

Understanding Uncertainty in Catastrophe Modelling For Non-Catastrophe Modellers

Introduction

The LMA Exposure Management Working Group (EMWG) was formed to look after the interests of catastrophe ("cat") modellers working in the Lloyd's market. Given the increasing use of cat models in the market in recent years and their perceived complexity and sophistication, the EMWG agreed that it would be useful to put together simple guides for colleagues not working on cat modelling.

In June 2013 the EMWG published 'Catastrophe Modelling Guidance for Non-Catastrophe Modellers', aiming to provide some of the background information as to what a cat model is, explain the terminology frequently used by modellers, and answer many of the frequently asked questions on cat models.

The aim of this latest guide is to focus on the subject of uncertainty in cat modelling, to clarify what is meant in this context, identify potential sources of uncertainty, what impact this may have on decision making and how they may be managed. This document is not intended to be a comprehensive guide to uncertainty or to answer all questions on this subject. It will hopefully provide non-cat modellers with a basic understanding of the subject, and also act as a quick reference document on uncertainty in cat modelling.

Lexicon

An essential component to robust understanding and communication of any topic is an agreed set of terms, whose meaning is clearly defined and consistently used. One of the biggest challenges identified in understanding uncertainty in cat modelling is the use of the term 'uncertainty' itself; which can have a number of different meanings depending on the context. For the purpose of this document, we will therefore establish the following terms:

- **Model Completeness** – A representation of how comprehensive a risk assessment is, based on an assessment of the sources of loss considered within an analysis against those considered to have not been included.
- **Exposure Data Ambiguity** – Reduction in the precision of modelling resulting from inaccurate or incomplete details of the insured risks used as an input to the model;

- **Natural Hazard Variability** – The unpredictability of the emergence of a natural cat event, and annual frequency of events. Often referred to as “primary uncertainty” in some contexts.
- **Event Impact Complexity** – The variation in impact to an insured risk subjected to a cat event, resulting from each individual component of the risk responding in a unique way. Often referred to as “secondary uncertainty” in some contexts.
- **Claims Obscurity** – The existence of multiple potential outcomes for the ultimate claims arising from the impact of a cat event due to the inability to precisely determine how individual contract wordings will be interpreted, how governments will respond, and how individuals will behave.

Uncertainty and Insurance

The future is uncertain. Despite the best efforts of humanity to date we are unable to accurately identify how many hurricanes will form next year, or where those that do form will make landfall. This is not a phenomenon limited to natural catastrophes either – be it ships running aground or terrorist attacks our exact future is unknown, and due to the complexities involved, it may always be so.

But, without this uncertainty, there would be no need for insurance.

It is exactly the purpose of the insurance industry to take from the individual the burden of uncertainty, to be replaced by the certainty of an annual premium. And it is the role of the risk managers, modellers and actuaries to accumulate, monitor and assess the combination of uncertainties being taken on into a form that can be used to make business decisions on risk and reward. The result can never be certainty, but robust approaches exist to provide quantifications on which decisions can be made. Where uncertainty cannot be quantified it must be managed and controlled, or risk undermining the whole.

When compared against other approaches to measuring risks typically considered by an insurance company, the level of investment, complexity and sophistication employed within cat modelling introduces a danger that the recipient of the results of the modelling process will have a limited ability or desire to challenge what they have been presented with.

Uncertainty and Cat Modelling

Natural catastrophes represent a significant contributor to insured losses, and as such their quantification represents a major challenge and investment for the insurance industry.

Their occurrence, although natural, remain unpredictable. In addition, the most catastrophic events occur infrequently, providing a limited source of information from which to understand them.

