EARTHQUAKE PROTECTION FOR BUSINESSES

Robert REITHERMAN[1], Guna S SELVADURAY[2], Morio INO[3] And Steven VUKAZICH[4]

SUMMARY

In most nations, the initial role in setting and implementing policies to reduce earthquake risk has been provided by the government, rather than the private sector. A common and extremely important example of the important contribution of government has been the adoption and enforcement of building codes. Over approximately the past two decades in many countries, there has also been an accelerating movement among businesses to set earthquake protection goals and implement them by investing in retrofits of existing facilities, higher than code-minimum design criteria for new facilities, and development of organizational response and recovery plans. In nations with capitalist economies, it is generally true that the larger share of risk exposure is born by the private rather than the public sector, simply because the preponderance of housing, factories, offices, and sometimes utility systems, is privately owned. A brief historical review of the earthquake protection programs of companies in California and Japan since the 1970s is provided here, along with some conclusions relating the specific implementation measures accomplished to the kinds of earthquake expertise or research which have supported such applications. The roles of the public sector in passing regulations or setting voluntary standards, offering guidance and motivating the public, and leading by example, are considered here to be very important in supporting private sector efforts.

INTRODUCTION

It is possible to recount a country's history of implementing earthquake risk reduction measures in terms of government actions, such as by listing dates of the adoption of building codes containing seismic provisions, but such accounts, at least in capitalist countries, do not describe the entire subject, because the majority of the country's risk exposure is born by the private rather than public sectors and in recent decades, a variety of earthquake protection activities have been engaged in by businesses as well as government agencies. Robert Whitman has made a related point as a Distinguished Lecturer for the Earthquake Engineering Research Institute, pointing out that with respect to the United States, the National Earthquake Hazards Reduction Program or NEHRP, which since 1977 has provided approximately $100 million per year to four Federal agencies, is not the same as and is smaller than the national earthquake hazard reduction program, i.e., the collection of various activities undertaken and funded by organizations other than those Federal agencies. While economies differ in their proportion of privately versus governmentally owned and controlled enterprises, in capitalist economies the private wealth and income streams at risk to earthquakes generally outweigh the governmental. In the United States, the national income from wages and salaries in recent years has tended to be about one fifth governmental and four fifths private, as one example.

One review of world seismicity as related to population found that approximately 40 nations are subject to moderate to high seismic risk. [Reitherman, 1996] Those 40 nations account for only about one fifth of the world's total number of nations but about two thirds of the world's population. Of these most seismic nations, all but approximately five have economies mostly based on private sector enterprises rather than socialism. Around the Pacific Rim, the two largest nations in Table 1 whose largest city is not in a high seismic zone as

[1] California Universities for Research in Earthquake Engineering (CUREe), USA; Email: reitherman@curee.org
[2] Dept of Chemical and Materials Engineering, San Jose State University, San Jose, CA, USA; Email: gunas@email.sjsu.edu
[3] Disaster Prevention and Information Center (DIPICS), Japan; website www.e-quakes.pref.shizuoka.jp
[4] Department of Civil Engineering, San Jose State University, San Jose, CA, USA; Email: vukazich@email.sjsu.edu

compared to the rest of the nation, the Peoples Republic of China and the United States, still have very large amounts of development in their highest zones of seismicity. Obviously China, with the most devastating earthquake in modern times, the 1976 Tangshan Earthquake, and the US, where frequent earthquakes occur in California (and within that state approximately 80% of the development is contained in the highest seismic zone in the US), are both nations with large amounts of earthquake risk. The ten countries in Table 1 with the highest ratio of largest city population to national population are shown in Table 2, which is a measure of the degree to which the "all your eggs are in one basket" concentration of risk applies. Half of the large cities in Table 2 have experienced a devastating earthquake in just the past few decades, and though data for some of the nations are not available, in the case of either all or almost all of those listed in Table 2, the majority of the nation's seismic risk exposure is born by the private sector.

