Paper No. 981. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

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CATASTROPHE RISK MANAGEMENT

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ABSTRACT

This paper reviews the evolution of catastrophe risk management (CRM) with emphasis on earthquakes. Past and present practices in earthquake risk management are described. The impact of earthquake engineering research on risk management effectiveness is delineated. In particular, it is shown how the systems approach in fusing advanced technologies has given rise to a new and more powerful generation of CRM tools. Future trends of interest to the earthquake engineering community are discussed

KEYWORDS

Catastrophe risk management; risk assessment systems; earthquake insurance; diversification

CATASTROPHE RISK MANAGEMENT (CRM)

Catastrophes have several unique characteristics. They occur infrequently, but when they do their large footprints can inflict significant losses ($30 billion for Hurricane Andrews and over $200 billion for the Hanshin-Kobe earthquake). Catastrophes also tend to be region specific: earthquakes in the Western U.S., hurricanes in the Southeast, snowstorms in the North and tornadoes in the Midwest.

Quite naturally, these elements are also the same ones that attract insurers to catastrophe events, and insurance has been proven an effective means of spreading catastrophic risks as evidenced by the $12 billion of insured losses in the Northridge earthquake of 1994. Large loss and footprint represent good market opportunity on the one hand but great risk on the other, just the usual niche for insurance. However, infrequent occurrence drives volatility which is exacerbated by the absence of norms or precedences. Catastrophes do not happen often enough to establish a track record in the actuary sense. Indeed, while most insurance contracts are directed primarily at protecting the individual risk, the catastrophe contract is designed primarily to reinsure the insurer against an accumulation of losses[1].

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[1] Which generally are a result of a single large occurrence such as a hurricane, tornado, flood or earthquake

The Past

No organized interest in CRM was evident until the 1970's, when several major earthquakes[2] took place that pointed to the need of treating catastrophes as distinct from conventional hazards such as fire and explosion. These events showed that the maximum loss estimates that hitherto had been considered adequate were not close to the actual loss potential. Furthermore, the necessary information did not exist; key data such as the sum amount insured, the quality of buildings, and geographic distribution of portfolios were not collected. As a result, an international group under the name of CRESTA was set up to address this problem.

CRESTA stands for Catastrophe Risk Evaluation and Standardizing Target Accumulations, and its objective is to promote the accurate and efficient identification, evaluation and control of catastrophe commitments in insurance and reinsurance on the basis of standardized information patterns. Studies have been carried out in 40 countries, focusing mainly on the earthquake sector. and the results are given in the CRESTA manual for each country called the CRESTA handbook. CRESTA recognizes that before a loss amount for a particular earthquake, storm or flood scenario can be calculated, the exposed values have to be known, broken down if possible by geographic location and type of risk or vulnerability. However, it does not answer the question of how much damage could occur in a large or extreme event. The CRESTA manual is only a quick guide to specific earthquake market, and is not an underwriting or rating tool.

Initial approach to earthquake CRM was sought in actuarial foundations that worked well for life and fire. However, it soon became obvious that the database for major earthquakes was too minuscule and a simple carryover of the methodology would be flawed. Hence, judgment and experience were combined with an approach based on the Probable Maximum Loss or **PML**. The PML concept was originated by Engle, and developed further by Steinbrugge (1982) and his colleagues for the insurance industry and government (Department of Insurance, U.S. Geological Survey). It is the main method of reporting on earthquake exposure for much of the 1980's, and is still in use today.

In this approach, the underwriting territory is divided into zones, each of which is assigned a maximum event and subjugated to its influence. The methodology enables, for the first time, an insurance company to estimate its exposure in each zone and determine its concentration of risk. It also identifies the risk between construction classes, so that if a company wishes to limit or expand its total earthquake exposure, it would know how to do so by changing the allocation among classes. Refinement of earthquake risks is possible by taking into consideration more detailed information such as age of structure, proximity to known faults, and soil conditions. Reinsurers can use the PML data to monitor the earthquake exposures of their ceding companies. The Department of Insurance uses the reports to monitor each company's exposure in relation to the company's surplus, and compiles aggregate industry exposure to damage from a great earthquake. Such information is also of interest to individual companies, reinsurers, investment analysts, the press, legislators, the general public, and government.

