SOME COMMENTS ON EXISTING MODELS OF SEISMIC RISKS TO INSURANCE INDUSTRY

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ABSTRACT :
The quantitative risk assessment of earthquake disaster is based on integrated procedures to quantify seismic, attenuation, sites, buildings and economical losses. Accordingly, seismic risk analysis has to be integrated in order to obtain reliable results. In this paper, the research progresses of the seismic risk assessment are reviewed, some considerations regarding the intensity and probability of occurrence of earthquakes and the vulnerability of constructions subjected to seismic actions are given. A soft risk map of earthquake, which is more informative than conventional ones, is aimed at the visualization of risk levels of Seismic disasters defined by the fuzzy probabilities, having the potential to be used for the adoption of risk mitigation measures, the assessment of the seismic losses and estimation of earthquake insurance rates.

KEYWORDS:
Quantitative risk analysis, Seismic risk, Seismic hazard, Risk zoning, Fuzzy probabilities, Earthquake insurance

1. INTRODUCTION

China locates in the joint of two major seismic belts that are the Circum-Pacific Seismic Belt and the Eurasia Seismic Belt. This is one of the most active seismic regions in the world and is characteristic by high frequency, large magnitude, broad distribution and shallow hypocenter. China has been plagued by numerous destructive earthquakes during its long history and suffered very serious earthquake damage. Although seismologists all over the world have developed unflagging and tireless inquiries about the Earthquake Mechanism, even some types of earthquakes could be predicted under certain conditions, it is still in the empirical and probing stage. The short and temporary earthquake forecasting is remains a global scientific challenge. So, this requires us to study on the transfer mechanism of seismic risk, and earthquake insurance can be considered as the main means and effective approach for such risk transfer.

Nevertheless, disaster industry sector in China is still under-developed, including earthquake insurance. Life insurance policies normally include earthquake coverage while most of the property insurance policies exclude such risk. In property insurance, liability in the earthquake-related insurance products experienced a number of changes and can be broadly divided into three stages[1]: before 1996, earthquake insurance was included in property insurance coverage; from 1996 to 2001, earthquake insurance and property insurance has excluded earthquake as exemptions; after 2001, earthquake insurance can be included in a rider contract.

The 8.0-magnitude earthquake that struck Sichuan Province on May 12th has triggered a rush to establish new disaster insurance system, especially for earthquake insurance. Although several domestic insurance companies have designed some earthquake insurance products and made some related explorations, however, for the earthquake insurance, there is still a very long and difficult way to go. Two basic problems in the Earthquake insurance have to be solved: one is setting the insurance premium, another is calculating possible losses. All insurance polices and risk management policies are based on calculation of possible losses. Until insurers think over risk and losses caused by earthquake sophisticatedly and comprehensively, they cannot safely undertake the earthquake insurance.

2. ANALYSIS OF LOSSES IN EARTHQUAKE FOR THE EARTHQUAKE INSURANCE

UN and ISDR define a conceptual superstructure of risk[2] as follows:

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \quad (2.1)$$

Thus, two elements are essential in the formulation of risk: a potential damaging event, phenomenon or human activity – hazard; and the degree of susceptibility of the elements exposed to that source – vulnerability. According to UN and ISDR, hazard refers to a potentially damaging physical event, phenomenon or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Vulnerability refers to the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

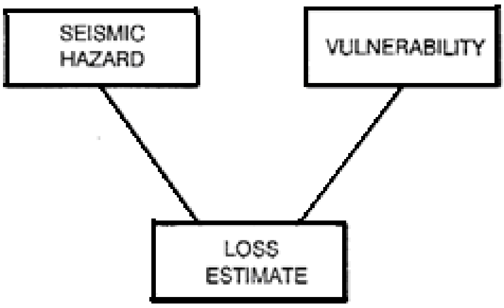

Figure 1 Basic structure of an earthquake loss estimation study (PEL EM, 1989)

Fig.1 illustrates two components, seismic hazard and vulnerability, comprising the basic structure of an earthquake loss estimation study. The information assembled form these two components is combined to produce the loss estimate[3].

