Measuring and Managing Catastrophe Risk

by Ronald T. Kozlowski
Stuart B. Mathewson

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Abstract:

This paper gives a basic introduction to the standard framework behind catastrophe modeling and explores the output of catastrophe modeling via modernized "pin maps" and loss likelihood curves. This paper also briefly discusses some of the uses of catastrophe modeling in addition to traditional probable maximum loss estimation and comments on the use of modeling for reinsurers. This article is intended to be "food for thought" and hopes to stimulate new catastrophe modeling ideas and enhancements.

Biography:

Ronald T. Kozlowski is a Fellow of the Casualty Actuarial Society, a Member of the American Academy of Actuaries, and a Consulting Actuary in the Hartford office of Tillinghast. Mr. Kozlowski holds a Bachelors degree in Actuarial Science from the University of Illinois at Champaign-Urbana. Among Mr Kozlowski's many assignments and responsibilities is the development of TOPCAT, Tillinghast's property catastrophe model.

Stuart B. Mathewson is a Fellow of the Casualty Actuarial Society, a Member of the American Academy of Actuaries, a Chartered Property Casualty Underwriter and a Consulting Actuary in the Chicago office of Tillinghast. Mr. Mathewson holds a Bachelors degree in Fire Protection Engineering from the Illinois Institute of Technology. Mr. Mathewson has spoken extensively at actuarial and other insurance group meetings on catastrophic loss modeling and heads the development of TOPCAT.

Measuring and Managing Catastrophe Risk

Introduction

Property insurance companies have been concerned with the risk of catastrophic loss and 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 was first 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. With the introduction of windstorm as a covered peril in the 1930's, companies used similar practices to assure that they were not overly concentrated for hurricane or tornado perils. These "pin maps" were used until the expense reductions of the 1960's forced companies to abandon 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 minimized the threat of conflagration. 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 well below long term needs. Primary companies were able to purchase property catastrophe reinsurance at low prices. Property catastrophe reinsurance purchasing decisions were centered mainly on the desired maximum limit; price considerations were not a significant concern. In essence, primary companies managed their catastrophe exposures simply by purchasing appropriate reinsurance and ignored their concentrations of exposure.

In 1989, this naive world changed. Hurricane Hugo caused the largest catastrophe loss in history, and the Loma Prieta earthquake re-awakened fears of earthquake losses. The reinsurance market reacted to these and other world-wide events. Catastrophe reinsurance prices started to increase and coverage was restricted.

On the heels of those events, Hurricane Andrew struck South Florida. 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 radically raising prices and retentions while restricting limits. Regulators, rating agencies, and boards of directors became instantly and intensely concerned about companies' abilities to manage their catastrophe exposures.

The Northridge Earthquake and the Kobe, Japan Earthquake have raised new concerns over the insurability of the "big one" and the sucess of engineering against earthquakes.

This paper will discuss some of the basics of catastrophe modeling, the current capabilities and some current modeling problems.

The Use of Quantitative Tools to Measure Catastrophic Risk

With advances in computer technology, new quantitative tools have been developed to help manage catastrophic risk. Geographic information systems have allowed companies to resurrect the "pin maps", with significant additional abilities. But, well beyond merely looking at exposures, catastrophe simulation models have given us the ability to estimate potential losses in a way that truly reflects the long term frequency and severity distributions.

As actuaries, we know that expected catastrophic losses and reinsurance decisions should not be based upon past catastrophic losses. Insured loss data from catastrophes has been captured for roughly the last 45 years. Severe hurricanes and earthquakes are so relatively infrequent that this body of experience cannot hope to represent the scope of potential occurrences. Also, the distribution of insured properties has changed dramatically over time with the population movement towards the Atlantic and Gulf Coasts and earthquake-prone areas of California.

