial distribution throughout the city. Results are presented by means of a Geographic Information System.

*Uses of earthquake damage scenarios to guide emergency response activity*

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Much of the emphasis in development of earthquake damage scenarios has been to provide loss estimates which might be compared with mitigation costs in order to identify rational levels of investment in earthquake hazard mitigation.

For this purpose current estimates of expected ground shaking and damage probability estimates related to building type have been adequate. These rather general scenarios have also been used for estimating the character and volume of post-disaster response needs.

However, there are immediate information needs in the post-disaster phase which could be met by a more dynamic application of earthquake scenario building. While errors in a simulation model tend to be cumulative and pre-disaster estimates are very unlikely to provide useful damage data for rescue operations, a model which could respond to updates on event parameters, duration, ground shaking and specific damage could provide "leading estimates" which would indicate likely search points and generate priorities for search and rescue operations and update logistical priorities and support requirements.

A damage and casualty model which could effectively incorporate actual post-event field operations could facilitate identification of specific secondary hazards as well as priorities for allocation of search and rescue assets. Reliability and specificity of these decisions would also be improved.

Such a dynamic model could also be of great assistance in the early estimation of relief needs for medical support, shelter, and food.

## SESSION IV. EARTHQUAKE DAMAGE SCENARIOS FOR MEETING THE NEEDS OF INTERNATIONAL INSURANCE COMPANIES

### *Earthquake hazard estimation by the insurance industry*

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Earthquake hazard estimation by the insurance industry has, generally speaking, not progressed beyond an embryonic state. This situation persists despite very heavy payments since the San Francisco Earthquake of 1906 and rapidly growing populations, concentration of values, and the vulnerability of risks insured and/or repair expenses. This paper therefore deals predominantly with desiderata and not with the situation prevailing today, although not few of those insurance companies concerned face bankruptcy in case a large city is affected by an earthquake catastrophe and face an especially great risk if several areas are hit.

The major reasons for the insurance industry to develop earthquake hazard estimations are:

1. Rating of earthquake risk is only viable if based on a sound assessment of the hazards. Technically correct rating, moreover, eventually determines not only the health of the individual insurance branches writing earthquake risks but, in the case several catastrophes coinciding, the fate of a company.
2. Underwriting, for instance, in terms of shares of earthquake business accepted, is only sound if professional hazard assessment has provided the information required.
3. Reinsurance of businesses must similarly be based on adequate knowledge of the specific and general hazards - unless a company is prepared to accept bankruptcy as a part of its business philosophy.
4. Catastrophe exposure (capacity required and available; solvency of companies, reinsurers and parties to whom business has been retroceded; and the reputation and survival of large sections of the market) can only be estimated if hazard scenarios have been developed in a professional manner.
5. Last but not least, many companies should acquire and use earthquake hazard expertise, as it is very undesirable for many reasons to depend on the opinion of a few sources.

The main fields of activity should be:

1. Event-probability functions for the different regions to permit establishing as accurately as possible the return periods of earthquakes of certain magnitudes, rupture characteristics, parameters of ground shaking and intensities.
2. Research into the questions of seismic gaps and local and global seismic trends.
3. Effects of hazards including liquefaction on particular types of regions and sites.
4. Vulnerability functions for all essential elements at risk which are or may be insured against direct damage, indirect damage and indirect economical losses in the widest sense.

5. Vulnerability functions for the exposure of people with respect to all essential parameters which contribute hereto.

6. Based on the above, earthquake damage scenarios should be developed in cooperation with other parties concerned and to the benefit of all exposed to these risks.

### *Practice of risk assessment and trends of world-wide risk in earthquake insurance*

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In consequence of the Guatemala earthquake of 1976 and its implications for earthquake loss potential in other, larger and more densely populated urban areas, the Munich Reinsurance Company proposed in the same year a zoning scheme for use in earthquake insurance. This scheme represented a comprehensive approach to the two basic problems of earthquake insurance, rate setting and catastrophic loss potential. The system comprises three different types of zones:

- the exposure zone
- the loss accumulation zone
- the accumulation assessment zone

Establishing exposure zones is intimately connected to the problem of rate setting. In order to introduce a mathematical basis and to guarantee worldwide comparability, a probabilistic zoning scheme had been suggested and applied in Munich Re's World Map of Natural Hazards of 1979 (completely revised in 1988). Probabilistic hazard mapping techniques have been used since then in numerous zoning projects serving insurance as well as other purposes.

The other vital problem, catastrophic loss potential, is addressed by means of loss accumulation and assessment zones. Assessment zones reflect the regional distribution of values-at-risk. They therefore have to be uniform for the whole insurance market of a country. They have also become known under the denomination CRESTA zones, named after an international insurance organization founded for the purpose of defining and introducing such zones in most countries with any significant earthquake risk. Loss accumulation zones describe the area affected by a catastrophic event. They are defined deterministically on the basis of earthquake scenarios and comprise usually several assessment zones. Thus, it is possible to calculate the expected loss as a function of the average earthquake intensities expected per assessment zone.

The future of risk assessment in earthquake insurance will be determined by several developments from the past decade:

- Scientifically, the Mexico earthquake of 1985

demonstrated the enormous influence of subsoil and other conditions on regional loss patterns, and in consequence on the projection of future catastrophic losses. The Loma Prieta earthquake of 1989 and the Philippine earthquake of 1990 confirmed the observations that within a very large area affected most of the damage happens within pockets of kilometer-size dimension. Future efforts should concentrate on identifying such highly damage-prone zones, above all in large conurbations.

· Economically, the mentioned earthquakes have demonstrated that the insured loss is only a fraction of the total loss even in a highly developed region like California. However, there is increasing pressure to make earthquake insurance available on a broader basis.

· Technically, PC program packages for probabilistic earthquake risk analysis have become available and are increasingly used in practice as a comprehensive tool for assessing rare catastrophic losses and projected overall loss experience.

It is fair to say, however, that mathematical models for risk assessment are far more advanced than the input data used. The trend of increasing risk as demonstrated by loss statistics over the last three decades makes it essential to create commonly accessible scientific data banks as a reliable basis for risk assessment. In spite of the advent of probabilistic risk analysis, the scenario approach is still supreme for estimating catastrophic losses, as more actors influencing the material damage can be taken into account, and consequential losses can be addressed in better detail.

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