LOSS MODELLING
FRAMEWORK

Given the inevitable uncertainty of vulnerability functions, how would you recommend that end users mitigate against this problem?

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Proper mitigation of uncertainty requires considering and preparing for many alternative scenarios. The vulnerability component of catastrophe models is not an exception to the rule. I want to encourage Oasis community colleagues to more enthusiastically engage in sensitivity testing and scientific benchmarking. These exercises do not mitigate uncertainty completely, but they help us be more at peace with it.

In my view, uncertainty in vulnerability functions arises from two fundamental sources: our limited knowledge of the physical characteristics of exposures and the existing computational constraints to simulate their behaviour in catastrophe (CAT) models.

Consider the first source. If you are working with a large portfolio of exposures, it is unlikely that you have coded all its characteristics such as construction material, structural type, height or occupancy. It is costly to gather this information and even if you invest good money to do so, it is unlikely you are going to always get them right. Have you ever tried, by observing from the street, to identify for instance, whether a structure is “confined masonry” or “reinforced concrete”? It is pretty hard. While on reconnaissance missions after earthquake events I sometimes get to do this exercise. I am far from accurate.

Consider that confined masonry, as strictly defined, requires that bricks be indented into the concrete columns. The way to do this properly is to build the walls first, leaving a series of “brick teeth” exposed, and then pour the concrete columns and beams along the perimeters. Once solidified, the concrete binds with the indented bricks, “confining” the walls, and providing lateral strength to the structure. But the execution of such buildings is often poor and the resulting indentation is either minimal or none at all. In that case, the bricks appear almost flush against the concrete. Is the building now a confined masonry structure according to our models?

Just as we cannot precisely classify buildings according to their structural type, we cannot be sure about the quality of the materials employed to build them, the exact geometry of beams and columns or really about any other physical characteristics. There are many examples of surprising outcomes following destructive events in Turkey, Chile and the United States observed in buildings that we thought we knew well. It is a sound practice to carry out a series of “what if” scenarios.

Recently, while advising a client on its Chilean exposures, we identified large portions of its portfolio classified as confined masonry, even in urban centres. This seemed a bit suspicious since we knew that the urban building stock in Chile is predominantly concrete. Therefore, we recommended exploring a range of building classification assumptions, some more optimistic and some more pessimistic, in order to quantify their impact on portfolio losses. With this simple exercise, the client was able to consider its modelled losses in the context of other plausible realities.

Let us explore the second source of uncertainty: our computational limitations. Once, in a discussion with a professor about potential collaboration, he told me that his pursuit was to build a realistic, immersive model of structural behaviour in earthquake scenarios. He wanted to simulate a three-dimensional landscape, complete with models of individual city buildings, so that an observer could virtually position him/herself inside any of the structures and “see” the deformations and damages that ensued. As exciting as this prospect is, the computational resources needed would be prohibitive for the average CAT model user.

Since their origins, CAT models have typically sacrificed detail for sampling size in numerical simulations. We prefer to run 100,000 simple and fast simulations than 1,000 convoluted and lengthy ones. This is reasonable if you consider that we do not know much about the details of the structures we simulate, as mentioned earlier.

But in order to produce simple and fast simulations, we have to use a conceptual model of a building that is quite inadequate for capturing the complex deformations of a real structure. Here, earthquake models, for instance, diverge in their approach. Some use the "capacity spectrum method," which is a way to condense the dynamic behaviour of a building as determined by a given earthquake to a couple curves. Some use "dynamic analysis," which relies on carrying out many sophisticated three-dimensional simulations that later get packaged into the model via a few pre-computed, simple curves. The classical method used just a "damage function," which associates a level of expected damage to a level of hazard. While we may argue that one method is better than the other, all of them ultimately provide just humble approximations of expected damages.

Over time, we have incorporated additional features in our simulations in order to compensate the limitations of these vulnerability modelling techniques. For example, "secondary uncertainty" captures the randomness of damage outcomes conditioned on a specific level of hazard. In other words, the expected damage ratio of a building subjected to 1 meter of flood depth might be 30 percent. But thanks to secondary uncertainty we can also model plausible scenarios of a damage ratio that might be 5 percent or 100 percent.

Sometimes, with the objective of streamlining computations, secondary uncertainty becomes a catch-all method to account for uncertainty arising in other model components, like hazard. Many houses in New Orleans in the aftermath of Katrina had to be demolished not because they experienced structural damage but because of the onset of mould. We certainly do not account for mould explicitly in our models today, so there is little choice but to attempt to capture this effect within secondary uncertainty.

Validation of damage functions or their secondary uncertainty is very difficult because good quality damage data from actual events is extremely scarce. Anecdotally, in one of our recent studies of about 1,000 flood damage functions completed in collaboration with the German Research Centre for Geosciences, we were dismayed to discover that about half of the curves published in the scientific literature provide no validation at all.

While sometimes the results may be inconclusive, we have found that benchmarking vulnerability models against the published scientific research is useful. Academics refer to this as second-order validation: the validation of a model against another – independent – model. Therefore, we routinely encourage our clients to compare the vulnerability curves from the models they use against large groups of damage functions from the scientific domain, which use different methodologies and datasets to provide a relationship of damage and hazard. Seeing the damage curve that you are using in the context of existing research is critical to acquiring a sense of the existing uncertainty and seeing where within that existing uncertainty you are operating. Are the damage functions you are using above all the published research (maybe overly conservative) or are they below (maybe overly aggressive)? I believe being able to answer these questions is critical to understanding the model's assumptions.

In sum, uncertainty in vulnerability exists because there are a lot of things we do not know (epistemic) and because we have computational constraints. Both are important but, in my view, the first is the largest cause. There are many things we do not know because it is difficult and costly to measure the relevant parameters and get good quality data. Until we are able to do that, sensitivity testing and scientific benchmarking are techniques that can help us understand and manage risk responsibly in the context of uncertainty.

Guy Carpenter helps clients undertake these activities efficiently and confidently through the Model Suitability Analysis (MSA)® initiative.