The seismic hazard analysis involves ground shaking, soil liquefaction, surface faulting, slope instabilities, tsunami, tectonic deformation, etc. In most loss estimates, the primary emphasis on hazard is the probability of occurrence of a specified level of ground shaking in a specified period of time.

The vulnerability analysis entails analysis of fragility or damageability, the relationship between hazard and damage, loss or disruption. The vulnerability of engineering structure refers to the probability of a certain damage degree under determined magnitude earthquake. It works with the structure's resistibility to seismic hazard and the regulations and standards of seismic fortification intensity. There are two steps in a vulnerability analysis (PEL EM, 1989): (1) developing an inventory of the buildings and other facilities to be considered in the study, and (2) establishing for each inventory category the relationships among intensity of ground shaking (and, in some cases, ground failures), resulting damage, and associated losses.

3. SOME COMMENTS ON EXISTING MODELS OF SEISMIC RISKS

Since 1968 Cornell published his famous "Engineering Seismic Risk Analysis" and 1973 Whitman introduced Damage Probability Matrices, there are tremendous papers and other publications have been published on these subjects. The most widely used models are Poisson model[4]. Various other kinds of models are developed to estimate seismic risk as well, such as RBF Neural Network model[5], Fuzzy Synthetical Judgment model[6], Fuzzy Random model[7]. However, most of these models are theory models and only a few of them can be applied, not to say can be accepted. Although some models are used practically, they still have disadvantages in different aspects.

3.1. Seismic Hazard Analysis Model

There are two general approaches for conducting site-specific analyses for determining site ground motions (Reiter 1991), the deterministic models and the probabilistic models. Either or both of these approaches may be used for a given site.

Deterministic Seismic Hazard Analysis (DSHA) is the earliest approach taken to seismic hazard analysis. The DSHA approach uses the known seismic sources near the site and available historical seismic and geological data to generate discrete single-valued events or models of ground motion at the site[8]. This approach is based on the premise that if an earthquake has occurred once, it can occur again. For example, the earthquake hazard for the site is a peak ground acceleration of 0.40g resulting from an earthquake of magnitude 6.3 on a certain Fault at a distance 50km from the site. It is originated in nuclear power industry applications. Nowadays, it is still used for some significant structures, such as large dams and large bridges. DSHA produces “scenario” earthquake for design earthquake, usually the worst-case scenario. DSHA calculations are relatively simple, but implementation of procedure in practice involves numerous difficult judgments. In a low-seismicity environment, a deterministic estimate for a maximum earthquake can never be exceeded or only have a lower probability of being exceeded. The frequency of earthquakes and resulting ground motions is not explicitly considered. Worse still, the lack of explicit consideration of uncertainties should not be taken to imply that those uncertainties do not exist.

Probabilistic Seismic Hazard Analysis (PSHA) is defined as site ground motions are estimated for selected values of the probability of ground motion exceedance in a design period of the structures or for selected values of annual frequency or return period for ground motion exceedance[9]. For instance, the earthquake hazard for the site is a peak ground acceleration of 0.32g with a 10% probability of being exceeded in a return period of 475 years. PSHA is the most commonly used approach to evaluate the seismic design load for the important engineering projects. PSHA method was initially proposed by Cornell in 1968 and developed in its computer form by McGuire (1976) and Geomatrix (1993). It is assumed that the occurrence of earthquakes in a seismic source results from a Poisson process. Most of the earlier models of seismic hazard assessment were based on the assumption that earthquake events are independent in space and time. Later studies considered the temporal dependence of earthquakes based on processes with Markovian characteristics[10]. Recently, a space–time model is developed. A random field model is developed to describe the occurrence of earthquake in the space-time domain is relatively new[11]. There are significant scientific uncertainties in earthquake source characterization and ground motion estimation means. So, there is not a unique result for the relationship between ground motion level and probability of exceedance. The probabilistic methods reflect the actual knowledge of the seismicity, however, their results are difficult to explain to non-specialists, they strongly depend on the probabilistic models used and it is difficult to evaluate how a given input parameter affects the final results[12].

