

Journal of Actuarial Practice

Volume 3, No. 2, 1995

REPRINT



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Journal of Actuarial Practice

Vol. 3, No. 2, 1995

Measuring and Managing Catastrophe Risk

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Abstract‡

We introduce some of the basic principles behind property catastrophe modeling via simulations. The output of such simulations can be explored via modernized pin maps and loss likelihood curves. We also briefly discuss some of the uses of catastrophe modeling in addition to traditional probable maximum loss estimation. Comments are made on the use of modeling by reinsurers. We hope that this article stimulates discussions on new approaches to catastrophe modeling.

Key words and phrases: *exposure, simulation, reinsurance, pin maps, concentration, market share*

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‡This article is based on the authors' article of the same name that appeared in the *Casualty Actuarial Society May 1995 Discussion Paper Program*.

1 Introduction

Property insurance companies have always been concerned with the risk of catastrophic loss. They have used mapping as a method to control their exposure since the 1800s when insurance companies were hit by fires in major cities (Boston, Chicago, and Philadelphia). Mapping first was used to measure conflagration exposure; at that time there was no coverage for perils other than fire and lightning. Underwriters would place pins on a map showing the location of their insured buildings, and they would restrict the exposure the company would retain in a block or town. When wind storm was introduced as a covered peril in the 1930s, companies used mapping to assure that they were not overly concentrated for hurricane or tornado perils.

Pin maps were used until the 1960s when companies abandoned this time-consuming practice. About this time the U.S. was experiencing a period of low frequency and severity of natural catastrophic events. Damaging hurricanes were scarce, especially in Florida, and a major earthquake had not occurred since 1906. Modern fire fighting and construction practices had made the threat of conflagration minimal. As a result, the insurance industry largely lost the discipline of measuring and managing exposures susceptible to catastrophic loss.

The property catastrophe reinsurance industry had done well in these fortunate times and subsequently reduced reinsurance rates to levels below long-term needs. Primary companies were able to purchase property catastrophe reinsurance at low prices. Property catastrophe reinsurance purchasing decisions were centered mainly around the desired maximum limit; price considerations were not a significant concern. Many primary companies managed their catastrophe exposures by purchasing reinsurance using crude rules of thumb and ignored their concentration of exposure.

Other companies, because of either expense savings or the lack of capacity in the reinsurance market for large companies, decided to go without reinsurance. Without reinsurance costs these companies were able to write business at lower prices and thereby increase their market share, further exposing themselves to large reductions in their surplus from catastrophic losses.

In 1989 this naive world changed. Hurricane Hugo swept through the Caribbean and hit the Atlantic coast of the United States, causing the largest catastrophe loss in history. The 1989 Loma Prieta earthquake in San Francisco reawakened fears of earthquake losses. The reinsurance market began to react to these and other international events. Catastrophe reinsurance prices started to increase, and coverage was restricted.

Hurricane Andrew struck South Florida in 1992 on the heels of those events. Some insurance companies took significant hits to their surplus; others went bankrupt. Many insurance companies had not realized the extent of their exposure concentrations. Reinsurance markets reacted swiftly by sharply raising prices and retentions while restricting limits. Regulators, rating agencies, and boards of directors became intensely concerned about their companies' abilities to manage their catastrophe exposures.

The Northridge, California earthquake and the Great Hanshin earthquake in Kobe, Japan have raised new concerns over the insurability of a major catastrophe and the success of engineering against earthquakes. Inadequate insurance pricing in catastrophe-prone areas has contributed to population growth and construction in some of the most catastrophe-prone areas in the United States.

We will now discuss some of the basics of catastrophe modeling, the current capabilities, and some current modeling problems, starting with the most important component of catastrophe modeling: exposure.

2 Exposure Data

All discussions of catastrophic exposure management must begin with the accuracy and availability of exposure data. The most sophisticated, complex catastrophe modeling systems cannot accurately estimate an insurer's losses if the insurer cannot identify what insurance coverages have been written and where those risks are physically located.

Company exposure databases vary considerably. The decisions to retain exposure information may be based on statistical agency, rate filing, or management information requirements. Budget constraints also have contributed to the design of some exposure databases. Catastrophe exposure management considerations are almost always of secondary importance.

Statistical plans for property coverages historically have been designed around fire insurance rating. Any shifts toward retaining information necessary for wind and earthquake insurance rating will not occur quickly, as changes to statistical plans have occurred infrequently.

Exposure information can be separated into two categories: physical characteristics and insurance coverage.

2.1 Physical Characteristics

Physical characteristics may include:

- Type of risk;
- Location;
- Construction;
- Number of stories;
- Age of risk;
- Number of risks.

The type of risk characteristic can be described in insurance terms through the line of business, classification, and type of policy codes. The line of business codes can distinguish personal property, commercial property, personal automobile, commercial automobile, personal inland marine, commercial inland marine, businessowner, or farmowner policies. Classification codes can distinguish the type of risks such as signs, boats, livestock, inventories, etc. The type of policy code can distinguish different types of commercial policies (mercantile, contracting, motel, office, apartment, etc.).

The quality of available location data varies substantially by company. The location recorded often is the billing location rather than the location of the property insured. While this may be only a moderate problem for personal lines, it can cause major distortions when modeling commercial lines. For more complex commercial policies many of the locations are not identified. This type of coding may produce a false measure of concentrations at the billing location, while understating other areas.

Some companies cannot provide location detail at zip code or street address. Location on a county or state detail can be spread to finer detail using population densities, census data, or credit reports, but this approach can lead to severe distortions in measuring the concentrations for a specific insurance company. The National Association of Insurance Commissioners (NAIC) is taking steps to force companies to collect zip code location information. The introduction of nine digit zip codes further will help to refine exposure location information. In the future exposure location identification could be determined within a few feet using satellite technology (global positioning systems).

2.2 Insurance Coverage

Insurance coverage data may include:

- Coverage type;
- Coverage amounts;
- Replacement cost provisions;
- Insurance-to-value provisions;
- Deductibles;
- Co-insurance;
- Reinsurance.

Coverage type distinguishes the type of insured exposure such as buildings, contents, appurtenant structures, vehicles, business interruption, etc. Replacement cost and insurance-to-value provisions identify those provisions where the insurance coverage may be greater than the specified coverage amount. Deductibles, co-insurance, and reinsurance provisions can reduce the insured loss to the company.

Insurance coverage data may vary by peril. For example, commercial earthquake policies may have sublimits. The hurricane peril may be excluded in some coastal counties due to wind coverage via windstorm pools. Companies also often impose higher deductibles for wind and earthquake perils.

2.3 Data Problems

Experience has shown that some insurance companies, particularly small to medium sized companies, have difficulty retrieving their data in a usable fashion. Extracted information may not balance with insurance company reports. Exposure data may be unreliable due to input errors or heavy reliance on defaults.