The purpose of the cat models is to attempt to quantify the risk that they pose. While we may never be able to predict them, certain features make it practical to attempt to model them:

- **Observable natural laws:** Events such as hurricanes or earthquakes follow natural laws, that can form the basis for prediction. In general larger earthquakes represent the release of greater levels of energy, so magnitude 9.0 earthquakes, for example, should occur less frequently than 8.0s, which in turn occur should occur less frequently than 7.0s.
- **Laws of physics:** The physical manifestation of an event will follow well understood laws of physics, allowing good predictions to be made of ground motion following an earthquake based on the geology of an area.
- **Replicated effects:** Engineers are then able to replicate the impact of ground motion, or wind speed, on buildings, for example, to provide a guide to how they would respond.

Put all together, our present generation of cat models represent a high level of sophistication in quantifying losses from perils that have affected humanity throughout its history.

But there is still a long way to go, and cat modelling practitioners know that there is almost no element where our understanding is currently complete.

It is therefore an essential part of the use of cat models that the sources of material uncertainty that remains in the output are understood by all decision makers.

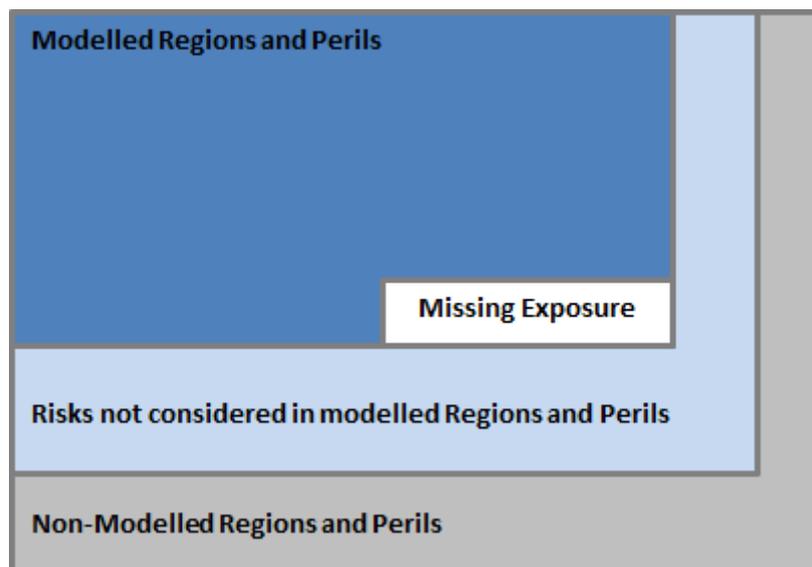
Sources of Uncertainty in Cat Modelling

This document will discuss five main sources of uncertainty in cat modelling. This is not an exhaustive list – it is beholden on each individual company to identify the material sources of uncertainty within their own operations – however it should assist with understanding the topic at large, and how the subject should be approached.

Non-Modelled Losses

Why is it a source of uncertainty?

Non-modelled losses can result from regions or perils not included in the modelling assessment, risks that are not considered by a model, or missing exposures.



Even within the most data rich modelled perils, our historical data only stretches back for a short period of history. Hurricane Wilma showed us that the extent to which we had considered the effect of tree damage on properties had not been sufficiently considered; and Hurricane Ike showed us that storms can maintain strength further inland than previously thought.

Key to managing cat risk for a business is the need to understand to a high degree of accuracy all such risks that are being underwritten, and any source of loss that is missing from an assessment represents a gap in your ability to adequately monitor and manage.

How does it affect results?

Most business decisions involving cat risk rarely refer to “only that bit that we model” and usually assumes that we are able to take all material sources of loss into account. There is nothing an executive likes to hear less than that a major loss was non-modelled.

In some cases not including all exposures in an analysis can still have an overall neutral, or immaterial, impact. For example, cover may already have been exhausted, or the risks uncorrelated with those driving the key losses.

However there are numerous examples where the non-modelled element of loss resulted in a significant deviation between assessed risk and reality. The impact of levee failure¹ during Hurricane Katrina; correlation between classes of business in the World Trade Centre attacks; and business interruption implications of clustered industries in the 2011 Thai floods² represents just three recent examples where the over-reliance on pure model output and cat modelling techniques led to business decisions being made on an incomplete view of risk.