Clark [1] and Friedman [2] have shown us alternative methods for determining catastrophe losses through the use of simulation modeling. This involves simulating the physical characteristics of a specific catastrophe, determining the damage to exposures, and calculating the potential insured losses from these damages. While specific catastrophe simulation models are different, they all operate within a simple framework. These three steps, which we named the *Science Module*, the *Engineering Module,* and the *Insurance Coverage Module*, will be discussed after we discuss the most important component of catastrophe modeling: *The Exposure.*

The Exposure

All discussions of catastrophic exposure management must begin with the accuracy and availability of exposure data. The most sophisticated, complex catastrophe modeling systems cannot estimate an insurer's losses if the insurer cannot identify what insurance coverages have been written and where those risks are 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 restraints have also contributed to the designs of some exposure databases. Catastrophe exposure management considerations are almost always of secondary importance.

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

Physical characteristics may include:

- type of risk
- location
- construction
- number of stories
- age of risk
- number of risks

The type of risk can be described in insurance terms through the line of business, classification and type of policy codes. The line of business codes can distinguish between 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 between different types of commercial policies (mercantile, contracting, motel, office, apartment, etc.).

The quality of location data available from companies varies substantially. Often, the location recorded 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 a more complex commercial policy, many of the locations will not be identified. This may cause a false measure of concentrations at the billing location, while understating other areas.

Some companies cannot provide location detail at zipcode or street address. Location on a county or state detail can be spread to finer detail using population densities or census data, but this can lead to severe distortions in measuring the concentrations for a specific insurance company. Insurance companies must be encouraged to retain fine location detail. Future exposure location identification could use the latest satelite technology (global positioning systems) to determine exposure locations within a few feet.

Insured 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.

Our experiences show that many insurance companies have difficulty retrieving their data in a useable fashion. Extracted information often does not balance with insurance company reports. Exposure data can be unreliable due to input errors or heavy reliance on default errors; for example, zipcodes often conflict with county or state coding.

The first step that many insurance companies need to take to accurately measure their exposures is to refine their data collection and retrieval so they can be assured that the data will give an accurate picture of their insured properties. Most insurance company's systems personnel do not understand underwriting specifications and therefore cannot verify the reasonability of the data provided. Underwriting and/or actuarial personnel must be involved to assure the reasonableness of exposure data.

Once exposure data is deemed to be reasonable, the modeling process can begin. We will now briefly discuss the three modules in any catastrophe simulation model.

The Science Module

The first module simulates the natural phenomenon (i.e., hurricanes, storm surge, earthquakes, fire following earthquake, tornadoes, hail, winter storms, etc.). The events can usually be described through a series of scientific equations and parameters that determine the resulting force that causes damage.

For hurricanes, numerous models exist to estimate windspeeds at risk locations caused by specific storms. A sample of a simplistic hurricane function might look like this:

$Wz = f(dp, r, s, l, a, t)$

where Wz = 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

t = Terrain or roughness coefficient at location z

Clark [1] describes one such modeling system. That paper shows in detail 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., zipcode or street address). One possible relationship may look like this:

$Iz = f(m, s, e, a, g, d)$

where Iz = 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

d = Distance from fault rupture or epicentral area

The equations underlying these functions are based upon scientific equations that are well beyond the scope of this paper. These equations can range from simple equations to more complicated series of differential equations.

The Engineering Module

The engineering module is used to determine the exposure damage resulting from the windspeeds or shaking intensities. Wind and earthquake engineering provide the research to determine these relationships. We can express these functions as follows:

$Pz,c,a,s,v = f(Wz, c, a, s, v)$, for hurricane or

$Pz,c,a,s,v = f(Iz, c, a, s, v)$, for earthquake where $P_{z,c,a,s,v}$ = Percent damage at location z for risk characterized by c, a, s and v

c = Construction of building

a = Age of building

s = Number of stories

v = Coverage, i.e.. building, contents, time element

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 catastrophe being simulated.

$D_{z,c,a,s,v} = E_{z,c,a,s,v} \times f(W_z, c, a, s, v)$ for hurricane

$= E_{z,c,a,s,v} \times f(I_z, c, a, s, v)$ for earthquake

where $D_{z,c,a,s,v}$ = Damage at location z for risk characterized by c, a, s, v

$E_{z,c,a,s,v}$ = \$ exposure at location z for risks characterized by c, a, s, v

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, etc.).

