

Learning Resources – Website Content CSCR Exam 2

Purpose: This document is intended to capture the website content of those sites referenced as learning resources for CSCR Exam 2. Note that only virtual resources are captured. Additional textbook study resources have not been included but are available for purchase as detailed on-line and in this document. If the “Initial Link” for a given assignment is still active, it can be leveraged. Otherwise, the contents that had previously been available at the “Initial Link” can be found later within this document by using the first link in each row.

Note that some materials can be listed multiple times within the Learning Objectives. In such instances, they will often appear only once in the below links. Additional materials, such as reference textbooks, are also further detailed within the Learning Objectives for this exam but may not be included in the following list. Candidates are encouraged to fully review both sets of resources.

1. Assignment 1, Modules 1 and 2: Sections from the Textbook authored by Mitchell-Wallace, J. Jones, et al.
2. Assignment 2, Module 1: Sections from the Textbook authored by Grossi, P. and Kunreuther, H.
3. [Assignment 3, Module 1: Catastrophe Risk: Initial Link](#)
4. [Assignment 3, Module 1: Uses of Catastrophe Modeling Output: Initial Link](#)
5. [Assignment 3, Module 2: Reanalysis Data: Initial Link](#)
6. [Assignment 3, Module 4: Study Note – Cat Risk Management: Initial Link](#)
7. [Assignment 3, Module 5: Cat Models – In the Eye of the Storm: Initial Link](#)
8. [Assignment 4, Module 1: Ill Facts and Figures: Initial Link](#)
9. [Assignment 4, Module 1: Munich Re NatCat Information: Initial Link](#)
10. [Assignment 4, Module 2: Insurance Gaps: Initial Link](#)
11. [Assignment 4, Module 2: Insurance Protection Gap \(2\): Initial Link](#)
12. [Assignment 4, Module 3: Continental US Landfall Frequency: Initial Link](#)
13. [Assignment 4, Module 3: IBHS Building Codes: Initial Link](#)
14. Assignment 4, Module 3: Hurricane Andrew: This link is a video and, as such, is not copied into this document: <https://vimeo.com/47966637>
15. [Assignment 4, Module 3: Rating the States: Initial Link](#)
16. [Assignment 4, Module 3: FEMA Building Codes: Initial Link](#)
17. [Assignment 5, Module 1: ASOP 23: Initial Link](#)
18. [Assignment 5, Module 1: ASOP 38: Initial Link](#)
19. [Assignment 5, Module 1: ASOP 39: Initial Link](#)
20. [Assignment 5, Module 1: ASOP 41: Initial Link](#)
21. [Assignment 6, Module 2: Industry Good Practice for Cat Modeling: Initial Link](#)
22. [Assignment 6, Module 2: NAIC ORSA: Initial Link](#)

3. Assignment 3, Module 1: Catastrophe Risk: https://www.catriskcredentials.org/wp-content/uploads/2025/03/Ch5_CatRisk_2015-08-12.pdf

IAA Risk Book
Chapter 5 - Catastrophe Risk

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1. Executive Summary

Catastrophe risk has become an increasing focus for those involved in risk management largely due to recent major earthquakes and windstorms in various parts of the world. This chapter, after a brief introduction, discusses how the risk of such events is generally quantified and the issues associated with such quantification. Key observations/findings from the chapter include:

1. Catastrophes result in a sudden and mass destruction of property, lives, environment, and/or the economy.
2. Catastrophes can be natural or man-made (e.g., terrorism)
3. The frequency and severity of catastrophe losses have been increasing over past several decades primarily due to increasing concentrations of population and property in geographical areas prone to disasters.
4. Catastrophes impact society first, and insurers only to the extent that the damages are insured.
5. Due to their infrequent nature, analysis of past losses can't sufficiently measure catastrophe risk so many insurers use catastrophe models to estimate potential losses.
6. Catastrophe models are based on four primary components – event catalogs, intensity formulas, damage functions and a financial module.
7. Model uncertainty is unavoidable, and is impacted by both data issues (related to quality and availability) and political issues (influencing how events will unfold in times of stress). This is in addition to the uncertainty related to random events.
8. Model development and usage is evolving, including a trend towards open models (as opposed to closed proprietary models) and their use for scenario analysis.
9. Catastrophe models are part of the risk management process both in terms of pricing/underwriting and in terms of solvency/capital management.

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2. Introduction

Catastrophes refer to certain adverse events whose occurrence result in a sudden and mass destruction of property, lives, environment, and/or economy. Catastrophes can be caused by natural or man-made events. An adverse event will not rise to the level of a catastrophe or disaster if it occurs in an area without a vulnerable population. Catastrophe risk is highest where significant potential for adverse events coincides with population and building density.

According to the statistics published in the International Emergency Disasters Databaseⁱ, the frequency, duration and magnitude of disasters have increased since 1975ⁱⁱ. Increasing population density and higher concentrations of property values in areas prone to disasters is leading to increased chances of mega-losses from natural and man-made events. According to a 2015 World Bank study of East Asia, in the decade 2000 to 2010, for urban areas with more than 100,000 people, population density increased from 5,400 to 5,800 per square kilometerⁱⁱⁱ. Coastal property values in the US have increased fourfold between 1988 and 2014 according to studies of population and property value growth^{iv}.

The risk arising from catastrophes can severely impact an individual insurer's solvency position if not properly managed. Effective catastrophe risk management requires a comprehensive approach to identifying, assessing, transferring, and mitigating the risk and large loss potential. This chapter provides an overview of the types of catastrophes faced by the global insurance industry and discusses how companies estimate and manage catastrophe risk. (While this chapter is written at a particular point in time, our understanding of catastrophes and the tools used to quantify and manage catastrophe risk continue to evolve.)

3. Causes and Risk Implications of Catastrophes

I. Causes of Catastrophes

Broadly, catastrophes can be categorized into two types—natural catastrophes and man-made catastrophes. A natural catastrophe is a major adverse impact from either weather or geological related events. Examples of weather related events include tropical cyclones¹, floods, tornadoes, hailstorms, wildfires, and blizzards. Geological events include earthquakes, tsunamis, volcanic eruptions, mudslides and avalanches. Natural catastrophes are relatively well understood by the scientific community but difficult to predict and impossible to prevent.

According to the most recent report by Intergovernmental Panel on Climate Change (IPCC), demographic changes are the main cause of increasing losses over the past few decades and not climate change. Catastrophe losses have grown and will likely continue to grow steadily over time, primarily due to increasing concentrations of people and property values in hazardous regions.

¹ This term is meant to include hurricanes, typhoons and cyclones – all the same phenomena but with different names based on where they occur.

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Man-made catastrophes refer to incidental or deliberate human actions such as aviation accidents, act of terrorism, cyber-attacks, civil unrest, wars, nuclear power plant explosions, and oil/chemical spills. These events can cause great damages to property and lives because malicious man-made events often target large cities and high-profile landmarks such as international airports and civilian government facilities.

II. Risk Implications of Catastrophes

While there is wide variation from year to year, annual global catastrophe losses regularly exceed \$100 billion and can top \$400 billion in one year according to statistics published by Swiss Re and Munich Re. Total economic losses from a major event will typically include damaged infrastructure, lost jobs, disruption to services, and other costs not covered by insurance policies. Additionally, insurance policies in many countries exclude or limit coverage for certain types of perils that are considered “uninsurable” due to their very infrequent but severe nature and because of that the inability to credibly price the coverage. However, insurers will still be impacted by the indirect costs of uninsured risks resulting from infrastructure damage, disruptions to supply-chains, etc.²

There is wide variation between countries with respect to how catastrophe losses are funded. Governmental policies can influence how much of these losses are pre-funded through mechanisms such as insurance versus post-funded through taxation, borrowing, and international disaster assistance.

Insurance can be provided by governments or the private market. For example, in New Zealand and California, earthquake insurance is provided through both the private market and government-sponsored entities. In New Zealand, earthquake insurance for households is compulsory while in California it is not. Where coverage is voluntary, there is the concept of “take-up rates” that indicate the percentage of policyholders purchasing certain coverages. For example, the earthquake insurance take-up rates in California can range between 10 and 30 percent depending on the length of time since the last major event.

Private market insurance and risk-based pricing are generally thought to be the most efficient ways to fund catastrophe losses. Immediately after an event, insurers can begin to adjust and settle claims so policyholders can start rebuilding homes and businesses. It will typically take several months, and possibly years, for all of the claims to be identified and paid by the insurance industry depending on the size of the event leading to a relatively long payout pattern. Risk-based pricing also encourages mitigation activities that can help societies become more resilient to future events.

Since 1975 natural and man-made catastrophe losses have hit the insurance industry very hard and resulted in insolvencies of small and large insurers.^v According to a 2013 A.M. Best’s Special Report^{vi}, annual insured catastrophe losses ranged from 2% to 14% of US Property/Casualty (P/C) insurance companies’ surplus during the period of 1969 – 2012 with two peaks—one in 1992 following Hurricane Andrew and the other in 2005 after

² Some also label pandemics as catastrophes. This paper instead focuses on those with a physical basis and not a biological basis. This paper also acknowledges emerging concerns with the risk of solar flares, but does not attempt to address that hazard at this time.

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Hurricane Katrina. In the same report, it indicates that catastrophe losses are among the top four causes for P/C insurance sector's financial impairments, accounting for 7.1% of failures.

According to the A.M. Best report, between 1969 and 2012 a total of 53 US-based property/casualty Insurance companies became impaired as a result of catastrophe losses and 11 became insolvent from one event—Hurricane Andrew. While private insurance covers only a fraction of total global economic losses, private insurers collectively pay out between \$50 and \$100 billion each year based on current economic conditions.

4. Estimating Losses from Catastrophes

Catastrophes are infrequent events in specific geographical regions which means there is a paucity of data for loss estimation. Standard actuarial approaches using historical claims and loss data to project future losses are not appropriate for most types of catastrophes. Because of the sparse historical data any approach will be characterized by significant uncertainty, so it's prudent for insurance companies to use a variety of methods to identify the types of events that could result in large losses and to estimate the magnitude of those losses.

One method that can be used even if there is no data on past events is to add up total insured values in specific regions exposed to severe events and apply factors representing the percentages of total values that could be lost in one event or an aggregation of events over some time period—usually a year. Total insured values³ obviously represent the upper bound of loss potential.

Scenario testing is another method used to estimate the losses from specific events. For example, Lloyd's of London has developed a set of Realistic Disaster Scenarios (RDS) and requires syndicates to report on their loss estimates from these scenarios each year. Many companies employ scenarios as part of their Enterprise Risk Management (ERM) framework.

Catastrophe models provide a robust structured approach for estimating a wide range of possible future scenario losses along with their associated probabilities. Because the catastrophe models provide full probability distributions, they are suitable for many types of actuarial analyses. Loss estimates produced from catastrophe models can be deterministic for a specific event (e.g., Hurricane Katrina, a magnitude 8.0 earthquake in San Francisco) or probabilistic from a catalog of hypothetical events.

The first catastrophe models were developed in the late 1980s to assess the risk from hurricanes, earthquakes, and other natural hazards. The adoption of the models by the insurance industry accelerated after Hurricane Andrew in 1992 and the Northridge Earthquake in 1994. Models for man-made catastrophes, such as terrorism, were constructed after the World Trade Center disaster.

I. Key Components of Catastrophe Models

For all types of catastrophes and for all peril regions, the models have the same four primary components as shown in Figure 1 below.

³ After adjustment for possible "replacement cost guarantees"

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Figure 1. Catastrophe Model Components	
Model Component	Description
Event Catalog	Defines event parameters including frequency and physical severity by geographical region
Intensity Formulas	Estimates the intensity experienced at each location in the area affected by each event
Damage Functions	Estimates the damages to building, contents, and time element exposures (may also estimate casualties)
Financial Module	Applies insurance policy conditions and reinsurance terms to estimate insured losses

A. Event Catalog

The event catalog includes the important parameters defining the characteristics of each simulated event, such as location, severity, and size. For tropical cyclones the event catalog includes landfall point, peak wind speed, and radius of maximum winds while for earthquakes it includes epicenter, depth, and magnitude. For terrorist attacks, the event catalog could include location, type and size of bomb.

For each event in the catalog, there is a rate of occurrence that is estimated using statistical analysis of historical information if there is enough data (tropical cyclones, other windstorms) or by scientific studies and expert opinion where there is less data (earthquakes, terrorist attacks). The catalogs typically include a large sample of events generated by Monte Carlo simulation or stratified sampling techniques.

The event catalog is extremely important because it defines the frequency and physical severity of events by geographic region. The reliability of the catalog varies considerably across peril regions depending on the quality and quantity of historical data and the scientific understanding of the hazard. For example, in California and Japan, there have been a number of significant earthquakes and the nature of the faulting is generally understood by scientists (although there are many unknowns with respect to the magnitudes and locations of future events). Even less is known about “intra-plate” regions, such as the central US and Australia.

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B. Intensity Formulas

For each event in the catalog, the models estimate the intensity at each affected location using the event parameters discussed above, site information, and scientific formulas developed by the wider scientific community. While scientists have collected and analyzed intensity data from past events to develop these formulas, the amount and quality of the intensity data varies significantly across perils and regions.

For example, tropical cyclone intensity is defined by wind speed and scientists have developed well established formulas for hurricane wind speeds over water. When a storm makes landfall however, wind speeds start to dissipate because the hurricane loses its source of energy and due to frictional effects from the rougher terrain. Because there are relatively few reliable over land wind speed measurements for historical events, a degree of judgment goes into estimating hurricane intensity over land.

For earthquakes, intensity is defined by ground motion and is estimated using attenuation equations developed by scientists around the world. Because there is not an abundance of observed ground motion data for past events, historically, earthquake intensity has been inferred from the damage using the Modified Mercalli Intensity (MMI) scale.

A further complication with earthquakes is that the ground motion experienced at a location will be influenced by the nature of the rock and soil the energy waves pass through before getting to that location—these complexities cannot be reliably modeled. A simplifying approach of applying factors based on local soil conditions is typically used where detailed soil data is available. Secondary hazards such as liquefaction and fire following earthquakes might also be considered by the model.

While the likely frequency and severity of future man-made catastrophes is highly uncertain, there is a wealth of information on the impacts of terrorist attacks, particularly attacks using conventional types of weapons.

C. Damage Functions

The model damage functions estimate for different intensity levels the damages that will be experienced by different types of exposures. For property exposures, the damage functions will consider the building construction type, occupancy, and other characteristics depending on the peril.

The damage functions are expressed as the ratio of the repair costs (as a result of the damage) to the building replacement value. Because the nature of actual damage is “spotty”, for any given wind speed and mean damage ratio, different properties will experience different levels of damage—potentially ranging from 0 to 100 percent.

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This uncertainty is typically called “secondary uncertainty” and includes the uncertainty in the intensity and damage calculations. In the catastrophe modeling terminology, “primary uncertainty” refers to uncertainty with respect to the events themselves.

D. Financial Module

After the building, contents, and time element “ground up” losses are calculated, the secondary uncertainty distributions are used to estimate the insured losses accounting for policy terms and conditions. Policy terms include loss triggers, deductibles by coverage, aggregate deductibles, total and sub limits, coinsurance, attachment points, and applicable reinsurance terms. This model component is essentially the same across all peril regions (except for accounting for country and peril-specific policy conditions).

To construct the first three model components for a specific peril region, e.g. US hurricane, Turkey earthquake, data and information is collected from external entities such as government bodies and scientific organizations. The models are, for the most part, based on the same information collected, published, and maintained by the wider scientific community—model differences result from how the data is interpreted and analyzed to develop the many model assumptions.

II. Model Input

Exposure inventory is the key input in the catastrophe models. The most basic information is the replacement value for building, contents and time element coverages. Ideally, this information would be provided for each insured property by geo-coded location. In reality, the resolution and quality of the exposure data varies by peril region.

For US perils, most companies can provide this level of detail to the models along with other building characteristics such as construction, occupancy and year built. The more detailed the information on the structure and contents, the more reliable the model loss estimates will be. In other regions, the data may be total insured values (TIVs), aggregated by CRESTA (Catastrophe Risk Evaluation and Standardizing Target Accumulations) zone and line of business (residential, commercial, industrial). For example, in France, insurers typically collect data on the number of rooms rather than TIVs, and the data are aggregated by CRESTA zone.

Exposure data quality is an important issue in the quantification of catastrophe risk. Because most types of catastrophes impact localized areas, detailed knowledge of where exposures are located and the replacement values of those exposures are critical for credible loss estimates. For example, for properties exposed to storm surge flooding, it’s important to know how far the properties are from the coast. In seismic regions, the risk depends heavily on how close the exposed properties are to active faults.

Regulators should inquire about the geographical resolution of the exposure data and whether it’s exact latitude-longitude coordinates, postal code centroids, or aggregates by CRESTA Zones. They should also know how building, contents, and time element values are being determined. The nature and extent of other building characteristics contained in

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the exposure data files would be an indication of the emphasis placed on exposure data quality.

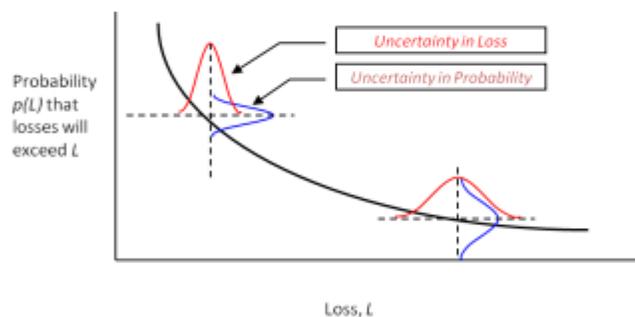
III. Model Output

The primary catastrophe model output is the exceedance probability (EP) curve that shows the probabilities of a portfolio of exposures exceeding losses of different amounts. The catastrophe models typically generate two types of EP curves—the annual occurrence distribution (OEP) and the annual aggregate distribution (AEP). The OEP gives the probabilities of losses from the maximum occurrence in a year, and the AEP gives the probabilities of total annual losses from multiple events in a year.

For very low frequency, high severity events, such as earthquakes, the curves will be very similar and typically converge in the tail. For more frequent events, such as tornado outbreaks, the AEP losses can be significantly higher than the OEP losses at all probability levels. The AEP losses will also be higher than the OEP losses for geographically diversified portfolios versus more concentrated books of business.

There are different techniques for estimating the AEP distribution. Generally, it is more challenging to estimate and less robust than the OEP distribution. Theoretically, average annual losses (AALs) should be calculated from the AEP.

Figure 2 – Illustrative Exceedance Probability (EP) Curve



Insurers and regulators have been relying on point estimates from this curve for risk management purposes. For example, in the US, insurers use the points on the curve where the estimated probabilities of loss exceedance are .01 and .004, popularly known as the 1 in 100 and 1 in 250 year losses, respectively. These points are also referred to as the 100 and 250 year Probable Maximum Losses (PMLs). In Europe, the .005 point estimate is used more heavily.