Even when less extreme, an incomplete assessment of exposure risks long term erosion of premium and capital, undermines ability to meet business plan and reduces the overall Return On Capital.

Approaches to measuring and managing

Given our lack of historical data for extreme events, it is better to approach the management of cat risk from the perspective of what can potentially go wrong, as opposed to what has gone wrong.

It is possible to identify in advance a number of sources of Non-Modelled loss material to a portfolio or analysis. Companies should already be aware of the classes of business, regions and perils representing material exposure, but excluded from the modelled assessment, and this should be regularly maintained and monitored.

In the absence of an available cat model, Actuarial techniques may be used to parameterise a risk profile that can be used; and external datasets may exist that can complement internal claims experience, such as PCS losses for the US.

Within the cat modelling process, identification and reporting of missing exposure should be standard within any analysis – but expert input may be required to ensure that this is adequately accounted for, perhaps through adjustments to final results, depending on the purpose of the analysis.

Within the cat model validation process, non-modelled elements of loss should form a key component of the assessment of the adequacy of a model, and may require model output to be systematically enhanced, or a capital load introduced, in order to ensure that a company's view of risk is being appropriately represented.

It will not be possible to identify all unknowns in advance, but the introduction of a strong culture of awareness, and a governance process around the use of models will ensure appropriate communication to decision makers.

¹ https://en.wikipedia.org/wiki/2005_levee_failures_in_Greater_New_Orleans

² https://en.wikipedia.org/wiki/2011_Thailand_floods

Exposure Data

Why is it a source of uncertainty?

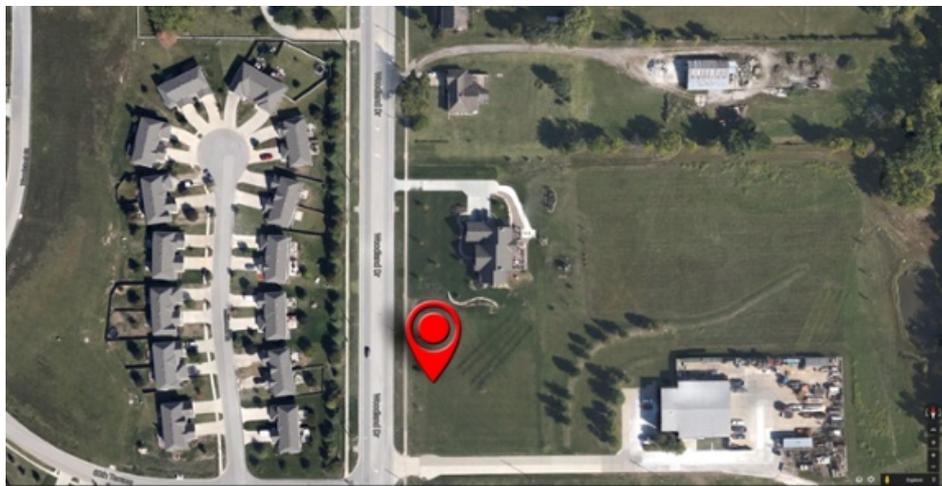
Cat modelling relies on receiving data that accurately represents the 'thing' being assessed.

All information is of value, but for any particular assessment there will be key characteristics that are the most important in identifying how a risk will respond. For a property, for example, this will include location, replacement value, construction (age, height, method/material), occupancy and size (floor area). Cat model documentation communicates the characteristics that are of greatest importance, so that these can be targeted.

To allow cat modelling to proceed despite missing information for key characteristics, an assumption must be made, either by the person preparing the data for modelling or by the cat model itself.

The accuracy of any assessment is reliant on the quality of the input data. Even where information is provided, there is the potential for it to be inaccurate. Considering the challenges of gathering and maintaining such a significant volume of data it is highly likely that any dataset contains inaccuracies.

Even the process of geocoding risks introduces additional challenges. This often requires the translation of address information into a precise latitude and longitude, for which there are a multitude of approaches that can result in different outcomes.