3.2. Vulnerability Analysis Model

There are two approaches to express the relationship between the intensity and the damage factor[13], one is through plots as vulnerability curve or as motion-damage relationship, and another is using the Damage Probability Matrix (DPM). Typically, the damage or vulnerability functions for a structure type are estimated through the use of historical loss data, engineering data, and expert opinion of structural engineers proficient in post-earthquake damage assessment[14].

The primary source of damage information utilized by most software modelers is from ATC-13 report[15], which was developed in 1985 by the Applied Technology Council (ATC) under a contract with the Federal Emergency Management Agency (FEMA). This included estimates of losses in California for industrial, commercial, residential, utility and transportation facilities, in all 78 different types of structures. Opinions from the thirteen members of the Project Engineering Panel (PEP), as well as 58 experts in earthquake engineering were adopted. ATC-13 bases its damage estimates on Modified Mercalli Intensity (MMI), from VI through XII, a scale that reflects the effects of an earthquake. A mean damage factor (MDF) was estimated, defined as the expected ratio of dollar loss to replacement value for the structure[14]. The outputs of the ATC-13 study included damage probability matrices and estimates of time required to restore damaged facilities to pre-earthquake usability. By using such matrices, it is possible to estimate the probability of a structure being in a particular damage state for a given MMI ground shaking intensity, and to estimate the expected dollar loss by multiplying the damage factors for the structure by the estimated replacement value[16].

In China, Yang Yucheng[17] offers a simple and practical quantitative method for three level design and earthquake hazard prediction of masonry structures. And also, an expert system called PDSMSMB-1 for predicting earthquake damage to multistory masonry buildings was developed[18]. This system was put into operation for evaluating vulnerability and seismic risk of 119 dwelling houses which were divided in 6 kinds by different ages and types.

According to China's 1986 National Urban Housing Census information, Yin Zhiqian[19] investigated more than 100 Medium-sized Cities and Metropolises and gained average annual growth rate of buildings from 1950s to 1980s (about 9%), then, calculated 18 seismic damage matrixes for 4 kinds of buildings around 2000. These damage matrixes are the most integrative and systematic approach to estimate seismic risk. They were accepted, even applied by many researchers. However, they are mostly derived from the empirical opinions of seismologists and hardly depended on the statistics as the above mentioned ATC-13 report.

After that, Yin Zhiqian[20] developed a dynamic earthquake damage matrix to solve the problem caused by significantly increased constructions. Hu Shaoqing[21] involved a method to improve the empirical seismic damage matrix by supposing that the damage probabilities for each intensity obeys the Beta-distribution and the parameter of Beta-distribution function is calculated from the expectation and variance in other intensities. Beiyes model[22] and Markov model[23] were also been used for the same end. Nevertheless, all of these improvements are theoretical models.

3.3. Seismic Risk Tools

Over the past decades, advanced software tools have emerged and serve to government agencies and individual insurance companies to more accurately assess seismic risk. Notable software packages include those by Applied Insurance Research, Inc. (AIR), EQECAT, and Risk Management Solutions, Inc. (RMS).[14]