Table 1: Relative Size of Primary City As Compared to National Population

Nation	National Pop. (millions)	LARGEST CITY	Pop. of Largest City (millions)	Largest City Pop. as % of National Pop.
Algeria	28.4	Algiers	1.5	5
Argentina	34.6	Buenos Aires	3.8	9
Armenia	3.7	Yerevan	1.4	39
Brazil	157.8	Sao Paulo	10.1	6
Canada	29.6	Toronto	3.9	13
Chile	14.3	Santiago	4.4	31
China (Peoples Rep.)	1,218.8	Shanghai	7.5	1
China (Republic of)	21.2	Taipei	2.7	13
Colombia	37.7	Bogota	6.5	17
Costa Rico	3.3	San Jose	0.3	9
Ecuador	11.5	Guayaquil	1.5	13
Egypt	61.9	Cairo	6.5	11
El Salvador	5.9	San Salvador	1.0	17
Greece	10.5	Athens	3.0	29
Guatemala	10.6	Guatemala City	2.0	19
India	930.6	Bombay	12.9	2
Indonesia	198.4	Jakarta	8.3	4
Iran	61.3	Teheran	6.5	11
Iraq	20.6	Baghdad	4.7	23
Italy	57.7	Rome	2.8	5
Japan	125.0	Tokyo	8.1	7
Macedonia	2.1	Skopje	0.5	24
Mexico	93.7	Mexico City	19.5	21
Miyanmar (Burma)	44.8	Yangon (Rangoon)		6
Morocco	29.2	Casablanca	3.5	12
Nepal	22.6	Kathmandu	0.4	2
New Zealand	3.5	Auckland	0.9	26
Nicaragua	4.4	Managua	1.0	23
Pakistan	129.7	Karachi	5.2	4
Peru	24.0	Lima	5.8	24
Philippines	68.4	Manila	1.6	2
Portugal	9.9	Lisbon	0.7	7
Romania	22.7	Bucharest	2.4	11
Russia	147.5	Moscow	8.7	6
Syria	14.7	Damascus	1.5	1
Turkey	61.6	Istanbul	6.6	11
Venezuela	21.8	Caracas	1.3	14
United States	256.6	New York	7.3	3
Yemen	15.8	Taiz	2.2	14

source: World Population Data Sheet, Population Reference Bureau, 1995

Table 2 Ten Highest Ratios of Largest City Population to National Population for Seismic Countries

Nation	National Pop. (millions)	LARGEST CITY	Pop. of Largest City (millions)	Largest City Pop. as % of National Pop.
Armenia	3.7	Yerevan	1.4	39
Chile	14.3	Santiago	4.4	31
Greece	10.5	Athens	3.0	29
New Zealand	3.5	Auckland	0.9	26
Peru	24.0	Lima	5.8	24
Macedonia	2.1	Skopje	0.5	24
Iraq	20.6	Baghdad	4.7	23
Nicaragua	4.4	Managua	1.0	23
Mexico	93.7	Mexico City	19.5	21
Guatemala	10.6	Guatemala City	2.0	19

source: World Population Data Sheet, Population Reference Bureau, 1995

Because the extent of the private sector risk exposure is often large, it follows that unless businesses achieve adequate levels of earthquake protection, there will be large amounts of earthquake risk and attendant losses even if governmental agencies were to be in the vanguard of risk reduction efforts and had protected public property and economic activities to a very high degree.

2. PRIVATE SECTOR ACCOMPLISHMENTS SINCE 1970

One should not presume that prior to the arbitrary cut-off date of 1970 used here that there were no significant efforts undertaken by businesses in seismic countries. In the two countries most studied by the authors, Japan and the United States, some large corporations had retained structural engineers to design buildings to above-code levels or had required earthquake-resistant design for their facilities even when not required by governmental regulations, such as has been the case with the design and construction of many industrial structures and equipment that have been traditionally outside the scope of building codes. Limiting ourselves here to the post 1970 period in this brief review, we find that these past three decades show a pattern of a modest level of business earthquake protection activity in the 1970s, a rapidly accelerating level in the 1980s, and by the 1990s, at least in countries with above-average risk and above-average levels of wealth to pay for earthquake protection--such as Japan, New Zealand, and California in the United States---the trend has continued to the point where for moderate to large size businesses, it is very common for them to have hired engineers to evaluate buildings, to have anchored nonstructural components, or to have developed and tested earthquake response plans.

In the United States, the 1971 San Fernando Earthquake had an impact on motivating businesses to undertake earthquake protection efforts, though until the 1980s, these efforts were generally limited to large companies and those with essential post-earthquake functions, such as the two largest telephone companies operating in California, the largest electronics firm in the state, a major petroleum company headquartered in Los Angeles, or a few banks or insurance companies with vital data processing facilities in high seismic areas of California. A 1985 survey of 157 companies in California that were selected because they were known to have earthquake protection programs [Reitherman, 1986] found that almost all had begun their programs between 1979 and 1981. During this same approximate timeframe, other risks (and the risk of being sued over such losses) also became of more concern to US businesses, such as those due to hazardous materials, reflecting a general societal tendency to continually expect higher levels of risk protection. Also beginning around 1980, the national government in the US, and some state and local governments, began to offer more services and guidance to businesses to encourage or guide their seismic protection efforts.

