Earthquake Modelling as a Risk Management Tool for Accumulation Control in the Insurance Industry

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Abstract

Earthquake insurance greatly advances the recovery and reconstruction process after destructive seismic events. However, rather than replace adequate loss prevention and loss reduction measures, insurance should contribute towards a comprehensive risk management approach. Providing earthquake insurance on a stable basis requires a sound risk assessment because earthquake insurance can be successful in the long term only if a reasonable balance is achieved between premiums and losses. The seismic hazard, the vulnerability of the insured objects, their geographical distribution and the impact of applied coverage conditions such as deductibles all need to be quantified as accurately as possible. Information of this kind enables insurers and reinsurers to manage their exposures appropriately. Still, potential losses from a severe earthquake affecting areas with vast amounts of values, such as Tokyo or Los Angeles, might exceed the financial capacity of the insurance and reinsurance industry. A further growth in values is likely in the future, owing partly to the fact that several earthquake-prone areas still have a low insurance density.

Key Words

Earthquake risk assessment, Hazard, Vulnerability, Insurance conditions, Earthquake Risk Premium, Traditional risk transfer, Accumulation control, CRESTA, Financial capacity

Introduction

Major earthquakes strike with some regularity. There is the tragedy of countless casualties following devastating earthquake events in regions with low construction standards regarding seismic resistance (Table 1). Conversely, relatively small events may result in unexpectedly severe economic damage (Table 1, Northridge 1994). This is often a consequence of increasing value concentration in high seismicity areas and the susceptibility of commercial and industrial facilities to business interruption.

However, as Table 1 indicates, the insured portion is usually small, in particular because coverage is either not (yet) widespread or subject to limits or deductibles. What is more, these perils largely affect the infrastructure (transportation, lifelines, etc.), which is normally uninsured.

Research in the fields of seismicity and earthquake impact as well as in antiseismic building construction standards have proved to be of great value regarding the prevention of casualties and damage to buildings. At the same time, the insurance industry assumes a major role with regard to mitigating the economic consequences following an earthquake.

This paper focuses on general aspects of earthquake insurability and the risk assessment models involved. It illustrates aspects of the current state of the art of portfolio analysis within the insurance industry.

Table 1: Major earthquakes 1985-1999 [*sigma* 1/1999, Schaad 1995]

Event	Date	Casualties	Total Loss [bn USD]	Insured Loss [bn USD]
ChiChi, Taiwan	09/99	>2400	14.1	1.0
Izmit, Turkey	08/99	>17’000	20	1.0
Kobe, Japan	01/95	6000	100	2.6
Northridge, USA	01/94	60	30	13.8
Latur, India	09/93	9500	0.3	-
Gilan, Iran	06/90	50’000	8.0	0.14
Newcastle, Australia	12/89	10	0.8	0.7
San Francisco, USA	10/89	63	7.0	1.3
Armenia	12/88	25’000	-	-
Mexico City	10/85	15’000	4.0	0.5

Earthquake Insurance – Risk Assessment

Defining the Need for a Risk Assessment Model

A key issue of insurability of natural catastrophes is the need to achieve an equilibrium of losses and premium income over time and space. A long-term equilibrium of this kind is obtained by way of a risk-adjusted premium level. Establishing such a premium framework requires in-depth risk assessment, involving quantification of loss frequencies and loss sizes. This risk assessment for natural hazards has proved to be a challenging task for the insurance industry.

Estimates of the expected losses to a portfolio of insured objects for a peril such as fire are usually based on claims statistics over a representative number of past years by indexing the losses to current price levels and considering changes regarding the amount of exposed values. For natural catastrophes, however, this top-down approach is often not applicable. For a particular portfolio under investigation there is usually no representative loss experience available as the return period for significant events can be decades or even centuries. In addition, it is difficult to index past loss events as the geographical distribution of the insured objects and their quality change considerably over time.

Therefore, the insurance industry generally tackles this problem by applying a bottom-up approach for the risk assessment. This modeling approach draws from scientific and engineering knowledge focusing on the task of estimating earthquake frequency and related structural damage. Expert judgement is applied in areas where specific basic data is missing. Where applicable, model parameters are calibrated to the rather sparse existing loss data.

Example of a Risk Assessment Model

Reinsurers bear a significant share of insured catastrophe losses and therefore have a vital interest in understanding the risks. The presented model set-up has been applied and continuously updated at Swiss Re for more than 20 years. It draws on the basic idea of simulating a representative set of earthquakes that might affect a portfolio of insured objects. For each of the simulated events the corresponding insured losses and the frequency of occurrence are estimated. The output of four independent model components is combined to a loss-frequency curve as shown in Figure 1.

