FROM SCIENTIFIC FINDINGS TO AN INSURANCE LOSS MODEL: CHALLENGES AND OPPORTUNITIES – GLOBAL CASE STUDIES

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ABSTRACT :

Probabilistic loss and risk assessment models for natural hazards have become essential tools for the insurance industry in recent years. They are not only used to determine insurance rates but also for risk management and decision making. Insurance loss models greatly benefit from the scientific and engineering findings on different components of loss modeling including hazard and vulnerability. On the other hand, the lessons learned by the insurance industry in developing these models can also offer insights to the research community and contribute to increasing the quality of current seismic risk assessment as they require a more holistic and integrated view. In this paper, we discuss the progress made and challenges faced by the insurance industry in modeling seismic risk through various global case studies including California, Japan, and China.

KEYWORDS: probabilistic loss model, risk assessment, hazard analysis, economic loss, insurance

1. INTRODUCTION

Probabilistic risk and loss modeling for natural hazards has become an important and essential tool for the insurance industry in recent years. It is used not only in determining insurance rates but also in quantifying and managing the overall risk assumed by the insurance/reinsurance companies. An insurance loss model can greatly benefit from the latest scientific advancements in hazard modeling. On the other hand, we believe that the earthquake risk modeling framework used by insurance industry can offer insights to the research community and contribute to increasing the quality of current seismic risk assessment.

Using various case studies, we first outline the main components of insurance risk modeling and discuss where it has common ground with the well established probabilistic seismic hazard (PSHA) and vulnerability analyses. Based on the lessons learned from these recent studies and development work, we have identified various opportunities for cross nurturing of insurance risk model output back to the classical disciplines of seismic risk assessment.

2. INSURANCE RISK MODELING – CONCEPTUAL THOUGHTS

Probabilistic risk assessment of natural hazards from an insurer's perspective entails the quantification of hazard and vulnerability, as well as the distribution of insured values and the effect of insurance conditions. The ultimate aim is to estimate the total insured loss from all affected objects under consideration. This is achieved by calculating the insured loss incurred by all affected properties and objects for one event and to repeat this process for a large number of events from a stochastic catalog, in analogy to the event catalog used for PSHA, in conjunction with an associated probability for each event (See Figure 1). By assigning an occurrence probability to each of these events, it is possible to obtain a probability distribution of losses through computation of a damage or loss-exceedance curve. Damage in this context refers to the repair and reconstruction cost for the physical damage, while loss would refer to any amount covered by insurance.

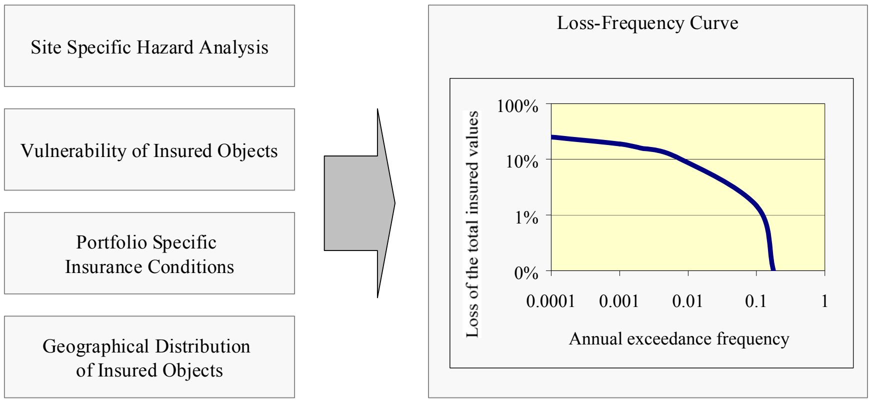

Figure 1: Key components of a probabilistic insurance loss model

There are four important aspects distinguishing the output and contents of an insurance loss model from those of the better known probabilistic seismic hazard models. First, the latter is used to produce a hazard curve or ground motion exceedance curve for a single geographical location. In contrast, the loss exceedance curve computed by using an insurance loss model, as the name states it, gives the probability of exceeding various levels of loss due to physical property damage. In contrast to the typical hazard or ground shaking intensity measures descriptors, be it Modified Mercalli Intensity (MMI), peak ground acceleration (PGA) or spectral acceleration (SA), property damage can often be better observed long after the occurrence of an earthquake and there exists longer historical records and data. This allows for additional frequency and size information about the event and its effects and generally provides very beneficial benchmarking opportunities of the ground shaking experienced at different locations.