The catastrophe models can generate the EP curves and the AALs at any level of resolution, bearing in mind that as the resolution increases, so does the uncertainty. Because the EP curve is a complete probability distribution, it is useful for many types of actuarial analyses, including pricing.

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IV. Model Uncertainty

As Figure 2 illustrates there's significant uncertainty surrounding the EP curves. The EP curves are better thought of as "fuzzy areas" versus lines. Apart from the model uncertainty, there's uncertainty in the exposure data input, with respect to the claims handling practices of individual insurers, and due to other factors external to the model such as political pressures after a major event. In large loss events, there can also be material and labor supply shortages causing the costs of repair to be higher than the replacement values of properties pre-event. This is typically referred to as "demand surge".

Model uncertainty stems from lack of high quality data in sufficient quantities to credibly estimate all of the model assumptions. Catastrophe models are constructed from historical data on past events, and for peril regions where events are infrequent there will be less reliable data and higher uncertainty. Even in geographical areas with more recent events, there is typically not a comprehensive network of highly calibrated instrumentation required to collect high resolution data.

The source and relative reliability of the data underlying the scientific and engineering model components are illustrated in Table 1 below. Green shading indicates a relative abundance of data and red indicates the least—yellow is in between. (Note that even for the green shaded area there is generally significant uncertainty, given the difficulty of obtaining useful data for extreme return periods, such as 1-in-250 years, especially if the climate or other factors are changing over time.)

Table 1 – Data Supporting the Catastrophe Model Components

	Event catalogs	Intensity formulas	Damage functions
Tropical cyclones	In most regions of the world, based on historical data collected and maintained by government organizations, such as the National Hurricane Center and the Japan Meteorological Agency. The modeling companies rely on these databases and apply some expert judgment for assumptions on the characteristics of future events in regions where the historical data are sparse.	Based on established meteorological formulas developed over the past several decades by government organizations and the wider research community. Formulas are well-documented in the scientific literature. Expert judgment is applied for some aspects of hurricane intensity such as varying terrain impacts on overland winds. Land use data is maintained by and available through government agencies.	For a few regions, such as Florida and the Gulf states, historical loss and claims data has been made available to the modelers by insurance companies, and this data can be used to fine-tune the damage functions. However, because there are thousands of damage functions reflecting different occupancies, construction and building characteristics, most of the functions are based on expert judgment.

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	Event catalogs	Intensity formulas	Damage functions
Earthquakes	<p>Historical data on earthquakes is collected and maintained by government organizations such as the US Geological Survey and European-Mediterranean Seismological Centre. These organizations also sponsor research such as paleo seismicity studies to supplement the historical record. Catastrophe modelers use this data and other information, such as hazard maps and scientific reports, as the bases for the earthquake event catalogs.</p>	<p>New generation attenuation (NGA) equations have been developed by a global consortium of earthquake experts using data on significant earthquakes around the world, and these form the bases of the ground motion formulas in the catastrophe models. Generally, soil data is inferred from geological data except in major urban areas where more detailed studies have been conducted.</p>	<p>There is limited claims data available to the modelers for construction of the earthquake damage functions. The global earthquake community compiles information and periodically publishes studies of building and contents vulnerability to ground motion. Limited, full scale, shake table tests and sophisticated engineering analyses are available, but this model component is still heavily reliant on expert judgment.</p>
Terrorist Attacks	<p>There are many types of terrorist attacks and tens of thousands of potential targets for which there are little or no data for estimating the likelihood of future events. Given that terrorists want to intimidate by surprise, past data may not be a reliable guide for future events. The models rely heavily on the judgment of counterterrorism specialists from the FBI, CIA and other government bodies.</p>	<p>The shock waves and pressure impacts of various types of bomb blasts are well studied and understood even though the density and complexity of an urban setting can distort the resulting intensity pattern. The intensity footprints of chemical, biological, radiological, and nuclear (CBRN) attacks are much larger and more difficult to project reliably, but these impacts have been studied and tools have been developed to estimate the effects.</p>	<p>Because attacks using conventional weapons such as bomb blasts and aviation incidents are localized events, and the damage is often complete, the model damage functions are straightforward. Much more judgment goes into the construction of damage functions for chemical, biological, radiological, and nuclear (i.e., CBRN) incidents.</p>

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Because of the paucity of data underlying the model components for many peril regions, model assumptions rely in large part on expert opinion and judgment. Model variability and volatility frequently arise from differing scientific opinions and perspectives.

The complexity and the infrequent nature of the natural hazards being represented by catastrophe models implies that the models will always contain a significant amount of uncertainty. This uncertainty is both aleatory (inherent process uncertainty) and epistemic (introduced by the incomplete knowledge of the process parameters and/or the proper model structure⁴). In theory, aleatory uncertainty is impossible to reduce due to the stochastic nature of the process and in a well designed model it is suitably represented by the probabilistic distribution of loss from a single model.

Estimation of epistemic uncertainty requires use of multiple models built using different parameterizations of the natural hazard process. Many insurance companies are moving towards the use of multiple catastrophe models (or multiple representations of the same catastrophe model enabled by newer, open loss models) to better manage the model risk arising from epistemic uncertainty. Various approaches have been devised to combine (blend) the output from these models to derive a more robust view of risk.

The models do not anticipate all sources of loss from an event and parameter risk cannot be accurately quantified. Typically they do not, but if the models do produce confidence bands around the EP curves, these will not be all-inclusive or robust. They may reflect process risk and/or the uncertainty around the losses for individual events.

V. Model Usage

While the models are useful tools to quantify the nature and uncertainty of catastrophe risk, it is important to recognize that they are often constrained in their ability to fully capture all the varied aspects of the hazard and its consequences - they reflect the model developer's inherent assumptions and scientific judgment. The onus is on the model user to determine if the model is fit for purpose; to use only credible models and adapt them to their specific business with appropriate settings.

If the model representation is fairly adequate but with certain gaps, then, to the extent possible, the model user may apply appropriate adjustments to the model output. If model adjustments are not possible due to the nature of the gap or the lack of transparency/flexibility in the model, the model gaps may need to be documented and accounted for separately. In some instances, addressing the gaps may necessitate significant amount of model development in itself because non-modeled gaps can be fairly material.

For instance, tsunami losses are not explicitly modeled in the earthquake models for many regions, nor are losses from inland floods triggered by tropical cyclones. In a similar vein, the model may not represent certain exposures, such as out-buildings in residential

⁴ For example, studies of some past hurricanes and floods have identified the level of soil saturation from previous rains as a factor in the extent of the hazard intensity or damage. This generally is not modeled currently (perhaps due to practical difficulties in doing so).

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exposures, contingent business insurance in commercial exposure, and potential loss to infrastructure assets.

There may also be residual market pools or other societal mechanisms to provide insurance policies to otherwise uninsured risks. To the extent these mechanisms are funded by assessments on the insurance industry, they may lead to otherwise non-modeled exposures. Of course, such gaps are model dependent and models continue to evolve to address some of these gaps. The model user may use underwriting insight, industry, and internal claims experience to calibrate and supplement the models.

The closed proprietary nature of the traditional catastrophe models makes it difficult to assess whether the portfolio risk is driven by the hazard (frequency, physical severity, and intensity of the events) or vulnerability component of the model. Often, decision makers are interested in such underlying detail to devise optimal risk management strategies. There are various other risk measures that allow risk managers to assess the risk in more intuitive ways.

One such approach is to track the portfolio risk for certain events, such as the Realistic Disaster Scenarios developed by Lloyds as discussed earlier. Many companies might complement probabilistic risk measures derived from the model EP curves with the development of their own internal catalogue of disaster scenarios to monitor accumulations and manage risk appetite. The uncertainty surrounding catastrophe risk, and its low frequency high severity nature, necessitates multiple approaches to estimating losses to help inform and arm decision makers.

VI. The Future Evolution of Catastrophe Models

Catastrophe models have made significant strides since the late 1980s and they will continue to evolve as actual events occur, scientific discoveries are incorporated, technology advances and new data is analyzed as well as when there is expansion to cover more perils and exposed regions. However, the models will never be complete or accurate so the onus will remain on the model user to fully understand, validate, and refine the model assumptions as appropriate.

Because catastrophe model development requires scientific, engineering and computer programming expertise not usually found within insurance companies, most insurers have been licensing catastrophe models from third party vendors. The proprietary nature of the third party models makes it difficult for insurers to ascertain which assumptions are driving the model loss estimates. Model updates add to the volatility of loss estimates, and it's very challenging and time consuming for insurers to determine what's causing the changes.

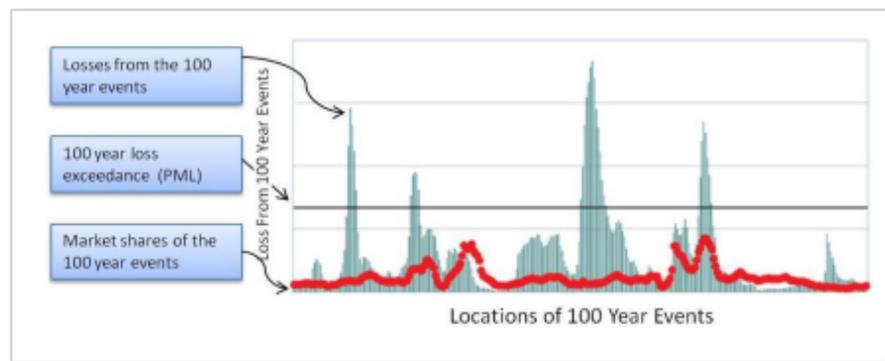
Open Models - The future evolution will be to more open models that allow for a greater ownership of risk as well as better appreciation of the inherent uncertainty in catastrophe risk. Open models are transparent enabling insurers to more fully understand the model assumptions and how different scientific opinions impact their losses. Open models enable users to test their portfolio losses against different sets of assumptions to clearly evaluate model sensitivities and key drivers of their loss estimates.

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New Risk Metrics - Future evolution will also be in the area of facilitating new and intuitive risk metrics that give decision makers more insight into their large loss potential. While the EP curve metrics are informative, they do not provide decision-makers with all of the risk information they need, and they can be misleading. For example, the 100 year PML can be misinterpreted as the 100 year “event” loss which can give a false sense of security. The largest losses incurred from the 100 year events will likely be much greater than the 100 year PML from the model-generated EP curve.

The new Characteristic Event (CE) approach in which the probabilities are based on the hazard versus the loss provides additional and more intuitive information for risk management purposes. It gives decision makers their losses from the 100 year (and other return period) events—information many may have thought they already had. The chart below shows the loss estimates for the 100 year event at different locations for a hypothetical company. The 100 year PML is the point on the EP curve that represents a one percent chance the company will have a greater loss; the 100 year CEs show how much greater and where the larger losses are likely to be.

Figure 3 – Example Characteristic Event (CE) Chart



The CEs help a company identify potential solvency-impairing exposure concentrations—information not provided by the EP curve metrics. The CEs are operational metrics that can be used to monitor and manage risk over time.

5. Catastrophe Risk Management

The first step in effective catastrophe risk management is to recognize the uncertainty inherent in estimating catastrophe losses and to utilize multiple approaches and risk metrics to gain as much insight as possible into large loss potential. Then insurers can determine if they’re overly exposed to specific events and decide how to underwrite and price the risk and how much to transfer to the reinsurance and financial markets.

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I. Underwriting and Pricing

For many insurance coverages, underwriting rules and rates (prices) are based on the “expected losses”, also called the average annual losses (AALs) to an insurance policy. A proportion of the standard deviation around the expected losses can also be applied.

For example, in the US, actuaries often use model-generated AALs by postal code to develop hurricane catastrophe loads for homeowners rating territories. The California Earthquake Authority (CEA) uses model-generated AALs to determine earthquake rates by territory. While it is less common outside the US to utilize the models for ratemaking, some global companies use AALs by location and policy to underwrite and price individual accounts. At this high resolution, however, and for specific types of risks, the traditional model output has the least credibility and is highly volatile.

Because of the nature of catastrophes and the skewed, thick-tailed loss distributions, insurers have moved from using expected losses and standard deviation metrics to catastrophe pricing approaches that factor in the capital consumed by different peril regions and even specific contracts. This is typically called “marginal impact” pricing because it’s based on the additional capital required to write the new policy, line of business, etc. Rather using the PML, a VaR measure, insurers are moving to metrics capturing more of the EP curve such as TVaR, or “tail-value-at risk” for their marginal impact decisions.

Apart from pricing considerations, it is also common for underwriters to manage the catastrophe risk in high hazard and accumulation zones by offering restrictive policy terms and conditions such as, sublimits, exclusions and higher deductibles, or by focusing on those building types/locations that are less susceptible to catastrophe losses⁵. Risk metrics, such as CEs, enable companies to see where they have exposure concentrations that need to be reduced.

II. Enterprise Risk Management and Transfer

For solvency and risk transfer purposes, insurance companies, rating agencies and regulators in the US, have come to rely most heavily on the .01 and .004 loss exceedance probabilities—the so called 100 and 250 year “probable maximum losses” (PMLs), respectively. These numbers are used to set capital requirements, determine how much reinsurance to buy, and for formal risk tolerance statements, but there’s a growing awareness of the danger in relying on point estimates from the EP curves.

To reduce the over-reliance on one point of an EP curve, companies are leveraging other more robust tail risk measures, such as Conditional Tail Exceedance (CTE, also known, as TVaR) or an Excess Annual Average Loss (XSAAL). The CTE or TVaR, represent the loss amount conditional on the loss exceeding a certain threshold (perhaps, at a certain exceedance probability) and XSAAL represents the (unconditional) average value of loss exceeding a certain threshold. Unlike the PML, both of these measures take into account the thickness of the tail, are not overly dependent on one point on the distribution, and they

⁵ For example, analyses of recent hurricanes and floods in the US have shown that it is possible in some cases to prevent or minimize susceptibility to damage through the use of certain building practices.

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have attractive coherent properties (such as, subadditivity), which make them attractive to risk aggregators and portfolio managers. (As a caution, however, such values are based on the most uncertain and hence least reliably estimable sections of the loss exceedance curve.)

Risk transfer is a key exposure accumulation management strategy for insurers in their quest to limit net aggregate risk to their balance sheet or earnings. Due to the high demand and supplier interest, over the years, many different risk transfer approaches have evolved. Risks can be transferred at various levels, at a single location or account or at a business unit or a corporate aggregate portfolio. The risk can be assumed by reinsurers, retrocessionaries and institutional investors⁶. The modes of risk transfer might include indemnity based or parametric/index based cessions or a hybrid of both.

The underwriting and pricing of risk transfer options fully leverages catastrophe model outputs, which are used to assess the expected loss in the contract, the marginal capital impact and the relative cost of that capital, in addition to corporate risk appetite considerations. Some firms may also use risk transfer to mitigate inherent model risk.

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⁶ See Chapter 6 - Non-Proportional Insurance for more details.

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ⁱ The International Emergency Disasters Database <http://datahub.io/dataset/emdat>

ⁱⁱ 2013 Global Assessment Report on International Disasters Reduction
http://www.preventionweb.net/english/hyogo/gar/2013/en/gar-pdf/GAR2013_EN.pdf

ⁱⁱⁱ East Asia's Changing Landscape: Measuring a Decade of Spatial Growth, World Bank 2015

^{iv} "Coastal Exposure and Community Protection: Hurricane Andrew's Legacy", Insurance Institute for Property Loss Reduction and Insurance Research Council, April 1995 and "The Coastline at Risk: 2013 Update to the Estimated Value of US Coastal Properties", AIR Worldwide Report, 2013

^v Swiss Re 2000, Mills et al. 2001

^{vi} A.M. Best's Impairment Review June 24, 2013 <http://www.reuters.com/article/2013/06/25/nj-am-best-idUSnBw256092a+100+BSW20130625>

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4. Assignment 3, Module 1: Uses of Catastrophe Modeling Output:
https://www.actuary.org/wp-content/uploads/2019/03/Catastrophe_Modeling_Monograph_07.25.2018.pdf



JULY 2018

USES OF CATASTROPHE MODEL OUTPUT

American Academy of Actuaries
Extreme Events and Property Lines Committee



American Academy of Actuaries Extreme Events and Property Lines Committee

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The American Academy of Actuaries is a 19,000-member professional association whose mission is to serve the public and the U.S. actuarial profession. For more than 50 years, the Academy has assisted public policymakers on all levels by providing leadership, objective expertise, and actuarial advice on risk and financial security issues. The Academy also sets qualification, practice, and professionalism standards for actuaries in the United States.



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Contents

Executive Summary	1
Purpose	3
Introduction	4
History	4
Governance of Models	5
Actuarial Standards of Practice	6
Florida Commission on Hurricane Loss Projection Methodology	6
The National Association of Insurance Commissioners	7
Enterprise Risk Management	8
Model Overview and Components	9
Use Cases	11
Ratemaking	12
Determine Rate Level	12
Determine Risk Relativities and Rating Factors	16
Deductible Relativities	16
Geographic Location Relativities	19
Underwriting and Risk Selection	20
Loss Metrics for an Insured Property at an Individual Location	20
Portfolio Metrics	23
Mitigation	24
Reinsurance	26
Florida Hurricane Catastrophe Fund	29
Public Policy and Catastrophe Models	30
Advantages and Limitations of Historical Data and Catastrophe Models	31
Limitations of relying on historical data	31
Advantages of Using Catastrophe Models	33
Limitations of Catastrophe Models	34
Summary	35
Appendix 1: Hypothetical Policies and Model Settings	36
Construction of Hypothetical Policies	36
Model Settings	36
Appendix 2: 2017 Florida Hurricane Mitigation Measures	37
Appendix 3: Disclaimers	38

Executive Summary

Historical information is generally insufficient for predictions related to future catastrophes. As a result, catastrophe modeling—which is more accurate, stable, and flexible—has been developed. Catastrophe models have become an important element in actuarial practice. This paper reviews four basic uses: ratemaking, loss mitigation, risk selection, and reinsurance. The review uses four of the many possible events as illustrations: Hurricane Wind, Storm Surge, Inland Flood, and Tornado and Straight Line Wind.

As these models proliferate, various organizations have established requirements governing their use. American Academy of Actuaries members are required to follow applicable actuarial standards of practice (ASOPs)¹ as adopted by the Actuarial Standards Board. Regulatory and standard-setting bodies—most notably the Florida Commission on Hurricane Loss Projection Methodology and the National Association of Insurance Commissioners—have taken a lead in analyzing the appropriateness of catastrophe models.

Models dealing with different catastrophes have several similar components:

1. Probability of the particular catastrophe occurring;
2. Intensity of the catastrophe;
3. Corresponding damage; and
4. Allocation of loss amounts among the various impacted entities.

Each of these components becomes a module in a catastrophe model.

In the first module, a mathematical simulation with a large number of iterations is undertaken. The process produces probabilities of the event occurring, and is concerned with answering the question: What is the chance of this event occurring?

