PART IV: EARTHQUAKE DAMAGE SCENARIOS FOR INTERNATIONAL INSURANCE COMPANIES

Åke Munkhammar, Chairman

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THE INSURANCE INDUSTRY'S CONCERN WITH EARTHQUAKES

Åke Munkhammar, Skandia Group, Sweden

While we do not know very much about the various types of natural hazards confronting human civilization, such as ground motion, tsunami, volcanic eruption, and land stability following an earthquake, we actually know less about the location and character of insured values. Although this may sound like a simple thing to understand and keep track of, in reality it is quite complicated and seldom done by the insurance companies. Oddly enough, we are better off on a society level where national censuses often can provide good information on the whole stock of buildings. But the insurance industry is only interested in those buildings that are insured. If we manage to get information on three key aspects of insurance--hazard, vulnerability, and insured value--we can generate what we call a "probable maximum loss" (PML) estimate, which is essentially a type of damage scenario.

Earthquake insurance is more than protecting against physical damage to property. That is a big and important part of what earthquake insurance does, but there is also the question of fires caused by earthquakes. In some markets, like the United States, this protection is included in regular fire protection policies. In most earthquake-prone countries, however, insurance against earthquake-related fire is provided as an addition to the fire policy, for an additional, separate premium. Likewise, insurance against damage caused by tsunamis is usually purchased as an addition to the fire policy.

Another aspect of insured loss is the economic loss caused by the downtime of support systems and lifelines such as sewage lines, water lines, and power supplies. A standstill period for manufacturing plants, for example, means a costly downtime for the insurance industry. The "just-in-time" concept in manufacturing makes small slowdowns in the delivery of raw materials, or stoppages anywhere along a production line, cause very big economic losses. Disruption of "just-in-time" loops can multiply the economic damage caused by an earthquake.

There is also third-party liability, whereby the employer has liability for customers or clients injured on the work site during or immediately after an earthquake. Third-party liability is important in the United States. Personnel accidents can place great demands on both health insurance and life insurance companies. Automobile policies are affected, as a large proportion of building rubble typically falls on automobiles. All goods that move in and out of harbors or are onshore within harbors are normally insured under marine insurance transport policies. Bonding insurance covers loans, for example, on the construction of buildings. If a building under

EARTHQUAKE HAZARD ESTIMATION BY THE INSURANCE INDUSTRY

Herbert Tiedemann, Swiss Reinsurance Company, Switzerland

Consultants and university researchers often ask, "Why does the insurance industry not give more money for us to do more research?" Today I will discuss what we in insurance need: researchers should consider whether they are in a position to supply the needed data. If so, insurance companies would probably be quite interested in assisting them with their research.

A simple formula, that I developed 30 years ago, when property insurance and risk assessment were still in Paleolithic states, is:

$$X_{0/00} = \frac{LE * f * u * P * 100}{SI * R}$$

This formula shows what we require in order to assess the exposure, or insured risk, for any particular event. X is the rate we should charge in order for our ship to travel on an even keel. LE (loss expected or mean-damage ratio) needs to be determined as a sum or percentage. The overhead is f, the uncertainty or safety is u and the period of exposure is P. SI is the sum insured (full new replacement value) and R is the loss-return period causing damage equal to LE.

A reinsurance company professionally insures insurance companies against large losses. Insurance companies, though, are generally as clever as insurance brokers: both like to pass on risk to avoid the true gamble involved in insurance. Brokers appraise insurable risks to the insurance companies in the most beautiful colors and ask high brokerage fees for them. Meanwhile, the insurance companies worry that the risks might, in fact, not be quite as good or safe as the broker made them out to be. To avoid a potential catastrophe, they transfer the majority share of the risk to the reinsurer, letting the reinsurer pay for the mistake if something happens. The reinsurer is thus interested in minimizing the potential for catastrophic damage. The reinsurer must be safer than the insurer, and the insurer must in turn be safer than the engineers. This explains to some extent why reinsurers tend to be conservative.

