

# Natural Catastrophe Loss modeling: The value of knowing how little you know.

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## **Abstract:**

Decisions are made and millions of dollars could be gained or lost based on the results of Catastrophe (CAT) models. It is therefore important to understand how they work, how they are used, and where uncertainties are within the CAT models, whether they can be reduced, and how to use them to make sound business decisions.

This paper intends to provide an insight on the application of catastrophe loss models in insurance industry, on how the industry uses such models and on how cat models could help higher penetration of property insurance. The paper includes introduction of major components of cat models, sources of common uncertainties in development and application of catastrophe loss models and areas for future research (hazard, vulnerability, and exposure).

*Keywords: Catastrophe loss modeling, Insurance, Risk modeling, Uncertainty treatment*

## **1. INTRODUCTION**

For the past 20 years the insurance sector has relied on Catastrophe (CAT) models to manage and evaluate the capacity to take risk, i.e., to rate the catastrophe exposures, to calculate the accumulation of risks on different perils and regions, to calculate the reserves, and check the capacities. Moreover, as the risk is now being passed on from insurers to reinsurers and to the capital markets with the development of CAT bonds and other risk-linked securities, the use of CAT models is now more important than ever.

Since 1987, natural catastrophes losses have accounted for a significant portion of the total insured losses paid each year by insurers. In 2008, they represented 86% of the total insured losses (Swiss Re, 2009). Insurers and reinsurers need to estimate the losses in order to develop business plans and to set reserves; however, as CAT modeling continues to evolve, underwriting needs become more complex every year.

Companies have to examine a wide range of issues and scenarios and combine various forms of analysis to make sure they are as up to date as possible when it comes to predict the next major disaster that may hit them. They need to look at as many areas as possible in an effort to spot potential hazards and develop a consistent business plan.

Companies will use one or multiple models to evaluate and estimate losses, sometimes not fully understanding what the model results mean. Decisions are made and millions of dollars could be gained or lost based on the results of CAT models. It is therefore important to understand how they work, how they are used, and where uncertainties are within the CAT models, whether they can be reduced, and how to use them to make sound business decisions.

The main concern for all users is the uncertainties in the models. Some time ago, the only way to estimate a probable loss was to trust few statistical studies of past losses from some historical events and or on the experience of the underwriter. The uncertainty in these models was quite large as confirmed once a new event took place. The main problem is that there is not enough historical data, and the standard actuarial techniques of loss estimation are inappropriate for catastrophe losses.

## 2. CAT MODELS

Catastrophe models are tools that generate different scenarios based on geographic and historical data, and calculate the probability of potential losses. They are based on the most recent scientific information of the hazard and building behavior to estimate the losses of a portfolio.

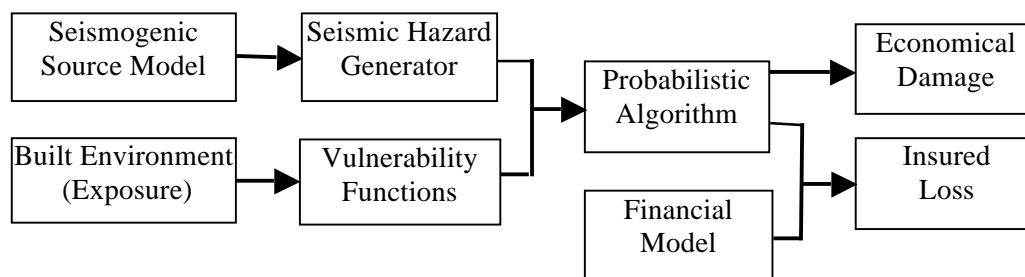
The insurance industry uses the CAT models to:

- Price catastrophe risks
- Control risk accumulation
- Diversify the risk
- Estimate the reserves in case of a loss
- Minimize the amount of capital required to cover the risks in their portfolios
- Transfer the risk

They allow the industry to have a more refined and detailed exposure control and help to standardize risk control within the market. They give objective risk assessment by relating insured loss to the physical event.

CAT models are used on the analysis on each submission, to evaluate the impact of new business on present portfolio, to study the effect of modifying contractual conditions, and to evaluate trigger group consolidation analysis when allocated capacity will be all used. (PartnerRe 2009).

In general, an insurance-based catastrophe risk model consists of several main components. Fig. 1 shows such steps for a seismic loss model. The hazard module generates event intensities for a range of stochastic earthquake scenarios. Data on historical earthquakes, in conjunction with understanding of tectonic features, are used to develop this module. The damage module, on the other hand, calculates the damage and monetary losses to built environment by using vulnerability functions as well as inventory of built environment. The insured loss calculation is made by applying the insurance, reinsurance and the retrocession conditions, if any, on the property damages produced by the damage module.