The first step to accurately measuring a company's exposures is to review the data collection and retrieval process to assure that the data give an accurate picture of insured properties. If the insurance company systems' personnel do not understand underwriting or insurance, they may not be able to verify the reasonableness of the data provided. Underwriting and/or actuarial personnel should be involved to assure the reasonableness of exposure data. Simple data checks on whether

the zip code is within the specified county or state or whether the implied premium-to-exposure ratios appear reasonable can identify problems with the exposure data.

Once exposure data are deemed to be reasonable, the modeling process can begin. If accurate exposure data are not available, a market share approach could be used. The market share approach models industry exposures and distributes the losses to company via their market share. Market share analysis can misrepresent an individual company's losses significantly.

Companies willing to invest in sophisticated databases to track their exposures and rate them using appropriate classification systems will have a competitive edge in coming years.

3 Catastrophe Simulation Modeling

Advances in computer technology have resulted in new quantitative tools developed to specifically manage catastrophic risk. Geographic information systems have allowed companies to resurrect pin maps with significant additional abilities. But beyond looking merely at exposures, catastrophe simulation models have given us the ability to estimate potential losses in a way that reflects current scientific thinking on frequency and severity distributions.

As actuaries we know that expected catastrophic losses and reinsurance decisions should not be based entirely on past catastrophic losses. Insured loss data from catastrophes have been recorded for roughly the last 45 years. During this period, severe hurricanes and earthquakes were so infrequent that this body of experience is not representative of the scope of potential occurrences. Also, the distribution of insured properties has changed dramatically over time due to the population shift toward the Atlantic and Gulf coasts and the earthquake-prone areas of California.

Clark (1986) and Friedman (1984) provide alternative methods for determining catastrophe losses through simulation modeling. Their methods involve first simulating the physical characteristics of a specific catastrophe, then determining damage to exposures, and then calculating potential insured losses from damages.

Although specific catastrophe simulation models are different, they all operate within a simple framework. The simulation models are based on three modules: (i) the science module, (ii) the engineering module, and (iii) the insurance coverage module. The specific functional form of the equations provided for these modules is not impor-

tant. The important elements are the types of variables the equations require. These modules are discussed below.

3.1 The Science Module

The science module simulates natural events such as hurricanes, storm surge, earthquakes, fire following earthquake, tornadoes, hail, winter storms, etc. The resulting force that causes damage by these events usually can be described through a series of equations.

For hurricanes, numerous models exist to estimate wind speeds at risk locations caused by specific storms. A simplistic function of hurricane wind speed at a location is shown below.

$$W_z = f_w(dp, r, s, l, a, t) \quad (1)$$

where:

- W_z = Wind speed at location z ;
- dp = Ambient pressure minus central pressure;
- r = Radius of maximum winds;
- s = Forward speed of the storm;
- l = Landfall location (longitude, latitude);
- a = Angle of incidence at landfall; and
- t = Terrain or roughness coefficient at location z .

Clark (1986) describes one such modeling system and shows how hurricanes can be simulated and used to estimate insurance losses.

For earthquakes, the result of this module is a shaking intensity at a specific location (i.e., zip code or street address). One possible relationship is:

$$I_z = f_1(m, s, e, a, g, d) \quad (2)$$

where:

- I_z = Shaking intensity at location z ;
- m = Magnitude of the earthquake;
- s = Fault or seismic area, including location and characteristics;
- e = Epicenter location;
- a = Angle of the fault rupture;
- g = Ground conditions, including poor soil and liquefaction potential; and
- d = Distance from fault rupture or epicentral area.

The specific forms of equations (1) and (2) are based upon meteorological and geological hypotheses and are beyond the scope of this paper as these equations can range from simple equations to more complicated series of differential equations. It is important, however, to note that the variables used by equations (1) and (2) are meteorological and geological in nature.

3.2 The Engineering Module

The engineering module is used to determine exposure damage resulting from wind speeds or shaking intensities. Wind and earthquake engineering research and historical loss information determine these relationships. We can express these functions as follows:

$$P_z^{(h)} = f_p^{(h)}(W_z, c, a, s, \nu), \quad \text{for hurricane} \quad (3)$$

$$P_z^{(e)} = f_p^{(e)}(I_z, c, a, s, \nu), \quad \text{for earthquake} \quad (4)$$

where:

- $P_z^{(h)}$ = Percent damage from a hurricane at location z ;
- $P_z^{(e)}$ = Percent damage from an earthquake at location z ;
- c = Construction of building;
- a = Age of building;
- s = Number of stories; and
- ν = Coverage (i.e., building, contents, time element).

The variables used by equations (3) and (4) are engineering in nature.

If we apply these damage percentages to the exposed properties from an insurance company's database, the result will be an estimate of the total damage to those properties caused by the simulated catastrophe.

$$D_z = E_z \times P_z^{(h)} \quad \text{or} \quad D_z = E_z \times P_z^{(e)} \quad (5)$$

where D_z is the damage at location z and E_z is the dollar exposure at location z .

Underlying each damage curve or damage function is a frequency component and a severity component. The frequency component determines the probability that a property will be damaged. The property is either damaged or not damaged. The severity component determines the percentage of the property that is damaged, given that damage has occurred.

Damages can vary by more than just construction type, number of stories, age of building, and type of coverage (e.g., regional construction practices, building code and building code enforcement, occupancy use, surrounding terrain). Friedman (1984) gives an example of damage relationships that form the basis of the earlier wind models. A study conducted by the Applied Technology Council (1985) provides much of the basis for earthquake damage relationships. More research is being done by the engineering community to refine these relationships. A cooperative action by insurance companies to share detailed historical loss data with the engineering community could validate the theoretical research now being done.

Recent studies have shown that additional exposure information such as window and door protection, roof covering, and roof sheathing attachment have the greatest influence on the overall resistance to hurricane damage (U.S. Department of Housing and Urban Development, 1993). New studies such as these are helping insurance companies identify those underwriting factors that promote loss mitigation. Just as fire peril concerns determined early statistical reporting, the wind and earthquake perils now may encourage finer detailed exposure information for underwriting control and exposure quantification. With the reporting of such important building characteristics, catastrophe models will improve their abilities to replicate historical storm losses.

3.3 The Insurance Coverage Module

The insurance coverage module translates the damaged exposure into insured damaged exposure. Data required by this module include limits, replacement cost provisions, and insurance-to-value provisions. This module also includes loss reduction provisions such as deductibles, co-insurance, and reinsurance.

The following example describes some of the considerations used when modeling a primary company's exposures. Different formulae may be used depending upon whether individual or aggregated exposure data are used or if the modeled company is a primary company or a reinsurance company.

$$\begin{aligned} (ID)_z &= f_{ID}(D_z, r, d, l) \\ &= \min[\max[(r \times D_z) - d, 0], l] + a \times D_z \end{aligned} \quad (6)$$

where:

$$(ID)_z = \text{Insured damage at location } z;$$

- D_z = Damage at location z ;
 r = Guaranteed replacement cost multiplier;
 d = Deductible;
 l = Reinsurance limit; and
 a = Allocated loss adjusted expense (ALAE) percentage.