The second key differentiator stems from the fact that an insurance loss model maintains through all stages, including the final output, the event perspective. An insurance underwriter has a focus both on the damage probability for a single object and the overall damage affecting a larger portfolio of objects from a single earthquake. For the latter aspect worst case considerations have historically been the focus for risk management purposes, i.e. finding the earthquakes which produce at a certain probability level the largest damage to an insured portfolio. Nowadays, the damage and associated probability for smaller earthquakes have become equally important, as it has become an important pricing element for insurance contracts worldwide. In particular for small to midsize earthquakes and their respective damages, there is significant damage experience available. The past 20 years of probabilistic insurance loss modeling have helped to calibrate these models with observed damage patterns. One result of this calibration is a continuing trend to gradually lower the overall risk level predicted in insurance EQ risk models, with some exceptions. The non-occurrence of significant losses from small to mid-sized earthquakes triggers the questioning of model components, both on the the seismic hazard and the vulnerability side.

The third differentiator is related to the integrative view of an insurance risk framework. The principal output of an insurance risk model is various aspects of damage or loss. The model output is always based on a combination of a hazard assessment including a stochastic event set, a set of attenuation equations, hazard uncertainty considerations, soil effects, building response and consequential building damage. Hence such a model provides a testing platform of all these sub-components and in particular also their links to each other. Inconsistencies between these modules can have a major impact on output. For an insurance risk modeler, significant work needs to be done not only to standardize the interfaces between components and make them compatible with each other but also to ensure consistency in model outputs through extensive benchmarking and calibration. For example, the output of the ground motion attenuation model including uncertainty components needs to be compatible with the parameters used by the building response model. While this is an obvious requirement, not all work from scientists and engineers would already comply with such compatability requirements as they generally focus on a specific topic or model. An insurance risk model through its integrated framework can help to identify gaps and highlight such requirements.

The fourth differentiator is the global scope of an insurance risk model. An insurance risk model has to have a certain level of output consistency in the risk landscape across all areas covered. Losses and associated probabilities for a seismically active region such as Taiwan have to be obviously higher than those of a less active region such as Australia. The needed benchmarking of the underlying hazard as well as the building vulnerability models add additional helpful calibration points, which may not necessarily be available for a PSHA study of a region or building vulnerability analysis performed separately, possibly for a geographically contained area. Furthermore, the global scale is widely used to transfer loss and damage experience from areas with a high frequency of damaging earthquakes (e.g. Japan, Taiwan, Turkey) to other areas with little or no loss experience.

Using lessons learned from building and using insurance risk models as a reality check, significant value can be added to the overall probabilistic models available for hazard or vulnerability analyses, beyond the strict application for the insurance industry only. This reality check would contribute to the accuracy and reliability of seismic risk assessments of these and other methods. We believe that not all of this value is being captured or utilized as of now. Recent work on creating open source loss models, e.g. HAZUS (FEMA, 2003), OpenRISK (Porter and Scawthorn, 2007), are important steps in this direction. By sharing our experiences from various cases, we aspire to trigger more discussion on this important topic.

3. GLOBAL CASE STUDIES

In the following, we discuss the progress made and challenges faced by the insurance industry in modeling seismic risk through various global case studies including California, Japan, and China. The combination of high exposure and high seismic hazard makes the former two regions key markets for the insurance industry. However, with the pace of ongoing industrial and infrastructure development and its vast size China may be a candidate to become one of the biggest insurance markets of the 21st century. Seismic hazard, loss, and risk modeling for each of these countries offer unique challenges and opportunities.