In Japan, businesses more commonly had an earlier start in developing ways to reduce their earthquake risk. Japanese businesses typically have used five-year plans for these earthquake programs as they do for their other activities, and by the mid-1980s, a number of the larger companies had already embarked on their second or third five-year earthquake protection plan cycle.

2.1 Earthquake Prediction

It is instructive to examine examples of linkages between the types of specific measures taken by businesses and the earthquake engineering research or knowledge that supported those measures. In the case of the largest electronics firm in the state, and at that time the nation, an influential motivating factor was the news coverage in the late 70s of the prospect of earthquake prediction. The successful 1975 Haicheng, China earthquake prediction [Adams, 1976] instantly made prediction a newsworthy topic. While earthquake prediction has not materialized to date, that research effort within seismology caused a temporary boost in the concern about earthquakes, in the late 70s and early 80s. For example, the Southern California Earthquake Preparedness Project, which included significant outreach efforts to businesses, originally had the word "Prediction" in its name. For a time, the "Palmdale Bulge," a suspected anomaly in the deformation pattern of the landscape along the Southern San Andreas Fault, was a highly publicized seismology story in the Los Angeles press. When that suspicion concerning unusual crustal deformation and an impending earthquake was not confirmed, there had already been set in motion at least a few corporate earthquake efforts because of the media coverage.

In Japan, the prospect of earthquake prediction, also unfulfilled to date, was an important motivator and probably remains a much more important source of motivation for undertaking business earthquake protection efforts there than anywhere else in the world, though optimism over the probability that a valid prediction for a major earthquake will be issued has faded in recent years. The Large-Scale Earthquake Countermeasures Act of 1978 singled out the Kanto and Tokai regions as especially earthquake-prone and deserving of special attention, and the Act was a direct result of earthquake prediction or earthquake probability forecasts publicized in the years just preceding its passage. The history of the Act and related seismic polices before and since in Japan is told by Selvaduray [1986, pp 20 ff].

As a motivational factor, earthquake prediction has proven quite influential, though the goal of the seismologists conducting research in that area, developing reliable and relatively precise predictions, has yet to materialize.

2.2 Earthquake Loss Estimation

Earthquake loss estimation is another field of earthquake research that has resulted in front page coverage of earthquake studies. The number of large-scale earthquake loss estimation studies in California (say on the level of an urban region with one million or greater population) in 1972 was exactly one [National Oceanic and Atmospheric Administration, 1972], a study of the effects of large earthquakes in the San Francisco Bay Area, followed by a companion report the following year [National Oceanic and Atmospheric Administration, 1973]. By 1983, there were 30 large-scale and well-publicized earthquake loss studies covering 13 different urban regions, with Los Angeles having been the subject of eight. [National Research Council, 1986] While of course there is no causal connection between the issuance of earthquake loss forecasts and the occurrence of earthquakes, it is not mere coincidence that the most studied urban region of the United States is also the place where the US earthquake with the greatest economic loss to date occurred, namely Los Angeles, which experienced the $50 billion 1994 Northridge Earthquake. [CUREe, 1998]

Especially for Tokyo, extensive earthquake loss estimation studies have been carried out that are widely publicized. For example, even foreign residents of Tokyo can obtain brochure summaries of these studies in languages other than Japanese. In general, the geographic scale of the Japanese studies has surpassed in detail those carried out in the United States. For example, Tokyo Metropolitan Government published in 1998 maps showing at the block (chome) level differences in fire hazard, building collapse hazard, and evacuation hazard. [Takami, 1998], although for an individual business, the building-specific scale is the one that matters, and in Japan as in the USA, this building-specific analysis for a business typically requires the services of a consulting engineering firm to assess vulnerabilities and design any associated retrofits.

How have earthquake loss studies supported business earthquake protection efforts? In terms of hazard reduction, these studies are usually too general to be of more than motivational use, though that is a significant factor in and of itself. Perhaps the one direct use that engineers have drawn from regional scale studies in conducting building-specific studies for corporate clients has been to borrow the consensus-blessed underlying earthquake scenario of public studies. For example, in the San Francisco Bay Area, since the original 1972 NOAA study, magnitudes and locations of earthquakes (ranging up to slightly over magnitude 8 for a San Andreas scenario and 7 for a Hayward Fault event) used in engineering consulting studies have often mirrored those in the published government studies. One shortcoming of this is that probabilistic analyses that consider the risk of experiencing a particular level of shaking regardless of which faults contribute to that combined risk, are not directly supported by single event scenarios.