The guaranteed replacement cost multiplier adjusts damage to reflect the cost of replacing an item. Policy conditions determine whether the insurance limit will have an impact on the replacement cost coverage.

Deductibles need to be modeled as a straight dollar deductible or percentage deductible. Models must consider the impact of the deductible upon the losses. If the model works on a per risk basis and simulates the varying severity levels of damage, the impact of the deductible can be determined easily. If the model uses aggregate exposure data, however, it must reflect that not all risks will suffer damage greater than their deductibles. As wind speed or shaking intensity increases, the average severity damage increases and more of the deductible is utilized.

Reinsurance adjustments should reflect both pro rata and per risk excess policies written on both a facultative and treaty basis. Reinsurance such as catastrophe reinsurance or other aggregate reinsurance can be incorporated after damage for an event is aggregated for all risks. Deductibles and reinsurance coverage may vary on a per building or per occurrence basis.

Unlike the science and engineering modules, the insurance module is based upon actuarial principles. Careful consideration of the impacts of deductibles, reinsurance, replacement cost provisions, and other insurance coverages must be made. The impact of these insurance coverages is discussed by other authors and will not be reproduced here. (See, for example, Head (1971) and Lee (1988).) This insurance module should include a reflection of allocated loss adjustment costs and loss of use or business interruption coverage.

3.4 Deterministic vs. Probabilistic Modeling

Models can be based on deterministic or probabilistic approaches. Deterministic modeling is the simulation of specific events, either historical or hypothetical, that are pertinent to the portfolio under study. This approach can be helpful for validating model results or for providing an estimate for an certain event that concerns management.

Probabilistic modeling, however, has the potential to provide much more information to management. It can provide information for primary or reinsurance pricing and for setting underwriting or marketing strategies. In probabilistic modeling the modeler runs a large set of hypothetical events (scenarios) that covers a range of potential events. The results from these simulations can be used to estimate the probabilities of various levels of loss to the company (i.e., loss likelihood). This approach allows the company to manage its exposure portfolio and make reinsurance decisions by comparing the potential losses with the company's appetite for risk.

4 Techniques to Locate and Prevent Concentrations

The modeling process ties the company's exposures with storm or earthquake frequency/severity information to determine the potential losses. The output of simulation modeling can provide considerable information beyond the potential loss levels and their attendant probabilities. An important byproduct of the modeling is information on the concentration of the company's losses.

With the introduction of computer mapping products, pin maps have been resurrected. Mapping packages can profile exposure concentrations on a county or zip code basis or, if necessary, show point locations. Mapping today is limited by the amount of exposure location information retained by insurance companies. Because most companies now retain zip code detail, the following section will assume this level of detail.

Summing exposures by zip code can be misleading, as zip codes can vary significantly in size. Using exposure densities can solve this problem. Exposures are summed by zip code and divided by the number of square miles within the zip code to yield the exposure density. Exposure density mapping tends to accentuate those inner city zip codes where more exposure typically is concentrated in a smaller area. Zip code exposure densities do not identify exposure concentrations within a zip code.

Analyzing loss potentials by examining only exposure densities can be misleading. Loss densities should be used. Loss densities are created by simulating a library of storms and retaining the losses on a zip code level. The losses on a per storm basis are multiplied by the probability of each event. After the losses are aggregated for all storms, the losses for a zip code are divided by the square miles within the zip code. The loss density maps combine both the exposure concentrations and

the frequency and severity of catastrophic events in that zip code. Loss densities can be used to determine catastrophic loss costs for ratemaking. The following maps show an example of the exposure density and loss density maps (Figures 1 and 2 respectively) for the northeast region for a sample insurance company.

Another graphical representation of a company's exposures is a histogram. Histograms can show the relative loss by landfall area for a specific type of storm or return period storm. These storms could be a specific class hurricane or they could be the 95th percentile storms for each area. Figures 3 and 4 are histograms showing the hypothetical results for the industry (Figure 3) and for sample insurance company (Figure 4). As can be seen from these histograms, our sample insurance company has significantly greater exposure to a hurricane hitting central Florida than the industry does. The results of modeling can be used to decide the most appropriate actions to address problem areas. The most likely areas of action are marketing, underwriting, pricing, and reinsurance.

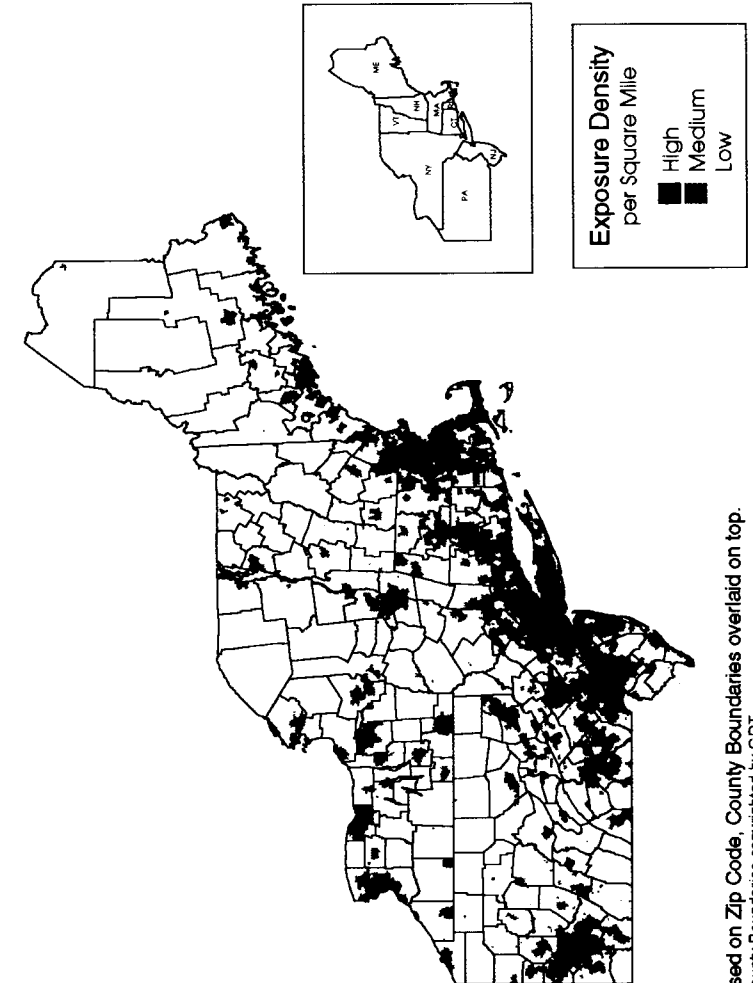
For many companies, the focus of marketing is their agency force. They can select, within limits, where to appoint their agents, how much business they will accept from each agent, and where that business is located. The results of probabilistic modeling can help a company considerably in this area. From those results management can determine which agents are producing business with a disproportional potential for catastrophic losses and work with those agents to reduce writings to acceptable levels while minimizing the effect on the agent. The company can identify areas where new agents can more safely be appointed, so that additional writings will not exacerbate the exposure problem. Similarly, underwriting standards can be established that discourage business in areas of dangerous concentration, while encouraging business elsewhere.