Together this results in Exposure Data Ambiguity. While the cat model runs and produces a precise set of losses, if we were to re-run with slightly different assumptions we would achieve a different outcome.

How does it affect results?

Generally "unknown" data is treated more conservatively, by the cat models or data cleansers. Unknown characteristics when used to assess vulnerability typically give higher results than for most specified classifications.

Systematic data issues or biases across a portfolio can result in losses being consistently under- or over-estimated. For example if Year Built is not provided on a book that is actually designed around providing cover to older or newer properties, then the assumptions used will likely be consistently out.

Once this has been dealt with, cat modelling can proceed despite the knowledge that there likely remains issues in the exposure data. Whether further mitigation or consideration of data issues is required depends on the analysis being performed and is the responsibility of the modeller to identify. For large, well balanced portfolios the overall impact of exposure data ambiguity may be neutral, whereas for assessments on individual locations the implications may be more severe.

Approaches to measuring and managing

Data completeness can be identified by a straight-forward analysis of the exposure data making up a schedule or portfolio. Measurement can be in a number of dimensions, including:

- A simple count of fields with missing information represents a simple initial check;
- A weighted average of Total Insured Value (TIV) or Insured Limit for risks with information missing, to identify where further investigation may be required; or
- A weighted average of modelled Expected Loss for risks with information missing, to identify how material the issue may be to the analysis.

Measuring data accuracy is more challenging, but can involve:

- Comparison to a reference dataset of known details, to gauge accuracy from a random sample;
- Identifying systematic issues or biases in the data, such as evidence of bulk coding, or combinations of data characteristics that are unlikely to be correct.

Accepting that exposure data will always contain a level of ambiguity, it is important to determine the appropriate level to which this should be managed to mitigate the risk.

Development of an internally communicated standard for exposure data provides a framework for discussing the subject. Different classes of business, regions and perils the quality of data available will vary and low data quality will have different impacts. Establishing appropriate levels at which business will be accepted is the starting point from which further mitigation strategies can be considered.

The only way to actively mitigate data issues is to survey every one of your insured locations, or to have a robust reference data set of all worldwide buildings. This latter option is being considered, and there are some data sets available that go some way towards this, however for some this would be extremely time consuming and expensive.

Event Frequency

Why is it a source of uncertainty?

Catastrophe insurance exists because of the unpredictable nature of natural hazards. The complexities involved may make their occurrence truly random events that cannot be individually forecast, however some generalisations across periods of time can be made.

Our historical records of events only represent a relatively short period of time, meaning that our ability to use this information to estimate the frequency of occurrence of events, or their expected annual impact, is limited. This forces us to make assumptions about those events that we believe to exist but have not yet seen, and rare phenomenon such as event clustering. History may also not be a reliable guide to how these events may occur in the future.

To address this, cat modelling vendors create their own event sets, with the intention of simulating thousands of years of potential events. This catalogue enables us to fill the gaps in our historical knowledge, project losses at return periods outside of our experience and produce both probabilistic loss estimates and annual expected losses.

The frequency and severity of these created events in the vendor catalogue are based upon their attempt at creating a “complete” historical set, from which to represent the Natural Hazard Variability.

They therefore need to make assumptions in regard to the frequency and severity to complete both the gaps within the historical record and to project a tail of low-frequency events.

How does it affect results?

For some regions and perils there may actually be little to no historical data on which to provide any benchmark. In this case the model vendors are forced to make predictive assumptions, based for example on information known about regions and perils with a greater availability of data, or using physics based simulation models. In such cases there is inevitably a higher degree of subjectivity than compared to data-rich regions and perils, and this naturally leads to a wider variability in potential outcome.

For example, for extra-tropical cyclones which hit Europe between October and March each year, there is no historical record set equivalent to HURDAT for US Hurricanes. The data that is available, ERA-40, represents a reconstructed view based on many different sources of meteorological records from different countries with different parameters and time periods. It isn't a set of historical events, but rather a data set from which events can be derived, and in doing so modellers and researchers come up with different results depending on the assumptions that they make.