**Figure 1.** Main components of an insurance-based seismic risk model (Zolfaghari 2009)

As expected, the whole process involves a certain degree of uncertainty, which needs to be taken into account when evaluating the resulting estimations. This uncertainty represents not only the approximation of the earthquake effects, but also the number and types of structures being analyzed,

the relationship between structural response and damage, the data being analyzed and how are they modeled.

### 3. HAZARD MODULE UNCERTAINTY

The models are constructed from the random variables that govern hazard event occurrence and severity, as well as the consequent effect on the locations of exposure sites. Only a few variables encountered in the study of natural hazards can be precisely determined through practical observation. From these, a stochastic hazard model is created. The model needs to account for the frequency and intensity of events and the possibility of having larger ones than those previously experienced. The models use the latest scientific and engineering knowledge, but this is not an exact science, scientists have different opinions when using the same information. There is still much to learn and as science evolves, the CAT models do too.

There is an inherent uncertainty also on the data that has been used to construct the model components. The instruments used to collect the data will also react to ambient noise and may give incorrect records if not properly calibrated, or if they are not properly anchored or attached to the ground (Chavez-Lopez 1986). Approximations will be unavoidably made when instruments are located in different places and not necessarily where the largest or most important intensity has happened.

Once the data has been cleansed, worked on, the modeler will make certain assumptions to reproduce the physical phenomena. For example, the information one would have for an earthquake is:

- Estimation of the location of the earthquake epicenter
- Estimation of the magnitude
- Estimation of earthquake recurrence
- Fault information such as mechanism, direction, dip, etc...
- The depth and size of the rupture
- Attenuation functions
- Soil and local site effects
- Secondary seismic hazard such as liquefaction, landslides, fire following earthquakes

The modeler will need to find how to best model these parameters and represent these by choosing:

- Event grid size
- Time dependency/independency
- Statistical distributions to generate the stochastic event set
- Number of events to be simulated
- Simulation technique
- Validation and calibration techniques

In spite of how much one would like to reduce uncertainty, it will always be there. Uncertainty in time, as we only estimate the frequency of occurrence, uncertainty in space, as we do not know exactly where the event will occur, uncertainty in the event intensity, and uncertainty in the spatial distribution of the hazard.

Thus, to reduce uncertainty at the hazard module level, the users need to provide accurate information. Location of the risk is important since the intensity of the event will be calculated at the position of the risk, and the impact of the soil behavior on the risks will depend on the location of these. If the risk is wrongly situated or if there is not enough information (CRESTA<sup>1</sup> level versus latitude and longitude

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<sup>1</sup>CRESTA was set up by the insurance industry in 1977 as an independent organization for the technical management of natural hazard coverage. It has established a globally uniform system for the accumulation risk control of natural hazards - particularly earthquakes, storms and floods.

coordinates for example), the uncertainty will be greater and this needs to be taken into account when evaluating the losses.

#### **4. VULNERABILITY MODULE UNCERTAINTY**

Damage potential to a structure at a specific location can be estimated from knowledge of the site property's design features. That is, it can be estimated if we know the construction materials used, the building code, the construction details, etc... but even knowing all these, the estimation will be just approximative since many random variables play a part on the actual structure behavior.

The damage of structures will depend on the following parameters:

1. Construction materials
2. Construction techniques
3. Quality of labor
4. Location of the structure
5. Efficiency of inspection
6. Financial affordability
7. Environment
8. Height
9. Floor plan
10. Age
11. Maintenance
12. Occupancy

All the mentioned parameters will vary depending on the country and the available resources to build the structure, but the quality of labor is one of the main causes of structural failure both for engineered and non-engineered structures under severe loads (Dimova 2006).

A structure main design will change if the occupancy of the building changes. For example, an office building could be retrofitted to be used as residential apartments. Among other things, interior non-bearing walls will be added, moved, or changed. The loads will be modified as well, as contents of an office are different from the ones of a residence, thus changing the original behavior of the building, the one it was designed for. For example, we have seen catastrophic consequences of this in Mexico City during the 1985 earthquake.

Behavior of structures will depend on all these parameters, but this is information which is not easily obtained by reinsurers or insurers.

Insurers and reinsurers need to know the replacement value of a risk, not the construction value. The building structure is covered but also the contents, and for some risks, also business interruption is considered. Besides, as the insurer/reinsurer covers the replacement cost, this can increase, and usually it does, after an event. This is what is called damage surge and will depend on the location, the intensity, the spatial distribution, and type of event.