Modeling can be used for many purposes:

- To monitor the catastrophe potential in all areas of the country;
- To warn of growing levels of concentration before they become a problem.
- To test the effects of various underwriting actions such as increased deductibles, policy sublimits, and selective policy non-renewals; and
- To identify those areas for more stringent individual risk protection requirements.

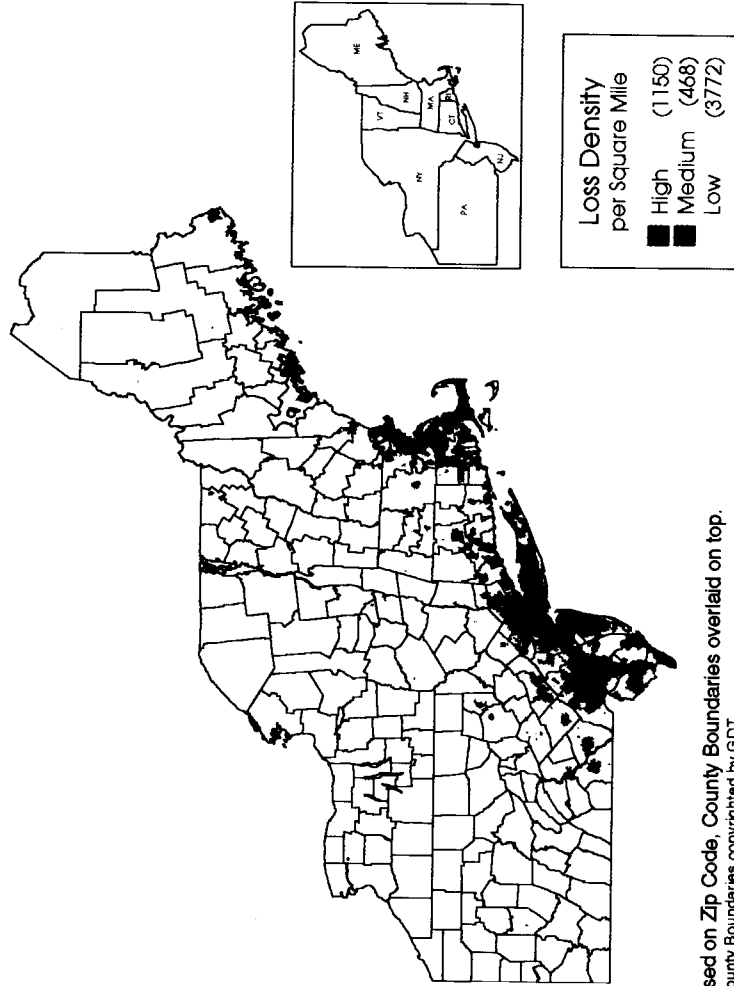
Pin maps are back!

Figure 1
Northeast Region Exposure Density



Densities based on Zip Code, County Boundaries overlaid on top.
Zip Code and County Boundaries copyrighted by GDT

Figure 2
Northeast Region Loss Density



Densities based on Zip Code, County Boundaries overlaid on top. Zip Code and County Boundaries copyrighted by GDT

Figure 3
Industry Histogram

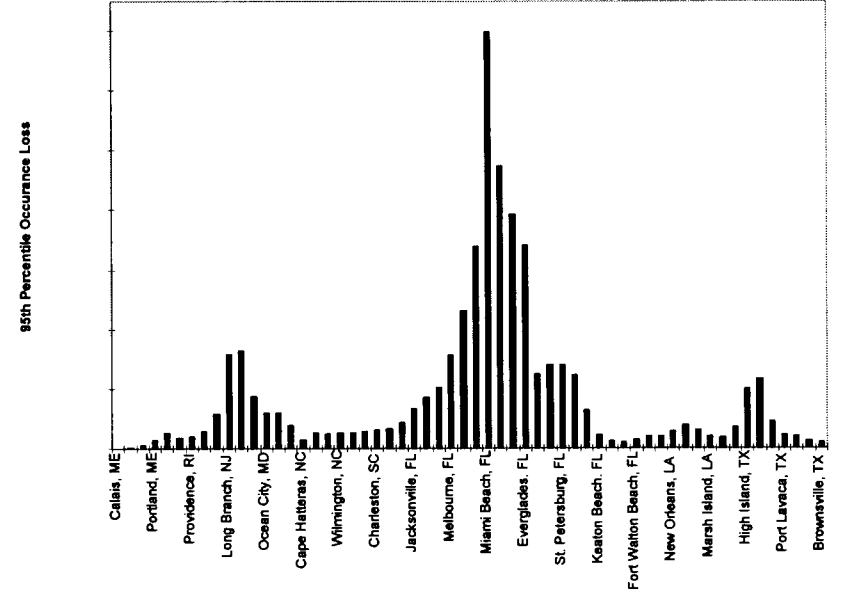
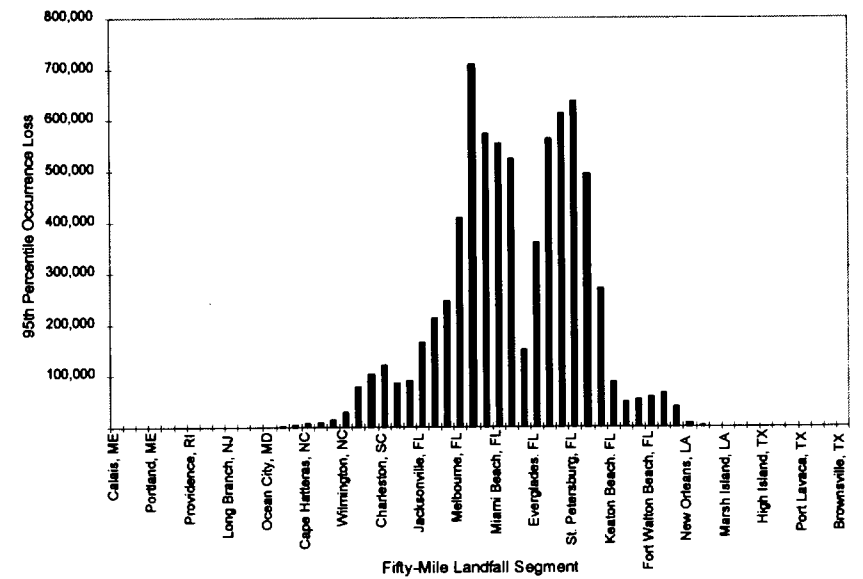


Figure 4
Sample Insurance Company Histogram



5 Reinsurance and Excess Modeling

There was a dramatic drop in catastrophe reinsurance availability following Hurricane Andrew. This drop was caused by fears among the reinsurers that they had become overextended in catastrophe business and that they needed to better control their aggregate exposures. The demise of the London Market Excess (LMX) market contributed to a reduction in retrocessional capacity available to reinsurers who wrote larger lines than were prudent. Reinsurance markets cut the capacity.