Friedman [2] gives an example of damage relationships, which form the basis of the earlier wind models. ATC-13 [3] provides much of the basis for earthquake damage relationships. More research is being done by the engineering community to refine these relationships to account for some of these factors. The engineering community would welcome a cooperative action by insurance companies to pool detailed historical loss data to add to 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 [4]. New studies like 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 should encourage finer detailed exposure information for underwriting control and exposure quantification.

The Insurance Coverage Module

The last module translates the damaged exposure into insured damaged exposure. This includes reflection of limits, replacement cost provisions, and insurance-to-value provisions. This module also includes loss reduction provisions such as deductibles, co-insurance, and reinsurance.

$$ID_{z,c,a,s,v} = f((D_{z,c,a,s,v}), r, d, l)$$

$$= \mathrm{Min}[\mathrm{Max}[((D_{z,c,a,s,v}) \times r) - d, 0], l] + [(D_{z,c,a,s,v}) \times a]$$

where $ID_{z,c,a,s,v}$ = Insured damage at location z for risk characterized by c, a, s, v

$D_{z,c,a,s,v}$ = Damage at location z for risk characterized by c, a, s, v

r = Guaranteed replacement cost multiplier

d = Deductible

l = Reinsurance limit

a = ALAE percentage

Deductibles need to be modeled on a straight dollar deductible or percentage deductible, especially for earthquakes. The deductible calculation needs to reflect that the damage factors used are based on the average damage and that, in some instances, the deductible may exceed the damage to the exposure. As the average damage value increases, the greater the utilization of the full deductible.

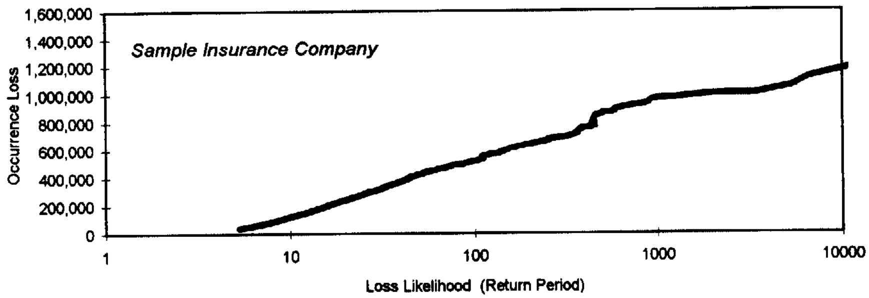
Reinsurance adjustments should reflect both pro rata and excess policies written on both a facultative and treaty basis. Deductibles and reinsurance coverage may vary on a per building or per occurrence basis.

This module can also include reflection of allocated loss adjustment costs and loss of use or business interruption policies.

Deterministic/Probabilistic Modeling

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

However, probabilistic modeling has the potential to provide much more information to management. In this method, the modeler runs a large library of hypothetical events that covers the range of potential events. From the results of all of these simulations, the modeler can estimate the probabilities of various levels of loss to the company (i.e., loss likelihood). This allows the company to manage its exposure portfolio and determine reinsurance decisions by comparing the potential losses with the company's appetite for risk. The graph below shows the probabilistic loss curve for a sample insurance company.



The above graph can also be depicted by a histogram, where the width of the bar is the probability of the loss and the height of the bar is the size of loss.

Probabilistic modeling can also provide information for primary or reinsurance pricing and for setting underwriting or marketing strategies.

Techniques to Locate and Prevent Dangerous Concentrations

The modeling process ties together the company's exposures with the storm frequency/severity information to determine the potential losses and dangerous concentrations for the company. The output of simulation modeling can provide a lot of useable information beyond the potential loss levels with their attendant likelihoods.