Despite its namesake the PML method is essentially a deterministic method that fit in well with the state of knowledge and technology 20 years ago to address the solvency issue. It is recognized that conventional rating methods applied in property insurance are not suitable for calculating the basic premium required to cover the earthquake risk; there is no proper record of past loss experience in a particular area that can be used as a statistical basis. One strategy that has been used in conjunction with PML is effectively amortizing the loss within the return period (Munich Reinsurance, 1988). The risk premium required for the period of

[2] San Fernando earthquake, 1971, with insured loss of US$30 millions; Managua earthquake, 1972, with insured loss of US$125 millions; Guatemala earthquake, 1976, with insured loss of US$90 millions.

one year, P, is the sum of the loss amounts[3] S (expressed as a percentage of the sum insured) divided by the return period N (in years) of an event of a given intensity.

$$P = \frac{S_{VI}}{N_{VI}} + \frac{S_{VII}}{N_{VII}} + \frac{S_{VIII}}{N_{VIII}} + \frac{S_{IX}}{N_{IX}}$$

Here, $N_{(I)}$ denotes the return period of an event X that will lead to an intensity I at the site of interest, and cause a damage of $S_{(I)}$. A suitable loading is added to the premium to cover uncertainties in the loss estimate. The gross premium contains adjustments for factors such as deductibles and limits of liability that have the effect of reducing the insured loss. Administrative costs and the costs of new business acquisition are added as appropriate. The premiums are calculated separately for every exposure zone and every type of risk.

The PML approach represents a break-through in earthquake risk management because liabilities are quantified clearly for the first time. This is accomplished by greatly simplifying the building loss estimate process and the ingenious use of class reference. For large portfolios involving thousands of buildings, the aggregate PML will be accurately portrayed by the class PML values. Adjustment factors correct for individual building features, site intensity and geological conditions. The implication is that while loss prediction for individual buildings may be difficult to make, classes of buildings can be treated with higher confidence in the average sense, and the latter is of most concern to insurers with regard to catastrophes. This basic philosophy remains true in all methodologies that come after the PML; most changes constitute refinement on detail.

The Present

Several refinements to the PML methodology, called **extended PML** are obvious when the constraint of hand calculation is removed. The refinements can best be described in the context of the damage assessment chain (viz., source modeling, site hazards, and building damage), which is what PML is designed to address. In particular, the rigid PML zones can be discarded and replaced with more rational determination of site hazards. Uncertainties in seismic event, shock propagation and building performance can be incorporated. Other refinements and enhancements related to insurance practice can also be added.

For computation expediency, the PML embodies a simplification which, in retrospect, is inappropriate. In an effort to retain a certain degree of conservatism in the loss estimate, the 9-out-of-10 rule is adopted. However, in so doing it obliterates the role of damage variability in risk tradeoff and management. It is now known that the distributedness of loss estimates is an inherent element of insurance/reinsurance strategies.

Along with the progress in our understanding of building response and damage, computer technology has made leaps and bounds since the time of Steinbrugge and Engle so that the underwriting industry needs no longer be constrained by hand calculations and table lookups. Consequently, very sophisticated engineering models can be tightly integrated with detailed, expert knowledge from various disciplines such as seismology, geology, geophysics and structural engineering, to generate in-depth damage estimates for the increasingly demanding risk management process (e.g., see Dong *et al.*, 1988). Furthermore, computer systems technology also enables broad and seamless integration of the phenomenological models with finance and decision models (e.g., Dong, 1994). This new generation of computer tools is called **CRM systems**.

CRM Systems

[3] The loss can be the amount obtained by the PML method, or any other method for that matter.