Across a selection of four available cat models, there is a difference of opinion in the number of large, rare events that differs by a factor of 5.5 between the lowest and highest.

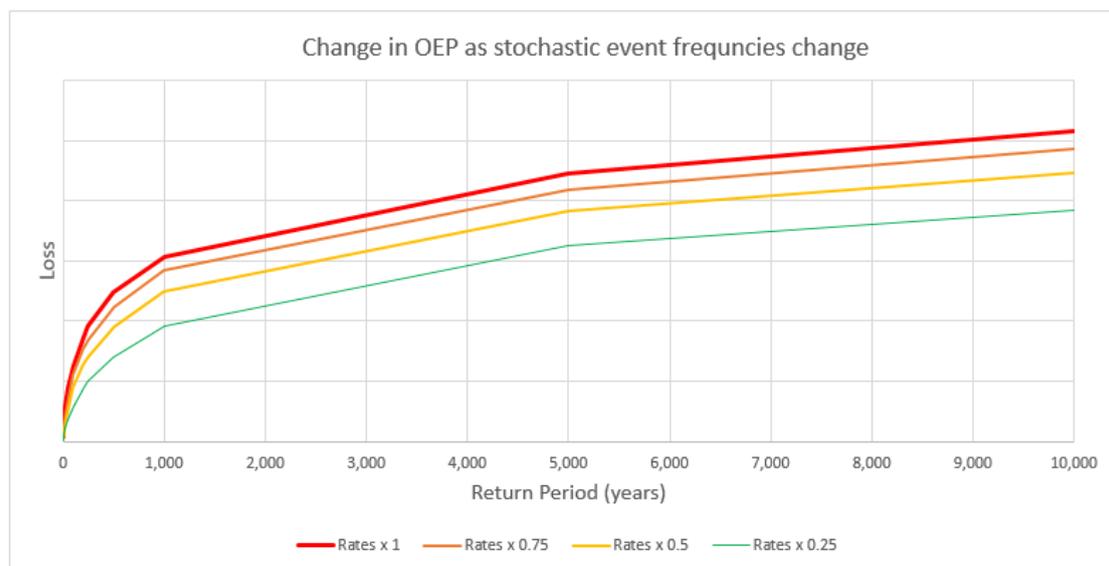
Approaches to measuring and managing

Insurance has become familiar with the EP (Exceedance Probability) curve, and the language of probability associated with it³. Premium or Capital are not derived from certainties, but from measures of standard deviation or 1-in-200 return periods.

These are our well established approaches to representing uncertainty – but it is important to be aware that this primarily represents the uncertainty in the occurrence and frequency of events, which here we term Natural Hazard Variability and doesn't by default include all consideration of other sources of uncertainty discussed within this document.

Running a particular model will produce an EP curve that is based on the set of assumptions made by that vendor, and this EP curve is the main way of representing Natural Hazard Variability in the portfolio.

Regarding differences of opinions between model vendors, users of cat models need to maintain a wider knowledge of the community, to be aware of the areas where there is agreement or divergence of opinion.



It is not a cost effective solution to licence all available models, but through public information, market initiatives or conferences or through the support of brokers, an awareness of the differences can be established, allowing for sensitivity testing to be performed on a portfolio.

This detail should be captured as part of the cat model validation process, allowing companies to establish a 'view of risk' that may adjust their internal modelling to account for areas of particular disagreement between vendors. In particular, in ensuring that the use of a catastrophe model is relevant to the company portfolio, back-testing of historical claims frequency will assist with ensuring the variability being represented is most relevant to the exposure.