Insurers are interested in the uncertainty associated with their risk assessment. Most engineers present their data on beautiful graphs without indicating the level of uncertainty associated with their projections. However, insurance people must have a clear sense of levels of uncertainty.

The insurance industry is also interested in the return periods, or annual probability, of high-

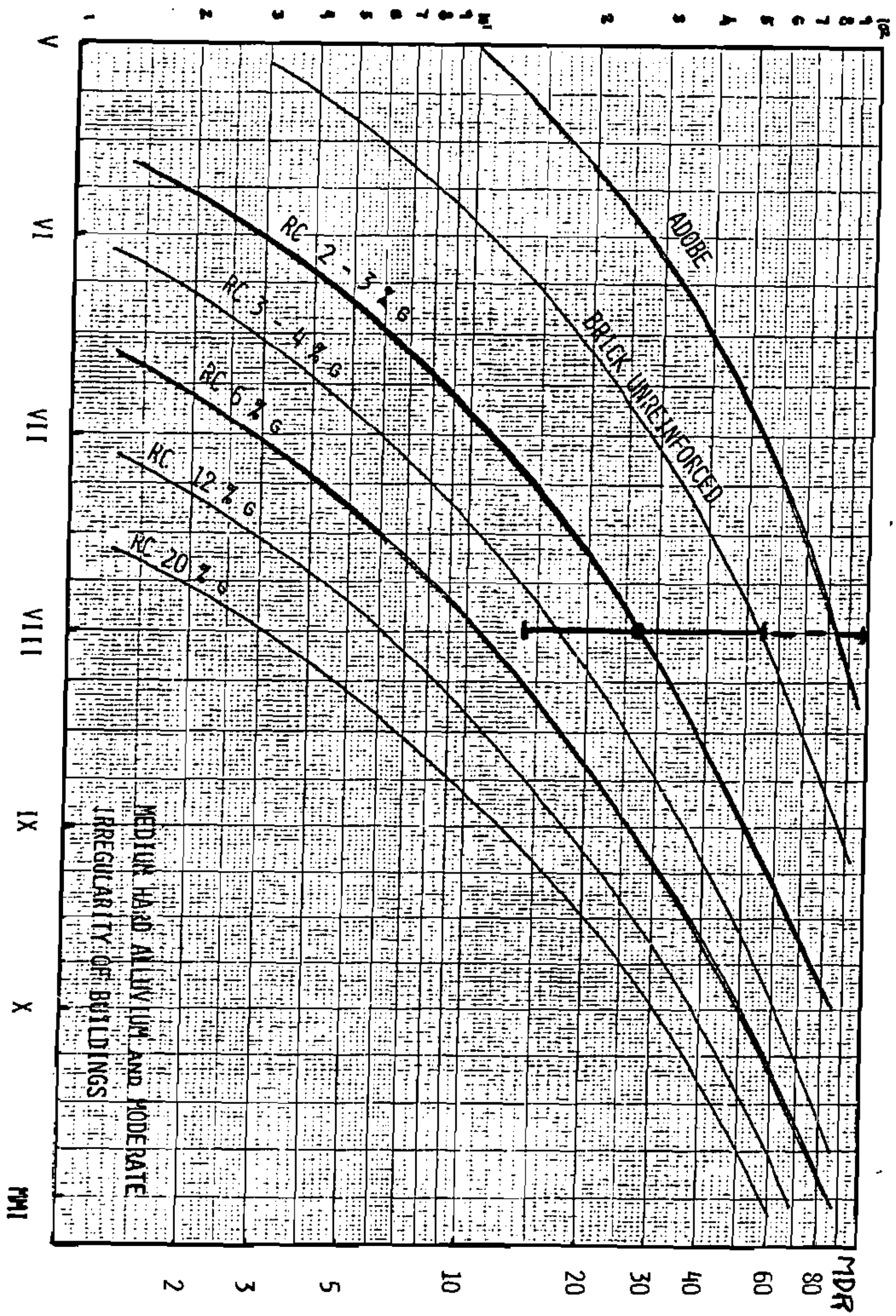

Figure IV.1 Graph of mean damage ratio as a function of shaking intensity and building type