CRM systems share some commonality with PML, but are each unique in the way they achieve improvement. The following discussion will emphasize the enhancement aspect of the new methodology, relying on examples taken from *IRAS*[4] for illustration. The same break-throughs carry over to hurricane risks and other catastrophic hazards. Indeed, as will be illustrated, much of the power of a tool such as *IRAS* is derived from its ability to treat multiple hazards and perils in a unified and synergistic manner.

The basic goal of a CRM system remains unchanged from that of PML, viz., to quantify loss and its associated uncertainty. PML first introduces the concept of class damage (class PML), which provides the needed reference for inferring the damage to individual building. This concept is retained. Variability in damage due to building class, site condition and other details is recognized, although handled in different ways in different systems. Similarly, integration of the estimated damage with prevalent underwriting practice is made.

Important enhancements of CRM systems over the PML approach, as exemplified by *IRAS*, include the following:

- State-of-the-art phenomenological and engineering models
- Integrated and constantly updated databases
- Comprehensive treatment of uncertainties
- Distributed loss algorithms
- Computation of losses and loss variability for all purposes
- Integrated engineering and financial models
- Integrated multiple peril capabilities

Other enhancements and details are described in Dong (1995).

POWER OF SYSTEM INTEGRATION

Perhaps the most distinguishing feature about the new generation of CRM tools such as *IRAS* is that they are comprehensive systems that address all aspects of risk management, from the underlying physical phenomenologies to their impact on the insurance and financial decision. The power that derives from comprehensiveness is made possible by exploiting technological advances in computer science: computation speed, mass storage, database, intelligent algorithms, client/server, and user interface. The power is readily and easily accessible to individuals or groups via the most common form of instrument - the desktop computer.

As illustration, Fig. 1 gives an overview of the *IRAS* architecture to indicate the scope of a modern computerized "system". The system can be viewed as consisting of four major groups of data layers:

- Basic Data Layers
- Inferred Hazard Layers
- Damage Layers, and
- Decision Index Layers

The data interact with one another through processors in the form of modules, only two of which are depicted in the figure for clarity. They correspond to the Hazard Analysis and Vulnerability analysis modules, and typical components of these modules are also indicated.

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[4] Insurance/Investment Risk Assessment Systems, a CRM support software for desktop computers developed by Risk Management Solutions, Inc.