Modeling allows a reinsurer to measure potential exposures, so that it can more efficiently write business while safeguarding its assets. Models allow it to measure the maximum losses possible to certain events, so that it isn't restricted to a certain amount of aggregate limit in an arbitrary geographic zone. By tying the models to the underwriting process, the reinsurer can determine the effect on its concentrations from adding a contract. This ability to better measure potential losses increases the underwriter's willingness to accept additional contracts, thus increasing the availability of reinsurance in the market.

5.1 Does Market Share Analysis Work?

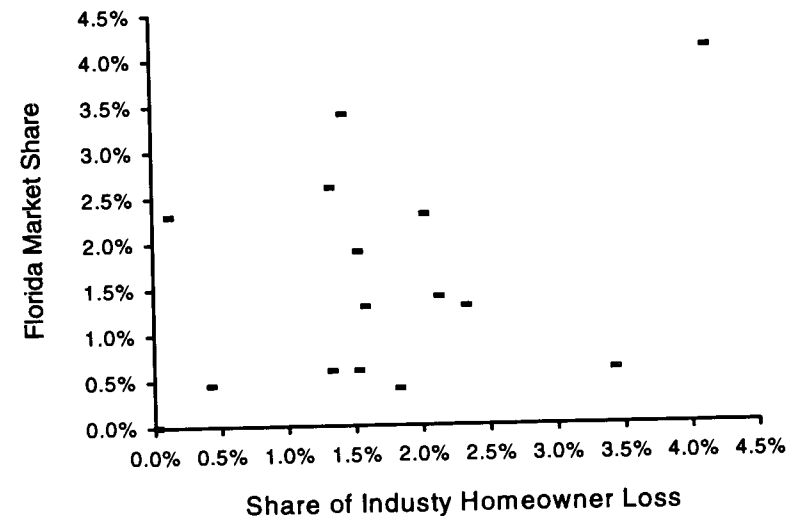
Unfortunately, modeling for reinsurers is not as easy as it is for primary companies. This is due to the differences in available data and the additional complexity of contract conditions.

Most primary companies have detailed exposure data, at least by zip code, allowing the modeler to estimate losses at that level. Until recently, however, reinsurers have been limited to premium data by state. This lack of detailed data necessitated a modeling approach wherein losses first were simulated for the entire insurance industry, then the individual ceding company losses were estimated using its market share. Figure 5 shows the relationship between the market share loss estimate and the actual loss for individual companies. There is little correlation between the two for individual companies.

Market share analysis for earthquake is even more difficult because current line of business structures do not define whether earthquake coverage is provided. For example, personal earthquake coverage can be reported under homeowners or personal earthquake policies.

In late 1993 exposure data by county were requested by many of the more technical reinsurance markets. This data enhanced reinsurers' abilities to estimate primary companies' losses, but not to the level of accuracy needed to price reinsurance.

Figure 5
Statewide Market Share



Market share analysis is even less accurate when modeling excess property or large account business. A market share approach for an excess writer treats that business as ground-up business (i.e., losses without reflection of deductibles), totally distorting the potential to the company. Similarly, large account businesses rarely carry accurate location codes on all the buildings in a schedule. Even if county exposure information is available, it is possible that the location data refer to the billing location rather than to the risk location. This type of coding usually puts large concentrations of exposure in a small number of locations, ignoring the real spread of risk.

While market share analysis is a significant step forward in analyzing reinsurers' loss potential, we believe that market share modeling based on county data leaves much to be desired. For instance, the differences in damages for those zip codes along the coast versus those inland can be substantial, yet market share modeling does not differentiate them.

Market share modeling can be particularly misleading for a company with a distribution of risks within a county that is different from the

industry distribution. Until either actual zip code exposures of the detailed results or the company's own modeling are readily available to the reinsurance market, the information used by all but the most sophisticated reinsurance markets will continue to be inadequate to properly underwrite their book of business. The most sophisticated reinsurance markets are using zip code information to underwrite their book of business.

One way to best utilize primary company modeling is for a reinsurer or the market as a whole to define a set of standard scenarios, either probabilistic or deterministic, to be modeled against the primary company exposures. The reinsurer can calculate contract losses based on contract terms to determine its portfolio losses from each scenario. This information provides a quantitative comparison of various contracts as well as the effect of any new contract to the portfolio for underwriting and pricing decisions. Adjustments may be necessary to compensate for differences among the various models used by the ceding companies.

5.2 How to Model Reinsurance Losses

While primary company loss modeling usually can be done on a policy or aggregate basis, reinsurance modeling should be done on a contract by contract basis. Combining contracts with different policy limits, quota share percentages, and attachment points can distort the modeling results.

Losses should be calculated using the total values exposed and then limited based upon the conditions of the reinsurance contracts. Policy limits apply to each individual risk location, whereas loss limits apply to all locations. The combinations of different contracts reduce the ability to model losses appropriately.

Mapping reinsured exposures is more difficult than primary company analysis. For example, assume three risks are covered under a \$10 million excess \$5 million reinsurance contract; see Table 1. Mapping the exposure to this policy could be done a number of ways. First, we could map the full exposure for each risk. The problem with this method is that it can overstate the importance of Risk B. Second, we could map the exposure inside the excess of loss on a per risk basis (\$10 million for Risk B, \$7 million for Risk C). But this method ignores Risk A.

One answer to catastrophe exposure mapping is to run the probabilistic database against all exposures. One event could cause losses to both Risk A and Risk B so that each resulting loss within the excess of

Table 1
Excess Reinsurance Contract Data

	Losses	City
Risk A	\$ 3 million	Palm Beach
Risk B	\$40 million	Miami
Risk C	\$12 million	Atlanta

loss agreement would be spread proportionately to each risk. Unlike the first suggestion, the exposure from Risk B would not be overemphasized. Unlike the second mapping suggestion, the exposure from Risk A can contribute toward losses.

Models that use only mean damage factors can distort loss potential, especially when an excess contract is being modeled. It is possible that using mean damage factors will result in an estimate of no losses to an excess contract, when losses are possible. For example, assume that a specific wind speed causes an average of 15 percent damage to a specific type of building. Within each estimate of damage, no matter how defined (frame construction, shingled hip roof), there always exists a range of damage potential. Risks having an average of 15 percent damage may consist of some risks having 5 percent damage and some having 75 percent damage. It is possible that the one risk having 75 percent damage may hit the reinsurance layer. In modeling reinsurance layers it is important to build in the variation in loss severity. The variation in damage severity can be built into the engineering module.