It is important not to jump to conclusions when developing damage scenarios. California's attenuation calculations have been used to estimate damage for earthquake-prone areas worldwide. A paper written by the United States Geological Survey 20 or 25 years ago extrapolated from damage records of the 1906 San Francisco Earthquake to arrive at a magnitude of 9.5 for the Lisbon Earthquake of 1755. Attenuation in Portugal, however, is different from that in Northern California, and the extrapolation is based on a faulty premise.

Insurance companies also need to know the average size of the area affected by an earthquake. Obviously, the larger the area, the higher the probability that more than one city is involved and the greater the probable loss. Average-size estimates are a complicated matter.

Moreover, insurers require indications of seismicity, such as seismic gaps. Swiss Reinsurance Company is interested in refining its data on seismic gaps, but this would require additional research that the company is too small to afford to undertake by itself.

If such information is compiled and supplied to insurance companies, then perhaps even less developed insurance companies, which are quite numerous even in the industrialized nations, will be able to use similar formulas to assess earthquake damage and calculate suitable rates.

Dr. Tiedemann is an engineering consultant with Swiss Reinsurance Company, the second-largest international reinsurance company in the world. He worked for many years on engineering projects in Asia and has worked with the United Nations and various governments as a senior consultant and leader of international teams of experts.

TRENDS IN WORLDWIDE EARTHQUAKE RISK TO INSURANCE COMPANIES

Anselm Smolka, Munich Reinsurance Company, Germany

I will attempt to expound on the Paleolithic stage of risk assessment in the insurance business.

The insurance industry faces two basic problems. The first is premium calculation. The second is catastrophic loss protection or, simply, preparation to withstand losses associated with a major earthquake.

Efforts to assess catastrophic earthquake losses go back to the late 1970s, when, largely as a result of the 1976 Guatemala Earthquake, Munich Reinsurance Company developed a zoning system to address earthquake insurance problems.

In order to obtain information on the values at risk, we introduced so-called accumulation-assessment zones, which show the regional distribution of insured values. We also introduced loss-accumulation zones, which define the areas affected by a particular large earthquake.

For a specific insurance market in a specific country, it is essential to get uniform information on the regional distribution of values. To this end, an organization called Catastrophic Risk Evaluating and Standardizing Target Accumulations (CRESTA) was founded in the late 1970s. CRESTA is a loose association of reinsurance companies and some primary companies with worldwide business. It has recently added some insurance brokers. CRESTA was founded to develop uniform criteria for reporting insured sums in all countries that have significant earthquake risk.

Figure IV.2 shows an example of earthquake accumulation-assessment zones for Mexico. The country is divided into 19 zones. The Valley of Mexico was divided into four specific zones because of the peculiar soil conditions there (Figure IV.3). These zones were actually determined at a time when personal computers were in their infancy; therefore, the figures show a basic approach lacking in regional detail. One of Mexico City's four zones, a zone of soft subsoil previously called Zone C, was subdivided after the 1985 earthquake. The area that was heavily affected in 1985, 1979, and 1957 was designated Zone G, and the remainder of the lake-bed zone became Zone H.