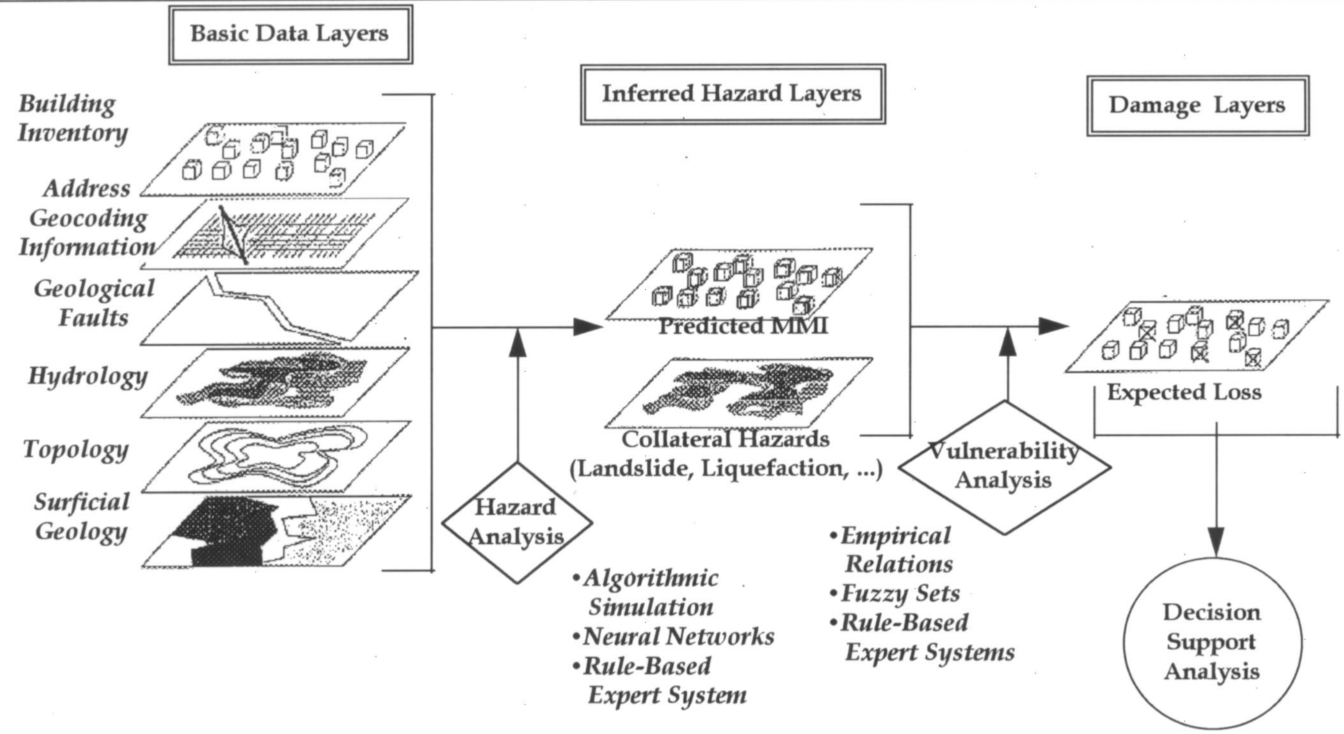

Figure 1. The *IRAS* framework.

Generally speaking, the construction of layers and modules is bottom up. Modules process data from layers and modules that are below them, and provide data for layers and modules above them. However, the sequencing of the layers and modules is not rigid, and the order in which they are presented in Fig.1 is for clarity of discussion only. A module can access directly any layer or module below it, even if there are many levels of separation. Additional groups of layers may be laid on top as required, and the details of the configuration above the damage layers often change in accordance with the client's requirements, e.g., insurance or investment. By the same token, the layers under damage are common to most applications save for the very special cases. However, since the common layers include data for all perils, not all layers are exercised in a particular application. For example, meteorology layers do not affect earthquake assessment and, hence, are not shown explicitly. A make-up of the Basic Data Layers when hurricane perils are of interest would look something like Fig.2, with similar changes in the Inferred Hazard Layers in the illustration as well as in the processing modules.

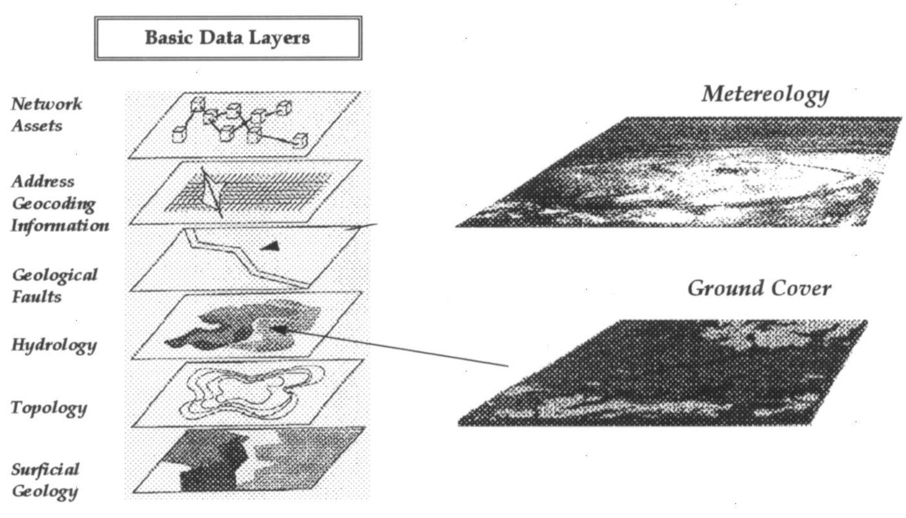

Figure 2. Basic data layers for hurricane damage assessment.