After a major event, the loss claims can be so overwhelming that the insurer cannot precisely evaluate the damage. A 100% loss for the insurer/reinsurer may not be a 100% loss for the building or buildings, or for commercial or even political reasons, a full payment is made after an event, even though the loss might not be complete. Damage to non-structural components could be a total loss for the insurer, depending on the wording of the policy. And even if the property has no physical damage, the loss due to business interruption could also be a total loss. In order to take all this into account, the modeler has to make certain assumptions to represent as accurately as possible these characteristics.

The model vulnerability curves are based on historically observed damage, experimental research, evaluations performed by engineers, claim data from all major events, and recorded demand surge. Difference in construction techniques by country is also taken into account. For earthquakes, historical data is scarce, therefore most of the models rely on experimental research and engineering principles complemented by claims data when available. Contents and business interruption damages depend on the damage to the building, thus these curves are constructed with a high correlation to the building damage curve.

Some measurement of uncertainty is made at the building code level, but this will not take into account the lack of maintenance, or the modifications to the use or plan configuration of the building after it was built, or hidden defects. And unless the policy is for a very important building, the details of construction, maintenance, and other information essential to evaluate building behavior are not available at all to the insurer/reinsurer.

As experience has taught us, there will usually be more than one way in which a building will suffer damage, thus the vulnerability curves must be probabilistic.

Vulnerability curves are constructed for specific perils, but some of the consequences or secondary perils are not considered, e.g., flood for windstorms or landslides for earthquakes. Thus the user needs to be aware that not all possible damages caused by the phenomena are been taken into account in the model for evaluation.

An insurer covers not one but many buildings, some times whole cities and whole countries, and a reinsurer covers many insurers. Each contract will involve a variety of structural types, of risks types, construction years, materials, good and bad quality of construction and maintenance, and there is no effective way to know the details. Some of the buildings will belong to different policies, one for the owner and one for the tenant for example. Besides, the portfolios are dynamic, forever changing as policy holders modify their policy or new insureds get covered (Chavez-Lopez 2009). As a consequence, for the insurer it is important to know how site correlation is accounted for to cover the clustering of risks affected by the same event.

Therefore, uncertainty on the evaluation of loss for a portfolio is unavoidable.

To reduce then the uncertainty, the user needs to provide as much accurate information as possible on the type of risk, its structure type and its use. The model will then assign the corresponding vulnerability curves for each coverage based on the structure type and occupancy, but if the information provided is incomplete or scarce, uncertainty will increase.

## **5. UNCERTAINTY USING THE TOOL**

As with everything, once the model is ready, the problem lies now on how the tool is used to evaluate the losses. Models have currently the capacity to analyze at different geocoding levels, with very detailed or very aggregate information and it is how it is used at the end, or how the data is interpreted, that the results will vary from one user to the next, even when using the same CAT model.

The user has to make a decision as to how the information supplied or available is going to be modeled. Does one require enough detail in the results that he or she needs to model at the site level or would it be enough to have an idea of the results at the policy level? If the information is so detailed that the import file is too big to be analyzed in a short time, can one wait until the analysis results are available several hours after, or does he or she need a quick response to make an urgent business decision? If one needs a quick decision, a quick analysis, how is he or she going to aggregate the information? If the exposure information is given in premium, which factor needs to be used to convert it into insured values? Can deductibles be applied as a monetary amount or are we applying them as a percentage of the insured value or a percentage of the loss? Is there a deductible for all

covers or is it cover specific, in other words, deductibles apply only to building damage or to contents damage, or to both? All these seemingly straightforward decisions can influence the resulting estimation of losses.

Whatever the decisions taken, the user would need to take into account that these will imply various degrees of uncertainty and it will be necessary to make sensitivity tests before business decisions are made. It would be important to have reliable information on total insured values, risk distribution, risk coverage, application of deductibles and limits. This also implies an understanding of the ability of the model to accurately represent from the simplest to the most complicated insurance and/or reinsurance structures.

The most important action the analyst can do to reduce the inherent uncertainty of the model is to closely work with the model developers to better understand the underlying assumptions made to create the model and to be in contact with the underwriters to better understand the portfolios, the risks covered, and how they are covered. It is also important to identify the strategy and the needs of the company, in order to make the correct modeling decisions and to be able to explain to top management the results of the model.