Hazard refers to how often earthquakes of a certain magnitude can be expected to occur in a particular region, irrespective of the coverage in place. The worldwide seismicity catalogues are used as basic input data to establish estimates of recurrence rates. These estimates are refined by incorporating regional seismicity models and site specific fault data. Finally, locally adjusted attenuation of earthquake waves from fault rupture and side- effects amplifying or damping the amount of ground shaking are included into the hazard modeling.

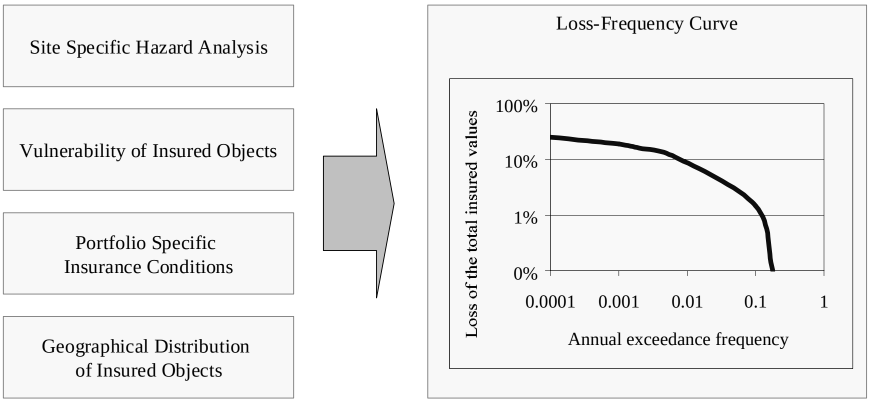

Figure 1: Model components

In all geographical areas seismic records are restricted in time, ie the local earthquake catalogues can cover a limited period of time. This time is often too short to be representative for the recurrence of rare, large magnitude earthquakes. Therefore, the general seismographic approach (Gutenberg-Richter relationship) to conclude from the frequency of small earthquakes to the frequency of large ones can result in an underestimation of the large magnitude earthquakes. This, time-independent approach, can be improved when *time-dependent processes* are included in the hazard assessment. There are two aspects of time dependency:

1) The time elapsed since the last (big) earthquake which happened on a fault. The longer this time, the higher the probability for another (big) earthquake on that fault segment.

2) New scientific findings indicate that the stress released by one earthquake is transferred from one fault to another, increasing (or decreasing) its probability to cause an earthquake on that neighbouring fault.

Although the time dependent processes should not be neglected when assessing earthquake hazard, its implications are geographically restricted. For local considerations it can be very important, however larger areas are hardly affected by its effects.

A *Vulnerability* relationship is used to express the degree of damage to an insured property or a portfolio of insured objects caused by a certain earthquake intensity [Eyer 1998]. The basic assessment of vulnerability relationships incorporated in the model comes from expert judgment, taking in account basic engineering know- how related to construction materials, age and quality and applied building codes. With Swiss Re, the analysis of the insured damage of many earthquakes over the past 20 years facilitated the continuous improvement of the calibration of the applied vulnerability relationships.

The *distribution of insured values* to geographical zones – eg counties, zip codes or even individual sites – and characteristics of the insured objects is crucial for the analysis of natural catastrophe risks. This model component focuses on assessing the extent of objects and values affected by the same event and on considering site specific hazard and vulnerability aspects.

The total amount of insured losses arising from an event is also heavily influenced by the *insurance conditions* – eg deductibles or limits – that apply to the original cover for each insured object. The core parameter to assess the impact of insurance conditions is the stochastic distribution of damage sizes in a specific portfolio, i.e. the balance of the number of large single and numerous nuisance damage. Such distribution functions were derived from actual loss data.

Setting up such a risk assessment model involves estimating a wide variety of parameters based on incomplete data and knowledge. Given the level of uncertainty of the model, a thorough analysis is required to test robustness. Owing to their complexity and the amount of numerical operations involved, these simulations can only be carried out with the help of a computer program.

Based on the representative set of simulated events and their estimated frequencies, the occurrence probability of each loss level is computed. The results are summarized in a *loss-frequency* or *exceedance-probability* curve (Figure 1). This curve displays the expected loss against the annual exceedance frequency. Evidently, an overall annual loss expectance for the portfolio under investigation may be calculated by integration of the respective curve.

Risk Transfer on the Traditional Earthquake Insurance Market

Earthquakes affect entire regions and insurance portfolios at once; this may cause an untold number of casualties and enormous property damage and consequential losses. With respect to the economical losses only, it is impossible, over a reasonable period of time, to achieve any form of balance between premiums and losses in the affected area alone. A local primary insurer issuing earthquake policies will therefore share a major part of the risks with one or several reinsurance companies.