For the first time, a large-scale loss estimation method has incorporated a detailed economic module for estimating direct and indirect economic impacts of scenario earthquakes. HAZUS, the FEMA-NIBS Earthquake Loss Estimation Method [NIBS, 1997], provides estimates of dollar losses because of property damage itself, as well as the impacts to business interruption, rental income, jobs, housing, and sector-by-sector forward-linked (supply changes) and backward linked (changes in demand) effects. To date, experience has not yet been accumulated to provide a basis for judging the utility of the economic analysis in HAZUS to businesses. A building-specific method of applying HAZUS is also under development.

For disaster planning purposes rather than for hazard reduction, large-scale scenario studies are more directly usable, providing not only the motivation but also the planning basis for deciding how many employees might not be able to drive home given a study's portrayal of highway and mass transit system functionality or what kind of utility outages might be expected. Disaster planners in the governmental sector have traditionally been the prime audience for loss estimation studies, so it is not surprising that emergency planners working on a business's response plan would find such studies useful as well.

In Japan, particularly in Shizuoka Prefecture, the effort of the government to provide consulting services to companies to assist them in their earthquake protection efforts is extensive and includes a variety of technical information. For example, of the 18 staff members of the Earthquake Preparedness Division of Shizuoka Prefectural Government in the mid 80s, 9 were architects or engineers, and a series of case studies of exemplary company earthquake programs had been compiled and published as guides to other firms. [Selvadurary, 1986, p 11]

2.3 Isolation and Damping Enhancement Technology

Seismic isolation research, beginning in New Zealand in the 1970s [see Skinner, Beck, and Bycroft, 1975] has increasingly resulted in applications, especially in Japan. As of 1990, there were slightly over 100 base isolated buildings in the world [Buckle and Mays, 1990], while by 1998, there were 427 isolated buildings built or under construction in Japan, and 225 permits for such buildings had been issued in 1996 alone. [Miyazaki and Saiki, 1997] Perhaps two reasons for the high adoption rate of this new technology in Japan are the more centralized building code adoption process, which extends nationwide, and the fact that the major architecture-engineering-construction firms in Japan themselves experimented with and helped to develop the technology. With these major firms in Japan using the technology on their own buildings, testing it in their own labs, and developing their own design procedures, the short step into practice was quickly taken, as compared to the USA where the technology more slowly emigrated from academia into codes, the practice of engineers, and use by companies. To date in Japan, a large number of companies have invested in the extra cost of isolation technology to protect their buildings at a higher level, whereas in the USA, the majority of projects have been government facilities. More recently, devices and designs to build into a structure enhanced levels of damping have become commercialized, and are beginning the same path that isolation products took a decade or more earlier. Selvaduray [1986, p 102] notes that other technologies for protecting nonstructural components and equipment in Japan have typically been "developed by the private sector at its own expense....and the major corporations whose products or services relate to earthquakes also feel an obligation to develop such products to fulfill their responsibility as leaders of industry and to maintain the prestige associated with that role."

3. INTERNATIONAL CORPORATE EARTHQUAKE PREPAREDNESS CONFERENCES

The First US-Japan Conference on Corporate Earthquake Programs was held September 24-26, 1991 in San Jose, California, hosted on the USA side by San Jose State University. [College of Engineering, 1991] The conference was initiated in recognition of the fact that while researchers, engineers, earth scientists, and public sector officials had frequent forums at which information could be exchanged, there were relatively few such occasions, if any, devoted to the earthquake subject from the viewpoint of facility managers, risk program administrators, and others responsible for protecting their businesses from earthquakes. A further motivation for initiating this first conference in the Corporate Earthquake Program series was the necessity for information exchange, especially between the two places on opposite sides of the Pacific where the largest concentration of private sector earthquake risk, and largest amount of earthquake preparedness activity by businesses, is located, namely Japan and California. As the private sector efforts of large companies in both countries accelerated in the 1970s and 1980s, it was clear that there was a great deal of experience being accumulated that was not being shared across the Pacific. The Corporate Earthquake Program conferences have been held once every two years since the initial 1991 event, alternating between Japan and California, except that the conference scheduled for

1995 was delayed for a year due to the January 17, 1995 Hyogo-Ken-Nambu or Kobe Earthquake. The 1993 conference was held at Tokyo Metropolitan University November 8-10, 1993 [Tokyo Metropolitan University, 1993], the 1996 conference November 5-7, 1996, at San Jose State University [College of Engineering, 1996], the 1998 conference at Shizuoka University, November 11-14, 1998 [University of Shizuoka, 1998], and the upcoming fifth conference in 2000 will be held at San Jose State University again [Selvaduray, 1999].