5.3 Payback

One of the pricing concepts in the catastrophe reinsurance market is that of payback or return time. When an underwriter considers the price he or she will charge for a treaty, the underwriter determines an approximate frequency of an event that will affect the layer in question. Thus, if the actuary is pricing a layer \$25,000,000 excess of \$25,000,000, he or she needs an idea of how often to expect an occurrence that will cause a loss to the ceding company of more than \$25,000,000. If the actuary believes that such an event will happen every five years and that every such event will exceed \$50,000,000, the actuary can estimate the amount necessary to charge for the loss portion of the price. Simply put, a \$25,000,000 limit with a five year payback should cost \$5,000,000, plus provisions for expenses, risk load, and profit. In

reality, this exercise is not as simple, but one can determine the expected cost in the \$25,000,000 excess of \$25,000,000 layer using a loss likelihood¹ curve produced from the probabilistic storm database.

Catastrophe modeling can help the underwriter estimate these return times or paybacks. By modeling the ceding company's exposures, the reinsurer can simulate the effects of various events on the proposed layers to be offered. The probabilities of loss levels that will hit each layer can be calculated; the underwriter can convey the probabilities (e.g., 5 percent) to return times (e.g., 20 years).

5.4 Additional Contract Pricing

The term *additional contract pricing* refers to determining the pricing and acceptability of a contract based upon the marginal profit and marginal risk that the contract adds to the portfolio. The adjustment for risk is based on how much the new contract adds to the chance of overconcentration. Using this method of judging a contract seems to give undo favoritism to those contracts written before the reinsurer has enough business to threaten overconcentration. From the reinsurer's point of view, however, once its capacity has been filled, it is less willing to write an additional contract and should be paid handsomely for doing so. Catastrophe modeling can be used to measure both the individual expected cost and marginal cost.

6 Pricing and Reinsurance Allocation Issues

Simulation models provide a long-needed tool to determine appropriate provisions for catastrophe losses in the primary rates. They can provide an estimate of the long range expected loss to the peril being modeled, and they can do this at the zip code level of detail. An actuary can combine zip codes into homogeneous territories to determine the appropriate catastrophe pure premium that should be included in the rate. A significant risk load also is warranted, given the level of uncertainty in writing catastrophic coverages. The loss distribution from the model can provide a starting point for estimating the risk load.

Similarly, a company can use modeling in determining appropriate allocations of its reinsurance costs. By running the probabilistic modeling against a company's exposures and its reinsurance program, the

¹The term *loss likelihood* is used loosely. Loss likelihood refers to the probability of a specific size loss (0.1 percent) or the return time in the number of years (1/0.1 percent = 1,000 years).

relative expected losses can be calculated for each layer by zip code. These expected losses can be combined to give the relative amount that a territory or state contributes to the catastrophe potential and, thus, the need for reinsurance. These indicated contributions can be used by the company in its decisions on rates, profit sharing, or agent compensation.

When establishing a price for a cover as uncertain as property catastrophe reinsurance the risk load becomes crucial. Actual risk loads charged in the market are most likely implicit in the market price and not actuarially determined. Modeling can provide the raw material for calculating a theoretical risk load for a technically oriented organization. The actuary can determine a measure of variation, e.g., the variance, from the loss distribution that results from a probabilistic model. This measure can be used to determine an appropriate risk load.

7 Conclusion

The risk of catastrophes to a portfolio of property exposures has been a problem for insurers in the recent past. The need to measure the extent of potential damage to a company is crucial, and the recent development of computer simulation modeling has provided techniques to measure this risk. Catastrophe modeling can be used for managing exposure concentrations, determining reinsurance programs, and pricing. Rating agencies such as A.M. Best and Standard & Poors require exposure management and catastrophe modeling for companies to retain a strong financial rating.

Models should be evaluated more for their qualitative value than for their quantitative value. Models are most useful when comparing the relative losses from specific events to different locations or different construction types. Models, however, seem to be graded more upon their ability to forecast damages from specific events such as Hurricane Andrew or the Northridge earthquake. To achieve greater individual event accuracy, several additional components need to be modeled. For hurricane/wind modeling, additional items such as rainfall, storm duration, humidity, downbursts, etc. need to be modeled. In addition, more detailed exposure data including door and window detail, roof sheathing attachment, and roof coverings are needed for more accurate projections of damages from such winds in a single event.

Catastrophe modeling today can be compared to some of the more rudimentary reserving methods. Neither of these approaches will produce the best answer in many situations; they are both rough estimates.

Just as a reserving actuary should use a number of reserving methods to estimate future liabilities, a pricing or reinsurance actuary should use more than one model when evaluating the catastrophe risk. Every model contains hundreds of assumptions. Scientists and engineers agree to disagree within their own fields on items such as return times of events or on the damageability of properties. Until these fields can come to a consensus, catastrophe models will differ. Recent hearings of the Florida Hurricane Commission on Loss Projection Methodologies show that while each model has reasonable assumptions, model results can vary immensely. As work in the catastrophe modeling field grows and as exposure data improve, more complicated and precise methods will develop.

Measuring the risk is only the first step. Management must manage its concentrations of exposure so that the company is not susceptible to bankruptcy when a catastrophe occurs. Simulation modeling is a helpful tool in this effort, but must be just one component of an integrated catastrophe management process.

References

- Clark, K.M. "A Formal Approach to Catastrophe Risk Assessment and Management." *Proceedings of the Casualty Actuarial Society* 73, (1986): 69-92.
- Friedman, D.G. "Natural Hazard Risk Assessment for an Insurance Program." *The Geneva Papers on Risk and Insurance* 9, no. 30 (January 1984): 57-128.
- Federal Emergency Management Agency. *Earthquake Damage Evaluation Data for California*. Report ATC-13. Redwood City, Calif.: Applied Technology Council, 1985.
- Head, G.L. *Insurance to Value*. Philadelphia, Pa.: Huebner Foundation, University of Pennsylvania, 1971.
- Lee, Y.S. "The Mathematics of Excess of Loss Coverage and Retrospective Rating—A Graphical Approach." *Proceedings of the Casualty Actuarial Society* 75, (1988): 49-78.
- U.S. Department of Housing and Urban Development. *Assessment of Damage to Single-Family Homes Caused by Hurricanes Andrew and Iniki*. Upper Marlboro, M.D.: NAHB Research Center, September 1993.

Discussion of Ronald T. Kozlowski and Stuart B. Mathewson's "Measuring and Managing Catastrophe Risk"

Rade T. Musulin*

1 Introduction

Mr. Kozlowski and Mr. Mathewson's paper provides a good introduction to the development and use of models in the property insurance industry. It will be a valuable addition to the regrettably sparse actuarial literature in this area. This discussion will offer several comments on the ideas raised in the paper, focusing on how models can be used to enhance an actuary's work.

The use of models has sparked major controversies between regulators and insurers in several jurisdictions, notably Florida. Controversy is not limited to the regulatory arena, however. Because models are being used by reinsurers to rate contracts and by A.M. Best to rate companies, management often must react to the application of modeling to the company. Many insurance company executives find themselves arguing with regulators for higher primary rate levels based on models but chafing under reinsurance costs developed using the same models.

