

# A Decade of Advances In Catastrophe Modeling and Risk Financing





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## INTRODUCTION

Ten years ago this summer, Hurricane Katrina pounded New Orleans with surprising intensity, becoming the costliest storm ever to hit the US. Three years later, damage from Hurricane Ike extended far deeper inland than previously thought possible. In 2012, Superstorm Sandy brought record levels of storm surge to the Northeast. And in recent years, major earthquakes off the coasts of Japan and Chile led to severe structural damage and massive tsunamis.

After a major catastrophe, individuals, businesses, governments, and others look for lessons to help decrease the potential impact from future events. In the insurance industry, much of the focus following disasters falls on catastrophe models, which have undergone several rounds of change as new events add new data. Advances in technology and analytics have also transformed the models and the way insureds view and deploy their insurance capital.

## THE EVOLUTION OF CATASTROPHE MODELING

The first hurricane loss model was introduced in the late 1980s by AIR Worldwide. But most insurers did not initially adopt catastrophe modeling, even after September 1989's Hurricane Hugo became the costliest hurricane in US history to that date (see Figure 1). Instead, the industry continued using traditional actuarial methods and past experience as a basis for estimating potential future losses.

That changed after Hurricane Andrew struck Florida and Louisiana in August 1992. Andrew cost insurers \$15 billion – nearly four times Hugo's cost – surprising them and leading to multiple bankruptcies. Andrew thus served as a wake-up call; insurers quickly embraced modeling, seeking a more scientific approach to estimating catastrophic loss exposure and risk aggregation.

In the two decades since Andrew, catastrophe modeling has become a necessary and permanent part of the underwriting process, and models have grown more sophisticated. New insights gained from successive hurricanes have revealed an important truth for underwriters and insurance buyers: Catastrophe models need constant updating based on experience. Even an up-to-date model can miscalculate the potential damage from a storm that behaves in an unforeseen manner – potentially by a significant margin.

Underwriters learned this the hard way when Hurricane Katrina struck in August 2005. The massive storm cost insurers more than \$41 billion, mostly in New Orleans. Hurricane models severely underestimated the loss potential, with initial damage estimates identifying only about one-fourth of that total.

After Katrina, analysis from actuaries and modelers revealed that many assumptions had been incorrect. For example, models underestimated the potential damage that could be caused by coastal flooding driven by wind or storm surge. Models also often incorrectly assumed that all properties were built to meet existing codes. This lesson was driven home by Hurricane Ike in 2008, which caused severe wind and flood damage to inland and Northern states – including Arkansas, Illinois, Indiana, Kentucky, Michigan, Missouri, New York, Ohio, Pennsylvania, Tennessee, and West Virginia – that far exceeded industry expectations.

Insureds and regulators have sometimes questioned changes to models as they can lead insurers to adjust rates, bringing increases to some buyers. For example, many risk managers criticized changes made in 2006, which projected a 40% increase in annual insured losses along the Gulf Coast, Florida, and Southeastern US compared to previous models. But overall, these changes have helped insurers and insureds alike to better understand and manage risk. For example, the lessons learned from Katrina, Ike, and other storms contributed to better preparation ahead of Sandy.

**FIGURE 1: Most Costly Hurricanes in US History (In Billions)**

Source: Insurance Information Institute

DATE	HURRICANE	DOLLARS WHEN OCCURRED	IN 2014 DOLLARS
AUGUST 2005	KATRINA	\$41.1	\$48.4
AUGUST 1992	ANDREW	\$15.5	\$23.8
OCTOBER 2012	SANDY	\$18.8	\$19.3
SEPTEMBER 2008	IKE	\$12.5	\$13.6
OCTOBER 2005	WILMA	\$10.3	\$12.1
AUGUST 2004	CHARLEY	\$7.5	\$9.1
SEPTEMBER 2004	IVAN	\$7.1	\$8.6
SEPTEMBER 1989	HUGO	\$4.2	\$7.1
SEPTEMBER 2005	RITA	\$5.6	\$6.6
SEPTEMBER 2004	FRANCES	\$4.6	\$5.6

## How Hurricane Models Have Improved Over Time



The three leading hurricane modeling firms — AIR Worldwide, EQECAT, and RMS — typically have made revisions based on the lessons learned following major storms such as Hurricanes Katrina and Ike and Superstorm Sandy. Updates to the widely used RMS model include the following:

- New models released after the 2004 and 2005 Atlantic hurricane seasons — which included Hurricanes Charley, Frances, Ivan, Jeanne, Katrina, Rita, and Wilma — reflected greater frequency of hurricanes and insured losses that modeling firms expected would continue for the next several years.
- After Hurricane Ike in 2008, models were updated with higher inland wind speeds and greater building vulnerability. Models also incorporated research about the weakness of commercial structures' roofs and poorer-than-expected construction quality in Texas and along the Gulf coast, and added new storm surge models.
- The storm surge models were updated with new flood data from FEMA and the NFIP following 2012's Superstorm Sandy.
- The latest updates include a recalibration of vulnerability curves based on recent hurricane-related claims, and new secondary modifiers that allow for improved accuracy of potential storm-surge damage.