The second module concerns the intensity of the occurrence. It answers the question: What are event conditions (such as windspeed or water depth) inside the footprint (the area impacted by the event)?

The third module quantifies the impact of the event on the structures (and related property, such as building contents). It answers the question: How badly damaged is the insured structure?

¹ Actuarial Standards Board; Actuarial Standards of Practice; available at <http://www.actuarialstandardsboard.org>.

The final allocates the damage among various parties (policyholder, insurance company, reinsurer) according to the terms of the insurance contract.

Models can be used in many applications. Common areas include ratemaking, risk selection, mitigation, and reinsurance. Expected losses, along with the associated volatility, are key building blocks in these and many other areas. Among other things, more accurate premiums can be determined, the potential benefit of mitigation features can be quantified, and changes to exposure characteristics and policy terms can be assessed.

Both state and federal public policymakers are using catastrophe models to address public policy issues. These efforts include analysis of the size of potential loss, the cost of a potential loss, appropriateness of territory and classifications, mitigation efforts, and insurance coverage modifications.

Catastrophe models offer many advantages compared to historical loss-based projections. Like any tool, understanding both their capabilities and shortcomings is of paramount importance.

Purpose

This paper is intended to provide an overview of how catastrophe models have developed and demonstrate how catastrophe model output can be used in selected actuarial tasks.

Much has been written about catastrophe models used for insurance. Modelers have published detailed information related to specific models including how they were developed and validated. High-level summaries have come out of the insurance sector's comparisons of output from model to model and to historical events. Practitioners have published papers highlighting and others discussing specific aspects of using model output for a given task. This paper was developed to help fill the gap between overviews and detailed description by describing some practical applications.

Catastrophe models were initially developed to address the shortcomings inherent in using historical data to project potential losses from infrequent, severe events that impacted many properties that were not geographically diverse. Knowledge about and acceptance of these models by risk-bearing entities and regulators have expanded along with the development of more and increasingly sophisticated models.

Model use has become required in many areas beyond those considered "traditional" areas of actuarial practice. These uses demonstrate the power and pervasiveness of models. Some of these are described in the Governance and Public Policy Uses section of this paper, while others have been espoused by the private market.

Also included are concrete examples of how expected losses and related metrics from catastrophe models can be used by private insurance companies, public policy experts, and others. Four basic use cases—ratemaking, loss mitigation, underwriting or risk selection, and reinsurance—are developed for four types of catastrophic events:

- Hurricane Wind (does not include tropical storms or Storm Surge)
- Flood: Storm Surge
- Flood: Inland
- Tornado and Straight-Line Wind (Tornado/SLW)

These types of events were selected as useful illustrations. Models also exist for many other causes of loss (earthquake, severe convective storm, wildfire, pandemic, etc.)

Appendices to this paper provide additional details on how the examples were developed.

Introduction

In perils where losses are dominated by reasonably predictable and frequent events, actuaries can use recent historical loss experience, adjusted for inflation and other appropriate changes, to estimate future losses. Where losses are infrequent events, such as those that arise from catastrophes, the available historical information may not be sufficient to reliably predict future loss potential. This problem has led to the development of sophisticated loss simulation models for perils such as hurricane, earthquake, and flood.

The actuarial profession has recognized the limitations of relying on historical data and has taken steps to incorporate model analyses into their work. Model development, expanding and enhancing their uses, and understanding their current and future potential contributions to analyses will continue for the foreseeable future.

History

Catastrophe modeling combines natural science with risk management practices, using computer power. Since the 1800s, property insurers have been visualizing exposure by mapping covered property. Likewise, scientists have been measuring wind speed and ground motion since the 1800s. In recent decades, many studies have been published asserting theories about the causes and expected frequency of natural disasters. “These two separate developments—mapping risk and measuring hazard—came together in a definitive way in the late 1980’s and early 1990’s” to create catastrophe models.² Increasing computer capabilities in that period were critical to model development.

Commercial modeling software was developed to estimate the potential cost of natural disasters. Initially, the use of these models was limited. However, in 1989, the \$4 billion price tag for Hurricane Hugo and \$6 billion for the Loma Prieta earthquake helped increase attention given to catastrophe models. In 1992, Hurricane Andrew (\$15.5 billion) clarified the critical need to manage risk and the importance of catastrophe models. A few hours after Hurricane Andrew struck southern Florida, one of the modelers shared its real-time modeling estimate of \$13 billion. Hurricane Andrew losses led to nine insurance company insolvencies.³

² *Catastrophe Modeling: A New Approach to Managing Risk*; edited by Patricia Grossi and Howard Kunreuther; 2005.

³ *Ibid.*

The insurance industry's use of catastrophe models to estimate potential future catastrophe losses has gained momentum and has become a standard risk management practice. Several additional factors contributed to the advancement of the catastrophe models. The primary driver was the realization that commonly used actuarial methods relying on five to 25 years of historical catastrophe losses were inadequate for pricing and risk management. Combined with the substantial improvement in computing power and sophistication, models became the tool of choice for helping to manage catastrophic risk.

The continuing development and increasing reliance on catastrophe models is evidence of their value and suggests catastrophe models are here to stay and will continue to play an important role in measuring catastrophe risk.

Governance of Models

Catastrophe models have expanded into many areas of actuarial practice and are available for an increasing number of perils and potentially impacted regions. As the use of and reliance on catastrophe models has increased, the need for appropriate guidance and oversight has also increased. Various requirements have been established to govern the use of models. In addition, indirect oversight is occurring through scrutiny of models and model results by the business parties involved. Model analyses and output are required by various entities.

The American Academy of Actuaries and insurance regulatory bodies have developed requirements and guidance for actuaries in their development, use, and reliance on catastrophe models. Enterprise Risk Management (ERM), rating agencies, and state insurance regulators mandate certain model output to be provided for use in evaluation of risk-bearing entities. Reinsurers and capital markets rely on the standard language and definitions developed by modelers, and the output is key in designing products, defining terms, and negotiating costs. The reliance on model metrics creates an incentive for robust, current, and useful model results. While this is true for any tool used to manage risk, the level of financial impact and inability to ascertain the "right" answer result in application of additional scrutiny.

Actuarial Standards of Practice

All actuaries who are members of the U.S. actuarial organizations that have adopted the Code of Professional Conduct are required to follow actuarial standards of practice (ASOPs), which are established by the Actuarial Standards Board. The ASOPs provide guidance for what an actuary should consider, document, and disclose when performing an actuarial assignment. Actuaries may wish to review the applicability guidelines for assistance in determining standards of practice relevant to the task being performed. Specifically focused on catastrophe model use are:

- ASOP No. 38, *Using Models Outside the Actuary's Area of Expertise (Property and Casualty)*, provides guidance to an actuary in using models that incorporate specialized knowledge outside of the actuary's own area of expertise.
- ASOP No. 39, *Treatment of Catastrophe Losses in Property/Casualty Insurance Ratemaking*, indicates that an actuary should consider models based on noninsurance data when available historical insurance data does not sufficiently represent the exposure to catastrophe losses. In addition, this ASOP provides guidance for acceptable use of such models.

Florida Commission on Hurricane Loss Projection Methodology.

In the 1995 Florida Legislative session, the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM) was created to evaluate hurricane models. "The Legislature specifically determined that reliable projections of hurricane losses for residential property insurance are necessary to assure rates are neither excessive nor inadequate, and that computer modeling has made it possible to improve upon the accuracy of hurricane loss projections."⁴ The FCHLPM's remit was expanded in 2014 to include the flood peril.

The FCHLPM publishes standards and related information in salient scientific disciplines as well as supporting activities such as software and security. The information submitted to the FCHLPM by the modeling firms is reviewed by an independent panel of experts. A company submitting a rate filing for residential property insurance in the state of Florida that relies on the results of a hurricane model is limited to those models that have been found acceptable by the FCHLPM. Several other states have interrogatories or questionnaires related to catastrophe models used in rate filing indications. Many of the states exposed to hurricanes request information about the FCHLPM review of any hurricane model used. Models that have been approved by the FCHLPM have been more likely to be found acceptable by other states than are non-FCHLPM accepted models.

⁴ Florida Commission on Hurricane Loss Projection Methodology website: www.shafja.com/methodology.

The National Association of Insurance Commissioners

The National Association of Insurance Commissioners (NAIC), representing the nation's state, territorial, and possession insurance regulators, certifies insurance regulatory sections of state government as being in compliance with its model laws (through an accreditation process), which creates an incentive for local regulators to follow what the NAIC has adopted. One requirement is assuring that companies have sufficient capital to withstand adverse events. While the review and determination of financial stability is up to a company's domiciliary state regulator, the NAIC has published a property/casualty risk-based capital (RBC) formula that quantifies many of the risks facing companies and relates it to solvency levels. One of the factors in the formula is catastrophic losses, and probable maximum losses (PMLs) at specified levels are required as input to this formula. Model use and results are also required in the completion of an Own Risk and Solvency Assessment (ORSA), which is a key part of Enterprise Risk Management (ERM)—discussed in more detail below).

The NAIC also offers educational sessions related to various topics of interest, including catastrophe models. It has provided a list of questions state regulators might ask.

Insurance regulators and policymakers recognize the importance of promoting insurance markets and supporting the use of models when historical data is limited or non-predictive of the future. For example, in 2015 the Florida Legislature wanted to stimulate growth of private flood insurance as an alternative to the National Flood Insurance Program (NFIP). The Florida Legislature passed a statute allowing private insurance companies to write flood insurance, beyond what can be offered via the NFIP's Write-Your-Own program. The Florida Office of Insurance regulation continues to review flood product and rate filings; however, insurance companies can introduce flood coverage without sharing specific details about how the flood rates were determined. The statute indicates that in 2025, insurance companies will be required to submit details of their models. This illustrates a recognition by regulators of the importance of models and how the regulatory environment can stimulate insurance coverage for a product that insurers have been historically reluctant to write. As mentioned above, the FCHLPM is responsible for developing flood standards designed to assure regulators that the flood models being used are accurate and reliable.

Enterprise Risk Management

Enterprise Risk Management (ERM) is defined as “[T]he discipline by which an organization in any industry assesses, controls, exploits, finances and monitors risks from all sources for the purpose of increasing the organization’s short- and long-term value to its stakeholders.”⁵

Companies are becoming increasingly aware of the need for systematic evaluation of the risks faced. ERM is useful for any enterprise and is not limited to insurance-related entities. Many companies have departments dedicated to evaluation of risk. Such evaluations for property/casualty insurance companies often rely heavily on catastrophe models. Simulations can increase a company’s understanding of the range of possibilities, concentration of risk, exposure overall, and the impact of any risk-transference mechanisms. The importance of catastrophe models in assessing an insurance company’s risk is substantiated by rigorous use of models by reinsurers and rating agencies. The reinsurers’ and rating agencies’ reliance on such models also provides a form of governance of the models used, since more useful models provide superior understanding of catastrophic risk.

As catastrophe models continue to develop and their use expands and deepens, direct and indirect requirements and influences are likely to become more sophisticated.

⁵ Actuarial Standard of Practice No. 46, *Risk Evaluation in Enterprise Risk Management*.

Model Overview and Components

While each peril model reflects multiple factors specific to the peril being modeled, catastrophe models have similar components:

Stochastic Event Generation. Contains event information generated by the model, including probability of occurring (known as event rate), or the sequence of the event within the simulated year.

Hazard/Local Intensity. Local intensity of the event; what conditions are inside the event footprint. For example, inundation depth of a flood, wind speed of a hurricane, or ground movement accelerations of an earthquake.

Vulnerability/Engineering. How the intensity impacts the structure and contents. The salient structure characteristics are specific to a peril, although some (such as the age of a building) are likely to be applicable to many perils.

Financial/Insurance. How the loss is allocated among those responsible for payment. Applies the insurance contract terms to the loss, assigning portions of the amount to policyholders (via deductibles), insurance, and reinsurance companies.

The modules listed proceed sequentially. Each module creates data. Some key information is passed on to the next module to enable the process to continue. Some module output is useful on its own for validation and other purposes. The flowchart below illustrates how the model components interact.



The first stage of catastrophe modeling is to generate a stochastic event set, which is a database of simulated events. The events follow logical scientific rules related to the type of event. Each event is characterized by a probability of occurrence (event rate) and geographic area affected. Thousands of possible event scenarios are simulated, based on realistic parameters and historical data, to probabilistically model what could happen in the future.

The hazard component of catastrophe models quantifies the severity of each event in a geographical area, once the event has occurred. An event footprint is generated, which is a spatial representation of hazard intensity from a specific event. For example, the model calculates the peak wind speeds at each location affected by the storm for hurricane wind.

Catastrophe models capture property vulnerability. Mean damage ratios (MDRs) are losses expressed as a percent of value, for a given hazard level (e.g., ground motion or wind speed) and location. These are the average percentages of damage that are expected for a structure with the characteristics input into the model. The uncertainty around the estimated property loss (sometimes referred to as secondary uncertainty) is often expressed in terms of a standard deviation or a coefficient of variation (CV). Standard deviations are used in the examples in this monograph.

Finally, a financial or insurance module quantifies the financial consequences of each event from various financial perspectives. The policy terms such as deductibles, limits, and reinsurance are applied to the damage from each insured property from the vulnerability model to calculate the allocation of the loss amount.

While some analysis settings can be selected by the user (such as whether demand surge will apply), most of the model workings have been developed by the modeling company scientists and can't be altered. Users must input information about the policies potentially impacted and characteristics about each property. Individual policies, groups of policies (termed portfolios), and subsets of portfolios can be analyzed.

Use Cases

This section gives explanations and numeric examples of how catastrophe model output can be used in several typical actuarial tasks. A hypothetical set of policies in the state of Florida was defined for use in this paper and used as input to a catastrophe model. Details on this portfolio of policies and on the model settings used can be found in the appendices.

Ratemaking. The annual cost of catastrophic events needs to be determined because most policy terms are for a year. Models generate Average Annual Loss (AAL) for each insured property. The cost of an insurance policy is comprised of AAL, expenses, and risk load. Appropriate reinsurance costs must be included, and their assignment to an expense category depends on what those costs consist of and how they are treated by the primary company. The examples, which use a methodology chosen for its simplicity, does not include reinsurance costs. The risk load depends on the variability (i.e., standard deviation or CV) or uncertainty in the loss estimates. The premiums developed in this paper are for the catastrophe peril risk only and do not contemplate any non-catastrophe causes of loss.

Underwriting and Risk Selection. Nearly any property can be insured if an appropriate rate can be calculated and charged. However, an insurance company must consider the financial health of its entire book of business, and some risks are a better component for any given portfolio than others. In addition, companies typically specialize in types of property and/or geographic areas. So, while a price that is commensurate with expected loss is critical, there are other factors to be taken into consideration. The impact of adding a given property to what an insurer already has on its books depends not only on the individual property, but also on how that property's potential for loss interacts with existing policies. Measures such as Probable Maximum Losses (PML) are considered. A PML, also known as a Return Period Loss (RPL), gives two pieces of information—an amount and a probability. It is an amount that is expected to be exceeded with a given probability by an event or in a year. For example, a 100-year occurrence PML of \$6 million (\$6M) means that there is a 1-in-100 (1 percent) chance of a loss of at least \$6M.

Loss Mitigation. Some characteristics that modelers have included have been shown to lessen the severity of loss. The impacts of these mitigation features can be evaluated by seeing how AALs and other measures react to the presence or absence of these features. Cost/Benefit tradeoffs can be evaluated. Strategies to encourage desired choices can be tied to potential loss dollar changes.

Catastrophe Reinsurance. Many insurance companies will themselves buy insurance (called catastrophe reinsurance) to assist in paying losses following a catastrophic event. In the case of a catastrophic event, insurance companies (primary insurers) are likely to quickly need large sums of money—more than what makes sense to accumulate. Because model output uses language and metrics that have become common among primary insurers, reinsurers, and others, transactions can be efficiently analyzed and terms agreed upon. Many reinsurers and reinsurance contracts are not focused on individual properties or everyday losses, but instead look at providing loss coverage to portfolios of policies. This allows primary companies to protect themselves from extreme events in accordance to their risk tolerance.

Ratemaking

Determine Rate Level

The ratemaking formula and assumptions used here are based on methods used by many property/casualty insurers. Simplifying assumptions have been made to facilitate understanding and highlight model output use. The price of insurance is based on the sum of three basic components. Companies may subdivide these three components and categorize the total premium in various ways. However, the basic principle is the same, which is to calculate the premium that is sufficient to cover expected loss, expenses, and risk load:

$$\text{Premium} = \text{AAL} + \text{Expense Load} + \text{Risk Load}$$

Catastrophe models are essential to calculate AAL and risk load. As noted above, AAL stands for Average Annual Loss; it is the expected loss per year, averaged over many years. AAL is calculated as the annualized cost of all potential stochastic events in a year:

$$AAL = \sum_i p_i L_i$$

Where: p_i is the annual probability of an event(i) occurring, and L_i is the expected loss of the event.

To adequately insure a risk, an insurer must commit a certain level of capital beyond the expected annual loss to cover the potential for catastrophic loss. This risk load should be sufficient to cover the cost of capital including a profit provision. Because catastrophe risk is volatile, the risk load can be multiples of AAL. The higher the volatilities, the higher the likelihood of insolvency, therefore the higher the risk load. There are different ways to develop the risk load. The standard deviation of the modeled losses (σ) is commonly used.

$$\sigma = \sqrt{\sum_i (p_i L_i^2) - AAL^2}$$

Table 1 shows the rate per \$1,000 of building coverage for our portfolio of hypothetical policies for hurricane wind losses. It is shown as AAL / \$1,000 building coverage. Tables 2, 3, and 4 show the same information for Tornado/Straight-Line Wind, Inland Flood, and Coastal Storm Surge. Nine counties in Florida and the entire state are shown to illustrate the potential variation of the costs. Insurance companies may use higher resolutions such as ZIP code or smaller grids in a rating plan to recognize the variations in the results.

The 27 percent expense load used in this example was judgmentally selected. An average building coverage limit of \$207,500 is used in developing premium examples. The risk load is presumed to include a provision for profit.