Figure 2A shows the traditional dependency of premium payment and insurance coverage between property owners, primary insurers and a reinsurer. The schematic loss-frequency curve in Figure 2B illustrates the respective parts of risk accepted by each party. The reinsurer typically covers the rare, but extreme losses, while the property owner covers nuisance losses himself.

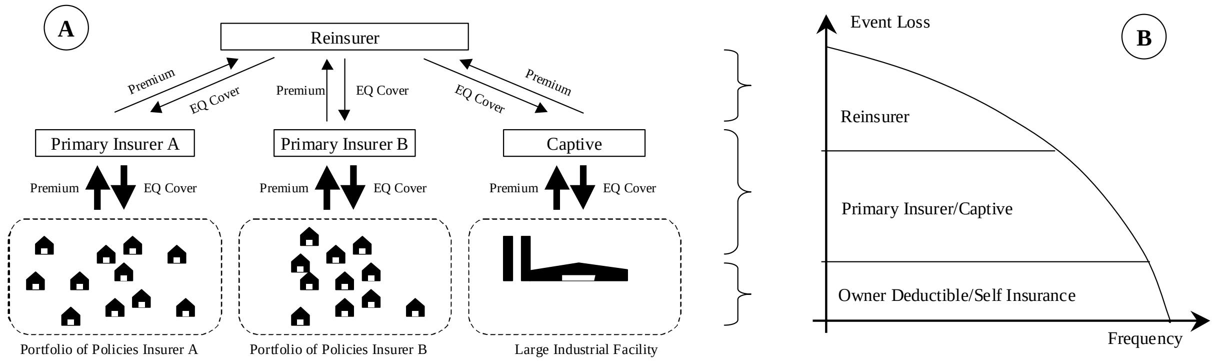

Figure 2: Structure of the traditional earthquake insurance market

A reinsurance company manages the risk by assuming many different, independent loss potentials and thus spreading its exposure on a world-wide scale, balancing the local losses with its world-wide premium income. The financial capacity of the insurance industry to absorb catastrophe losses has grown substantially by spreading large loss potentials both over world-wide markets and over different lines of insurance.

Accumulation control to ensure financial capacity

The map in Figure 3 indicates the locations with the highest anticipated potential insurance losses. The map is a result of Swiss Re risk assessment models applied to the world-wide earthquake insurance market. Local seismicity and vulnerability data has been combined with information regarding regional value concentration and insurance penetration. Insurance penetration varies widely between 0%, e.g. in developing countries, and close to 100% , e.g. in the UK, Australia, South Africa or Israel. While the loss potential in parts of South America or South East Asia is also significant, the insured losses are moderate due to low insurance penetration (mostly below 10%).

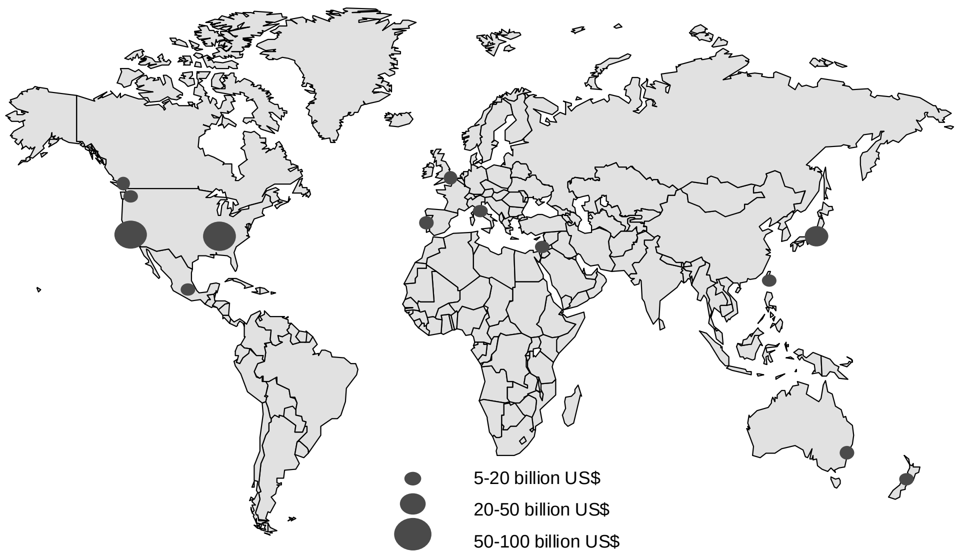

Figure 3: Insured loss potential from earthquakes

A high loss potential is found in the area of Los Angeles, mainly due to the exceptionally high value concentration in an area with a high earthquake intensity potential. A California wide reference loss (with a recurrence period of about 500 years) for an earthquake is estimated at USD 100 bn for the insured portion, with a current insurance penetration of approximately 20% to 30% only. Considering the comparatively low insurance penetration, there is a considerable growth potential for insured losses in the future.