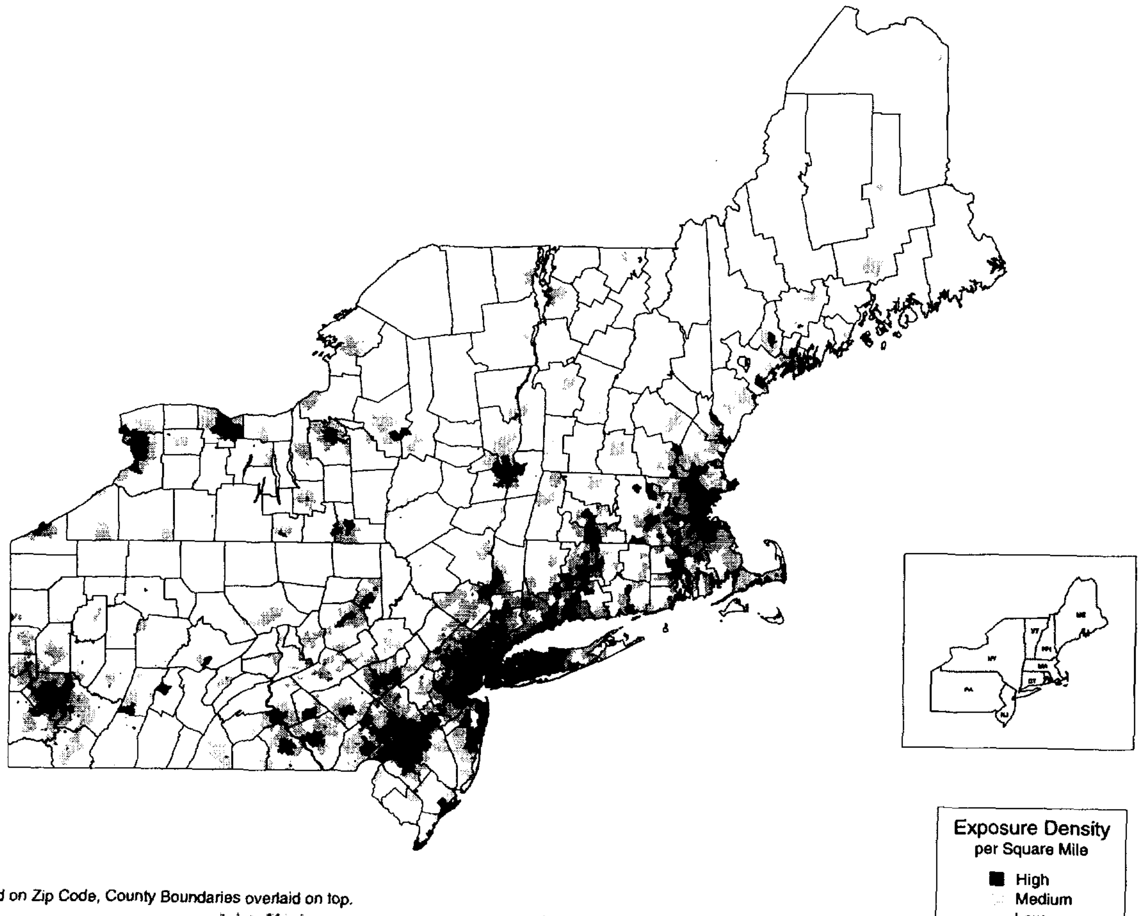
With the introduction of computer mapping products, "pin maps" have essentially been brought back. Mapping packages can profile exposure concentrations on a county or zipcode basis or, if necessary, show point locations. Mapping today is primarily limited by the amount of exposure location information retained by insurance companies.

Since most companies retain zipcode detail, the following section will assume this level of detail. Summing exposures by zipcode can be misleading, since zipcodes can vary significantly in size. Using exposure densities solves this problem. Exposures are summed by zipcode and divided by the number of square miles within the zipcode. This tends to accentuate those inner city zipcodes where more exposure is typically concentrated in a smaller area.

Analyzing loss potentials by looking only at exposure densities can also be misleading. Loss densities should be used. Loss densities are created by simulating a library of storms and retaining the losses on a zipcode level. The losses on a per storm basis are multiplied by the probabilities of each event. After the losses are aggregated for all storms, the losses for a zipcode are divided by the square miles within the zipcode. The loss density maps thus combine both the exposure concentrations and the frequency and severity of catastrophic events in that zipcode. Loss densities can also be used to determine catastrophic loss costs for ratemaking. The maps on the next pages show an example of the exposure density and loss density maps for the northeast region for a sample insurance company.