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2 Ratemaking: Models vs. Traditional Approaches

2.1 Loss Cost Issues

In the introduction the authors discuss how events of the late 1980s and early 1990s led to severe disruptions in property insurance markets. The factors driving the property insurance crisis are complex and beyond the scope of their paper. A brief discussion of how traditional actuarial methods led to errors in estimates of loss costs and probable maximum losses, however, is an excellent way to emphasize the need for the development of computer models.

Ratemaking problems developed due to:

- An abnormal lull in catastrophic activity;
- A substantial shift of population to high risk areas;
- Use of actuarial techniques whose basic assumptions were violated by both of the above factors; and
- Limited availability of data and the computer power necessary to analyze it.

Prior to the late 1980s actuaries used a technique known as the *excess wind procedure* to estimate hurricane catastrophe provisions in rates. This technique examines the ratio of excess to normal losses in statewide aggregations of annual loss data and measures excess losses as those that exceed some multiple of a long-term mean. Losses above this threshold are excluded from the traditional five year ratemaking experience period and spread over a long (30 year) experience period. This method assumes that the last 30 years were typical in terms of storm frequency/severity and that the ratio of wind to non-wind (i.e., fire, theft, and liability) losses is constant over time. Both of these assumptions were grossly violated from 1960 to 1990 by abnormally low hurricane activity and explosive population growth in coastal areas.

In 1992 the Insurance Service Office calculated an excess wind factor of 1.14 for Florida homeowners, which would have generated approximately \$80 million in premiums for the entire Florida insurance industry annually.¹ At this funding rate it would have taken over 100

¹This figure is developed as follows: Total homeowners premium volume was approximately \$1 billion. Assuming an expected loss ratio of 65 percent, this yields \$650 million in loss cost, which equals normal losses multiplied by 1.14. Thus, normal losses were \$570 million, leaving \$80 million for excess catastrophe losses. While this calculation is a crude approximation of a complicated ratemaking process, it illustrates the magnitude of the pricing error.

years just to pay for Hurricane Andrew's homeowner losses, assuming no other storms in the interim.

Computer modeling techniques now allow actuaries to project the actual storm data of the 1920s onto the population and construction patterns of the 1990s, overcoming the limitations of the prior method.

2.2 Risk Load Issues

The authors also discuss the relationship between the purchase of reinsurance and primary price adequacy. In their Section 1 (fifth paragraph) the authors state "Without reinsurance costs these companies were able to write business at lower prices and thereby increase their market share, . . ." This raises another significant point about the actuarial techniques employed in the past.

Risk loads generally are considered to be an essential ingredient of an actuarially sound rate in lines subject to highly variable losses. While reinsurers long have considered risk load explicitly in their ratemaking, traditional primary ratemaking procedures used in property ratemaking did not. Companies that purchase reinsurance and reflected those costs in primary rates thereby included some risk load.

Standard techniques used by many insurers and rating bureaus for primary ratemaking focused on mean loss costs, ignoring potential variance of these loss costs. Risk loads were accounted for in profit and contingency factors often set using rule-of-thumb figures such as 5 percent or industry average return on equity adjusted for anticipated investment income. It has not been unusual for primary profit and contingency factors to be the same for low risk auto physical damage and high risk coastal homeowners. Even rarer was any consideration of differing risk load within a book of business. One might expect that a risk load would be different for homeowner risks in coastal areas versus risks in inland areas, but the notion of varying the risk load within a filing was virtually nonexistent.

As is the case with loss costs, computer models provide a wealth of information to actuaries on the variance and skewness of the aggregate loss distribution. The authors note that modeling provides the raw material for calculating theoretical risk loads, but they discuss the issue only in the context of pricing property catastrophe reinsurance. The issue is also of critical importance in pricing primary insurance; the lack of generally accepted actuarial and regulatory methods of handling this problem is related directly to the shortage of primary insurer capacity in high risk areas.

3 Building Models

3.1 Exposure Considerations

Their paper discusses the key elements of exposure data needed in the modeling process. But the actuary should not forget that the exposure on the statistical record may not be the actual level of exposure on which the loss will be adjusted. For example, many companies offer guaranteed replacement cost coverage that will pay the insured an amount greater than that shown on the policy declaration if the actual loss exceeds that amount. This feature contributed to far greater than expected losses in Hurricane Andrew, when a demand surge for materials and labor caused prices to inflate after the loss. The actuary must understand what policy provisions may be lurking behind the statistical records in order to accurately use a computer model.

Insurance to value is also critical. Most models assume that property is insured to 100 percent of replacement cost. If the company insures to 80 percent of value, the reduction in expected losses will not be 20 percent because most catastrophe losses are not total.² The actuary must work with the modeling vendor to correctly adjust for the actual insurance-to-value practices of the company.

The authors state in their Section 2.2: "Replacement cost and insurance-to-value provisions identify those provisions where the insurance coverage may be greater than the specified coverage amount." Company-specific practices in these areas could result in insurance coverage either above or below the specified coverage amount. For example, most models assume replacement cost, but the company's contract provisions may provide for actual cash value settlement of contents or roof claims.

3.2 Statistical Considerations

The authors make a key point that most insurance company property statistical systems are designed for traditional perils of fire and

²For example, consider two \$100,000 houses, one insured for \$100,000 and the other for \$80,000. A partial loss requiring the roof to be replaced will result in the same loss to the insurer on both homes. Because only a small proportion of risks is totally destroyed in a given event, the reduction in insured losses must be less than the reduction in coverage amount when a book of business' insurance to value standard is reduced from 100 percent to 80 percent. If actuaries are not careful, a mismatch of assumption between the modeler and the company can lead to significant errors in estimated losses.

theft, rather than wind or earthquake. Thus, the actuary may have detailed coding on whether a home has fire extinguishers or how close it is to a fire hydrant, but no information on type of roof, existence of storm shutters, etc. Addressing this issue is perhaps the most daunting challenge modelers face in improving accuracy, given the enormous expense that is required to change established statistical systems.

3.3 The Authors' Insurance Coverage Module

The reader may gain additional insight into the authors' presentation of the insurance coverage module by more fully exploring the assumptions underlying their equation (6), which is repeated here for convenience:

$$\begin{aligned}(ID)_z &= f_{ID}(D_z, r, d, l) \\ &= \min[\max[(r \times D_z) - d, 0], l] + a \times D_z\end{aligned}$$

where

- $(ID)_z$ = Insured damage at location z ;
- D_z = Damage at location z ;
- r = Guaranteed replacement cost multiplier;
- d = Deductible;
- l = Reinsurance limit; and
- a = ALAE percentage.

This form assumes (i) a single risk subject to a per risk excess contract that does not cover loss adjustment expense; (ii) guaranteed replacement cost applies; and (iii) ALAE is a function of damage (excluding guaranteed replacement cost and deductible).