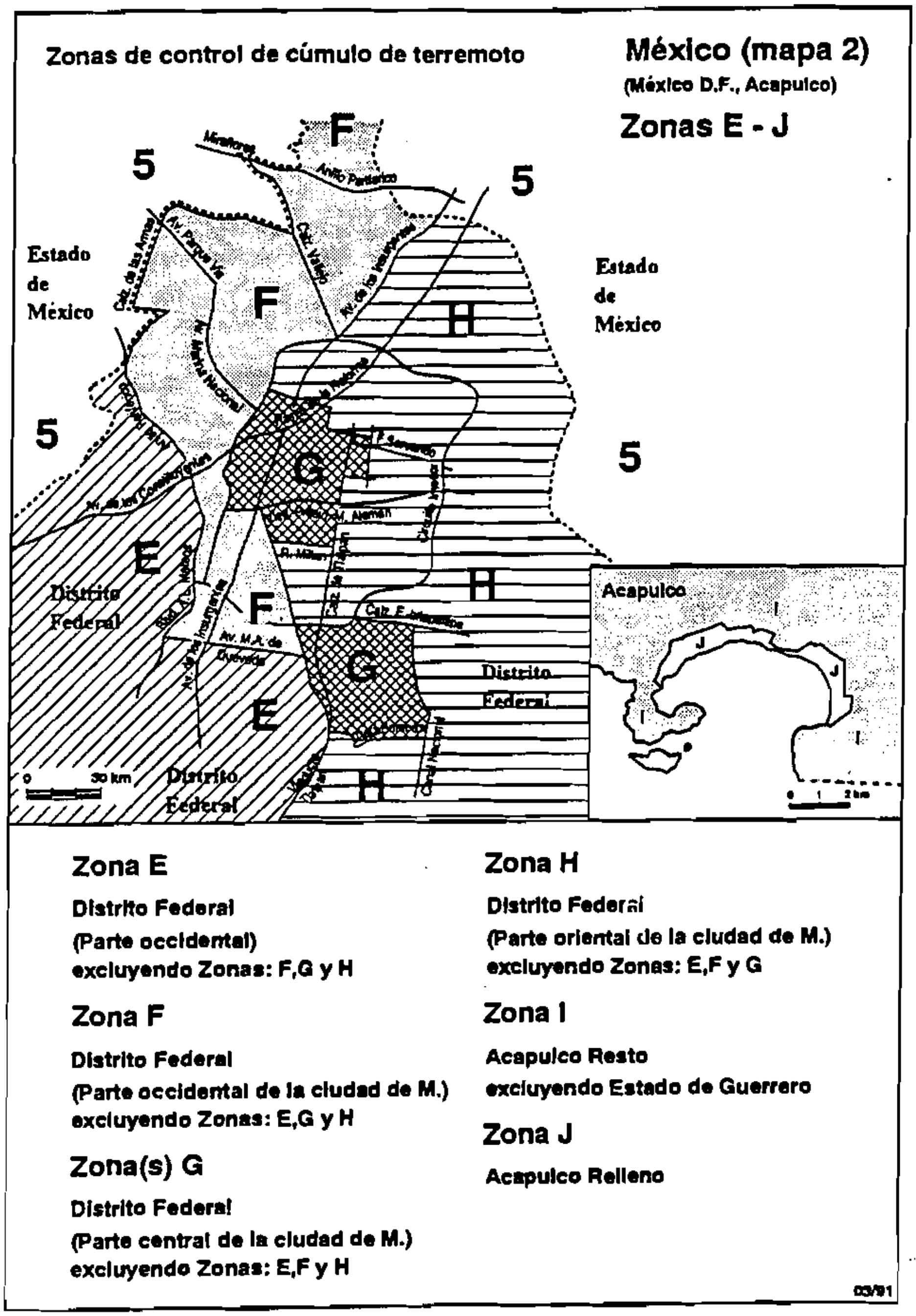

Figure IV.3 Earthquake accumulation assessment zones in the Valley of Mexico

Several events during the 1980s made clear the need for more details about regional distributions of insured values. The single most significant of these events was the Mexico City Earthquake of 1985. Table IV.2 shows the geographical loss distribution for that event based on insured damage. Ninety percent of the total insured losses were concentrated in a single zone, Zone C, of Mexico City. Ninety percent of that figure was concentrated in what since 1985 has been called Zone G; 2.5% of the losses were in the rest of the Valley of Mexico, and 7.5% were in the rest of the country, primarily on the Pacific coast.