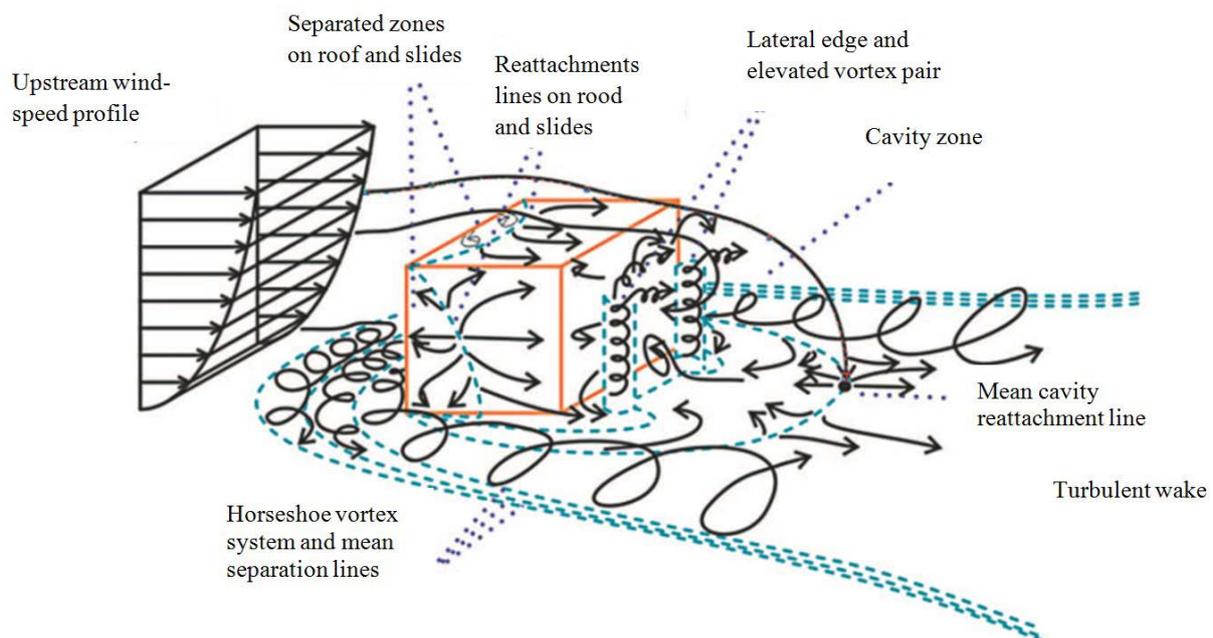
³ http://www.lmalloyds.com/lma/finance/Cat_Modelling_Guidance.aspx

Risk Vulnerability

Why is it a source of uncertainty?

Vulnerability describes the relationship between particular characteristics of a hazard (such as wind-speed, or ground shaking intensity) and the effect that it will have on the damage incurred to a particular risk.

We are here terming the uncertainty in the level of vulnerability a particular risk will have as Event Impact Complexity, and this may represent the biggest source of uncertainty in cat modelling. It is also probably the most complicated.



Challenges facing both the developer of the cat model and the user include:

- Poor availability of good quality claims data to help calibrate losses
- An inability to separate out the damage caused by different elements of the hazard (e.g. direct wind damage vs. flood damage)
- The need to use a smooth damage distribution during modelling to quantify a loss that may occur in a more complex manner (although this is being addressed in newer model developments).

While most models will attempt to take certain specific characteristics of a risk into account where provided (such as roof type or presence of sprinklers), these often result in minor adjustments being made to a base vulnerability curve that dictates how much damage a risk can expect to receive when subjected to the given hazard; and therefore necessarily has to be largely generic.

Even the most sophisticated models will therefore need to make generalisations about a risk in order to assign it to one of the specified base vulnerability curves.

How does it affect results?

Fortunately, for a large portfolio the effect of this complexity is often reduced, since unbiased errors are watered down by the large number of risks. In addition, with financial conditions such as policy limits and deductibles, the effects are further dampened.

Generalisation to a base vulnerability curve works when the set of risks being analysed is large, representative of the data from which the model vendor has derived its curves, and where overestimates in one area can be cancelled out by underestimates elsewhere.