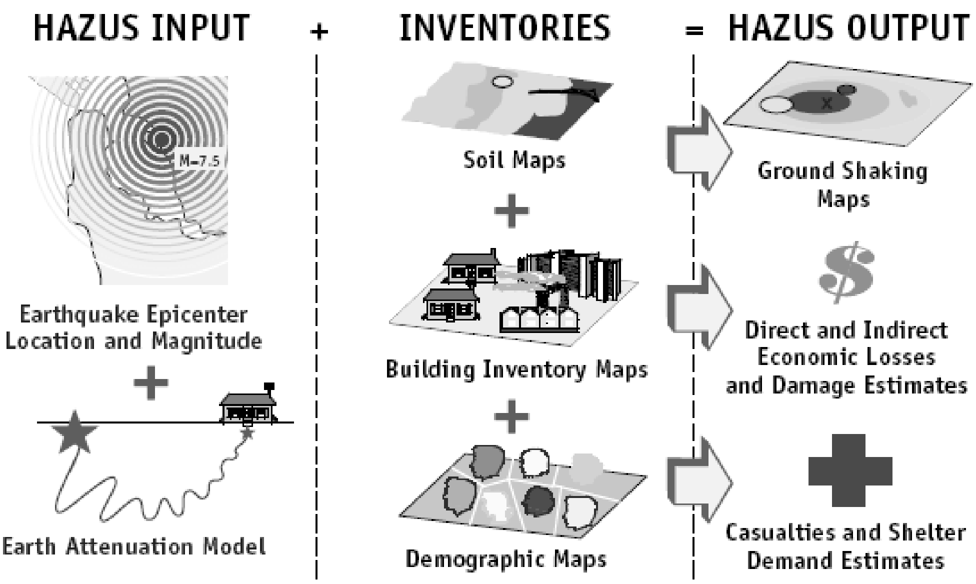

Figure 2 Earthquake loss estimation using HAZUS (FEMA)

Under agreements with the Federal Emergency Management Agency (FEMA), NIBS develops HAZUS, a nationally applicable GIS-based tool for estimating hurricane, flood and earthquake damage and economic loss. The HAZUS-MH MR3 Earthquake Model[24] provides estimates of damage and loss to buildings, essential facilities, transportation lifelines, utility lifelines, and population based on scenario or probabilistic earthquakes. The HAZUS model employs both earthquake hazard and structural fragility terms to calculate damage ratios and estimate damage costs (Fig.2).

Though this software package is commonly accepted by many experts and widely used in some areas in the United States, disadvantages still exist. The Earthquake Model assumes the same soil condition for all locations[25]; also the model depends largely upon the integrity and comprehensiveness of input inventories.

Uncertainties are inherent in any loss estimation methodology. There are two types of uncertainty in methods of seismic hazard and risk analysis (McGuire): one is aleatory (random) uncertainty, which is inherent in a random phenomenon, such as the complexity of seismic system,; another is epistemic (or knowledge) uncertainty, which stems from lack of knowledge about some model or parameter, for instance, incomplete or inaccurate inventories of the built environment, demographics and economic parameters.

4. SOFT RISK MAP

Traditional methods for seismic zoning use either a deterministic or a probabilistic approach and base their analysis on empirically-derived laws for ground motion attenuation. With the deterministic approach, maps have been prepared showing maximum displacements and velocities and design ground acceleration. Nowadays most of the seismic risk maps, based upon probabilistic seismic hazard assessment, depict the global seismic hazard as peak ground acceleration (PGA) with a certain chance of exceedance in a specified period of time. This corresponds to a return period for the maximum likely regional earthquake.