CRM SYSTEMS AND EARTHQUAKE INSURANCE

Although the general wisdom of spread, diversification and coinsurance are well-known in insurance circles, earthquake risks pose challenges that have not been fully met despite many studies (Meyers, 1994; Schnieper, 1992; Steigler, 1987). The main reason is the lack of an integrated quantitative computation model that can provide the necessary risk information; this need has only recently begun to be filled. System integration not

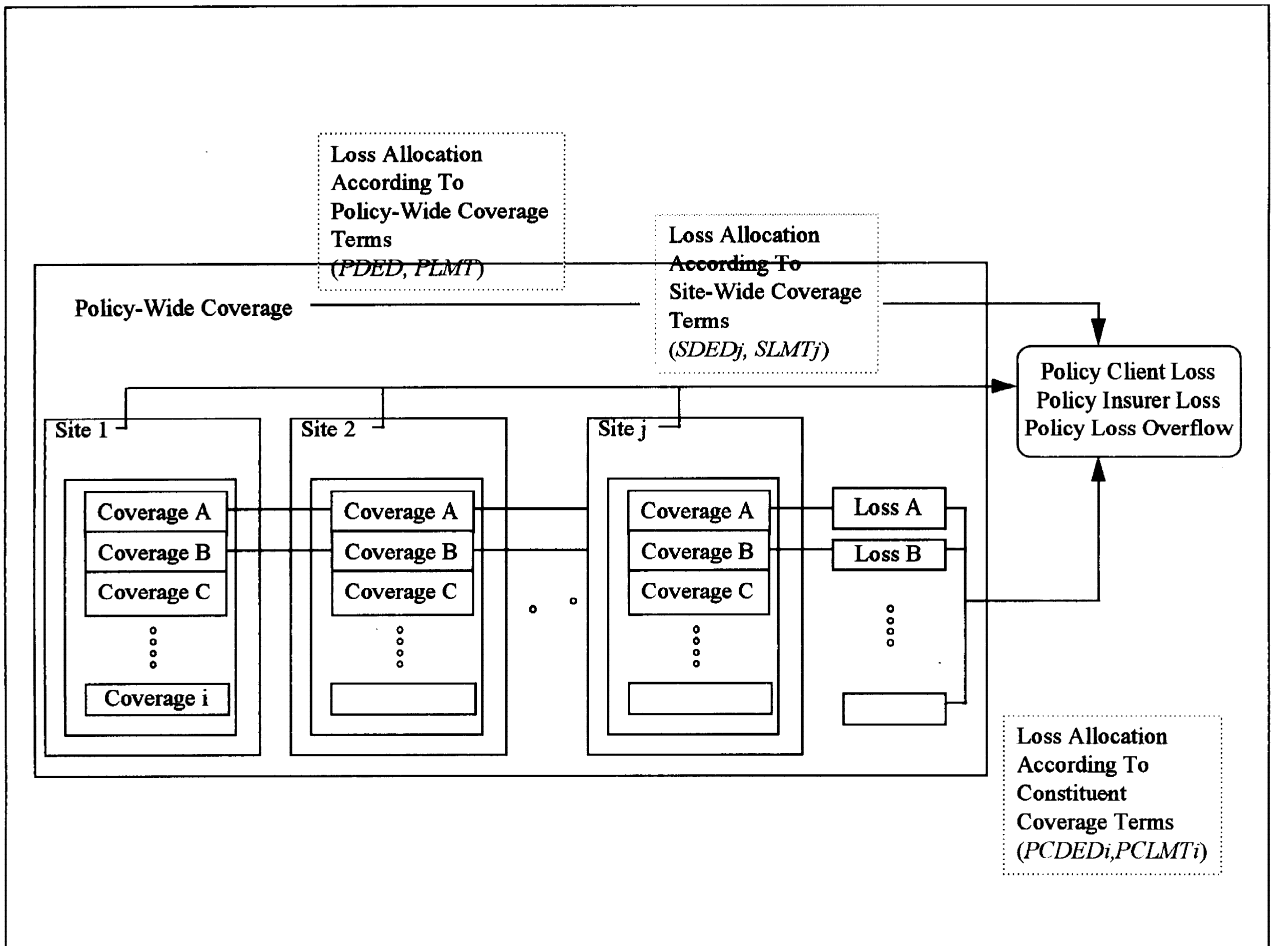

Figure 3. Loss allocation per coverage, per site and per policy.