In the following case studies, we identify areas where the insurance risk models can directly utilize data and knowledge from scientific or engineering analyses. Beyond this, we illustrate particular challenges faced during the development of integrated insurance loss models. Finally, we conclude the case studies by pointing to the lessons learned from a holistic risk assessment view.

3.1 California – An Ideal Case?

California is one of most studied seismically active regions of the world. There are detailed scientific models for modeling not only seismicity of the region but also the resulting ground motions and corresponding losses. The recently released Uniform California Earthquake Rupture Forecast (UCERF) Model is one example of such detailed seismicity models. The model creates time-dependent and time-independent earthquake rupture forecasts for the whole state of California considering various seismic sources in the region (WGCEP, 2008).

Swiss Re, through collaboration with Southern California Earthquake Center and the U.S. Geological Survey, in leveraging the results of this study to develop a stochastic earthquake event set for California to be used in its seismic risk assessment models. The event set being developed also uses the Next Generation Attenuation (NGA) relationships recently developed by the Pacific Earthquake Research Center to estimate ground motions (Power et al, 2008). It includes thousands of events from various seismic sources affecting California. We calculate the predicted ground motions across California for each event using the NGA relationships considering the soil amplification effects .The scatter in ground motions and corresponding loss differences across sites are included in the process through explicit consideration of inter- and intra-event uncertainty in ground motions.

One of the challenges faced is downsampling of the relatively large number of events to a number that will produce loss estimates in a reasonable amount of time but also with sufficient accuracy. Also, generation and calibration of the vulnerability curves for the ground motion intensity measures considered in the event set requires significant effort as earthquake loss data are relatively scarce. Some of the past analytical and numerical studies on building vulnerabilities have used intensity measures or ground motion parameters different from the ones used in the current event set. Creating a detailed and coherent seismic risk assessment model requires significant research and development effort not only for the individual components of the model, i.e. hazard and vulnerability, but also when these components are put together. The results obtained from the probabilistic model is checked and compared with historical losses from previous events, and necessary calibrations are done to the relevant model components. Sensitivity analysis is a major part of this process to identify the components and parameters that the final loss estimates are most sensitive to. For example, the estimated losses are very sensitive to the choice of ground motion attenuation relations.

However, while the availability of detailed scientific models are available for this seismically active region, data from previous experience regarding ground motions and losses is still relatively scarce, especially for large earthquakes. This, in turn, introduces significant uncertainty in the results. Loss data from previous events are extremely valuable in developing more realistic and reliable loss models, and every effort should be made in collection and dissemination of such data. So even for a well researched area like California, there is a need to cross-check insurance loss model outputs with loss experience from other areas, to fill the gaps in terms of verification.

3.3. Japan, China, and Taiwan – The value of the dense measurement networks and historical data

While above arguments are generally valid for seismic risk models developed for other regions of the world, different regions offer different challenges and opportunities and may require different approaches. California and Japan for example both have a long history of earthquakes. However, Japan in comparison to California has earthquake shaking intensity and damage data covering a much longer time period, which can be used in development and calibration of earthquake loss models. While more recent intensity measures such as spectral accelerations are used in these models, in Japan the preferred choice is generally the JMA intensity. Stein et al (2006), for example, through a project sponsored by Swiss Re and several other public and private entities, collected historical seismic intensity data for the last 400 years from various sources and performed a probabilistic seismic hazard assessment of greater Tokyo (Bozkurt et al, 2007).

Japan also has a very dense and modern seismic network, which is becoming more widely used along with the historical intensity data. From an insurance perspective Japan also presents a unique challenge in terms of the insurance products sold in this market. While in most insurance markets, the typical insurance cover is linked to the indemnity loss experienced by the property owner, the market in Japan has in recent years also developed a variety of derivative covers. These covers make a pay-out, in a most typical set-up, upon exceedance of pre-specified intensity levels at pre-specified seismograph stations, regardless of the damage or loss experienced at the location.