The reality is that nature will at times deliver an unexpected twist into the way a storm behaves. And modelers will respond by analyzing the losses and recalibrating their models.

# MODELING'S ROLE IN UNDERWRITING AND RISK MANAGEMENT

The catastrophe modeling process includes four key steps:

1. **Event generation:** A computer-run model pulls from a database representing the full spectrum of likely events that can impact the insured's exposures. Each event is described by physical characteristics, location, and frequency of occurrence, and the model calculates the likelihood and severity of an event at various insured locations.
2. **Hazard:** The model determines the event intensity at each insured property for every simulated event that is likely to cause a loss at that location. It examines important site characteristics, including soil condition, distance from the coastline, and elevation to determine ground motion, peak wind gust, and other location-specific conditions.

3. **Vulnerability:** The model calculates the mean damage ratio and coefficient of variation to buildings and their contents, and the resulting loss of use — for example, business interruption.

4. **Financial model:** This model calculates losses to different financial participants, including the insured, insurers, and reinsurers.

Insurers use catastrophe models to determine their probable maximum loss (PML) for various return periods. This allows them to calculate an average annual loss (AAL), which indicates the minimum annual premium that the insurer would need to collect over that return period to cover its expected loss. This ultimately informs insurers' decisions about how to manage risk aggregations, deploy capital, and price insurance

coverage. It also allows insurers to demonstrate capital adequacy to rating agencies.

Meanwhile, insureds and their brokers primarily use models to help make choices about how much property insurance to purchase and how to structure those policies. By running a catastrophe model, an insured can develop a set of losses for various return periods, usually from 100 years to 1,000 years. The insured can then choose a return period that matches its risk appetite and current market conditions and insurance pricing to gain a greater understanding of its total property portfolio risk and catastrophe exposure. In turn, this informs decisions about limits, retentions, and other terms and conditions.



## REFINING EARTHQUAKE MODELS

Although revisions to hurricane models have more frequently grabbed the attention of insurers and risk professionals, earthquake models have also evolved over time. The most recent US earthquake model updates, released in 2009 by AIR and RMS, were not spurred by any single earthquake. Instead, the catalyst was the release of the United States Geological Survey's National Seismic Hazard Mapping Project (NSHMP), a scientific consensus on earthquake hazards.

Most notably, the 2009 updates included next generational attenuation (NGA) relationships; earthquake attenuation quantifies the rate of decay of ground shaking as the distance from the earthquake's epicenter increases. Incorporating the new NGA information, along with updated data sets on soil type, liquefaction, and landslide potential, had significant loss impacts across the country.

Modelers also used the update as an opportunity to recalibrate building vulnerability curves, incorporating claims data from international events and engineering studies. These vulnerability curves show the relationships between the amount of ground shaking and expected damage to a building given its construction characteristics.

Subsequent earthquake models for other regions have also incorporated lessons learned from recent events. For example, both RMS and AIR prioritized the modeling of tsunami risks following the March 2011 earthquake and tsunami that struck the Tōhoku region of Japan. Tsunami loss estimates have since been incorporated into various global earthquake model updates by the two organizations; AIR's recently released South American earthquake model also includes findings from earthquakes and tsunamis off the coast of Chile in February 2010 and April 2014. The next update to the US earthquake models, expected to be released by 2017, will likely include similar revisions.

## A FOCUS ON DATA QUALITY

A major reason why the initial estimates of Katrina's damage were off was that insureds and insurers were feeding bad information into their models. So beyond specific changes and corrected assumptions built into today's catastrophe models, the biggest lesson from Katrina and other major storms is that models are only as useful as the data that go into them.

Katrina showed how sensitive modeling results can be to gaps or inaccuracies in data. Historically, insurers had done a poor job of collecting information from policyholders, but the industry quickly added staff and invested in other resources to improve data collection efforts. Modeling firms have also done their part, adding internal data solutions teams and licensing additional databases to fill gaps in data.

Still, the lion's share of responsibility for ensuring data quality lies with property owners. And while data

quality today is typically far better than it was a decade ago, many organizations continue to submit inaccurate or incomplete data (see sidebar). This includes poor information about the primary attributes or modifiers of their properties that are central to catastrophe modeling, including:

- Geocoding — street address and latitude/longitude information.
- Occupancy.
- Construction type.
- Year of construction.
- Number of stories.