TABLE 1 Hurricane Wind Rate and Premium Example

County	Modeled Gross Hurricane Wind Loss \$ Per \$1000 Cov A	Selected Risk Load (Standard Deviation)	Expense Load \$	Hurricane Wind Premium \$ Per \$1000 Cov A	Hurricane Wind Premium \$ for \$207.5K Cov A Home
(A)	(B)	(C)	$(D) = ((B)+(C))/(.73 - ((B)+(C)))$	$(E) = (B)+(C)+(D)$	$(F) = (E) * 207.5$
Monroe	13.82	27.65	15.34	56.81	11,788.23
Broward	5.54	11.08	6.15	22.77	4,723.82
Palm Beach	5.26	10.51	5.83	21.60	4,482.44
Miami-Dade	7.60	15.21	8.44	31.25	6,484.54
Hillsborough	0.75	1.51	0.83	3.09	641.70
Orange	0.36	0.72	0.40	1.48	306.28
Okeechobee	1.91	3.81	2.11	7.83	1,624.67
Duval	0.25	0.49	0.27	1.01	209.96
Sarasota	1.74	3.48	1.93	7.14	1,481.68
Statewide	2.64	5.29	2.93	10.86	2,253.96

TABLE 2 Tornado/Straight-Line Wind Rate Premium Example

County	Modeled Gross Tornado/Straight-Line Wind Loss \$ Per \$1000 Cov A	Selected Risk Load (Standard Deviation)	Expense Load \$	Tornado/Straight-Line Wind Premium \$ Per \$1000 Cov A	Tornado/Straight-Line Wind Premium \$ for \$207.5K Cov A Home
(A)	(B)	(C)	$(D) = ((B)+(C))/(.73 - ((B)+(C)))$	$(E) = (B)+(C)+(D)$	$(F) = (E) * 207.5$
Monroe	0.02	0.01	0.01	0.05	9.76
Broward	0.06	0.03	0.04	0.13	27.52
Palm Beach	0.08	0.04	0.04	0.16	33.49
Miami-Dade	0.06	0.03	0.03	0.12	24.84
Hillsborough	0.17	0.08	0.09	0.34	71.14
Orange	0.20	0.10	0.11	0.41	85.57
Okeechobee	0.13	0.06	0.07	0.26	54.25
Duval	0.16	0.08	0.09	0.32	67.18
Sarasota	0.13	0.06	0.07	0.26	53.90
Statewide	0.14	0.07	0.08	0.28	58.92

TABLE 3 Inland Flood Rate and Premium Example

County	Modeled Gross Inland Flood Loss\$ Per \$1000 Cov A	Selected Risk Load (Standard Deviation)	Expense Load \$	Inland Flood Premium \$ Per \$1000 Cov A	Inland Flood Premium \$ for \$207.5K Cov A Home
(A)	(B)	(C)	$(D) = ((B)+(C))/\sqrt{.73-((B)+(C))}$	$(E) = (B)+(C)+(D)$	$(F) = (E) * 207.5$
Monroe	0.18	0.28	0.17	0.63	131.29
Broward	0.65	0.98	0.61	2.24	465.14
Palm Beach	0.56	0.84	0.52	1.92	398.48
Miami-Dade	0.97	1.45	0.90	3.32	687.94
Hillsborough	0.25	0.38	0.23	0.86	178.72
Orange	0.40	0.59	0.37	1.36	281.65
Okeechobee	1.02	1.53	0.94	3.48	722.78
Duval	0.69	1.03	0.64	2.36	489.99
Sarasota	0.15	0.23	0.14	0.52	107.20
Statewide	0.59	0.89	0.55	2.04	422.64

TABLE 4 Storm Surge Rate and Premium Example

County	Modeled Gross Storm Surge Loss\$ Per \$1000 Cov A	Selected Risk Load (Standard Deviation)	Expense Load \$	Storm Surge Premium \$ Per \$1000 Cov A	Storm Surge Premium \$ for \$207.5K Cov A Home
(A)	(B)	(C)	$(D) = ((B)+(C))/\sqrt{.73-((B)+(C))}$	$(E) = (B)+(C)+(D)$	$(F) = (E) * 207.5$
Monroe	2.05	3.08	1.90	7.02	1,457.25
Broward	0.32	0.48	0.30	1.10	227.97
Palm Beach	0.05	0.07	0.04	0.17	34.25
Miami-Dade	0.23	0.34	0.21	0.79	162.97
Hillsborough	0.07	0.10	0.06	0.23	47.10
Orange*	—	—	—	—	—
Okeechobee*	—	—	—	—	—
Duval	0.70	1.05	0.65	2.40	498.68
Sarasota	0.26	0.39	0.24	0.89	184.26
Statewide	0.27	0.40	0.25	0.91	189.01

*These counties are inland, and not exposed to coastal storm surge.

Determine Risk Relativities and Rating Factors

An insured risk's potential insured loss propensity in a catastrophic event varies by many factors, including geographic location, physical characteristics of the building, and policy terms. Catastrophe models can be used to determine the impact of each rating factor, such as construction, year built, occupancy, and territory relativities.

Deductible Relativities

A deductible is the amount "deducted" from an insured loss before payment is made. Deductibles have been an essential part of insurance contracts for many years and are a sharing of the risk between the insurance company and the policyholder. When repairing a damaged home or replacing personal possessions, the amount of the deductible would come out of policyholder's own pocket.

Deductible relativities can be estimated by models using gross losses (loss after application of the deductible) divided by ground up losses (total amount of loss without any adjustments).

$$\text{Deductible loss elimination ratio} = 1 - (\text{Gross Loss}/\text{Ground Up loss}).$$

Deductible relativity examples for 2 percent deductibles for Hurricane Wind, Tornado/Straight-Line Wind, Inland Flood, and Storm Surge are shown in tables 5 through 8. Two percent deductibles are standard in Florida for hurricane wind and are shown here for the other perils for comparison.

For hurricane wind deductible relativities in Table 5, non-coastal counties, such as Orange and Okeechobee, have higher deductible loss elimination ratios than coastal counties. This is because coastal regions experience higher wind speeds and losses are more likely to be severe, so deductibles tend to be a smaller portion of the overall loss. Because inland counties' hurricane wind losses are likely to be lower, deductibles tend to be a higher percentage of overall loss.

TABLE 5 Hurricane Wind Deductible Loss Elimination Ratio

County	Avg Hurricane Wind Ground Up AAL \$	Avg Hurricane Wind Gross AAL \$ @2% Deductible	2% Deductible Hurricane Wind Loss Elimination Ratio
(A)	(B)	(C)	(D) = 1-(C)/(B)
Monroe	3,577.20	2,868.47	19.8%
Broward	1,704.98	1,149.46	32.6%
Palm Beach	1,636.70	1,090.73	33.4%
Miami-Dade	2,190.53	1,577.90	28.0%
Hillsborough	365.76	156.15	57.3%
Orange	274.57	74.53	72.9%
Okeechobee	796.42	395.34	50.4%
Duval	182.22	51.09	72.0%
Sarasota	629.12	360.54	42.7%
Statewide	885.65	548.46	38.1%

TABLE 6 Tornado/Straight-Line Wind Deductible Loss Elimination Ratio

County	Avg Tornado/Straight-Line Wind Ground Up AAL \$	Avg Tornado/Straight-Line Wind Gross AAL \$ @2% Deductible	2% Deductible Tornado/Straight-Line Wind Loss Elimination Ratio
(A)	(B)	(C)	(D) = 1-(C)/(B)
Monroe	5.56	4.75	14.6%
Broward	15.80	13.39	15.2%
Palm Beach	18.98	16.30	14.1%
Miami-Dade	14.28	12.09	15.4%
Hillsborough	40.24	34.62	14.0%
Orange	47.58	41.64	12.5%
Okeechobee	29.64	26.40	10.9%
Duval	37.39	32.70	12.6%
Sarasota	30.27	26.23	13.4%
Statewide	33.00	28.67	13.1%

TABLE 7 Inland Flood Deductible Loss Elimination Ratio

County	Avg Inland Flood Ground Up AAL \$	Avg Inland Flood Gross AAL \$ @2% Deductible	2% Deductible Inland Flood Loss Elimination Ratio
(A)	(B)	(C)	(D) = 1-(C)/(B)
Monroe	55.37	38.34	30.8%
Broward	172.41	135.82	21.2%
Palm Beach	148.83	116.36	21.8%
Miami-Dade	250.88	200.88	19.9%
Hillsborough	64.38	52.19	18.9%
Orange	101.51	82.24	19.0%
Okeechobee	269.06	211.05	21.6%
Duval	164.52	143.08	13.0%
Sarasota	40.17	31.30	22.1%
Statewide	151.07	123.41	18.3%

TABLE 8 Storm Surge Deductible Loss Elimination Ratio

County	Avg Storm Surge Ground Up AAL \$	Avg Storm Surge Gross AAL \$ @2% Deductible	2% Deductible Storm Surge Loss Elimination Ratio
(A)	(B)	(C)	(D) = 1-(C)/(B)
Monroe	469.04	425.52	9.3%
Broward	70.67	66.57	5.8%
Palm Beach	10.56	10.00	5.3%
Miami-Dade	50.50	47.59	5.8%
Hillsborough	15.38	13.75	10.6%
Orange	—	—	—
Okeechobee	—	—	—
Duval	159.58	145.62	8.8%
Sarasota	58.88	53.81	8.6%
Statewide	60.48	55.19	8.7%

Geographic Location Relativities

The propensity for catastrophe damage depends highly on geographic locations. Models can be used to determine the location relativities under various resolutions. The relative frequency and severity of events are critical to determining rating territories, rate levels, and underwriting/risk selection criteria. The granularity of the meaningful variation is different for the various perils. For example, storm surge damage is generally more severe for properties closest to the coast. However, depending on the elevation, the expected damage can be quite different for areas near each other. Table 9 shows the geographic relativities for selected counties in Florida for Hurricane Wind, Tornado/Straight-Line Wind, Inland Flood, and Coastal Storm Surge risks.

TABLE 9 Territory Relativities

County	Hurricane Wind Gross Avg AAL \$	Hurricane Territory Relativities	Tornado/Straight-Line Wind Avg Gross AAL \$	Tornado/Straight-Line Wind Territory Relativities	Inland Flood Avg Gross AAL \$	Inland Flood Territory Relativities	Storm Surge Avg Gross AAL \$	Storm Surge Territory Relativities
(A)	(B)	(C) = (B)/Statewide(B)	(D)	(E) = (D)/Statewide(D)	(F)	(G) = (F)/Statewide(F)	(H)	(I) = (H)/Statewide(H)
Monroe	2,868.47	5.230	4.75	0.166	38.34	0.311	425.52	7.710
Broward	1,149.46	2.096	13.39	0.467	135.82	1.101	66.57	1.206
Palm Beach	1,090.73	1.989	16.30	0.568	116.36	0.943	10.00	0.181
Miami-Dade	1,577.90	2.877	12.09	0.422	200.88	1.628	47.59	0.862
Hillsborough	156.15	0.285	34.62	1.207	52.19	0.423	13.75	0.249
Orange	74.53	0.136	41.64	1.452	82.24	0.666	—	—
Okeechobee	395.34	0.721	26.40	0.921	211.05	1.710	—	—
Duval	51.09	0.093	32.70	1.140	143.08	1.159	145.62	2.638
Sarasota	360.54	0.657	26.23	0.915	31.30	0.254	53.81	0.975
Statewide	548.46	1.000	28.67	1.000	123.41	1.000	55.19	1.000

Underwriting and Risk Selection

Insurance premiums commensurate with risk are critical to a robust insurance market and to the continuing ability of companies to remain solvent and provide needed protection to policyholders. Besides the business need for accurate premiums, insurance premiums that reflect risk can inform individuals as to how safe or exposed they are and can promote mitigating behavior. Along with adequate rates, companies monitor how much business they write and their aggregate exposure to loss from extreme events. For catastrophic events, this can be critical because many properties may be damaged from one event. Insuring 1,000 homes around the state of Florida may not be problematic while insuring 1,000 homes in the coastal Miami-Dade area may expose the company to an unacceptable level of loss. Managing aggregate risk minimizes the risk of insolvency. In addition, minimizing the concentration of risk may help reduce reinsurance costs and limit the number of claims following an event to a manageable level.

Risk selection initially was used as a binary decision tool—a property was acceptable to insure based only on its characteristics, or it was not acceptable. Catastrophe models also allow a property to be evaluated based on its risk in the context of a company's entire book of business. In some cases, catastrophe models may also facilitate premium changes or coverage adjustments to make the premium commensurate with the associated risk. Rather than yes/no decisions, these coverage and premium adjustments allow previously uninsurable properties to obtain coverage. More accurate premiums can be determined and charged for all risks.

Loss Metrics for an Insured Property at an Individual Location

Underwriters and risk selection algorithms can use many metrics, or combinations of them, to provide additional information to help understand the risk for an individual insured property location. Models consider both environmental and building characteristic variables to provide information relevant to the property being reviewed. Companies may set up guidelines around various ranges of these metrics, with these ranges set based on the risk tolerance that the company has decided to follow. A few examples of these metrics are:

1. **AAL/TIV:** The ratio of the AAL to the Total Insured Value (TIV) provides a metric that shows the long-term risk at a location. This can be useful in evaluating how properties that are close geographically can have significantly different expected losses AAL. Some examples are given in the tables that follow. Because all our hypothetical policies have been defined as having the same TIV, the division to put our metrics on a comparable basis is not needed.

Tables 10 through 13 demonstrate the importance of accurate detailed geographic information. For each catastrophic peril, ZIP-level AALs vary significantly from state-level, and location-level information within a ZIP also varies. This can be helpful in determining, for example, how large rating territories should be. In the tables below, Inland Flood and Storm Surge show the widest ranges of AAL values, compared to Tornado/Straight-Line Wind. One possible conclusion could be that differentiating Tornado/Straight-Line Wind loss potential by territory does not add much value. Inland Flood loss potential appears to be concentrated in fewer than a third of the locations within one ZIP code. Comparing this information to a map would be informative and could provide additional information besides proximity to a water source.

Other metrics besides AAL provide more depth, and it should be emphasized that relying solely on information such as that shown in the tables is not recommended. In addition, the ZIP codes shown below were selected to illustrate the variability among loss costs.

TABLE 10 **Hurricane Wind AAL**

ZIP Code	# Locations	Average AAL	Lowest AAL	Highest AAL
(A)	(B)	(C)	(D)	(E)
32327	121	\$156.83	\$85.20	\$505.54
All (Statewide)	100,000	\$885.65	\$61.07	\$5,931.26

TABLE 11 **Inland Flood AAL**

ZIP Code	# Locations	Average AAL	Lowest AAL	Highest AAL
(A)	(B)	(C)	(D)	(E)
32043	155	\$218.86	\$0.00	\$9,927.00
32043	105 of the 155	\$0.00	\$0.00	\$0.00
All (Statewide)	100,000	\$151.07	\$0.00	\$21,632.46

TABLE 12 Storm Surge AAL

ZIP Code	# Locations	Average AAL	Lowest AAL	Highest AAL
(A)	(B)	(C)	(D)	(E)
34689	123	\$403.51	\$0.00	\$4,708.26
34689	3 of 123	\$0.00	\$0.00	\$0.00
All (Statewide)	100,000	\$60.48	\$0.00	\$19,686.13

TABLE 13 Tornado / Straight-Line Wind AAL

ZIP Code	# Locations	Average AAL	Lowest AAL	Highest AAL
(A)	(B)	(C)	(D)	(E)
32534	79	\$81.09	\$75.11	\$117.70
All (Statewide)	100,000	\$33.00	\$1.88	\$157.78

2. **PML/TIV ratio:** The ratio of a PML at a specified return period, to the TIV gives an indication of the possible severity at a location. Combining this view with locations that have similar AAL/TIV ratios gives an indication of the variability of risk at a location.

Hurricane wind example: Here are two locations from different parts of the state with similar AALs but different 250-year PML/AAL ratios. As this example shows, a location in ZIP code 32053 has a slightly higher AAL, but the PML for ZIP code 32311 has a PML that is 20 percent larger (suggesting higher loss potential from extreme events).

TABLE 14 Hurricane Wind PML/TIV

ZIP Code	AAL	250-year PML	PML / AAL
(A)	(B)	(C)	(D)
32053	\$98.16	\$5,024.54	51.19
32311	\$91.88	\$6,025.14	65.58

Portfolio Metrics

It can be instructive to see how adding or removing a property affects PML for a book of business. A property could have a relatively high AAL, but if it's in an area with low concentration in the current book, and doesn't impact the total book's PML and resulting reinsurance costs, the property could still be acceptable to an insurer, especially if capital allocated to writing property insurance is limited. Another way that some companies do this is to review their Tail Value at Risk (TVaR). Like the PML process, a company may review its TVaR to see if adding locations has a significant impact on the tail/extreme risk at various return periods.

An extension of the process described above is portfolio optimization. In this process, the insurance company chooses the modeled metric that is important to it, and then builds a geographically distributed portfolio that optimizes that metric relative to premium or insurance values (exposure). For example, if a company has the capital allocated to be able to write \$100 million in premiums in a state, it may design a portfolio that minimizes a specified return period PML (like a 100-year PML).

Consider two separate insurance carriers in a state having similar 100-year PMLs, even though they have very different distribution of risk across the state. Both are considering acquiring a portfolio of locations. However, given their different current distributions, the acquisition could cause significantly different marginal changes to their PMLs.

Mitigation

Mitigation involves efforts to prevent hazards from developing into disasters and to reduce the effects of disasters when they occur. There are many different types of mitigation efforts. Some apply to individuals and some to communities, and they can be structural (e.g., window shutters, flood levees) or nonstructural (e.g., land-use planning). In all these situations, catastrophe models can help quantify the costs and benefits.

In the case of an individual structure, mitigation decisions often occur when insurance for the home is purchased. As an example, consider a hypothetical homeowner in Monroe County, Florida, who is debating whether to install hurricane shutters on her home. From Table 1 in the Ratemaking section above, she would be considering a premium (based on the hypothetical portfolio) of \$11,788 for hurricane wind coverage. A catastrophe model used to calculate the premium can also be used to explore the savings from installing shutters. The following table shows output of this analysis.

TABLE 15 Hurricane Wind Shutter Impact on AAL

County	Hurricane Wind Gross AAL \$ Without Shutter	Hurricane Wind Gross AAL \$ With Shutter	Hurricane Shutter Discount
(A)	(B)	(C)	(D) = 1-(C)/(B)
Monroe	2,872.35	2,479.14	13.7%
Broward	1,377.11	1,154.62	16.2%
Palm Beach	1,170.99	970.26	17.1%
Miami-Dade	1,732.43	1,459.86	15.7%
Hillsborough	169.17	131.77	22.1%
Orange	77.21	54.90	28.9%
Okeechobee	420.06	326.71	22.2%
Duval	53.94	39.41	26.9%
Sarasota	440.52	363.29	17.5%
Statewide	483.87	398.29	17.7%

Recalculating the premium to reflect the hurricane wind savings would proceed as follows:

AAL with savings = (Col C from Table 15, per thousand) + Risk Load Expenses (Col C from Table 1), loaded for expenses.

$$= ((2,479 / 207.50) + 27.65) / (1-0.27) = \$54.23 \text{ per thousand}$$

Compared to the calculated Hurricane Wind premium per thousand from Table 1 of \$56.81, this results in savings of 4.5% ($54.23/56.81 - 1$). The premium savings would be $0.045 \times \$11,788.23 = \534 .

The company may decide to adjust loss elimination ratios (LER) and expenses for mitigated properties as well. To the degree expenses vary with claim costs, additional savings could be realized. LERs could be increased or decreased. Because there tend to be more minor losses than extreme losses, more relative weight would be in the LER.