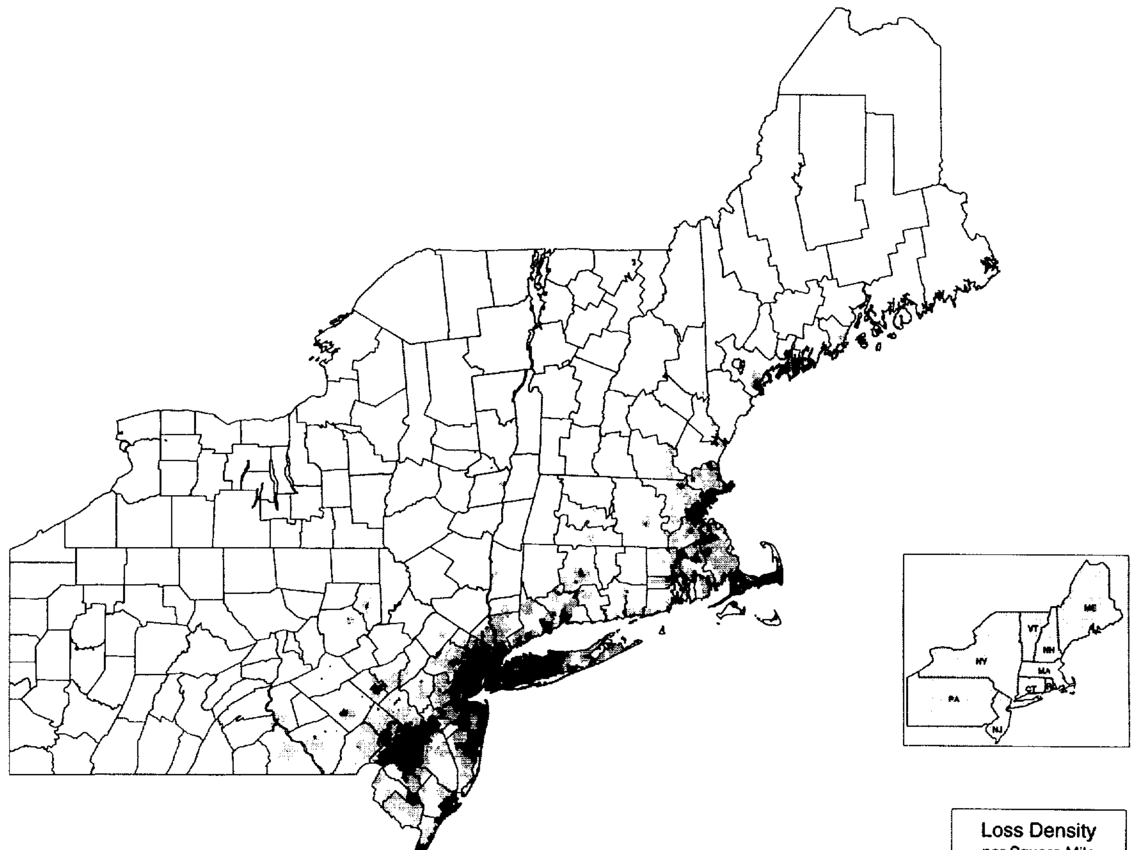
Exhibit I

Exposure Density for Northeast Region



Densities based on Zip Code, County Boundaries overlaid on top.