Greater care is required when the number of risks is smaller, or when analysing only a small number of events rather than the full catalogue (such as during a post-event assessment); or where there are biases or complexities in the exposure data that may make this normalising assumption inappropriate.

Approaches to measuring and managing

Cat models often allow users to view the vulnerability curves directly, or even supply their own. In this way a portfolio's sensitivity to these curves can be assessed. At the least the generalising assumptions made by the model vendor must be clearly understood and compared against the portfolio of business being analysed to identify any biases or complexities that may require further investigation.

Where the assumptions made by the model vendor are not appropriate to the portfolio being analysed, external data sets or internal claims experience may provide a source of information from which updated vulnerability curves can be introduced.

As a minimum, a portfolio's sensitivity to these assumptions should be tested in order to understand the materiality from which to judge whether further analysis is required.

Financial Calculations

Why is it a source of uncertainty?

Even once the challenges of estimating the frequency of a natural catastrophe, and then establishing how a risk will physically respond, have been dealt with, to make the result relevant to the insurance industry, how this will translate into a claim needs to be determined.

At some stage in the process, individuals are required to translate and enter details of the relevant financials:

- All policy data, including limits, deductibles, sub-limits and perils, must be entered correctly to adequately represent the written risk.
- All per risk and portfolio level reinsurance must be detailed correctly.
- Portfolios, bringing together all underlying exposure, including both direct and treaty portfolios that themselves may have many underlying exposures, must be created accurately.

Models must then be run with the correct settings and options.

Most models, in order to operate in practical timescales, use approximations in their calculations, such as forcing the output of individual stages into pre-determined distributions; or through sampling techniques, where direct calculation would be too complex.

In certain circumstances it can be difficult to determine the proximate cause of loss. For example, for a policy that covers wind damage only but the insured property has sustained damage from both wind and storm surge it is difficult post-event to determine whether the damage was caused by one or other, or a combination of both.

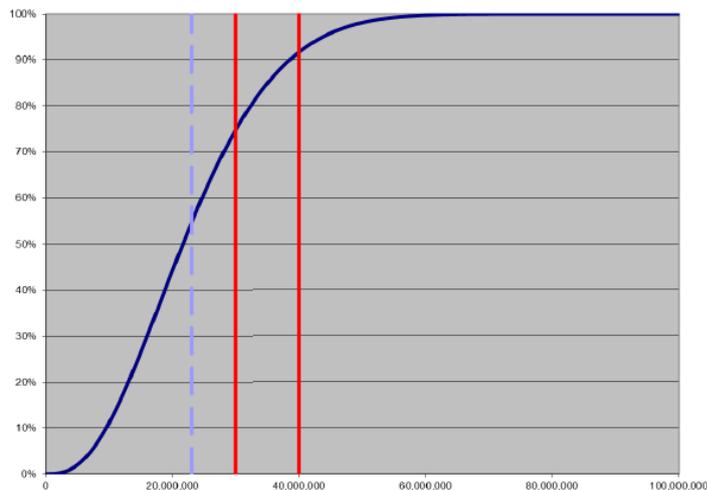
Political pressure can lead to adverse court decisions against insurers, with insurers having to pay claims that weren't intended to be covered by the policy. For example, fire following an earthquake in California where the take-up of earthquake insurance for homeowners is very low.

There are also legal issues that may arise affecting the claim itself, which can be hard to assess in advance.

Most cat models already include the ability to add some form of post-event demand surge. In more extreme events, the level of demand surge is likely to increase given the shortage of materials and labour. Political pressure may also lead to restrictions on the movement of labour from one state to another or one country to another.

How does it affect results?

A robust financial modelling engine is essential to be able to move from 'ground up' damage to insured loss. The ever more complex interaction of different insurance structures to the final loss is a very important part of the results.



The overall uncertainty, here termed Claims Obscurity, can be neutral if unbiased and spread evenly throughout a large number of risks – however in general the issues raised will more often increase losses than decrease them; and a portfolio's sensitivity to this effect should be understood.