Beginning with the fourth conference, the name was changed from "US-Japan" to "International" in hopes of broadening the participation. While attendance had always been open to others, and modest advertising efforts in countries with significant earthquake risk such as New Zealand, Canada, Italy, Mexico, and others had been mounted, there has yet to be significant involvement from individuals in other countries in this conference series.

The formats for the conferences have included plenary sessions, working group sessions, and concluding sessions where lists of findings or recommendations have been adopted. Over the span of seven years and four conferences, a number of recommendations have been made, the chief one being to continue the international business-oriented earthquake meetings at which successes and failures can be shared, analogously to the much more voluminous engineering and seismological congregations of colleagues that occur with significant government funding. (To date, zero Federal support from the USA has been awarded in response to funding requests; on the Japanese side, significant governmental support has been forthcoming). Among the recommendations and emphases of the conferences: the need for employee public education and awareness about earthquakes is a continuing rather than one-step process that requires program maintenance activities; business earthquake protection measures have proven themselves in recent earthquakes, such as the 1989 Loma Prieta and 1994 Northridge in California or the 1995 Kobe in Japan, providing a rationale for the expense of such programs; adequate budgets are always a problem; the potential for private-public partnerships has not yet been fully exploited.

4. PUBLIC SECTOR ROLES

A number of efforts on the governmental side reaching out to businesses can be cited, again drawing on experiences in Japan and the USA. In the United States, an initial outreach effort was launched by the Southern California Earthquake Preparedness Project (SCEPP) in the early 80s, which included among its guidance materials a Corporate Earthquake Planning manual [Goltz, 1985]. A similar organization for the San Francisco Bay Region, Bay Area Regional Earthquake Preparedness Project (BAREPP), also developed guidance materials and held conferences at which business earthquake protection was featured. Prior to BAREPP in the Bay Area, the American Red Cross was a central point for information exchange via quarterly conferences in San Francisco for businesses, and Red Cross activities in various regions of the USA remain active. Both BAREPP and SCEPP were primarily funded by the Federal Emergency Management Agency (FEMA), which has recently published documents on "Protecting Business Operations" [FEMA, 1998], and "Emergency Guide for Business and Industry" [FEMA, n.d.], both of which include all natural hazards within their scope, as do informational materials under development by a non-profit organization, the Institute for Business and Home Safety. In the early 90s, the Southern California Earthquake Center (SCEC) mounted a major outreach effort focused on the earthquake hazard, including within its scope businesses [Andrews, 1998].

Leading by example is always a convincing argument, and conversely, if the government agency that is advising others to undertake hazard reduction measures is not carrying out those measures itself, it undercuts its message. A decisive step in the US was taken in 1990 when for the first time, Federal agencies were required to use earthquake-resistant design codes for their own buildings (which are exempt from local building codes). This policy, Executive Order 12699 [President, 1990] was a significant step toward leading by example.

Regulations imposed on the private sector in Japan and the US are primarily limited in the earthquake field to building codes. In Japan, the building code development and adoption process tends to be more national than in the United States, where states and even some cities adopt their own codes. Seismic codes in the USA are tending to become more uniform as the NEHRP Provisions promulgated with funding by FEMA become the basis for the soon to be released International Building Code, which has been made possible by a merging of the three major model codes organizations in the US.

5. CONCLUSIONS

While sometimes public awareness is only a vague and indirect route to action that will reduce earthquake risk, it is one important role of government. Given the motivation, many businesses will find the way to have their buildings evaluated for structural and nonstructural hazards, to consider their site (geologic) hazards, and to improve their capability to respond and recover. Research and other information can be used as a technical basis for developing earthquake countermeasures, and it can also be used as a motivator. Sometimes it is not clear at the outset which of these applications will materialize, as has been the case with earthquake prediction, which began with the role of providing specific technical information for pre-earthquake response actions, but has remained instead only a source of motivation to undertake long term protection programs.

Most accounts of the progress being made around the world in reducing earthquake risk tend to focus on governmental actions, such as passage of building code provisions of various editions. However, the majority of the risk in most highly seismic nations is born by the private sector, and only through private sector earthquake protection efforts can this risk be controlled to a reasonable level. While trends since the 1970s to the present in Japan and in California have been marked by an increasing level of interest in and support for earthquake protection on the part of businesses and a continuation of this trend and extension elsewhere is likely, the authors stop short of stating this trend as a prediction.

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