If we assume, however, (i) the risk were subject to quota share reinsurance (at percentage q); (ii) guaranteed replacement cost applies; (iii) ALAE is assumed to be a function of loss adjusted for guaranteed replacement cost before application of the deductible; and (iv) ALAE is covered under the quota share, then

$$(ID)_z = [\max[(r \times D_z) - d, 0] + r \times a \times D_z] \times (1 - q).$$

This example illustrates the importance of constructing the insurance coverage module with a full understanding of the underlying assumptions. Actual insurance coverage models can become extremely complex, particularly if several types of policies with differing reinsurance coverages are involved.

4 Exposure Management Considerations

The authors discuss several techniques to locate and prevent dangerous concentrations. Their main focus is the aggregate level of exposure in a given area and its density within a given zip code. They show how models can be used to estimate loss potentials and control the writing of business in areas of dangerous concentration. I see this problem from a slightly different perspective. The analysis should not be limited to the quantity of risk, but also should consider the types of risks within a given area of concentration, their levels of coverage, etc. The model can be used to devise strategies (such as making coverage changes) to manage the exposure without necessarily reducing writings.

The key issue facing a company is how to decide whether \$X of aggregate liability can be supported by the company's capitalization and reinsurance. From this standpoint, \$100 million of concrete bunkers may be as attractive as \$10 million of glass greenhouses. Holding construction constant, \$100 million in exposure in Inland City may be as attractive as \$20 million in Beach City. The probable maximum loss of a \$100 million aggregate exposure in Inland City at a \$250 deductible may equal a \$100 million aggregate exposure in Beach City with a 5 percent deductible. Comparisons of this type require models—comparisons cannot be performed by simply looking at aggregations of exposure on a map.

5 Reinsurance and Excess Modeling

In this section of the paper the authors discuss how modeling can increase availability of reinsurance coverage in the market. It is also important to understand the relationship between the use of models among reinsurers, primary companies, and regulators.

As the authors note, models help reinsurers to measure potential losses more accurately, increasing their confidence in both pricing and amount of capital exposed. Unfortunately, unless the reinsured primary company also considers modeled loss costs and an appropriate risk load in its rates, there will be insufficient funds to pay for needed reinsurance, leading to the appearance of a capacity shortage. Even if the reinsurer and primary reinsurer can synchronize their pricing, a clash between an unregulated reinsurance market and the highly regulated primary market still can pose difficulties. Thus, it is important that a common understanding of the elements of modeled loss costs

and needed risk loads be developed between reinsurers, primary insurers, and regulators.

The authors do an excellent job of showing why the traditional practice of using a market share analysis to estimate individual company loss potential is seriously flawed. I have had firsthand experience with the pitfalls of using market share-based methods by working for an insurer that specializes in farm insurance. The company's book of business contains a large amount of rural property in Florida. The rural book's high fire rates cause the premium market share to be substantially higher than the exposure market share. The market share approach also assumes that the farms are distributed in the same manner as the population, which generally lives much closer to the coast. The combination of these factors leads to dramatic differences between loss estimates derived from geocoded exposure data and premium-driven county market share estimates.

Market share approaches also are biased by the level of rate adequacy in the company, with more adequately rated companies having relatively higher market shares and apparently greater loss potentials. This creates the ironic situation whereby companies that ought to be viewed more favorably by reinsurers (due to adequate rates and a greater ability to afford coverage) appear to be less desirable because their rate-inflated market shares overstate their true catastrophic loss exposure.

For these reasons, the ability of primary company actuaries to provide their reinsurance counterparts with high quality information is critical.

6 Pricing and Reinsurance Allocation Issues

The authors state that modeling can be used to help a company determine the appropriate allocations of reinsurance costs. An often neglected but important area of actuarial work is the communication of the components of rate levels to other persons in the organization.

Consider the example of an underwriter making decisions on agent performance based on a loss ratio. Often such loss ratios are direct incurred loss over earned premium, with an adjustment to remove large or catastrophic losses in consideration for some reinsurance cost. If the underwriter has two agents writing property insurance, one in Beach City and another in Inland City, it is likely that the rate level in Beach City has a significant catastrophic load. If the loss ratio described above is used without an accurate allocation of the reinsurance cost, the Beach

City agent can be expected to post a better loss ratio, even if the book is less profitable. The underwriter could draw inaccurate conclusions about the profitability of the book and write more business at a less adequate rate. This could prompt the actuary to raise the price, leading the underwriter's report to show the Beach City agent to be even more profitable, and thus continuing the cycle.

In situations such as this, the actuary must use tools such as catastrophe models to assure that internal management information reports allow users to make accurate decisions. The actuary's job does not end when the rate filing is approved.

7 Conclusion

Computer modes will become increasingly important to actuaries in coming years. An actuary's ability to use these tools effectively is critical to the future health of our organizations and the property insurance industry as a whole. Actuaries must play a key role in educating the public about this issue and must combat the impression that models are incomprehensible black boxes.

Mr. Kozlowski and Mr. Mathewson's paper is an important step to educate the actuarial profession about the development and use of catastrophe models. I share their hope that the paper will stimulate new modeling ideas and enhancements.

Authors' Reply to Discussion

Ronald T. Kozlowski and Stuart B. Mathewson

We greatly appreciate the discussion of our paper that Mr. Musulin has provided. It adds further understanding to the use of catastrophe loss modeling in property insurance management.

Mr. Musulin commented that in 1992 the Insurance Services Office (ISO) used an excess wind factor based upon historical loss information. Today ISO recognizes the value of catastrophe modeling and now creates loss costs using these same models.

In his discussion of the insurance coverage module, Mr. Musulin expands the formula that we offered. We would like to clarify that the formula in our paper was simply a representative way to view the process. There are a myriad of possible combinations that will govern

terms. The equation also varies depending upon whether policy levels or aggregated exposure data are provided. The discussant has shown how one of those more complex situations can be represented. We are grateful for Mr. Musulin's additional equation, as it gives one example of the complications that can arise in modeling insured loss, given a certain amount of damages to the insured property.

In Mr. Musulin's discussion of the section on reinsurance and excess modeling, he re-emphasizes the problem between pricing an unregulated reinsurance market and a highly regulated primary market. In some states regulators allow catastrophe reinsurance to be loaded as an expense in primary company rates.

We also would like to add that additional research can improve significantly the results of these models. The insurance industry needs more information about the long-term history of catastrophic occurrences as well as better information on actual building damage from these events. Today catastrophe modelers are using historical weather data from the past 100 years to predict losses at return times of 250 years or more. Current scientific research using pollen dating, coastal sediment, and tree rings can be used to estimate hurricane severity thousands of years ago. Earthquake scientists also are using new methods to better estimate earthquake frequency. For instance, paleoseismologists are using evidence from trenching to uncover evidence of large earthquakes that occurred before records were kept.

We believe that the insurance industry would be best served if insurance companies would pool their catastrophe loss data to validate the damage functions used in catastrophe models. These data should be provided in detail by location indicator (e.g., zip code), by construction, by policy type, and by any other factor deemed important to damage estimation. This type of validation should convince doubters that models are credible in their calculation of damages.

Again, we thank Mr. Musulin for his thoughtful discussion, as it offers significant additional insight into this area.