A community can also use a catastrophe model to weigh public policy decisions. Because a model can easily be applied to groups of individual risks, it can help a community understand aggregate costs and benefits stemming from a widespread implementation of a mitigation effort (e.g., a building code change).

As part of its review, the Florida Commission on Hurricane Loss Projection Methodology requires catastrophe modeling firms to make extensive regular submissions which, among many other things, must include the modeling firm's measurement of various mitigation measures. A copy of the relevant table for the model used in this paper from the April 2017 submissions is shown in Appendix 2. The first few rows are reproduced here to demonstrate the high level of detail that a catastrophe model can provide policymakers. With aggregated calculations like those used in the individual case above, a community can use these rates to measure the effect of mitigation efforts on its housing stock.

Figure 1: Response to FCHLPM Form V-2

INDIVIDUAL MITIGATION MEASURES		PERCENTAGE CHANGES IN DAMAGE* (REFERENCE DAMAGE RATE - MITIGATED DAMAGE RATE) / REFERENCE DAMAGE RATE * 100									
		FRAME STRUCTURE					MASONRY STRUCTURE				
		WINDSPEED (MPH)					WINDSPEED (MPH)				
		60	85	110	135	160	60	85	110	135	160
	REFERENCE STRUCTURE	0	0	0	0	0	0	0	0	0	0
ROOF SUPPORTS	BRACED GABLE ENDS	15.1%	14.6%	12.4%	9.9%	4.8%	13.6%	13.4%	11.6%	9.4%	5.9%
	HIP ROOF	19.0%	18.2%	15.5%	12.5%	6.2%	17.3%	16.8%	14.5%	11.9%	7.5%
ROOF COVERING	METAL	-8.7%	-8.6%	-7.3%	-5.7%	-2.7%	-8.1%	-8.3%	-7.1%	-5.6%	-3.4%
	ASTM D7158 CLASS H SHINGLES (150 MPH)	1.9%	1.9%	1.6%	1.2%	0.6%	1.7%	1.7%	1.5%	1.2%	0.7%
	MEMBRANE	-5.2%	-5.1%	-4.3%	-3.4%	-1.8%	-5.0%	-5.1%	-4.4%	-3.5%	-2.1%
	NAILING OF DECK	1.9%	1.9%	1.6%	1.2%	0.6%	1.7%	1.7%	1.5%	1.2%	0.7%

Reinsurance

Reinsurance and other risk transfer mechanisms play a valuable role in the insurance market. The risk of insolvency increases for primary insurance companies when many policies are likely to have a claim at the same time. For many types of claims, the correlation between policies is low (e.g., slip-and-fall claims). However, catastrophes increase the likelihood of many claims in close geographic proximity occurring all at once. Primary insurance companies manage this exposure by transferring the risk to other parties. Other parties with less concentrated exposure (e.g., investors or reinsurers with worldwide portfolios) are in a better position to manage this risk. This process expands the capacity of the insurance market by adding capital and efficiently managing risk.

Reinsurance pricing for catastrophe losses relies heavily on model results. Clearly defined measures and terms facilitate communication and negotiation of contract terms between various parties.

For example, a catastrophe reinsurance contract may cover losses between the 100-year and 250-year PMLs for specific causes of loss. As stated earlier, a PML or Return Period Loss is an amount that is expected to be exceeded by an event with a given probability. Table 16 shows 100-year and 250-year PMLs for our hypothetical policies for each of our four causes of loss. The probabilities in column (B) are the reciprocals of the Return Period years, (e.g., $1.0\% = 1 / 100$ and $0.4\% = 1 / 250$.) The PMLs in columns (C) through (G), shown in millions USD, are the model-generated expected loss amounts. As shown in Table 16, there is a 1.0% chance of hurricane wind causing damage costing at least \$1,315 million, and a 0.4% chance of hurricane wind causing damage of at least \$1,902 million. As expected, lower probabilities are associated with higher PMLs. For our hypothetical group of policies, at the probabilities shown, Hurricane Wind is likely to cause the most severe loss, followed by Inland Flood, Storm Surge (Coastal Flood), and finally Tornado/Straight-Line Wind.

TABLE 16 PML Amounts in \$ millions by Peril

Return Period	Probability	Hurricane Wind	Flood Inland	Flood Storm Surge	Tornado/SLW	All Causes Combined
(A)	(B)	(C)	(D)	(E)	(F)	(G)
100-year	1.0%	1,315	202	97	37	1,458
250-year	0.4%	1,902	384	157	52	2,031

Although AALs are additive, PMLs are not. Note that the PML for All Causes Combined is less than the sum of the PMLs from each cause of loss. To illustrate why PMLs are not additive, consider the probability that a one in 100-year event occurs for each cause of loss. The probability that all causes have a one in 100-year event in the same year is much less than 1 percent; therefore, the sum of the one in 100-year PMLs is associated with a much longer return period.

A reinsurance company may decide to sell coverage for a loss of at least \$1,315M up to \$1,902M to a primary company for wind damage from hurricane wind. This layer can be evaluated based on the AALs and standard deviations. Reinsurance pricing discussions often begin with the AAL plus a factor times the standard deviation for the layer. The factors used vary over time and under differing circumstances, but for a given layer at a fixed point in time, factors from similarly exposed companies and/or similar market conditions can serve as useful benchmarks.

Table I7 shows AALs, standard deviations, and coefficients of variation for the 100-year PML to the 250-year PML layer for the same causes of loss as in Table 16. The probability of reaching an amount of loss that activates the reinsurance coverage, called the layer retention, is 1.0 percent, and the probability of a loss using the entire layer, known as hitting the layer limit, is 0.4 percent.

TABLE 17 Layer Statistics for 100- to 250-year PML

	Hurricane Wind	Flood Inland	Flood Storm Surge	Tornado/SLW	All Causes Combined
(A)	(B)	(C)	(D)	(E)	(F)
AAL in layer 100-year to 250-year	3,412	248	161	0	3,821
Standard Deviation in layer 100-year to 250-year	39,649	8,385	2,652	0	43,441
Coefficient of Variation 100-year to 250-year layer	11.6	33.8	16.5	na	11.4

Table 18 adds a layer covering expected losses in the 250-year to the 500-year return periods. Note that as the probability of loss to a layer decreases, the AAL also decreases and the coefficient of variation increases. This makes intuitive sense by recognizing:

- the probability of a loss in the 100- to 250-year layer return period is 1.0 percent;
- the probability of a loss in the 250- to 500-year layer return period is 0.4 percent; and
- layers with less frequent occurrences are less predictable, thus, volatility is higher.

TABLE 18 Layer Statistics for 100- to 250- and 250- to 500-year PMLs

	Hurricane Wind	Flood Inland	Flood Storm Surge	Tornado/SLW	All Causes Combined
(A)	(B)	(C)	(D)	(E)	(F)
AAL in layer 100-year to 250-year	3,412	248	161	0	3,821
Standard deviation in layer 100-year to 250-year	39,649	8,385	2,652	0	43,441
Coefficient of Variation in layer 100-year to 250-year	11.6	33.8	16.5	na	11.4
AAL in layer 250-year to 500-year	1,348	35	64	0	1,448
Standard deviation in layer 250-year to 500-year	23,863	1,808	1,548	0	25,331
Coefficient of Variation in layer 250-year to 500-year	17.7	51.7	24.2	na	17.5

Reinsurance costs are often negotiated and can be influenced by market conditions. More judgment is applied to pricing reinsurance compared to primary coverage. Pricing and availability of coverage is information that is disseminated throughout the market. Catastrophe modeling provides an important source of quantitative information to evaluate risk and objectively evaluate reinsurance pricing. Moreover, catastrophe modeling provides quantitative information to financial markets in developing catastrophe bonds and other risk-linked securities.

Florida Hurricane Catastrophe Fund

Following Hurricane Andrew in 1992, the state of Florida created the Florida Hurricane Catastrophe Fund (FHCF) in a special legislative session to “provide a stable and ongoing source of reimbursement to insurers for a portion of their catastrophic hurricane losses; (to) create additional insurance capacity sufficient to ameliorate the current dangers to the state’s economy and to the public health, safety, and welfare.” (F.S. 215.555). The Fund operates as an independent state-run reinsurer for primary insurance companies selling residential property insurance in the state. Each company must participate in the Fund, but can select from various participation percentages. The Fund’s capacity, retention, and limits are set by statute, and are adjusted annually based on specified Fund and market demographics. Statewide capacity was originally set to \$17 billion for a hurricane season, and was later amended to include an additional \$17 billion for a subsequent season, based on exposure growth and capacity.

The FHCF is required to use the results of all models found acceptable by the Florida Commission on Hurricane Loss Projection Methodology in determining the premiums charged to participants.

Public Policy and Catastrophe Models

The value of catastrophe models is recognized by public policymakers and those who provide them with analyses. As mentioned above, the Florida Hurricane Catastrophe Fund is required to use FCHLPM's approved models in its determining the premium it charges to participants.

On the federal level, the Congressional Budget Office's September 2017 study "The National Flood Insurance Program: Financial Soundness and Affordability"⁶ made use of models in quantifying its analyses and conclusions. The Federal Emergency Management Agency is working with a private catastrophe modeling firm to "leverage a probabilistic modeling approach to assess the flood program's overall risk and potential payouts to property owners. The model will also be used to help the NFIP evaluate actuarially sound rates for its policies and to assess the impacts of major flooding events in real time."

All the use cases cited above, as well as many other applications, can inform public policy issues. Some policy questions that can be addressed include:

1. What is the probability of an event occurring that is too big for an entity to handle?
2. Do the premiums reflect an actuarially sound estimate of the expected value of all future costs associated with an individual risk transfer?
3. Have appropriate rating territories and classifications been identified?
4. Are there mitigation features that would reduce the costs to the entity in an advantageous cost/benefit way?
5. Are there reasonable coverage modifications (such as increasing deductibles) that could be useful?

Improvements in federal, statewide, and regional programs require the cooperation of several stakeholders. Objective quantification of potential losses can facilitate these efforts. Mitigation features, once identified and deemed feasible, can eventually become standards. One such example is the Insurance Services Office's Building Code Effectiveness Grading Schedule (BCEGS®).⁷ Building codes and their enforcement can be considered in catastrophe models. For example, it was discovered that a significant amount of the damage from Hurricane Andrew could have been avoided if the building codes in effect had been more rigorously enforced. Hurricane models highlighted the pervasiveness of the issue, demonstrated the cost savings that could be generated, and facilitated decisions to improve building codes.

⁶ Congressional Budget Office; "The National Flood Insurance Program: Financial Soundness and Affordability"; September 2017.
⁷ ISO Mitigation; "What Determines a Municipality's Code Effectiveness Classification?"; Undated.

Advantages and Limitations of Historical Data and Catastrophe Models

Limitations of relying on historical data

1. Frequency and severity of catastrophe activity has not been constant over time. Climate conditions and sea surface temperatures, among other things, influence tropical cyclone activities. Although far better understood than in the previous century, there is still much that remains unknown about tropical cyclones. How much reliance is appropriate for data from past cycles and how long do those cycles tend to last? Damaging earthquake activity occurrence data is even sparser. The last major earthquakes in the New Madrid seismic zone happened in 1811 and 1812. Clearly, five to 25 years' experience is not nearly enough to evaluate the expected catastrophe costs.
2. In addition to limitations associated with historical frequency and severity, the attributes of historical events may be quite different from future events. Storm surge heights and the resulting damage from Hurricane Katrina, Hurricane Ike, Superstorm Sandy, and Hurricane Harvey were much greater than what would be expected from a surge estimation strictly tied to a wind event. Because this is a relatively recent recognition, historical records are unlikely to provide helpful experience that accurately separates wind and surge.
3. Geographical patterns and physical characteristics of the historical record do not reflect the full range of possible catastrophe events. Many areas may not have had any historical losses at all, but are clearly at risk. For example, a Texas 150-year experience period does not include a Category 5 hurricane. As a result, the frequency and severity of such an event would not be anticipated in the loss experience. Inland flood has catastrophic event potential across large areas, but there are usually specific places within those areas that experience a loss. Focusing on historical damage would overstate the loss potential in some areas and understate the potential in areas that are in very close proximity and equally likely to experience a loss.
4. Property distributions and characteristics have changed. Population has increased in high-risk areas near the coast, lakes, and rivers. Housing units have grown significantly in high-risk areas during the last few decades. Construction methods and building codes have changed. Modern building codes require wind- and water-resistive design elements that will reduce the likelihood of damage in the catastrophe. Historical

losses based on old exposure distribution can't be used without appropriate actuarial adjustments. Adjustments based on assumptions introduce more uncertainties to the process.

5. Many important property characteristics are not available in historical records. Expected catastrophe loss is highly dependent on a property's specific characteristics. Flood loss, for example, is affected by elevation, proximity to rivers or oceans, whether the building site is on the ground or on stilts, the bathymetry or contour of the ocean floors, the local flood mitigation features, etc. It is likely that two houses next to each other may have very different damage ratios from the same flood event due to their unique characteristics. This type of information may not have been collected in the past, and may not lend itself to reliable reconstruction.
6. Claim payment records may be limited or inaccurate and claim practices may have changed over time. In addition, exposure information related to the claim may not have been kept. Exposure information about properties exposed to loss but not damaged or having only negligible damage (especially below the deductible) may not be available. Understandably, claims adjusters focus on making policyholders whole following an event and may not be as meticulous as they might otherwise be in their documentation.
7. Information related to older events is not always reliable. Extreme events might have damaged or destroyed instruments. Events that occurred where the population was sparse or limited may have only the most general information recorded or may not have been noted at all. The exposure information related to the insured losses may not contain information that allows matching to claim payments, and, as noted above, exposure information for properties that did not suffer damage may not have been kept.
8. For these reasons and others, while historical data does bring valuable insight about catastrophe losses, it is insufficient in many cases to make proper projections for future catastrophe losses. This has led to extensive efforts to develop catastrophe models, which are a better alternative for estimating catastrophe losses.

Advantages of Using Catastrophe Models

Catastrophe models overcome the limitations of the historical records in several ways.

1. Catastrophe models simulate significantly more realistically plausible events than are contained in the historical record. Catastrophe simulation models use a database of scenario events that are designed to be comprehensive and realistic. The frequency of each event is calibrated to reflect the scientific view of the likelihood of that event. For example, if a coastal segment has experienced more Category 3 storms than category 4 or 5 storms, then the event database will take this into account. Category 3 storms would make up a bigger portion of the storms affecting the area in the model analysis. These event parameters are smoothed to minimize the gaps in the historical records. Similar scientific knowledge is incorporated into each of the model modules as appropriate.
2. Catastrophe models allow users to import and analyze the current exposure and settlement terms, therefore avoiding the pitfalls in adjusting historical experience to reflect changes in the number, types, and values of structures exposed to the hazard. The models can also account for changes in building practices, building code, and loss-mitigation features.
3. Catastrophe models are updated regularly and often. This enables catastrophe models to incorporate the most advanced science in meteorology, hydrology, seismology, statistics, and structural engineering into the models. Catastrophe models incorporate the most current information on land use/land cover, surface roughness, soil type, flood defense, flood control measures, ZIP code boundary, etc.
4. Catastrophe models allow the insurance industry to develop forward-looking views. It allows users to analyze “what if” scenarios to assess the impact of certain catastrophe risk management strategies.
5. Catastrophe models encourage sensitivity testing, which leads to more frequent and thorough testing. These analyses can provide valuable information about characteristics to investigate more thoroughly, provide additional viewpoints to consider, and stress-test scenarios.
6. There are several catastrophe models available to the insurance industry. Having several viewpoints can provide additional, valuable information related to risk management.

Limitations of Catastrophe Models

1. There are significant uncertainties around model estimates and large ranges of output values among different models. Many assumptions are involved in creating catastrophe models. A large range of output does not mean that any model is inaccurate or unreliable. The uncertainty is, to a large degree, expected, and its sources understood by actuaries. Uncertainties in alternate methods of estimating catastrophe damage are likely to be even larger and more difficult or impossible to quantify. However, a wide range of model output can cause concerns with consumers, regulators, and executives.
2. Collecting important building characteristics is not an easy task for an insurance company and may require a substantial financial output before any benefit is realized.
3. There may be damage or causes of loss that happen due to or concurrent with a catastrophic event that are not included in model output. These need to be treated separately. This is not usually problematic, but does emphasize the importance of understanding what the model assumptions are.
4. Model changes with software update can cause stability concerns. As science continues to evolve, and more data becomes available, modeling vendors have opportunities to incorporate new sciences and learnings into the models. As a result, the industry may experience large swings in the estimates from year to year. However, these changes are far smaller than what could happen when relying on historical experience.
5. Given the complexity of catastrophe models, using models requires either reliance on a company's reinsurance broker or other third party, or significant investment in training, software, and hardware to develop and maintain internal expertise.
6. While the technical documentation of the models is available to users for their general knowledge, some core assumptions are considered proprietary and are not readily accessible to users. A catastrophe model is developed by a group of scientists (meteorologist, seismologist, hydrologist, statisticians, engineers, actuaries, computer scientist, etc.) with specialized knowledge in different fields. It is not an easy task for model users to develop even a basic understanding of the model, as required by U.S. actuaries' standards of practice.⁸
7. Catastrophe models are tools to help insurers assess and understand catastrophe risks. Like other tools, catastrophe models have limitations. Due to the uncertainties discussed above, it is impossible and unrealistic to expect a catastrophe model to produce perfect answers. However, this is not a reason to discredit a modeling approach, as relying solely on historical records is less reliable.

⁸ ASOP No. 38, Op. cit.

Summary

Use of computer models to estimate catastrophe losses for the insurance industry has gained momentum and has become a standard risk management practice. Hurricane Andrew in 1992 highlighted the shortcomings of processes used up until that time and how those shortcomings could create problems for the industry. Hurricane and earthquake models were introduced first to the market, followed by severe convective storm, wildfire, flood, terrorism, and pandemics. Several factors contributed to the advancement of the catastrophe models. The primary driver was the realization that the unpredictability of catastrophe events and limitations of traditional actuarial methods that rely on five to 25 years' historical records were not adequate to plan for future extreme events. Combined with the substantial improvement in computing power and sophistication, models became the tool of choice for managing catastrophic risk.

This monograph is offered to provide the reader with an overview of how actuaries use catastrophe model output for various analyses. Examples based on defined exposure input for selected causes of loss provide insight into these applications and show uses of modeled output.