Most specifically, it would be important to identify particularly susceptible features, such as accumulations of risks vulnerable to claims leakage.

Of greatest importance is understanding how the particular model intends on representing all uncertainties in the final result. This is usually a pre-established design decision, to which calculations are fit.

Approaches to measuring and managing

Issues due to human error will arise in any manual process. The establishment of a control framework, including reconciliation checks and peer reviews, is essential.

Sensitivity testing and stress testing can help to determine the sensitivity of approximations in the calculation process.

Different model vendors use different methodologies in developing their models. They have different estimation, fitting and smoothing techniques as well as different representations of scientific details.

Where different models can be used, this can identify where the greatest sensitivities lie in the different financial calculation processes.

Blending the results from different models can reduce the risk of reliance on a single vendor opinion, however it may introduce new obscurities into the process.

Communication of uncertainty

It is not enough for the users of cat models to understand the forms of uncertainty present. Ensuring this is adequately communicated can be the difference in having the correct decision result from the analysis.

Communication of the material sources of uncertainty aims to address two issues: over-confidence and under-confidence in results.

When compared against other approaches to measure risks typically considered by an insurance company, the level of investment, complexity and sophistication employed within cat modelling introduces a danger that the recipient of the results of the modelling process will have a limited ability or desire to challenge what they have been presented with. Coupled with the general habit of presenting output in its raw form, to as many decimal places as will fit, risks communicating an over-confidence in the output.

On the other hand, efforts to address this, by modellers who are familiar with the limitations present throughout the process, if not handled carefully, can have the opposite effect – of communicating such lack of certainty that the recipient feels that they lack the relevant insight with which to appropriately use the results – and therefore that they do not use them at all.

Good communication requires an understanding of the question being asked, and the purpose to which to results will be used. The recipient should be left comfortable with the general result, clear on the key sensitivities and aware of the questions to ask if more precision is required.

Exposure Data Ambiguity

When presenting the cat modelling results of any analysis a consideration of the appropriate message on the level of exposure data ambiguity should be included, to ensure that the decision maker has sufficient information on which to form a judgement.

This might take the form of a simple factual report of underlying data quality (against a minimum / target data quality standard), on which to communicate the level of confidence that can be attributed to the analysis; or a visualisation of the range of outcomes that would result if more optimistic or pessimistic assumptions had been used (where the aim would be to communicate the sensitivity of the results to these assumptions, rather than identify the full range of potential outcomes).

Natural Hazard Variability

When communicating model output the default approaches give equal weighting to all elements. To the person receiving the results the Average Annual Loss (AAL) appears as precise as the 1-in-1000 year loss, and yet in reality we may have a high degree of confidence in the AAL, have a historical record spanning 50 years from which to achieve a moderate confidence in 1-in-30 year losses, and yet be aware of significant challenges and disagreement affecting anything further in the tail.

The extent to which this is communicated depends on the purpose of the analysis being performed.

In some cases it may be of value to visualise this within the EP curve itself – for example, highlighting the return period for which the model has a historical record for calibration.

Risk Vulnerability and Financial Calculations

In other situations, a box-and-whisker plot around key return periods, based on sensitivity testing, can visualise the variability to decision makers.

Conclusion

The material sources of uncertainty for a company, or for a particular analysis, will vary and are the responsibility of those performing the modelling and presenting the results to identify and communicate.

The information provided in the document is not intended to be an exhaustive study of the subject, but hopefully gives those who receive cat modelled results the confidence to address the topic and some questions to be asking of their cat modellers.

“Arrogance is the opposite of curiosity. So to make good decisions you really need to be someone who’s willing to look at things that are difficult. And if you get knowledge or information that makes you feel uncomfortable, rather than run away, you need to pursue those doubts.”

-- Prof David Tuckett, director of University College London’s Centre for the Study of Decision-Making Uncertainty.

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