Area	Distribution of claims (%)	Net claims rate (%)
Mexico City Zone "C"	90	4.5
Rest of Valley	2.5	0.1
Rest of Mexico	7.5	0.07

Table IV.2 Geographical loss profile, Mexico earthquake, 1985

Figure IV.5 shows the total losses caused by earthquakes in the last three decades. The thick black line gives the average dollar losses for each decade and shows a clear trend of increasing costs over time. Losses are listed in indexed figures tabulated in 1991 values. Solid bars indicate insured losses. These were minimal in the 1960s and only become a factor in the 1970s. The figure for total insured loss for the year 1976, which saw five large earthquakes worldwide, shows that only an extremely small fraction of the total loss was insured. The decade of the 1980s showed an increasing trend toward insured earthquake losses.

Several trends in recent decades have contributed to the increase in dollar losses: increasing values; increasing concentration of people in conurbations; increasing significance of consequential and infrastructure losses in the developing countries; and increasing insurance density, or numbers of people insured against earthquakes.

Generally, the focus of attention shifts with the increasing degree of a country's development from loss of life to monetary loss. Of course, what interests insurance companies primarily is monetary loss. On the other hand, the focus also shifts from large-scale assessment to assessment of smaller-scale areas because the highest loss potential is located in heavily developed and industrialized urban regions.

I have observed several trends of likely future developments in the insurance sector. The increasing threat of catastrophic earthquake damage will unavoidably cause some capacity problems following major events. There were horrible losses to the insurance sector due to natural catastrophes in the 1980s, and we can already observe that not as much capacity is available now as in earlier years. Loss potential now tends to be concentrated in pockets, as was seen in the Mexico City, Loma Prieta (Northern California), and Philippines earthquakes.

Probable maximum loss (PML) estimations must be improved in order to generate better-quality data. Microzonation would be a useful tool for improving PML estimates and thereby diminishing the degree of uncertainty in loss estimates. These are among the changes that would be necessary to optimize existing insurance capacity for the future.

There is obviously a need for risk data that are, on one hand, accessible and comprehensible to the manager or decision maker of a company and, on the other hand, sufficiently detailed to give a realistic picture of the situation. Earthquake scenarios are certainly an efficient tool for presenting risk data in a clear and easily comprehensible form. Several important qualifications to this statement must, however, be observed.

Scenarios should not present general solutions, but should instead specify problems and raise salient questions. After the Mexico City earthquake, I had a chance to analyze earthquake-related insurance losses company by company. The average percentage of loss suffered by different companies varied by a factor of 10. There is nothing approaching a general PML for a given insurance market, since PML for a particular earthquake may vary widely from company to company, depending entirely on the composition of that company's portfolio. But if the manager of an insurance company is asked what results he or she would like to see from an earthquake damage scenario, in 95% of the cases the manager will ask to see a PML figure for the area in question. The manager may not know exactly what is meant by that and will most likely be unaware that generalized PML figures are not very useful.

Earthquake damage scenarios must be sold to, and accepted as a useful tool by, the user. Selling to the user is just a starting point, however. A scenario should ideally serve as the basis for decisions to reduce future losses. Therefore, the implicit message that scenarios carry about needed mitigation measures must also be sold to the user. Insurance companies in New Zealand have used a straightforward strategy. Based on scenario loss estimates, insurance companies there try to avoid renewing policies or writing more business in heavily exposed areas. That is, companies shift their portfolios away from these areas. This, however, is only a solution to the problem in the narrow sense of helping to ensure an individual insurance company's continuing viability. A comprehensive approach should reduce the losses themselves by using earthquake scenarios as a basis for defining risk-mitigation measures.