Secondary building characteristics that can affect modeling results include roof characteristics, such as its age; how building foundations are reinforced and connected to building frames; cladding style; and whether a building had cripple walls or soft stories. Other secondary modifiers vary by specific model.

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### BAD DATA, BAD RESULTS

With so much at stake, the question remains: Why do insureds submit poor data? There are a number of possible reasons:

- In many cases, they simply don't have access to accurate data about their properties, or the information is not readily available because it's held by several sources.
- Data may have been collected several years ago, but they have not devoted the resources required to continually update and validate it.

- Some fail to add or delete information as property portfolios change over time, for example, through mergers, acquisitions, and divestitures.

Unfortunately, some organizations continue to underestimate the substantial effect that poor data can have on their insurance programs — and aren't willing to devote time or money to improve data quality. Such a view can be shortsighted as incorrect base loss projections from catastrophe models can translate into additional premium spent on coverage that isn't needed. By investing in data quality, companies

can help assure more effective use of limited capital.

Brokers and other risk advisors — with support from construction and engineering experts — can help organizations validate and update the primary attribute and secondary modifier data submitted to underwriters, which can allow risk managers and insurers to better quantify and qualify catastrophe risk. Generally, this will translate into less uncertainty in catastrophe models, lower AAL estimates, and premium savings.

Data quality can be improved through a six-step process.

### Step 1: Natural Hazard Data Management

Prior to renewal, an organization should review its portfolio and identify any additions, deletions, or other changes in values since its last catastrophe modeling exercise. Brokers and risk advisors can review an organization's statement of values to ensure the accurate transposition of changed values; loss control provider reports can also be used to validate or update new information being entered into the model input data spreadsheet.

### Step 2: "Pre-Modeling" Assessment

Next, an organization should perform an initial modeling run to generate AAL results by location. This can help to identify any deficiencies in primary data and determine the secondary attributes that can help to better quantify risk.

### Step 3: Initial Assessment

With these preliminary modeling results in hand, a broker's data verification tools can help assess the quality of existing data, including any items that may be inaccurate or incomplete. These tools can also help identify questionable data — for example, a property that is listed as both wood construction and 10 stories tall should be flagged for review.

### Step 4: Engineering Review

This baseline data should next be reviewed by outside engineering specialists, whose experts may be secured via a broker. Using engineering reports provided by the property owner, online tools, and other means — and without making undue assumptions about specific properties — these experts can begin to verify and validate existing data and fill in many gaps.

### Step 5: Secondary Assessment

An organization should next re-run the updated data set in its broker's verification tools, which should be able to provide a data quality score. Generally, organizations should look to achieve a score of at least 90% complete/accurate data. At that threshold, a risk manager can generally be confident that modeling results provide a reasonable basis for property risk management decisions.

### Step 6: Site Visit

The final step is the collection and validation of primary information and secondary modifiers. This is achieved through a site visit by engineering experts to fill in any gaps for underwriters. An important output of this process is a detailed report explaining results and assessment methodology to underwriters, including engineering analyses and photo evidence as needed.



## IMPROVING DATA QUALITY TO REDUCE INSURANCE PREMIUMS

A large, US-based restaurant chain was preparing for its property insurance program renewal. Preliminary market indications pointed to an increase in premiums due to perceived wind exposures in its occupancy class and the company's recent loss history. Historically, this occupancy class has not fared well due to inherent construction vulnerabilities, such as large expanses of glass and the generally lightweight nature of typical construction. These factors cause catastrophic loss models to generate significantly higher loss projections than most other occupancy classes.

But unlike many of its peers, this company closely controls the construction of its restaurants and tends to build more robust buildings. The company felt that the modeling results misrepresented its exposures and did not accurately portray the vulnerability of its portfolio. The restaurant chain sought the advice of Marsh Risk Consulting to address this issue.

A natural hazards risk assessment determined that the elevated loss projections were the result of poor data quality used to model the portfolio. Key loss driver locations were identified, and a focus was put on improving accuracy and reducing uncertainty in the modeling by improving the quality of data inputs.

Following the initial analysis, 10 locations identified as having some of the highest average annual losses (AAL) were looked at in more detail. New data was gathered and validated on primary and secondary characteristics and extrapolated over all of the company's restaurants, where possible, to improve the input data for the entire portfolio. The portfolio was then remodeled using this improved data.

Ultimately, the company reduced its portfolio AAL by approximately 25%. The data was then used in negotiations with insurers, helping the company significantly reduce the potential increase in its premium.

## RISK FINANCE OPTIMIZATION

Advances over the past decade in modeling, technology, and big data and analytics have helped companies to better understand their unique risks from hurricanes and other disasters. At the same time, risk professionals have advanced the methods used to value insurance and decide if it is the most effective use of capital under a given scenario. This approach allows organizations to gain perspective on their risk tolerance levels and the potential impact a disaster may have on their return on capital, which in turn can help them make more informed risk financing decisions to protect their bottom lines.