only leads to enriched engineering models, but also enables, for the first time, the quantification of the impact of various risk management options through seamless fusion with insurance decision models. The process is by no means trivial. Figure 3 gives only a glimpse of the complexity involved; it shows the algorithm by which loss is allocated to the insured, insurer and reinsurer on the per-coverage, per-site and per-policy basis.

However, once accomplished, CRM systems can address insurance decisions not possible before. Take diversification for example. Figures 4 and 5 depict a tradeoff study in which the effect on risk of different degrees of spatial spread in a large portfolio in California is evaluated. In the figures the location and size of the circles denote, respectively, the placement of the asset and the amount of coverage. Some 4,000 policies are involved.

Another diversification technique is layering. Layering refers to the vertical division of the potential loss with the intention of assigning the layers to other insurers or reinsurers (see Fig.6), and is another powerful technique which cannot be exercised with PMLs. Multiple peril diversification shown in Fig.7 is yet another example, and so on. Although emphasis of this paper is on earthquake risk and insurance, it is easy to see CRM systems evoke a synergism that extends beyond the nature of the catastrophes.

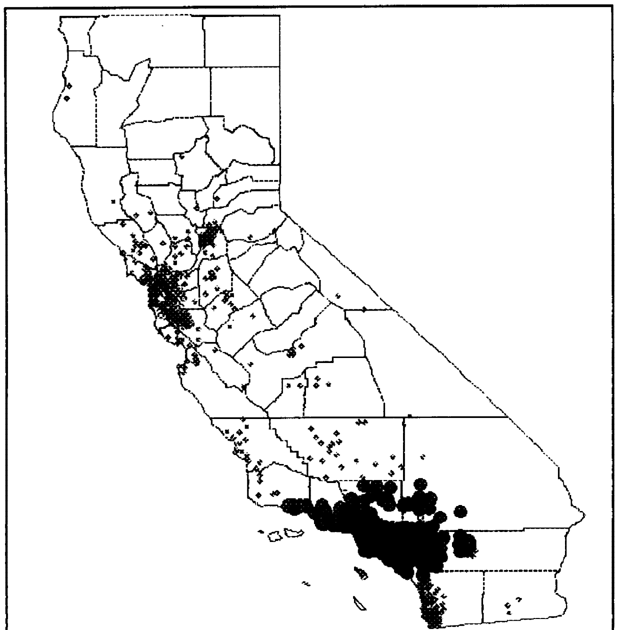

Figure 4. A relatively (spatially) diversified portfolio, state of California.

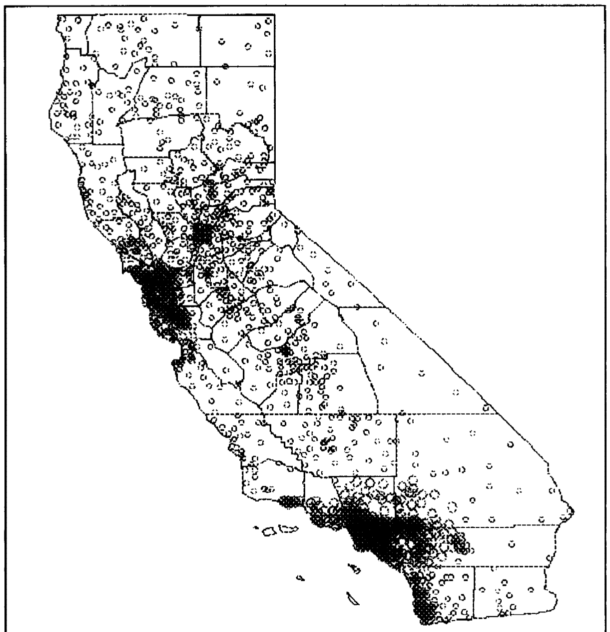

Figure 5. A well-diversified portfolio in the state of California.