Loss Density for Northeast Region

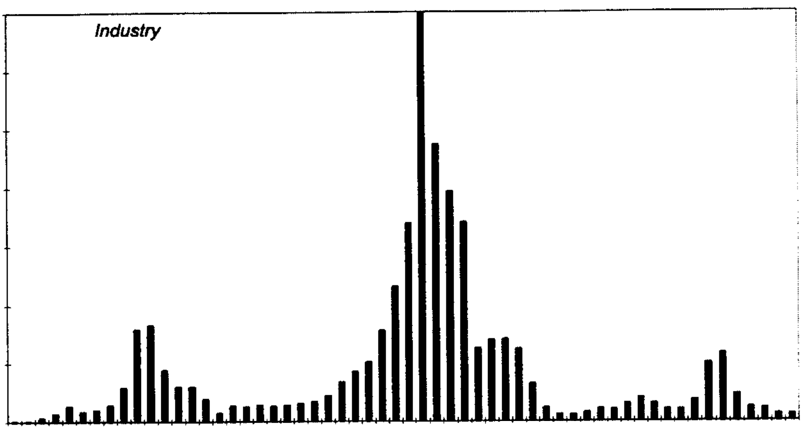


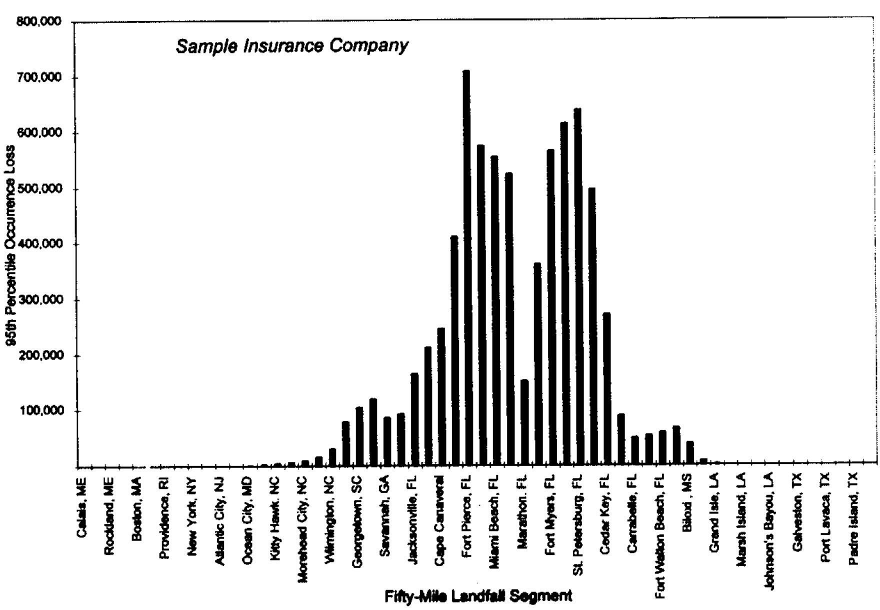
Loss Density
per Square Mile

■	High	(1150)
░	Medium	(468)
	Low	(3772)

Densities based on Zip Code, County Boundaries overlaid on top.

Another graphical representation of a company's exposures can be seen through the use of a histogram. The histogram shows 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. The histogram below shows the hypothetical results for the sample insurance company and the industry.





As can be seen from the histogram, our sample insurance company has significantly greater exposure to a hurricane hitting central Florida than the industry.

The results of the modeling can be used to help decide the most appropriate actions to address the 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, within limits, select where to appoint their agents, how much business they will accept from each agent, and where that business is to be located. The results of probabilistic modeling can give a company some real help in this area. From those results, management can determine which agents are producing business with a disproportional potential for catastrophic loss, and work with those agents to reduce writings to acceptable levels while minimizing the effect on the agent. The company can also 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 effected that discourage business in areas of dangerous concentration, while encouraging business elsewhere. Modeling can be used to constantly monitor the catastrophe potential in all areas of the country and to warn of growing levels of concentration before they become a problem. It can also help test the effects of various underwriting actions such as increased deductibles, policy sub-limits, and selective policy non-renewals. And, it can be useful identifying those areas for more stringent individual risk protection requirements. "Pin maps" are back!

Reinsurance and Excess Modeling

As mentioned earlier, 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 over-extended in catastrophe business and that they needed to better control their aggregate exposures. With the demise of the London Market Excess (LMX) market, there was very little retrocessional capacity to fall back upon if they wrote larger lines than were prudent. Therefore, the reinsurance markets cut back on their capacity.

Modeling offers the ability for a reinsurance market to measure the potential exposures, so that it can more efficiently write business while safe-guarding its assets. Models allow it to measure the maximum losses possible to certain events, so that it isn't restricted merely to a certain amount of aggregate limit in an arbitrary geographic "zone". By tying in the models to the underwriting process, the market can determine the effect on its concentrations from adding a contract. This ability to better measure potential losses increases the comfort of the underwriter, thus increasing the availability in the market.

Does Market Share Analysis Work?