Appendix 1

Hypothetical Policies and Model Settings

Construction of Hypothetical Policies

We distributed 100,000 single-residential policies geographically throughout the state of Florida, representing approximately 1 percent of the market's policy count.⁹ The 100,000 policies were assigned to ZIP codes in proportion to the population of that ZIP.¹⁰ Random parcels within the ZIP were assigned to each policy that had been allocated to that ZIP. The building value for each structure is \$207,500.¹¹ Appurtenant structure values were 10 percent of building value (\$20,750); Contents coverage value was set to 50 percent of building value (\$103,750); and Additional Living Expense was 20 percent of building coverage, or \$41,500. Each policy had a 2 percent blanket deductible (2 percent of the sum of all coverages combined, applied against losses from all coverages combined). Note that Florida requires 2 percent of building value be offered, and that choice is virtually universal in the admitted market in that state.

Construction, year of construction, and foundation type were left as default values. No basement or NFIP coverage was assumed to exist.

Model Settings

CoreLogic's RQE (Risk Quantification and Engineering) catastrophe model was used to generate the metrics shown in the tables.

Settings were selected that are, in the authors' experience, typical for model use. The expected losses include potential impacts of demand surge. All residential property coverages were included: Building, Appurtenant Structures, Contents, and Additional Living Expense. Except where otherwise indicated, the expected losses are ground-up, occurrence losses.

⁹ SNL data
¹⁰ IRS data
¹¹ Median value per Zillow.com

Appendix 2 2017 Florida Hurricane Mitigation Measures

INDIVIDUAL MITIGATION MEASURES		PERCENTAGE CHANGES IN DAMAGE* (REFERENCE DAMAGE RATE - MITIGATED DAMAGE RATE) / REFERENCE DAMAGE RATE * 100										
		FRAME STRUCTURE					MASONRY STRUCTURE					
		WINDSPEED (MPH)					WINDSPEED (MPH)					
		60	85	110	135	160	60	85	110	135	160	
	REFERENCE STRUCTURE	0	0	0	0	0	0	0	0	0	0	
ROOF STRENGTH	BRACED GABLE ENDS	15.1%	14.6%	12.4%	9.9%	4.8%	13.6%	13.4%	11.6%	9.4%	5.9%	
	HIP ROOF	19.0%	18.2%	15.5%	12.5%	6.2%	17.3%	16.8%	14.5%	11.9%	7.5%	
ROOF COVERING	METAL	-8.7%	-8.6%	-7.3%	-5.7%	-2.7%	-8.1%	-8.3%	-7.1%	-5.6%	-3.4%	
	ASTM D7158 Class H Shingles (150 MPH)	1.9%	1.9%	1.6%	1.2%	0.6%	1.7%	1.7%	1.5%	1.2%	0.7%	
	MEMBRANE	-5.2%	-5.1%	-4.3%	-3.4%	-1.6%	-5.0%	-5.1%	-4.4%	-3.5%	-2.1%	
ROOF-WALL STRENGTH	NAILING OF DECK	8d	1.9%	1.9%	1.6%	1.2%	0.6%	1.7%	1.7%	1.5%	1.2%	0.7%
	CLIPS		17.8%	17.1%	14.6%	11.6%	5.8%	16.2%	15.8%	13.7%	11.1%	7.1%
WALL-FLOOR STRENGTH	STRAPS		17.8%	17.1%	14.6%	11.6%	5.8%	16.2%	15.8%	13.7%	11.1%	7.1%
	TIES OR CLIPS		4.6%	4.6%	3.9%	3.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%
WALL- FOUNDATION STRENGTH	STRAPS		4.6%	4.6%	3.9%	3.0%	1.4%	0.0%	0.0%	0.0%	0.0%	
	LARGER ANCHORS OR CLOSER SPACING		0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	
	VERTICAL REINFORCING		-	-	-	-	-	-	-	-	-	
OPENING PROTECTION	WINDOW	PLYWOOD	12.1%	12.0%	10.1%	7.9%	3.8%	11.0%	11.0%	9.4%	7.6%	4.7%
	SHUTTERS	METAL	12.1%	12.0%	10.1%	7.9%	3.8%	11.0%	11.0%	9.4%	7.6%	4.7%
	DOOR AND SKYLIGHT COVERS		21.8%	20.6%	17.7%	14.3%	7.2%	19.9%	19.2%	16.6%	13.6%	8.7%
	WINDOW	IMPACT RATED	10.6%	10.5%	8.9%	7.0%	3.3%	9.7%	9.8%	8.4%	6.7%	4.1%
	ENTRY DOORS	MEETS WINDBORNE DEBRIS REQUIREMENTS	10.6%	10.5%	8.9%	7.0%	3.3%	9.7%	9.8%	8.4%	6.7%	4.1%
	GARAGE DOORS		10.6%	10.5%	8.9%	7.0%	3.3%	9.7%	9.8%	8.4%	6.7%	4.1%
	SLIDING GLASS DOORS		18.8%	18.0%	15.4%	12.3%	6.2%	17.3%	16.8%	14.5%	11.9%	7.5%
SKYLIGHT	IMPACT RATED	13.8%	13.5%	11.4%	9.0%	4.4%	12.3%	12.2%	10.5%	8.5%	5.3%	
MITIGATION MEASURES IN COMBINATION		PERCENTAGE CHANGES IN DAMAGE* (REFERENCE DAMAGE RATE - MITIGATED DAMAGE RATE) / REFERENCE DAMAGE RATE * 100										
		FRAME STRUCTURE					MASONRY STRUCTURE					
		WINDSPEED (MPH)					WINDSPEED (MPH)					
		60	85	110	135	160	60	85	110	135	160	
STRUCTURE	MITIGATED STRUCTURE	27.2%	25.6%	22.0%	17.8%	9.1%	25.2%	24.0%	20.8%	17.2%	11.1%	

* Note: Larger or closer spaced anchor bolts: not currently distinguished in the model, as other aspects are deemed more important; also difficult to ascertain vertical reinforcing for masonry walls: this feature is accounted for through the selection of the base structure; vertically reinforced masonry walls are considered by the CoreLogic model as Reinforced Masonry (RM).

The input one-minute sustained 10-meter wind speeds were assumed to be over-water and were converted to over-land peak gust wind speeds using the minimum direction-dependent roughness length for the ZIP Code centroid and the model's standard gust factor formulation.

Source: FCHLPM; CoreLogic

Appendix 3 Disclaimers

This paper is not intended to be an interpretation of the actuarial standards of practice and is not meant to be a codification of generally accepted or appropriate actuarial practice. Actuaries are not in any way bound to comply with this paper or to conform their work to the practices described herein.

The use of the CoreLogic RQE model does not imply any recommendation or preference of that model over any other model.

The results shown in this paper have been derived as described. While accurate based on the exposures and assumptions described here, they are not realistic quantifications of expected loss and are not meant to be used for any purpose other than illustration.

5. Assignment 3, Module 2: Reanalysis Data:

https://www.aoml.noaa.gov/hrd/data_sub/re_anal.html

Link to the Reanalysis Data

The Atlantic Hurricane Database Re-analysis Project is an effort to extend and revise the National Hurricane Center's North Atlantic hurricane database (or HURDAT). Going back to 1851 and revisiting storms in more recent years, information on tropical cyclones is revised using an enhanced collection of historical meteorological data in the context of today's scientific understanding of hurricanes and analysis techniques.

To receive email updates about progress in the Atlantic Hurricane Re-analysis Project, send an email to [Chris Landsea](#).

What's New

May 2024 - HURDAT2 has been updated to include the 2023 Atlantic and Northeast Pacific best tracks.

February 2024 - Radius of Maximum Wind (RMW) has been included into the Atlantic HURDAT2 for historic U.S. impacting hurricanes. This is based upon the work of Delían Colon Burgós while a Hollings Scholar at the National Hurricane Center during the summer of 2022.

April 2023 - The Atlantic and North East/North Central Pacific hurricane seasons for 2022 have been added to the hurricane databases (HURDAT2).

September 2022 - The 1944 Great Atlantic Hurricane has been upgraded to a Category 5 hurricane over the open ocean based upon recently rediscovered ship logs from the ship *USS Alacrity*. This was research provided by Jack Beven.

April 2022 - The Atlantic and North East/North Central Pacific hurricane seasons for 2021 have been added to the hurricane databases (HURDAT2). Of note is that Radius of Maximum Wind (RMW) has been included for the first time.

February 2022 - Reanalysis of the 1966 to 1970 Atlantic Hurricane Seasons:

A systematic study of the 1966 to 1970 Atlantic hurricane seasons has discovered 14 new tropical storms. Additionally, two new hurricanes were diagnosed, which previously were only considered to be a tropical depression (AL151970) and a tropical storm (AL081970). These systems were all added into the hurricane database (HURDAT2) based upon a re-examination of all weather station, ship, Hurricane Hunter, and satellite observations using today's understanding of tropical cyclone structure and life cycle. On the flip side, two major hurricanes (Frankelia - AL131969 and Inga - AL201969) were downgraded to a Saffir-Simpson Hurricane Scale category 2 hurricane. For U.S. hurricanes, 1966's Alma (AL011966) was upgraded from a Category 2 to a Category 3 hurricane impact in southwest Florida, 1966's Inez (AL091966) was upgraded from a Category 1 to a Category 2 hurricane in south Florida, 1970's Celia (AL041970) was upgraded from a Category 3 to a Category 4 hurricane in lower Texas, and 1969's Gerda (AL161969) was downgraded from a Category 1 hurricane to a tropical storm in Maine.

[Archive of What's New](#)

1. Re-analysis results:
 - a. [Documentation for 1851 to 1910](#)
 - b. [Documentation for 1911 to 1920](#)
 - c. [Documentation for 1921 to 1930](#)
 - d. [Documentation for 1931 to 1943](#)
(Supplemental Information)
 - e. [Documentation for 1944 to 1953](#)
 - f. [Documentation for 1954 to 1963](#)
 - g. [Data](#)
2. [How to submit changes to the HURDAT](#)
3. [Hurricane Andrew's Upgrade](#)
4. [U.S. Hurricane History by State \(NWS sites\)](#)
5. [HURDAT Reanalysis Related Publications](#)
6. [Publications of Chris Landsea](#)

6. Assignment 3, Module 4: Study Note – Cat Risk Management:
https://www.catriskcredentials.org/wp-content/uploads/2019/04/Cat_Risk_Management_Study_Note_LO15.pdf

Exam 2: Cat Risk Management Insurance Fundamentals

Part B – Learning Objective No. 15

Study Note

Learning Objective 15:

Describe the types of disclosures related to catastrophe modeling results that appear in the 10-K and why they are important.

This document contains content from the following websites, along with original content.

<https://www.sec.gov/fast-answers/answersreada10k.htm>

<https://www.sec.gov/fast-answers/answers-form10k.htm>

United States securities laws require public companies to disclose information on an ongoing basis. For example, domestic companies must submit annual reports on Form 10-K. The annual report on Form 10-K provides a comprehensive overview of the company's business and financial condition and includes audited financial statements. Although similarly named, the annual report on Form 10-K is distinct from the "annual report to shareholders," which a company must send to its shareholders when it holds an annual meeting to elect directors.

The company writes the 10-K and files it with the U.S. Securities and Exchange Commission (SEC). Laws and regulations prohibit companies from making materially false or misleading statements in their 10-Ks. Likewise, companies are prohibited from omitting material information that is needed to make the disclosure not misleading. In addition, the Sarbanes-Oxley Act requires a company's CFO and CEO to certify the accuracy of the 10-K. There can be both financial and criminal penalties for filing false information with the SEC.

The SEC neither writes the 10-K nor vouches for its accuracy. The SEC sets the disclosure requirements and the SEC staff reviews 10-Ks to monitor and enhance companies' compliance with the requirements. All 10-Ks filed with SEC are available to the public on the SEC's website (www.sec.gov). Most companies also post their 10-Ks on their own websites.

The measurement of catastrophe risk through the utilization of catastrophe models is prevalent for property insurance companies who write business in cat prone areas. Therefore, it is common for property insurance companies to report catastrophe modeling results within the 10-K form, although where in the form and the format used to display these figures will vary by company. For example, you may find references to catastrophe modeling in certain sections of the 10-K such as;

Part I, Item 1 - Business

Part II, Item 7 – Management's Discussion and Analysis of Financial Condition and Results of Operations

Because there are no explicit instructions, the level of detail provided in the 10-K will vary by company. Most companies will reference the inherent uncertainty and risk in using catastrophe models along with some measurement of the catastrophe risk produced by a catastrophe model.

Examples of disclosures for three parent companies whose holdings include property insurance companies are shown below. As you review these disclosures, make note of the differences in how information is shared for each company. Since the 10-K forms are public and available for anyone to review, it is common to use this information for industry or peer benchmarking purposes and to better understand a given company's approach to catastrophe management and catastrophe exposure appetite. Current and historical filings for public companies can be found on the SEC's website (link provided below). Companies can be searched by name or ticker. 10-K forms are filed for the company that is publicly traded. You may need to do some research to identify the parent company of an insurance company, as their names are often different. For example, GEICO Insurance is owned by Berkshire Hathaway (Ticker: BRK).

<https://www.sec.gov/edgar/searchedgar/companysearch.html>

Exam 2: Cat Risk Management Insurance Fundamentals

Part B – Learning Objective No. 15

Study Note

American Financial Group (Ticker: AFG)

Parent of Great American Insurance Company, et al.

p.4 – Part I, Item 1 - Business

“AFG generally seeks to reduce its exposure to catastrophes through individual risk selection, including minimizing coastal and known fault-line exposures, and the purchase of reinsurance. AFG’s net exposure to a catastrophic earthquake or windstorm that industry models indicate could occur once in every 500 years (a “500-year event”) is expected to be less than 4% of AFG’s Shareholders’ Equity.”

p. 61 - Part II, Item 7 - Result of Operations, Property and Casualty Insurance

Catastrophe losses

“AFG generally seeks to reduce its exposure to catastrophes through individual risk selection, including minimizing coastal and known fault-line exposures, and the purchase of reinsurance. Based on data available at December 31, 2017, AFG’s exposure to a catastrophic earthquake or windstorm that industry models indicate should statistically occur once in every 100, 250 or 500 years as a percentage of AFG’s Shareholders’ Equity is shown below:”

Impact of modeled loss on AFG’s

<i>Industry Model</i>	<i>Shareholders’ Equity</i>
<i>100-year event</i>	<i>Less than 1%</i>
<i>250-year event</i>	<i>Less than 2%</i>
<i>500-year event</i>	<i>Less than 4%</i>

“AFG maintains comprehensive catastrophe reinsurance coverage, including a \$15 million per occurrence net retention for its U.S.-based property and casualty insurance operations for losses up to \$100 million and a separate \$15 million per occurrence retention for Neon for losses up to \$200 million (\$225 million for U.S. catastrophe events). AFG’s property and casualty insurance operations further maintain supplemental fully collateralized reinsurance coverage up to 95% of \$200 million for catastrophe losses in excess of \$100 million of traditional catastrophe reinsurance through a catastrophe bond.”

RLI Corporation (Ticker: RLI)

Parent of RLI Insurance Company, et al.

p.12 – Part I, Item 1 - Business

“We continuously monitor and quantify our exposure to catastrophes including earthquakes, hurricanes, floods, convective storms, terrorist acts and other aggregating events. In the normal course of business, we manage our concentrations of exposures to catastrophic events, primarily by limiting concentrations of locations insured to acceptable levels and by purchasing reinsurance. Exposure and coverage detail is recorded for each risk location. We quantify and monitor the total policy limit insured in each geographical region. In addition, we use third-party CAT exposure models and an internally developed analysis to assess each risk to ensure we include an appropriate charge for assumed CAT risks. CAT exposure modeling is inherently uncertain due to the model’s reliance on an infrequent observation of actual events and exposure data, increasing the importance of capturing accurate policy coverage data. The model results are used both in the underwriting analysis of individual risks and at a corporate level for the aggregate book of CAT-exposed business. From both perspectives, we consider the potential loss produced by individual events that represent moderate-to-high loss potential at varying probabilities and magnitudes. In calculating potential losses, we select appropriate assumptions including, but not limited to, loss amplification and loss adjustment expense. We establish risk tolerances at the portfolio level based on market conditions, the level of reinsurance available, changes to the assumptions in the CAT models, rating agency capital constraints, underwriting guidelines and coverages and internal preferences. Our risk tolerances for each type of CAT, and for all perils in aggregate, change over time as these internal and external conditions change. We are required to report to the rating agencies estimated loss to a single event that could include all potential earthquakes and hurricanes contemplated by the CAT modeling software. This reported loss includes the impact of insured

Exam 2: Cat Risk Management Insurance Fundamentals

Part B – Learning Objective No. 15

Study Note

losses based on the estimated frequency and severity of potential events, loss adjustment expense, reinstatements paid after the loss, reinsurance recoveries and taxes. Based on the CAT reinsurance treaty purchased on January 1, 2018, there is a 99.6 percent likelihood that the loss will be less than 14.2 percent of policyholders' surplus as of December 31, 2017. The exposure levels are within our tolerances for this risk."

Hartford Financial Services Group (Ticker: HIG)

Parent of Hartford Fire Insurance Company, et al.

p. 82, Part II – Item 7 - Management's Discussion and Analysis of Financial Condition and Results of Operations

"The Company's policies and procedures for managing these risks include disciplined underwriting protocols, exposure controls, sophisticated risk-based pricing, risk modeling, risk transfer, and capital management strategies. The Company has established underwriting guidelines for both individual risks, including individual policy limits, and risks in the aggregate, including aggregate exposure limits by geographic zone and peril. The Company uses both internal and third-party models to estimate the potential loss resulting from various catastrophe events and the potential financial impact those events would have on the Company's financial position and results of operations across its businesses. Among specific risk tolerances set by the Company, risk limits are set for natural catastrophes, terrorism risk and pandemic risk.

The Company generally limits its estimated pre-tax loss as a result of natural catastrophes for property & casualty exposures from a single 250-year event to less than 30% of statutory surplus of the property and casualty insurance subsidiaries prior to reinsurance and to less than 15% of statutory surplus of the property and casualty insurance subsidiaries after reinsurance. From time to time the estimated loss to natural catastrophes from a single 250-year event prior to reinsurance may fluctuate above or below these limits due to changes in modeled loss estimates, exposures or statutory surplus.

- The estimated 250 year pre-tax probable maximum loss from earthquake events is estimated to be \$982 before reinsurance and \$515 net of reinsurance. [1]

- The estimated 250 year pre-tax probable maximum losses from hurricane events are estimated to be \$1.6 billion before reinsurance and \$777 net of reinsurance. [1]

[1] The loss estimates represent total property losses for hurricane events and property and workers compensation losses for earthquake events resulting from a single event. The estimates provided are based on 250-year return period loss estimates that have a 0.4% likelihood of being exceeded in any single year. The net loss estimates provided assume that the Company is able to recover all losses ceded to reinsurers under its reinsurance programs. The Company also manages natural catastrophe risk for group life and group disability, which in combination with property and workers compensation loss estimates are subject to separate enterprise risk management net aggregate loss limits as a percent of enterprise surplus."