One variation of such a product required an expansion of model capabilities and output, based on an analysis of JMA data of past earthquake occurrence. The offered cover required a trigger based on any of three neighboring measuring stations reporting a JMA instrumental intensity level of 6.0 for a particular earthquake. Based on a PSHA-type analysis, a probability assessment for a single station can be performed in a straightforward manner, for example, by an engineering or risk modeling firm or recent work performed by JSHIS can be used. However, computation of trigger activation probabilities in this framework, i.e. activation by “any of the three” stations, requires a more customized analysis accounting for correlations in intensities of the three stations, i.e. maintaining the event perspective at all times and fully accounting for the epistemic and aleatory uncertainty of the measurements at the three stations.

The model output for estimated intensities at multiple but neighboring stations for a given event should not only account for the random scatter of intensities for the individual stations (modeled by intra-event uncertainty), but also by deviations from the underlying assumed attenuation model (included as inter-event uncertainty). Some of this inter-event and intra-event uncertainties can be explained by subsoil characteristics or limitations in the attenuation models used (an approximate contribution of 0.13 JMA units to model uncertainty), while some of it is thought to be of strong aleatory nature (an approximate contribution of 0.30 JMA units to model uncertainty). These values have been obtained based on a thorough analysis of the instrumental earthquake intensity data collected by JMA between 2001 and 2007. By using Monte Carlo simulation techniques within the established model framework, this risk assessment for such unique products could be performed. In addition, the knowledge gained during the process now allows improvement of the existing loss models to obtain improved event loss estimates by more specifically accounting for scatter in intensity throughout the affected portfolio area and the spatial correlation of intensities.

China, in addition to Japan, is another country which has a significant database of observed intensities covering a long time period. This is a very valuable source of information that is used in seismic risk models for this large country covering regions with different levels of seismic activity. In addition, there have been increased activity and efforts in recent years in establishing modern seismic monitoring networks, which can be expected to have significant contributions to available seismic data for the region. This would in turn enable better characterization of seismic sources and ground motion related parameters. Taiwan, for example, had a very dense modern network of seismographs operational during the 1999 Chi-Chi earthquake, which resulted in collection of hundreds of ground motion recordings. The data collected from this single earthquake already had significant impact on science and engineering. For example, near source ground motion data obtained from this earthquake, which is rare for large magnitude earthquakes, was heavily used in development of the NGA relations. Establishment of increased number of such modern seismic monitoring networks in seismically active regions of the world will ensure collection of valuable seismic data from future events to be used in improvement of ground motion attenuation relations.

4. FINDINGS AND CONCLUSIONS

Insurance risk models have become commonplace across the entire insurance industry. Their output has lead to more stability in catastrophe insurance and reinsurance markets. While the value of these probabilistic loss models to insurance industry is unquestionable, there might be additional value to gain for the entire community engaged in earthquake risk evaluation and management by sharing the experiences and lessons learned during development of such models.

While these models are readily being adapted to recent findings in seismological or seismic engineering models, not many attempts have been undertaken to make the insights gained from these models available to the scientific and engineering community. Loss models are relatively easier to benchmark and validate against historical experience compared to numerical scientific models for which no past data is available. Use of available loss data and models for testing and validation of seismic hazard and building response and vulnerability, may contribute to better understanding of these components and also highlight possible areas of further research and development.

Past and ongoing open-source hazard and loss modeling efforts such as HAZUS (FEMA, 2003), OpenRISK (Porter and Scawthorn, 2007), OpenSHA (Field et al, 2005), and GEM may be of help in increasing the communication and collaboration among researchers, model developers and end users. In addition, increasing the transparency of currently available proprietary models and sharing global benchmarking information will contribute to the ongoing efforts to improve the quality and reliability of probabilistic risk assessment results with ensuing benefits for all risk management needs.

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