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

Most primary companies have detailed exposure data, at least by zipcode, allowing the modeler to estimate losses at that level. However, until recently, reinsurers have been limited to premium data by state. This necessitated a modeling approach wherein losses were first simulated for the entire insurance industry, then the individual ceding company losses were estimated by using its market share. Exhibit III shows the relationship between the market share homeowner loss estimate and the actual loss for Hurricane Andrew. As is evident, there is very little correlation between the two for individual companies.

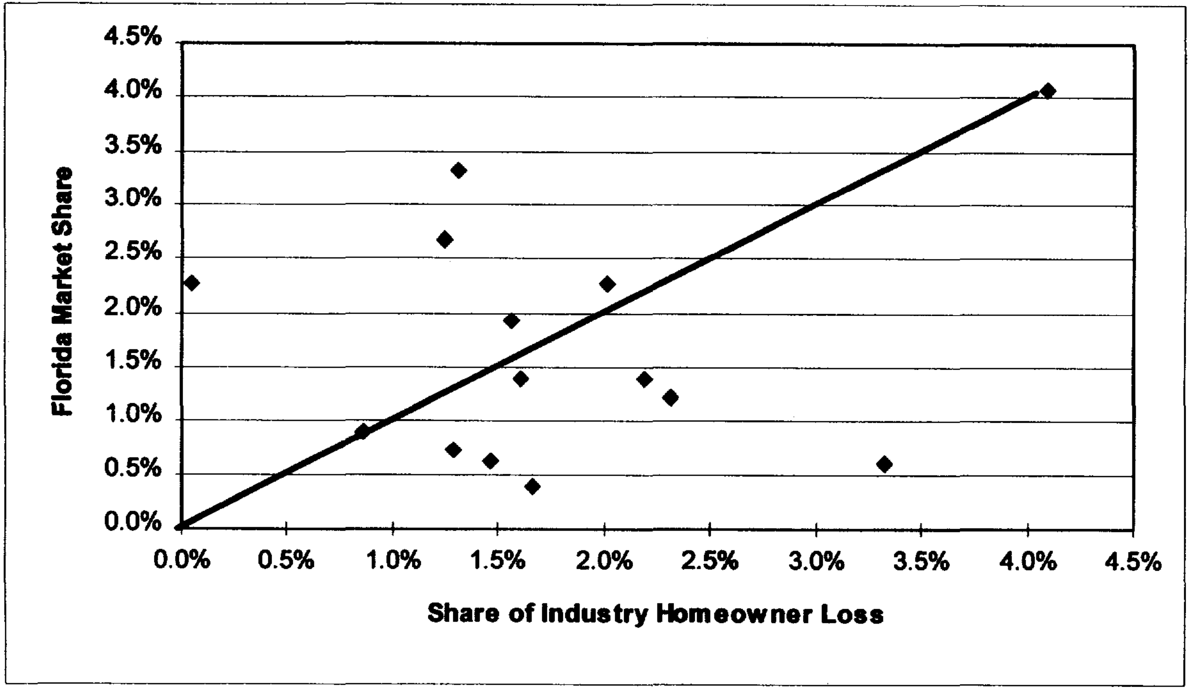
Market share analysis for earthquake is even more difficult since current line of business strucures do not clearly define whether earthquake coverage is provided. For example, personal earthquake coverage can be reported under homeowners or personal earthquake.

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

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, totally distorting the actual potential to the company. Similarly, large account business rarely carries accurate location information for all the buildings in a schedule. Even if county exposure information is available, it is likely that the location data refers to the billing location rather than the risk location. This usually puts large concentrations of exposure in a small number of locations, ignoring the real spread of risk.

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

Statewide market share was not a good indicator of losses—for Hurricane Andrew



among them. This 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 zipcode exposures of the detailed results or the company's own modeling are available to the reinsurance market, the information used by the most sophisticated reinsurance markets will continue to be inadequate to properly underwrite or price 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 to be modeled against the primary company exposures. Then, the reinsurer can calculate contract losses based on contract terms to figure its portfolio losses from each scenario. This information can help with underwriting and pricing decisions by providing a quantitative comparison of various contracts as well as the effect of any new contract to the portfolio. Adjustments may be necessary to compensate for differences among the various models used by the ceding companies.