Exam 2: Cat Risk Management Insurance Fundamentals
Part B – Learning Objective No. 15
Study Note

From <https://www.sec.gov/fast-answers/answersreada10khtm.html>

How to Read a 10-K

If you want to follow or invest in a U.S. public company, you can find a wealth of information in the company's annual report on Form 10-K. Among other things, the 10-K offers a detailed picture of a company's business, the risks it faces, and the operating and financial results for the fiscal year. Company management also discusses its perspective on the business results and what is driving them.

Most U.S. public companies are required to produce a 10-K each year and file it with the U.S. Securities and Exchange Commission (SEC). (Non-U.S. public companies usually file their annual reports with the SEC on different forms.) SEC rules require that 10-Ks follow a set order of topics.

SEC rules also require companies to send an annual report to their shareholders when they are holding annual meetings to elect members of their boards of directors. There is a lot of overlap in the requirements for the 10-K and the annual report to shareholders, but there are also important differences. The 10-K typically includes more detailed information than the annual report to shareholders. The annual report to shareholders, unlike the 10-K, sometimes appears as a colorful, glossy publication. A number of companies, however, simply take their 10-K and send it as their annual report to shareholders. In those cases, the 10-K filed with the SEC and the annual report to shareholders are the same document. For more information on the annual report to shareholders, please click [here](#).

Following is a description of each section of Form 10-K, along with some suggestions on how to use the information. At the end of this document, we explain the role of public companies in ensuring the accuracy of their 10-Ks and the role of the SEC in reviewing the documents. We also tell you how to find company 10-Ks.

PART I

Item 1 - "Business" requires a description of the company's business, including its main products and services, what subsidiaries it owns, and what markets it operates in. This section may also include information about recent events, competition the company faces, regulations that apply to it, labor issues, special operating costs, or seasonal factors. This is a good place to start to understand how the company operates.

Item 1A - "Risk Factors" includes information about the most significant risks that apply to the company or to its securities. Companies generally list the risk factors in order of their importance. In practice, this section focuses on the risks themselves, not how the company addresses those risks. Some risks may be true for the entire economy, some may apply only to the company's industry sector or geographic region, and some may be unique to the company.

Item 1B - "Unresolved Staff Comments" requires the company to explain certain comments it has received from the SEC staff on previously filed reports that have not been resolved after an extended period of time. Check here to see whether the SEC has raised any questions about the company's statements that have not been resolved.

Item 2 - "Properties" includes information about the company's significant properties, such as principal plants, mines and other materially important physical properties.

Item 3 - "Legal Proceedings" requires the company to include information about significant pending lawsuits or other legal proceedings, other than ordinary litigation.

Item 4 - This item has no required information, but is reserved by the SEC for future rulemaking.

PART II

Item 5 - "Market for Registrant's Common Equity, Related Stockholder Matters and Issuer Purchases of Equity Securities" requires information about the company's equity securities, including market information, the number of holders of the shares, dividends, stock repurchases by the company, and similar information.

Exam 2: Cat Risk Management Insurance Fundamentals

Part B – Learning Objective No. 15

Study Note

Item 6 - "Selected Financial Data" provides certain financial information about the company for the last five years. You can find much more detailed financial information on the past three years in a separate section – Item 8, "Financial Statements and Supplementary Data."

Item 7 - "Management's Discussion and Analysis of Financial Condition and Results of Operations" gives the company's perspective on the business results of the past financial year. This section, known as the MD&A for short, allows company management to tell its story in its own words. The MD&A presents:

The company's operations and financial results, including information about the company's liquidity and capital resources and any known trends or uncertainties that could materially affect the company's results. This section may also discuss management's views of key business risks and what it is doing to address them.

Material changes in the company's results compared to the prior period, as well as off-balance sheet arrangements and the company's contractual obligations.

Critical accounting judgments, such as estimates and assumptions. These accounting judgments – and any changes from previous years – can have a significant impact on the numbers in the financial statements, such as assets, costs, and net income.

Item 7A - "Quantitative and Qualitative Disclosures about Market Risk" requires information about the company's exposure to market risk, such as interest rate risk, foreign currency exchange risk, commodity price risk or equity price risk. The company may discuss how it manages its market risk exposures.

Item 8 - "Financial Statements and Supplementary Data" requires the company's audited financial statements. This includes the company's income statement (which is sometimes called the statement of earnings or the statement of operations), balance sheets, statement of cash flows and statement of stockholders' equity. The financial statements are accompanied by notes that explain the information presented in the financial statements.

U.S. companies are required to present their financial statements according to a set of accounting standards, conventions and rules known as Generally Accepted Accounting Principles, or GAAP. An independent accountant audits the company's financial statements. For large companies, the independent accountant also reports on a company's internal controls over financial reporting. The auditor's report is a key part of the 10-K. Most audit reports express an "unqualified opinion" that the financial statements fairly present the company's financial position in conformity with GAAP. If, however, an auditor expresses a "qualified opinion" or a "disclaimer of opinion," investors should look carefully at what kept the auditor from expressing an unqualified opinion. Likewise, investors should carefully evaluate material weaknesses disclosed on internal controls over financial reporting.

In addition, the Sarbanes-Oxley Act of 2002 requires the company's CEO and CFO to certify that the 10-K is both accurate and complete. These are called Sections 302 and 906 certifications, and you can usually find them in Exhibits 31 and 32.

You may also find "non-GAAP financial measures" in the 10-K. That means that the numbers do NOT conform to GAAP. While companies are permitted to present non-GAAP measures, they must also show how they differ from the most comparable corresponding GAAP financial measure. As an investor, it is up to you to decide how much weight to give to non-GAAP measures.

Item 9 - "Changes in and Disagreements with Accountants on Accounting and Financial Disclosure" requires a company, if there has been a change in its accountants, to discuss any disagreements it had with those accountants. Many investors view this disclosure as a red flag.

Item 9A - "Controls and Procedures" includes information about the company's disclosure controls and procedures and its internal control over financial reporting.

Item 9B - "Other Information" includes any information that was required to be reported on a different form during the fourth quarter of the year covered by the 10-K, but was not yet reported.

Exam 2: Cat Risk Management Insurance Fundamentals

Part B – Learning Objective No. 15

Study Note

PART III

These items cover the following topics.

Item 10 “Directors, Executive Officers and Corporate Governance” requires information about the background and experience of the company’s directors and executive officers, the company’s code of ethics, and certain qualifications for directors and committees of the board of directors.

Item 11 “Executive Compensation” includes detailed disclosure about the company’s compensation policies and programs and how much compensation was paid to the top executive officers of the company in the past year.

Item 12 “Security Ownership of Certain Beneficial Owners and Management and Related Stockholder Matters” requires information about the shares owned by the company’s directors, officers and certain large shareholders, and about shares covered by equity compensation plans.

Item 13 “Certain Relationships and Related Transactions, and Director Independence” includes information about relationships and transactions between the company and its directors, officers and their family members. It also includes information about whether each director of the company is independent.

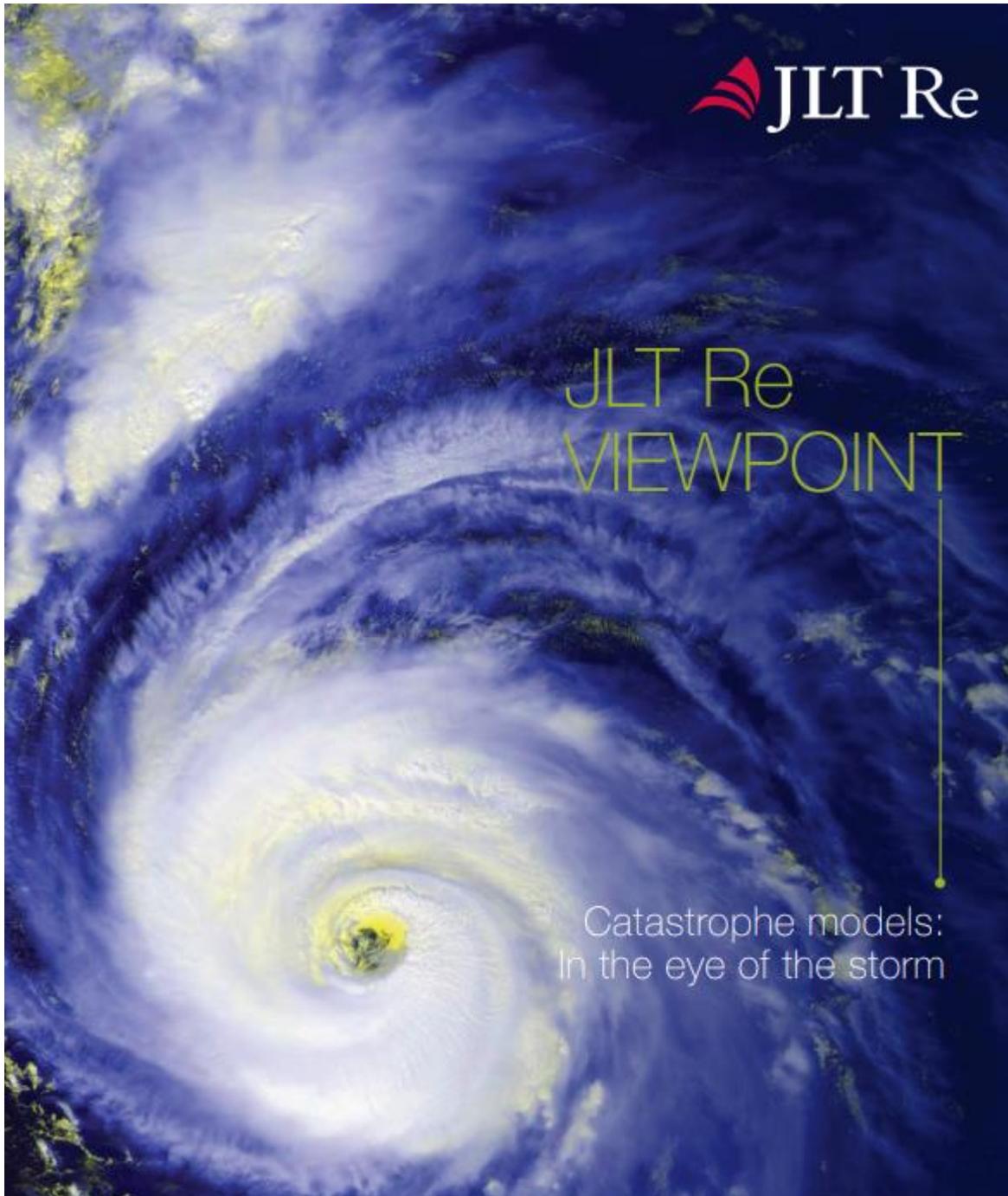
Item 14 “Principal Accountant Fees and Services” requires companies to disclose the fees they paid to their accounting firm for various types of services during the year.

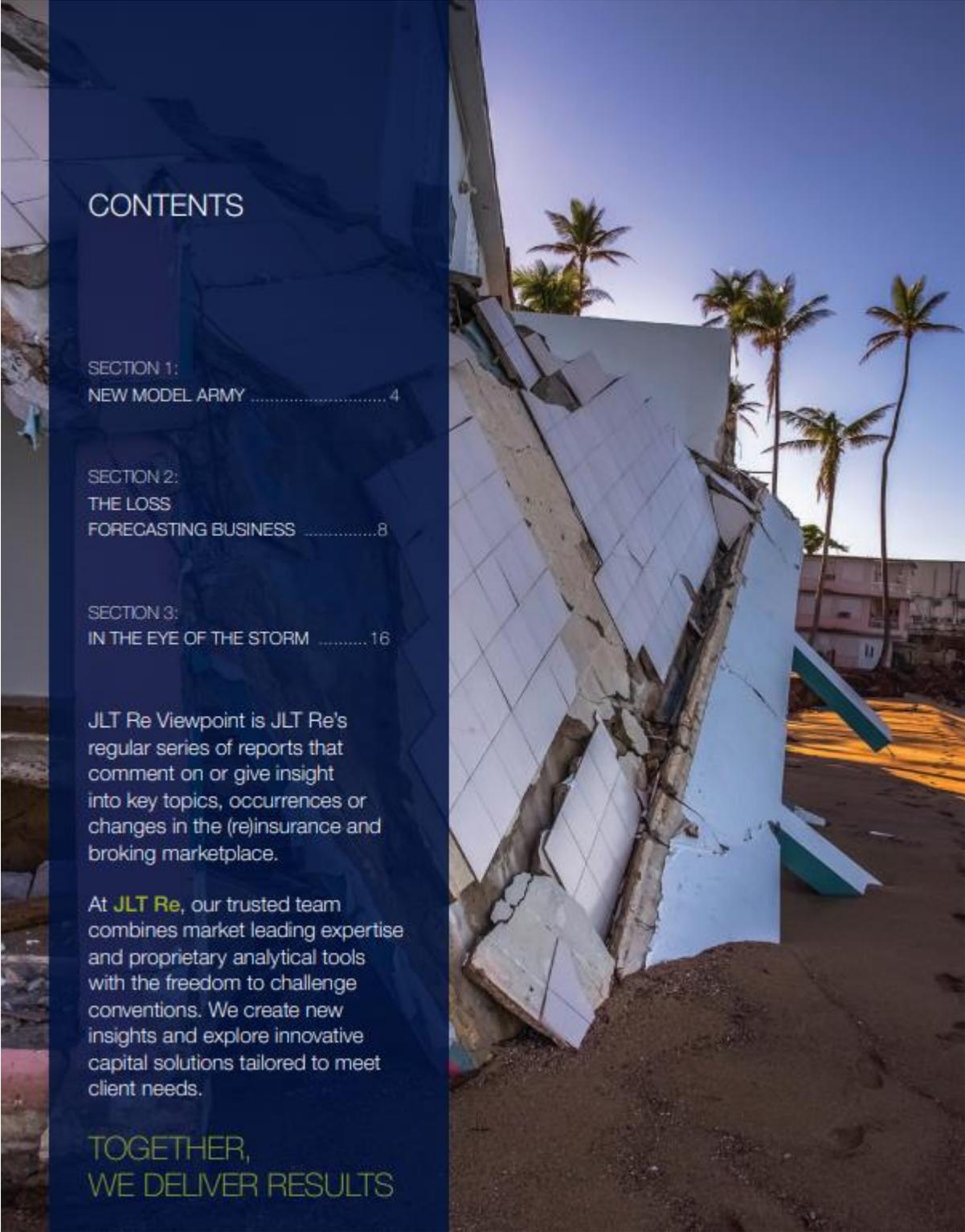
Although these disclosures are required by the 10-K, most companies meet this requirement by providing the information in a separate document called the proxy statement, which companies provide to their shareholders in connection with annual meetings. If the information is provided through the proxy statement, the 10-K would include a statement from the company that it is incorporating the information from the proxy statement by reference – in effect directing readers to go to the proxy statement document to find this information. Keep in mind that the proxy statement is typically filed a month or two after the 10-K. For more information on proxy statements and shareholder voting in corporate elections, see the SEC’s [Spotlight on Proxy Matters](#). And for information on how to find company proxy statements on the SEC’s EDGAR database, click [here](#).

PART IV

Item 15 - “Exhibits, Financial Statement Schedules” requires a list of the financial statements and exhibits included as part of the Form 10-K. Many exhibits are required, including documents such as the company’s bylaws, copies of its material contracts, and a list of the company’s subsidiaries.

7. Assignment 3, Module 5: Cat Models – In the Eye of the Storm:
<https://www.catriskcredentials.org/wp-content/uploads/2021/07/Viewpoint-catastrophe-models.pdf>





CONTENTS

SECTION 1:
NEW MODEL ARMY 4

SECTION 2:
THE LOSS
FORECASTING BUSINESS 8

SECTION 3:
IN THE EYE OF THE STORM 16

JLT Re Viewpoint is JLT Re's regular series of reports that comment on or give insight into key topics, occurrences or changes in the (re)insurance and broking marketplace.

At **JLT Re**, our trusted team combines market leading expertise and proprietary analytical tools with the freedom to challenge conventions. We create new insights and explore innovative capital solutions tailored to meet client needs.

**TOGETHER,
WE DELIVER RESULTS**

EXECUTIVE SUMMARY

Catastrophe models are once again firmly under the spotlight. Nearly a year on since hurricanes Harvey, Irma and Maria (HIM) devastated coastal regions of the United States and parts of the Caribbean, there is continued uncertainty about the magnitude of insured losses for all three events. How much HIM will ultimately cost the (re)insurance sector remains unclear, and divergent views amongst vendor catastrophe modelling firms are contributing to this uncertainty. As a result, modelled loss estimates are coming in for additional scrutiny, both at industry and individual company levels. The lack of consensus around modelled market losses potentially points to even greater levels of uncertainty for company-level loss estimates.

Scepticism of vendor models is not new. Model limitations exposed by events such as hurricanes Katrina and Ike and Superstorm Sandy have led to recalibrations to address issues such as coastal flooding, storm surge and inland damage. The events of 2017 were therefore an important test for the latest generation of commercial hurricane models. Given the unease expressed by many market participants over the wide-ranging modelled loss estimates that followed HIM, this JLT Re Viewpoint report examines how the vendor firms have performed in predicting industry-wide losses for North Atlantic hurricane events in previous large-loss years, and how the results in 2017 compared.

By analysing modelled estimates released by both AIR Worldwide (AIR) and Risk Management Solutions (RMS) for significant hurricanes since 2004, and comparing them to fully incurred losses for each respective event, this report provides a unique perspective in assessing the modelling companies' real-time loss estimation process. One key takeaway to emerge from the study was that modelled loss accuracy for hurricanes suffers when events are both costly and complex (often due to an array of un-modelled loss components). Other conclusions were more illuminating. For example, strong model performance was observed when hurricane losses are both anticipated and contained. In addition, whilst the accuracy of the modelled losses released for HIM in 2017 was mixed, certain results taken in isolation revealed some encouraging signs given the levels of complexities involved. Important lessons learned during HIM, along with technological advancements, should allow for improved accuracy going forward as they are incorporated into future generations of hurricane models.

That said, due to multiple areas of uncertainty in predicting industry-wide losses, vendor firms are likely struggling to satisfy market expectations for real-time loss information. Catastrophe models, after all, were not designed to predict losses for individual events immediately. And it is important to recognise the wider role that catastrophe modelling companies play in the (re)insurance market. Carriers today have a better understanding of their catastrophe risk potential than ever before. Equally importantly, catastrophe models have been crucial in helping to attract a permanent allocation of third-party capital to the reinsurance market by increasing investor confidence in pricing catastrophe risk. As a result, buyers of reinsurance are today benefitting from competitively priced capacity, even after the most expensive catastrophe loss year on record.

This paper is a continuation of a series of JLT Re Viewpoint reports which endeavour to provide impactful analysis for the benefit of clients. With the peak months of this year's hurricane season fast approaching, it is hoped that the study in this report will assist investors, catastrophe modellers and reinsurance buyers in assessing how any modelled industry losses released in the coming months are likely to perform by considering the levels of uncertainty associated with each estimate. Additionally, we hope it will encourage an open dialogue within the catastrophe modelling community that leads to greater levels of transparency and increased market confidence in the post-event loss estimation process.