Conversely, in Israel the insurance penetration amounts to over 90%. The seismic activity is relatively low, resulting in a reduced awareness for EQ-resistant building construction. In this low probability/high severity situation a reference loss potential of USD 15 bn has been calculated (with a recurrence period of about 1000 years).

Taking a look back in history, there were two earthquakes - Managua (1972), Guatemala (1976) - triggering the need for an accurate exposure and accumulation control not only for primary insurers but especially for reinsurers. The maximum anticipated losses of insurers were by far underestimated or largely unknown. This was mainly due to a lack of knowledge of the geographical value distribution and their vulnerability. A group of reinsurers and insurers initiated the CRESTA (Catastrophe Risk Evaluating and Standardizing Target Accumulations [www.cresta.org]) study group. This group has focused on data standardization between insurers and reinsurers to enhance exposure accumulation control. This in turn allows for adequate allocation or restriction of capacity for individual loss scenarios according to the risk management goals of the company.

A second loss cycle at the beginning of this decade – Earthquakes Newcastle and Loma Prieta (1989), Winter storms Daria and Vivian in Europe (1990), Typhoon Mireille in Japan (1991) and Hurricanes Andrew and Iniki in USA (1992) – underlined the need for adequate exposure control also for primary insurers. Hurricane Andrew caused the highest insured loss for the insurance industry ever recorded. More than sixty property/casualty insurers became insolvent, mainly as a consequence of this single event. Therefore it is crucial for any insurer to continuously monitor its catastrophe risk and also be prepared for rare – e.g. once in 500 years – losses by way of own capital reserves or via reinsurance.

Unfortunately, due to the – from an insurance perspective – low catastrophe frequency after 1992, awareness for the issue of catastrophe risk is decreasing again.

New Sources of Financial Capacity for Earthquake Insurance

The demand for earthquake insurance in highly exposed areas is ever growing. Demographic projections indicate a continuing population growth in such areas. However, the financial capacity offered by the insurance industry for high risk areas – e.g. Los Angeles and Tokyo – is restricted due to loss accumulation criteria. Especially for such areas new sources of insurance capacity are being sought.

On the other hand, the size of the US capital market is estimated to be some USD 20 000 bn. Daily changes are assumed to be about 0.7% which equals about USD 140 billion. Comparing this fluctuation to the economic damage of USD 100 billion of the Great Hanshin Earthquake in Kobe (Table 1) it is an appealing idea to cover the high incident volatility of earthquake damages by the means of the vast capital market.

To draw from this source, innovative insurers started in the beginning of the 90ies to package catastrophe risk into financial products. The basic idea behind these *Insurance-Linked Securities (ILS)* is to attract investors from outside the insurance industry. An investor assumes the credit default risk linked to defined trigger events and obtains a higher return in exchange. From the investor's point of view, catastrophic risks may be a highly attractive option. In addition to higher returns, the ILS are largely uncorrelated to the financial risks associated with the broader market. These instruments therefore represent important portfolio diversification vehicles for investors.

Discussion and Conclusions

The risk management process for the mitigation of earthquake hazard involves the collaboration of many different parties with different tasks. The focal issues of the process are risk prevention and reduction. The major players in the process are:

- the seismological research community supplying input data for engineering calculations and probabilistic risk assessment;
- structural and building engineers providing and advancing the knowledge for earthquake resistant construction;
- property owners taking preventive action when reinforcing or retrofitting their properties;
- the government taking regulatory action with building codes and land planning guidelines;
- insurance companies establishing risk-adjusted premiums to motivate insureds to invest in risk reduction measures;
- reinsurance companies by spreading the risk on a world-wide scale;
- the capital markets acting as a "lender of last resort" in the overall process of financial earthquake risk management, including self-insurance, primary insurance, reinsurance and governmental support.

From the viewpoint of expanding insurance coverage for potential economical losses from earthquakes the following aspects are to be highlighted: Advances in earthquake engineering and seismic modeling provide valuable input for refining risk assessment models. Such models facilitate a more accurate capacity allocation within the insurance industry. Careful loss assessment after earthquakes, focusing on the financial consequences i.e. the repair cost, prove to be particularly helpful for calibrating vulnerability models.

The unpredictability of loss events is a precondition for insurability. Are the new seismic hazard assessment (like the the implementation of time dependent processes) methods jeopardising the insurability of earthquake losses? The answer must be a clear no because even the most advanced methods do not provide earthquake predictions, but allow a more accurate estimate for the probability of future earthquakes. Hence exact time, location and magnitude of an earthquake and even more so the associated damage to individual buildings remain absolutely unpredictable.

- It is important to realise that these new findings do not represent earthquake prediction. But they are a more sophisticated approach to calculate probabilities of earthquake occurrence.

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