It is important to include probability in earthquake scenarios by specifying the probability of a

DISCUSSION

Haresh Shah, Stanford University, USA

Earthquake risk is assumed by insurance and reinsurance companies as well as companies dealing with mortgage-backed securities, and retirement accounts. No one party is solely responsible for our relatively poor earthquake-response capacity. Insurance companies, and financial institutions in general, have not until recently begun talking to the technologists who possess the earthquake-mitigating tools. In addition, the engineers, or toolmakers, have for their part generally been rather bad at articulating what they know. Both sides are therefore to blame.

We need better channels of communication between knowledge users and knowledge generators. Continued poor communication between these two groups may condemn large segments of the insurance community to continued reliance on the sort of archaic methods used 20 years ago. At that time, insurers would essentially wet their finger, put it in the air, see which way the wind was blowing, and then take their risk.

On a more hopeful note, some technologies in use today do take into account many of the important issues that Dr. Tiedemann eloquently raised. Certain technologies incorporate state-of-the-art uncertainty gauges and are able to handle fuzzy data.

Recently, I was in Lloyds of London and learned something about how Lloyds takes risks. Seeing how the major reinsurance companies underwrite risks was highly educational and aroused in me a sense of humility. These reinsurers, it seems, typically do not even have a clear sense of what the insurance companies are selling them. They do not know where the portfolio is or where the insured structures are located, but only that they are taking a certain percentage of risk.

Both the technologies and the aggregate data necessary to inform companies like Lloyds about the risks they are taking are available, but they are not being used. The data could be manipulated, perhaps through pattern recognition, to come up with systems by which the impact of a given disaster on a specific reinsurance company could be determined.

Earthquakes need not pose an ominous threat to the insurance industry, if only we can begin talking to each other more often and more clearly.

by Åke Munkhammar, Skandia Group, Sweden

On this point, Walter Hays of the United States Geological Survey (USGS) has started a needed now are input data, and the current relative lack of input data is a big problem. Even in California, for instance, surface geology is still being used to establish subsoil zoning. An inadequate method is still used in what may be the most developed earthquake insurance market in the world.

Ernst Leffelaar, Cologne Reinsurance Company, Germany

Probability is a key concept. From the insurance industry's viewpoint, no loss scenario should be produced without figures stating the probability that the scenario event will occur. We must be careful to ask the right questions regarding probability, however. We could ask, for instance, what the probability is that an earthquake will occur on a certain fault. This will give one answer. Or we could ask what the probability is that Los Angeles will be affected by a Modified Mercalli Intensity VII earthquake. This is an entirely different question that will have an entirely different answer. We could ask still another question about the probability that an event will occur causing losses of a certain dimension. This will give still another response.

Probability estimates are important for public services, too. If the authorities calculate the size of the fire brigade necessary to respond to a once-in-a-thousand-year event striking Los Angeles, the level will be quite high. If, instead, they make calculations for an event likely to repeat every 25 years, a much smaller fire brigade would be sufficient. Having a clear sense of the probability of a given event can help public policy planners make informed judgments about appropriate earthquake-response preparations.

Herbert Tiedemann, Swiss Reinsurance Company, Switzerland

Unfortunately, most universities are not yet oriented toward, funded for, or interested in investigating actual earthquake losses to develop informed vulnerability functions. Consequently, we in the insurance industry often have to do this legwork ourselves. Collecting field data and developing vulnerability functions are not as academic or prestigious a job as running an elaborate computer program, but models not firmly grounded in sound data and practical experience are not useful. The insurance industry must worry about the soundness of its data because it has to put its money where its mouth is.

Dr. Smolka is right to say that far more data are needed. It is unacceptable, however, that the reinsurers and a few international insurance companies, Skandia Group, for example, are saddled with the task of collecting and analyzing data from which the rest of humanity is profiting. This is

SUBMITTED COMMENTS

Thomas Anderson, Fluor Daniel, Inc., USA

Efforts to include statements or definitions of uncertainty in government codes are misguided. Public code drafters, building officials, plan-check agencies, and design engineers must all employ specified, unvarying numerical values, formulas, and limits if they realistically expect their designs to be carried through to the construction phase. Uncertainty could be expressed in a parallel but separate document, as we currently do for the design basis for a project. The design basis explains how and why risk choices were made in establishing the actual fixed criteria.