FUTURE TRENDS IN CRM

From an earthquake engineer's viewpoint, the confluence of several trends will make CRM in this and next decade even more challenging. One is increasing valuation of building stock and infrastructure assets. The price for a major event, based on the Hanshin-Kobe figure, is staggering. The second is demographic. It is estimated that by the year 2000, 75% of the nation's population will live within 10 miles of the coast. The implication is that there will be significantly increased concentration of population, with the accompanying increase in manufactured housing, in urban centers susceptible to catastrophes. Aging and poor ground also add to vulnerability of buildings.

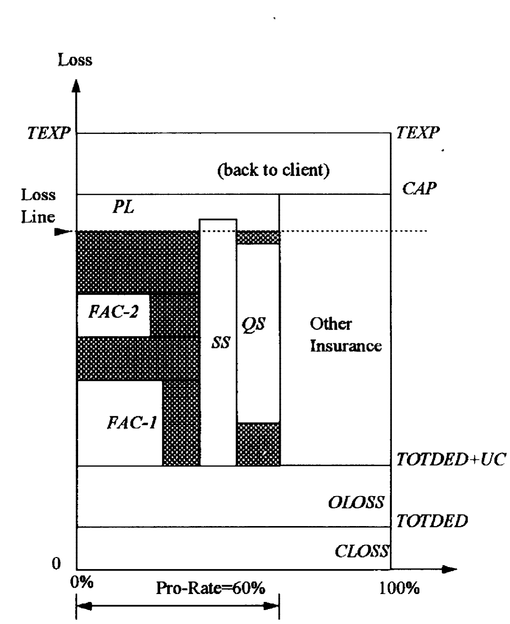

Figure 6. Layers in a client/insurer/reinsurer agreement.

The insurance business in the meantime becomes ever-more global and competitive. There is need for increased sharing of information on global events, between insurers and reinsurers, and with clients. The extent of government involvement will likely change but the trend can only be postulated. Currently, federal and state relief varies with the type of catastrophe. Along with government relief will be a need for increased sharing of information between the insurance industry and government officials whether or not changes in policy are contemplated. Finally, back-end financial tools are getting very sophisticated, and demand to be integrated with the engineering tools. Better loss quantification procedures and improved assessment accuracy will have much greater financial impact than never before.

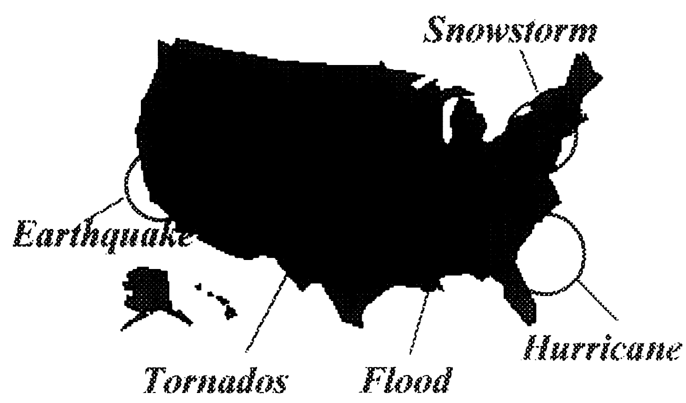

Figure 7. Spreading to all parts of the U.S. via multiple peril diversification.

CRM can channel these pressures into advantages by leveraging advances in technology and engineering, and by extending interdisciplinary integration to the global scale. Great demands lie ahead for the earthquake engineering community not only to advance the state of knowledge but also to encapsulate and transfer that knowledge so that it can be used in CRM. It is no longer sufficient to limit ourselves to our own specialty. Multiple and interdisciplinary integration will be the norm of the day. Effective CRM requires investigating all options, which means that models for all perils such as earthquakes, hurricanes and floods must be brought under one roof, and that catastrophe impacts be considered in the global scale.

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