Too often, organizations have seen insurance as merely an expense, basing decisions purely on premium cost or the purchasing habits of other organizations. But when viewed through the lens of a company's specific risk tolerance and cost of capital, it can be demonstrated that insurance provides significant contingent capital if priced properly. Alternatively, insurance can consume too much capital if priced incorrectly.

Risk finance optimization (RFO) provides insurance buyers with a view similar to those used by insurers to calculate how much their risk is worth to the market. By modeling potential scenarios of insured and uninsured losses, an organization can make smarter decisions about whether to retain risk on its own balance sheet or transfer the risk to an insurer. If transferring risk, the RFO

process can help an organization determine how to appropriately structure its insurance program based on its unique risk.

The first step in the RFO process is a risk-tolerance analysis, which seeks to answer two questions:

- How large a loss is our organization willing and able to take?
- How does our risk tolerance inform our risk financing decisions?

The next step is to simulate potential loss outcomes, which represent what could happen over the next 12 months based on the company's specific risks. Using catastrophe modeling results, an organization can calculate its average or expected losses in various return periods, and the amount of certainty (the standard deviation) around that calculated average. This information can ultimately help an organization determine what limits it would need to set for an insurance purchase and how much it should pay to remove that risk from its financial statements and transfer it to an insurer.

Based on this loss distribution and the organization's unique cost of capital, an organization can calculate its economic cost of risk (ECOR). Traditionally, businesses have measured risk exposure through total cost of risk (TCOR), which represents the sum of insurance premium spend, retained loss costs, broker



### MAKING SMARTER DECISIONS THROUGH RISK FINANCE OPTIMIZATION

An organization planning to divide itself into two separate companies had to determine the appropriate structure and pricing for the two new entities' property insurance programs. The two new companies had vastly different exposures; one would have a relatively balanced portfolio of fire, wind, and earthquake perils, while the other would have a disproportionate share of earthquake risk. The two new companies' risk management teams sought objective, data-driven guidance about the optimal insurance structure and appropriate target pricing for each company before approaching underwriters.

Marsh Global Analytics performed property catastrophe modeling and risk finance optimization exercises for both companies. This included parsing out global exposure data for each entity and reviewing how their new exposure bases contributed to key loss drivers from catastrophe modeling outputs. An economic cost of risk study and review of potential alternative structures were then performed to assess the most appropriate program structures in comparison to break-even premiums by layer.

The work was critical to setting retention levels for the two companies: Given their vastly different volatility levels, one entity decided to take a much lower retention — less than 50% of the combined organization's historical retention. The relationship between the catastrophe model outputs and market pricing were provided and scrutinized to guide the placement team on appropriate premiums to target. And both organizations ultimately had a better understanding of how geographic exposures and volatility impacted their total program limits.

fees, taxes, and other administrative expenses. But this assumes that all losses are known, and does not account for loss volatility — the main reason why companies purchase insurance.

This uncertainty can be measured via economic cost of risk (ECOR), which is the sum of:

- Expected retained losses.
- Premiums.
- Implied risk charge.
- Other expenses, including claims fees and collateral costs.

The implied risk charge included in ECOR represents the cost of capital exposed to unexpected losses — for example, catastrophic losses from a major hurricane or other event that exceed insurance coverage limits and the interest charges a company may incur if it needs to borrow money to cover this shortfall. Underwriters consider the cost of volatility, including their version of implied risk charge calculations, which makes ECOR a more effective way for risk managers to measure risk.

By quantifying ECOR for various risk financing structures — including traditional property

insurance, a captive program, and other options — an organization determines which is most economically efficient. A risk manager can then make a more informed decision about how to finance risk based on each option's return on investment and the organization's overall financial goals and risk tolerance.

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## CONCLUSION

It's impossible to know when the next major storm or earthquake will hit. However, continued advances in modeling, data, analytics, and technology are allowing companies to better understand their exposures. As organizations become more aware of the potential return on investing in areas such as data accuracy, risk engineering, and risk finance optimization, they can expect to see more efficient pricing of their risk from insurers, leading to more confidence as they decide how to deploy limited capital.



## About Marsh

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## About this Report

This report was prepared by Marsh Global Analytics (MGA) in conjunction with Marsh Risk Consulting's (MRC) Property Risk Consulting Practice and Marsh's Property Practice. Through catastrophe modeling services and other data, analytics, and technology solutions, MGA provides insights that empower companies to take a holistic view of property catastrophe risk. This expertise is augmented by MRC's CatDQ process, which can help to reduce uncertainty in catastrophe modeling by improving data inputs and outputs. With more accurate modeling results in hand, our team of property insurance brokers can help you better negotiate with underwriters to build effective insurance programs with efficient pricing to address your unique risks.



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