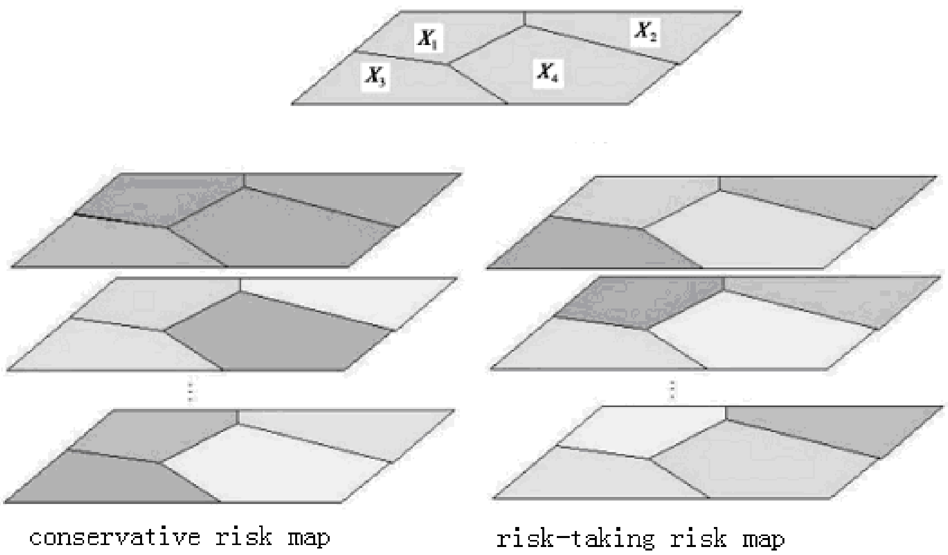

Figure 3 Possibility-probability risk analysis and soft risk zoning map[27]

It is a deep-seated problem that how to express the imprecision of risk assessments in probabilistic-model based seismic risk maps. We introduce possibility-probability in the field of seismic risk mapping to express fuzzy risk and the Interior-outer-set model to calculate such probability[26]. This kind of risk map is called soft risk map due to that it is achieved by using the idea and method of the soft computing. Soft risk map of earthquake disasters not only can express the imprecision of risk value estimates, but also can express the reliability of risk information with hierarchy and multiple values[27]. Soft risk map is superiority to and more enriched than traditional probability risk map in aspect of forms and contents. It can be considered as the intending evaluative direction for probability-risk map[28]. Additionally, a simple algorithm of the interior-outer-set model was suggested to avoid complex combination calculus[29]. It provides convenience for widely using the model in fuzzy risk assessment of seismic risk.

Since China has a vast territory and the differences between urban and rural areas are significant, establishment of residential earthquake insurance system for urban and rural residents should be divided into two parts. In the process of producing soft risk map, the possibility-probability was calculated; the conservative risk map and risk-taking risk map were gained (Fig.3), which can be used under different levels of requirement. This will provide references for earthquake insurance under various conditions. However, it will be necessary to further consider how to select risk levels for earthquake insurance.

5. CONCLUSION

On the current stage of seismic study, earthquake is inevitable. How to cope with seismic hazard and mitigate earthquake losses is not only the research field that many scientists with great concentration on, but also the social problems that at all levels of government are very concerned about. How to deal with earthquake prevention and disaster reduction is already an important task for us. China has gradually formed a relatively feasible program for earthquake disaster prevention and mitigation. Earthquake insurance, as compensation to disaster risk, plays an irreplaceable role for comprehensive disaster reduction. In addition, it is one of the important measures against earthquake prevention and disaster reduction.

Song Ruixiang, Director-General of China Earthquake Administration (CEA), said earthquake insurance is a well-recognized cornerstone of any plan for economic compensation, since it reduces the government's economic burden, speeds recovery of the disaster area, and stabilizes society. However, lacking strong policy support and other reasons, a 20-year earthquake insurance scheme ceased in China in 1996. Since then, disaster recovery has been supported mainly by government funds and social donations[30].

Catastrophe modeling firm AIR Worldwide suggests that total property losses from the devastating earthquake that struck Sichuan Province will likely exceed RMB 140 billion (USD 20 billion) while insured losses will likely exceed RMB 2 billion (USD 300 million) and could reach RMB 7 billion (USD 1 billion). The total insurance claims will be no more than a few percentage points of the total economic loss caused by the earthquake.

In China, the establishment of viable insurance system has already stared us in the face. The China Insurance Regulatory Commission has already set up a team to research earthquake insurance, said China Insurance News. Just as many counties which have established the system of earthquake insurance, not all the schemes in such system can be described as the so-called "perfect". What we can do is to establish a relatively reasonable system as soon as possible, and, in the process of practice, keep improvement and perfection continuously. We need to invest resources and energy on seismic risk model studies, in order to establish a solid theoretical foundation for an earthquake insurance system adapted to the current China's national conditions. By other's faults, wise men correct their own; however, blind reference and imitation are unadvisable.

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