How to Model Reinsurance Losses

While primary company loss modeling can usually be done on either a policy or aggreagate basis, reinsurance modeling should be done only on a contract by contract basis. Combining contracts with different policy limits, loss limits, quota share percentages, and attachment points for modeling purposes can severely distort your results.

Losses should always be calculated using the total values exposed, 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 reduces the ability to model losses appropriately.

Compared to primary company analysis, mapping exposures is more difficult. For example, let's assume that there are three risks covered under a $10 million excess $5 million reinsurance contract.

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

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 it can severely overstate the importance of the second risk. 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). The problem with this method is that it ignores Risk A.

The answer to catastrophe exposure mapping is to run the probabilistic database against all exposures under the same contract. One event could cause losses to both Risk A and Risk B. The resulting loss within the excess of loss agreement should be spread proportionately to each risk. Unlike our first suggestion, Risk B won't be over emphasized. Unlike our second mapping suggestion, Risk A does pose some exposure.

Models that use only mean damage factors can also distrort loss potential especially when an excess contract is being modeled. It is posssible that using mean damage factors would result in an estimate of no losses to an excess contract, when losses are possible. For example, let's assume that a specific windspeed causes an average of 15% 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% damage may consist of some risks having 5% damage and some having 75% damage. It is possible that the one risk having 75% damage may actually hit the reinsurance layer. In modeling reinsurance layers or when modeling a small number of risks, it is important to build in this variation.

"Payback"

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

Catastrophe modeling can help the underwriter estimate these return times, or paybacks. By modeling the ceding company 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, so the underwriter needs merely to take them (e.g., 5%) and convert to return times (e.g., 20 years).

"Additional Contract Pricing"

"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 over-concentration. Using this method of judging a contract seems to give undo favoritism to those contracts that are written early on, before the reinsurer has written enough business to threaten over-concentration. Catastrophe modeling can be used to measure both the individual expected cost and the marginal cost.

Pricing and Reinsurance Allocation Issues

Simulation models provide a long-needed tool to help actuaries determine appropriate provisions for catastrophe losses in the primary rates. They can provide the actuary with an estimate of the long range, fully credible expected loss to the peril being modeled; and they can do this at the zipcode level of detail. An actuary can then combine the zipcodes into homogeneous territories to determine the appropriate catastrophe pure premium which should be included in the rate. Of course, a significant risk load is also warranted given the level of uncertainty in writing catastrophe coverages. The loss distribution from the model can provide a starting point for estimating the risk load.

Similarly, the modeling can be used to help a company determine appropriate allocations of its reinsurance costs. By running the probabilistic modeling against a company's exposures and its reinsurance program, the relative expected losses can be calculated for each layer, by zipcode. 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. However, modeling can provide the raw material for calculating a theoretical risk load for a technically oriented organization. From the loss distribution that results from a probabilistic model, the actuary can determine a measure of variation, e.g., the variance. One can then use this to determine an appropriate risk load as one would in any other risky line of business.

Conclusion

The risk of catastrophes to a portfolio of property exposures has shown itself to be a very real 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 accomplish this. Catastrophe modeling can now be used for managing exposure concentrations, determining reinsurance programs, and pricing.

While models have come a long way, models should be evaluated more for their qualitative value rather than their quantitative value. In other words models are most useful when comparing the relative losses from specific events at different locations or from 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. However, to achieve greater individual event accuracy, there are a number of additional components that would need to be modeled. For hurricane/wind modeling, additional items such as rainfall, storm duration, humidity, "down-bursts", etc. would need to be modeled. In addition, more detailed exposure data including door and window detail, roof sheathing attachment, and roof coverings would be needed for more accurate projections of the damages from those 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 "ballpark" figures. Just as a reserving actuary should use a number of reserving methods to estimate his future liabilities, pricing or reinsurance actuary should use more than one model when evaluating the catastrophe risk. As work in this field grows and as exposure data improves, more complicated and precise methods will develop.

Measuring the risk is only the first step. Management must manage its concentrations of exposure so that it does not allow its company to be susceptible to ruin when the catastrophe occurs. Simulation modeling is a helpful tool in this, along with other good management practices but must be just one piece of an integrated catstrophe management process.

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