David Dowrick, Institute of Geological & Nuclear Sciences, Ltd., New Zealand

For the past five years I have been studying New Zealand's 1987 Edgecumbe Earthquake, a moderate-size event for which we were able to collect a highly complete data set on damage to commercial and industrial property. Damage to buildings, building contents, and various types of equipment, stock, and manufactured goods were considered. The study dealt specifically with costs incurred by insurance organizations as a result of earthquake damage. These statistical data on property damage and insured losses can be useful to urban planners and others interested in estimating likely levels of damage or potential danger to people.

The study considered all statistically relevant factors. It considered damage in terms of building age, for instance, because the quality of a building's structure depends to a large extent on the codes that were in effect at the time it was built. It looked at buildings with different uses, including residential buildings, hotels, shops, offices, industrial buildings, and community halls, and derived statistics on the average damage ratio and probability distributions for each class. It also looked at different building materials and found that steel was the worst building material instead of the best (as is sometimes thought), since steel buildings typically sustain high levels of nonstructural damage due to their extreme flexibility. Data about property damage and insured losses, then, can facilitate efforts to predict likely levels of earthquake damage to specific structures. This information, in turn, can be used to support the efforts of people working in three key areas: minimizing casualties, minimizing damage costs, and encouraging earthquake-responsive engineering practices.

in San Francisco, the seismologist will likely present them with a tectonic map, which, on the basis of numerous faults and past earthquakes, is supposed to demonstrate that San Francisco is greatly at risk. The seismologist will indicate all earthquakes occurring in San Francisco and specify their Richter magnitude. From a scientific point of view, this type of information is undoubtedly interesting, but for the local authorities it has basically no value.

For the purposes of disaster-mitigation planning, however, municipal authorities should ask questions such as, "How often and with what degree of severity do earthquakes occur in the city limits of San Francisco?" In this context, the exact magnitudes and locations of earthquake epicenters are of no significance at all. What is important, instead, is the intensity of the earthquakes at the earth's surface and the expected frequency of such occurrences in the area under consideration. Having obtained these data from a geoscientist, the next step is to ask a civil engineer for information on the expected structural damage in the event of an earthquake with the specified characteristics. Questions about the effects of earthquakes of various magnitudes on lifelines such as electricity supply, gas supply, and water supply must also be addressed by specialists from the appropriate disciplines.

A loss scenario for an earthquake, for instance in San Francisco, should be based on several epicenters with earthquakes of various magnitudes for each epicenter. If scenario makers selected, for example, 10 different potential epicenters each with four different magnitudes ranging from 5 to 8, the model would have to simulate a total of 10 x 4 = 40 hypothetical earthquakes. Additionally, a geophysicist would have to indicate the return period, or probability of occurrence, for each earthquake. In each case, the effect of these different earthquakes on San Francisco is crucially dependent upon the earthquake's magnitude, the depth of its hypocenter, and its distance from the city. These factors must be incorporated into the scenario using the appropriate attenuation functions.

By considering a mathematical combination of all 40 model earthquakes and their frequency, or return period, it is possible to ascertain the city's earthquake hazard. In addition to its immediate usefulness to the municipal authorities and others, this information provides a starting point for further studies, such as expected damage ratios for buildings. One should strive to obtain the curve shown in Figure IV.6.

On the basis of these findings, the municipal authorities must decide, for example, how many hospital beds are to be made ready in order to cope with a once-in-a-century event. If they base their decision on such an event, then they must recognize that they are not prepared for a once-in-a-millennium event and must draw up supplementary rescue measures for the resulting surplus of