## **6. SENSITIVITY TESTING USED BY THE INSURANCE INDUSTRY**

The Insurance industry has now been using CAT models as part of their regular business process for the last two decades. Some use vendor models and some of them have created their own internal ones. In order to make sound business decisions, the results of these models need to be understood and validated, so that the analyst feels comfortable when using them. Therefore several tests are performed to understand the results. These will vary from one company to the other, but are fairly standard in the industry.

The first test relates to data quality. Insurers/reinsurers will receive data in different formats and at different levels of detail. The more detailed the information, the resulting loss evaluation will have less uncertainty.

For the location of the risk, the information could come at country level, CRESTA zone level, postal codes, specific address, and latitude/longitude. For the description of the risks, the information could come at the occupancy type level (residential, commercial, industrial, or agricultural), detailed occupancy (single house, apartment...), structural type (wood, reinforced concrete...), and sometimes it may include age, height, engineering report, or secondary features. Insurers/reinsurers need to obtain as much detailed information as possible.

The second test would be the sensitivity to different structural types and occupancies. Every model has a number of different vulnerability curves that will evaluate the damage to structures if the user knows the construction material but in case he or she does not, there is an option to choose an unknown material, which could be an average of all materials, an average of construction types by country or by region. These curves will impact the amount of losses when combined with occupancy vulnerability curves. Some models will also consider age and height of the building to modify the damage calculation, as well as other components as sprinkle leakage, secondary structures and quality of construction. A set of test will be performed to know the impact of the interactions of each combination.

Another test will be the impact of application of deductible and limits. These can be applied in different forms depending on the policy conditions and the model flexibility. Deductibles could be applied as a monetary amount, as a percentage of losses, in days, and at the site level and or at policy level. They would be applied to all covers or a combination, or to single covers.

One last sensitivity test would be to calculate historical losses by using historical scenario events within the model and compare them with actual losses for their portfolio. This is not always easy, since data from historical losses may not be available for some regions as it is the case for earthquake exposed areas.

And finally, if the company has several models it will then compare the results from all of them.

## **7. THE USE OF CAT MODELS TO OPEN NEW MARKETS**

As we have seen, CAT models play an important role in the assessment of potential financial losses to insurance portfolios. Understanding of the causes of possible losses due to natural catastrophes will help the governments to plan and develop strategies to reduce losses, to open the market for insurers and reinsurers as it will be possible to develop sound insurance rates and underwriting guidelines, as well as to create ways to protect people who cannot afford insurance using catastrophe funds or national pools.

As with the chicken and the egg causality dilemma, what should come first? Model developers find it difficult to introduce CAT models where insurance penetration is not developed, thus hesitate in developing them, but the creation of these models will eventually open the market and raise risk awareness, as people may be less aware of their exposure in regions where earthquakes are infrequent but potentially destructive.

The main concern remains with the data available to develop these models. First, because data from the hazard and damages may not be available due to the low frequency of the events, second, because the markets with little or no insurance penetration will not have enough claims information to develop reliable vulnerability curves to be used for insurance. But even with these shortcomings, the development of these models will allow the risk to be better shared. Science and engineering principles can be applied to create a first generation models that will develop as more information would be available.

These models are especially useful in hazard prone areas, where population is growing, where the replacement value of the properties is increasing, and where there are changes in building practices, codes and their enforcement.

## **8. CONCLUSIONS**

There is a need to understand the uncertainty involved in the process of estimating the losses produced by catastrophic events as large amounts of money depend on the decisions made using the results of CAT models. Future research from the model developers on the amount of uncertainty captured in the CAT models is essential. Failure to include the major sources of uncertainty in CAT models will lead to a systematic understatement of risk.

We do not know when a major event will happen, but it will happen and when it does, those affected will turn to the insurance industry to obtain the financial resources to reconstruct their properties, and if the industry has correctly estimated the risk, it will be able to compensate them according to the terms of their insurance policy. For this to happen, the insurance industry needs to understand the risk it is taking and the use of CAT models will help it estimate the premium to charge, the reserves to set aside, the capacity it can take, and the amount of risk it would need to transfer elsewhere, being it reinsurance, retrocession, or capital markets. A bad decision could make the company lose capital and in the worst case, go out of business.

As such, models are very useful for the insurance industry as well as for the governments, but a clear understanding of the assumptions used to construct them and their inherent uncertainties are key

factors to make sound business decisions and to prepare and coordinate national policy to deal with major events. For this reason, the industry performs sensitivity testing to feel comfortable with the model results.

Models where insurance penetration is low will help open the market and raise risk awareness. Further research is needed to develop first generation CAT models for regions where the hazard has low frequency of occurrence.

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