SECTION 1: NEW MODEL ARMY

Catastrophe modelling was a concept born in the late 1980s to assist insurers and reinsurers in analysing, pricing and underwriting natural catastrophe risk. Up to this point, risk carriers typically relied on actuarial models to help estimate losses, the focus of which was on hurricanes in the United States, given the loss potential from the peril. Whilst these statistical models enabled carriers to make loss projections based on historical event frequency and claims data, they did not consider changing demographics such as new building codes or shifting meteorological conditions.

Lulled into a false sense of security by relatively quiet hurricane activity in the United States during the two preceding decades (with the exception of Hugo), most (re)insurers were grossly underestimating the full loss potential of hurricane risk in the country.

A MODEL BREAKTHROUGH

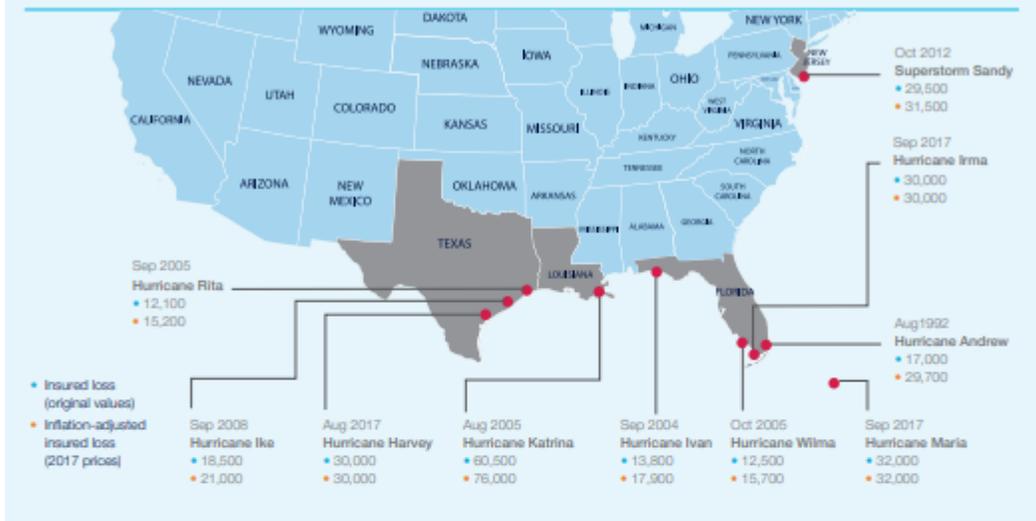
This became painfully clear when Hurricane Andrew made landfall as a category 5 storm in southern Florida in August 1992. With sustained winds in excess of 150 miles per hour, more than 63,000 houses were destroyed and another 125,000 were damaged. Andrew's intensity and landfall location meant that the magnitude of the loss was well beyond market expectations, exposing the limitations of using past experience alone as a basis for estimating future losses.

Aside from the devastating costs Andrew caused, the storm was also instrumental in bringing about a sea change to the (re)insurance market as the industry moved quickly to embrace scientifically-derived models. Prior to

1992, start-up modelling companies such as AIR and RMS had struggled to persuade sceptical (re)insurers of the value catastrophe models could bring in informing risk management decisions. Indeed, the sector responded with incredulity when AIR estimated shortly after Andrew's landfall that total insured losses would reach approximately USD 13 billion.

Attitudes quickly changed, however, as claims mounted. Andrew ultimately cost the (re)insurance market USD 17 billion (at original values), discrediting figures projected by actuarial models at the time, which typically pointed to a mid-single digit loss. Given this vast disparity, a number of carriers were unable to pay claims, leading to several bankruptcies and a Florida property market in dire need of reconstruction. It also brought about a widespread recognition in the post-Andrew world that a more scientific approach was needed for natural catastrophe risk, particularly low frequency, high-severity hurricane events. As a result, catastrophe models soon became fundamental to carriers' underwriting and capital

Figure 1: Top 10 Most Costly North Atlantic Tropical Cyclones (USD million) (Source: JLT Re, Munich Re)



management processes. Both AIR and RMS benefitted as they quickly established themselves as major players in the catastrophe market.

MODEL DEVELOPMENT

In the 25 years since Andrew came ashore, catastrophe models' theoretical framework has remained essentially the same. Models still consist of three basic components: hazard, vulnerability and loss. They also still simulate the impacts hazards have on built environments in order to estimate costs to insurable assets.

The sophistication and range of modelling products have nevertheless changed during this time, due in large part to increasing computer processing power and the growing availability of high-resolution hazard data. And new generations of models

have been created on the back of lessons learned from recent events. The wealth of claims data post-event has enabled modelling companies to significantly refine the damageability curves for specific aspects of exposure such as occupancy, construction, year of construction, number of storeys, as well as a host of secondary characteristics. This is especially true for North Atlantic hurricane models after successive storms have caused significant insured losses this century (see Figure 1 for the top 10 most costly hurricanes on record).

Katrina, Ike and Sandy in particular brought about significant revisions to hurricane models as each storm's distinct characteristics exposed their limitations and weaknesses. The unexpected levee failure in New Orleans after Katrina made landfall,

for example, showed that the models did not capture adequately the impacts from flooding and storm surge. And the costs associated with loss amplification, event clustering (after Rita and Wilma quickly followed) and other 'super-cat' characteristics (such as civil unrest, evacuations and National Guard deployment) were likewise not anticipated. Both AIR and RMS responded to these developments by recalibrating their models. Similar updates followed Ike and Sandy as new lessons were learned about inland damage and building code adherence (Ike), as well as storm surge along the US Northeast coast (Sandy).

After experiencing disruption from some of these revisions, the industry will be closely monitoring how the modelling companies respond to last year's successive landfalls of HIM,



all three of which rank in the top five most expensive hurricanes on record (in terms of inflation-adjusted insured losses). Both AIR and RMS have already indicated that insights obtained from HIM will be important factors in future hurricane model releases.

MARKET IMPACT

Using history as a guide, these recalibrations could have an important bearing on the property-catastrophe market. Figure 2 illustrates how the evolution of catastrophe modelling has been crucial to the development of the property market over the last 25 years. During this time, catastrophe models have become integral to the property underwriting process by assisting decision-making on exposure management, risk aggregation, pricing and reinsurance buying.

Hurricane Katrina was a watershed moment for the market for two key reasons.

First, catastrophe modelling became embedded into carriers' risk management strategies as metrics made readily available by the probabilistic vendor models were used to satisfy new rating agency requirements around capital allocation for catastrophe risks. Second, catastrophe models facilitated the rapid expansion of the insurance-linked securities (ILS) market as institutional investors utilised recalibrated models (post-Katrina and Ike) to price catastrophe risks. It is no exaggeration to say that the ILS market in its current form would not exist today without catastrophe modelling.

The impact alternative capital has had on the reinsurance sector is difficult to overstate. It has brought about a structural change in how capital is provided to the market and in how much capital can enter (and exit) the sector.

Figure 2: Key Developments in the Property-Catastrophe Market (Source: JLT Re)



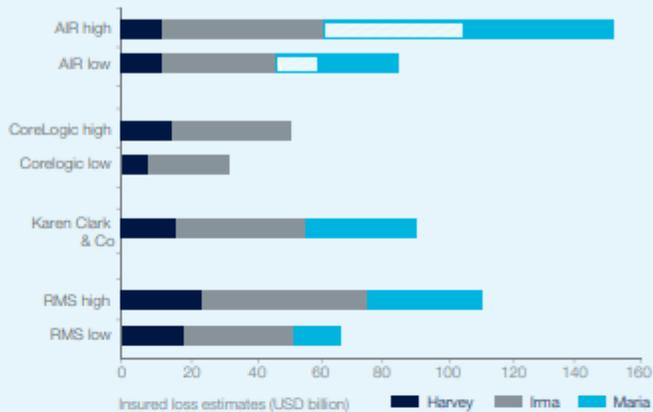
And, as JLT Re's Risk-Adjusted Global Property-Catastrophe Reinsurance Rate-on-Line (ROL) Index in Figure 2 shows, it has played a leading role in driving pricing down to levels last seen in the early 2000s. Whilst traditional capital levels have essentially remained flat since 2012, alternative capital (which is overwhelmingly focused on US wind risks) has doubled. Investor confidence in the current suite of catastrophe modelling applications has underpinned this growth.

Of course, these new capital inflows coincided with an unusual lull in hurricane activity, meaning recent model recalibrations had gone largely untested. Indeed, the period of no major US hurricane landfalls in the decade between 2005 (Wilma) and 2016 was historically unprecedented. But then the 2017 hurricane season happened, bringing three massive hurricane strikes to US territories and causing widespread devastation across the Caribbean as hurricanes Harvey, Irma and Maria formed in quick succession.

UNDER THE SPOTLIGHT

After every large-loss year, it seems questions are asked about the accuracy of vendor market loss estimates, and the value they bring. This was the case in 2005, 2008, 2011 and 2012. And 2017 was no different. Figure 3 shows the high and low post-landfall estimates provided by different modelling firms for HIM. Subsequent (and significant) revisions made to estimates are also captured in the chart, with the patterned and filled (combined) entries of the same colour representing initial estimates

Figure 3: Loss Estimates for HIM by Catastrophe Modelling Company
(Source: JLT Re, AIR, CoreLogic, KCC, RMS)



and the filled entries showing most recent updates. The fact that such significant ranges were generated for HIM has raised questions over whether modelling tools can be relied upon to produce credible information for catastrophes in real time.

But are these charges fair? After all, catastrophe models are built to provide probabilistic outcomes for a wide range of scenarios rather than predict the monetary cost of any single event in real time. And, in doing the latter, catastrophe modelling firms are responding to intense pressure from various market participants, including carriers, brokers, investors and the media, to release market loss estimates as quickly as possible. In fact, HIM reinforced the need for real-time loss information as modelled estimates were used to inform traditional carriers' loss guidance and post-event capital deployment strategies. Additionally, pressing

reporting requirements saw many ILS funds rely on modelled loss estimates to provide initial loss evaluations to investors.

But with greater reliance comes greater scrutiny. Given the large divergences of loss estimates for HIM, catastrophe models are once again under the spotlight. And as the peak months of this year's hurricane season approach, several questions remain unanswered. Are unfavourable perceptions with regard to historical modelled loss estimates justified? Did 2017 mark a deterioration in accuracy compared to previous large-loss years? How did the modelling companies perform last year when compared to other significant hurricane events? And can the market expect modelled loss estimates to become more accurate and narrow as techniques and technologies mature? All these points will be explored in the following pages.

SECTION 2: THE LOSS FORECASTING BUSINESS

To help inform the debate, JLT Re has undertaken an exercise to explore the precision of modelled market loss estimates for significant hurricanes since 2004 by comparing them to fully incurred losses for each respective event¹. The purpose of this study is to gauge the performance of loss estimates during the lifespan of hurricane events and assess whether any trends or lessons can be gleaned for future reference.

The parameters of the analysis have been restricted to North Atlantic hurricanes, given they are the world's most comprehensively analysed region and peril. Ultimately, if US hurricane estimates do not stand up to scrutiny, they will not do so anywhere else. Loss estimates provided by AIR and RMS have been used in the exercise².

METHODS AND TIMELINES

Figure 4 shows the timeline that catastrophe modelling firms typically work towards when releasing market loss estimates for significant hurricane events. Whilst this, of course, only applies to storms that develop out at sea with sufficient lead time before US landfall (i.e. three to four days), it illustrates the rigorous steps these companies undertake when compiling market loss estimates.

In the lead up to, and immediately after, landfall, meticulous work goes into modelling unique scenarios for each event by selecting tracks from hundreds of thousands of stochastic events that closely resemble forecasted path and intensity. The number of tracks dwindles quickly as landfall nears as factors such as location, forward speed and windfield size are almost impossible to replicate in combination. After all, every storm is unique and whilst the imminent release of high-definition models will help provide more clarity going forward, this will continue to be a major source of uncertainty.

Once a range of simulated events has been selected, they are then applied to industry exposure databases (IEDs) to calculate market loss estimates. This is a crucial step in the process as recent events have highlighted how differing exposure assumptions can lead to hugely divergent views.

For major events, loss estimates are further refined once post-landfall hazard data are made available from the National Hurricane Center (NHC) and incorporated into the models to create bespoke wind and storm surge footprints. During this entire process, crucial judgements are made by catastrophe modelling experts when examining the models' statistical outcomes and determining where in the distribution losses are likely to occur.

During the entire loss estimation process, crucial judgements are made by the vendors when examining the models' statistical outcomes and determining where in the distribution losses are likely to occur.

¹ The sample of hurricanes used in the study included: Charley, Frances, Ivan, Jeanne, Katrina, Rita, Wilma, Gustav, Ike, Irene, Sandy, Harvey, Irma and Maria.

² Catastrophe modelling firms' loss data points have been compiled from a variety of sources, including firms' websites, press releases and media reports.

Figure 4: Timelines for US Hurricane Loss Estimation (Source: JLT Re)



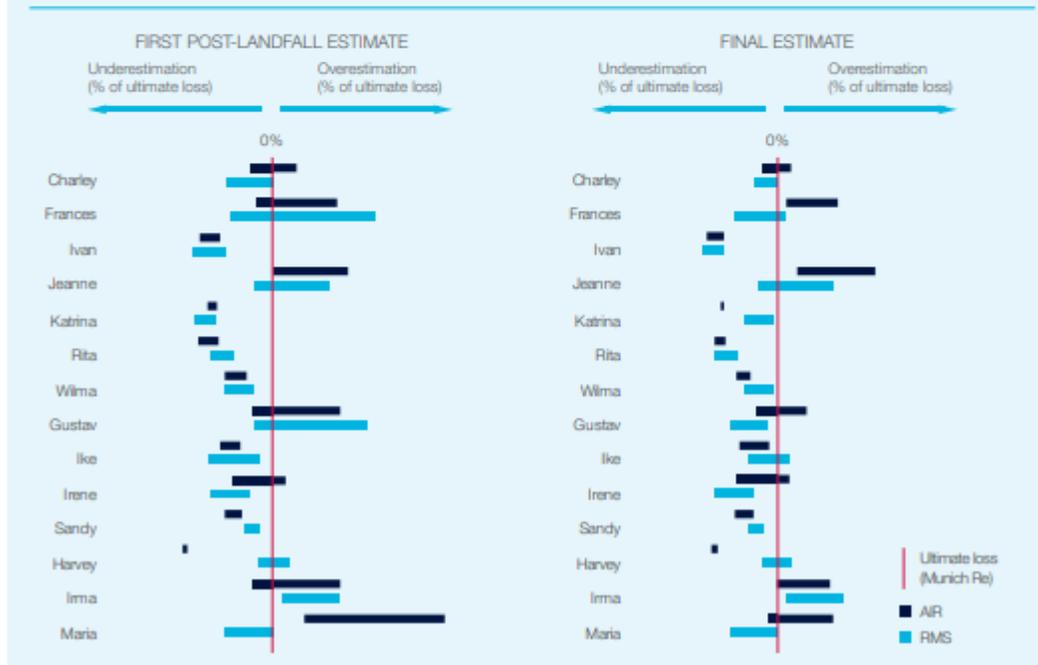
MODELLED LOSS (IN)ACCURACY

The culmination of these efforts is shown in Figure 5, which provides a helicopter view of how the modelled industry loss estimates collected in our study evolved during the loss estimation period. The line in the middle of both graphics represents the final, total insured loss for each respective hurricane as per Munich Re (including flood losses) and the bars show how AIR's (dark blue) and RMS's (light blue) estimates compared as a percentage of this total.

Pre-landfall industry loss estimates, which AIR provides to its clients up to 48 hours or 24 hours before US mainland landfall, and which will be shown in the individual case studies that follow, have not been included in Figure 5 as the huge permutations around track trajectories and storm parameters at landfall typically result in ranges that deviate massively from the actual insured loss. RMS, meanwhile, does not provide any predictions before or immediately after landfall, focusing instead on post-landfall industry loss estimates.

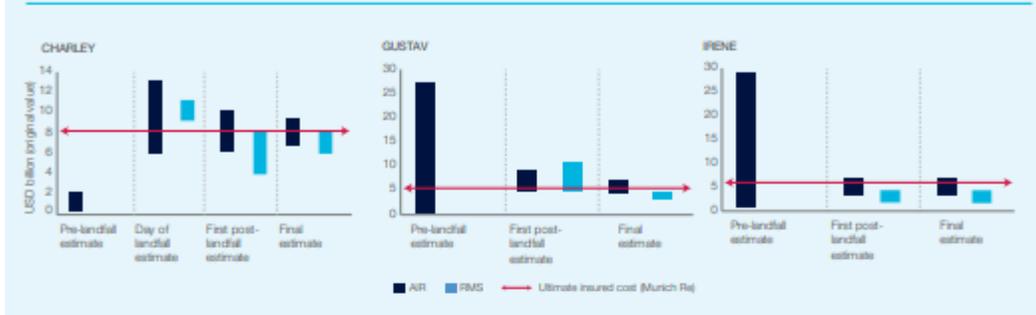
Whilst the uncertainty in vendor-modelled loss estimates decreases significantly after landfall, this has not always translated into increased accuracy relative to the ultimate loss. It is important to note here that the ultimate loss data used in our study will occasionally include loss components – such as flood, loss adjustment expenses (LAE) and contingent business interruption (CBI) – that are un-modelled by AIR and RMS and are therefore not included in their loss estimates.

Figure 5: Evolution of Modelled Loss Estimates for Select US Hurricanes – 2004 to 2017² (Source: JLT Re, AIR, RMS, Munich Re)



² Please note that for Harvey, AIR's estimates (both 'first post-landfall' and 'final') do not include National Flood Insurance Program (NFIP) losses whilst RMS's and Munich Re's figures do.

Figure 6: Favourable Performance of Modelled Losses (Source: JLT Re, AIR, RMS, Munich Re)



Nevertheless, it is equally important to acknowledge that market participants look to the catastrophe modelling firms to provide comprehensive loss estimates and any restrictions in what they capture are often viewed as significant limitations that need to be addressed.

Ultimately, Figure 5 shows a trend towards loss underestimation for the majority of initial post-landfall estimates, with HIM the clear exception (left of chart). Additionally, subsequent revisions made to both AIR's and RMS's ranges, which often attempted to account for significant un-modelled losses, frequently continued to miss on the downside. Overall, the majority of final estimates settled on a range that fell outside the ultimate insured loss window (right of chart).

This snapshot goes some way to explaining why the industry loss estimates provided by catastrophe modelling firms have led to general scepticism within the (re)insurance market over the last 15 years or so.

There is an overriding trend towards significant loss underestimation, and it is not even immediately apparent that the range of loss estimates narrows during the lifespan of storms, or that they always become more accurate.

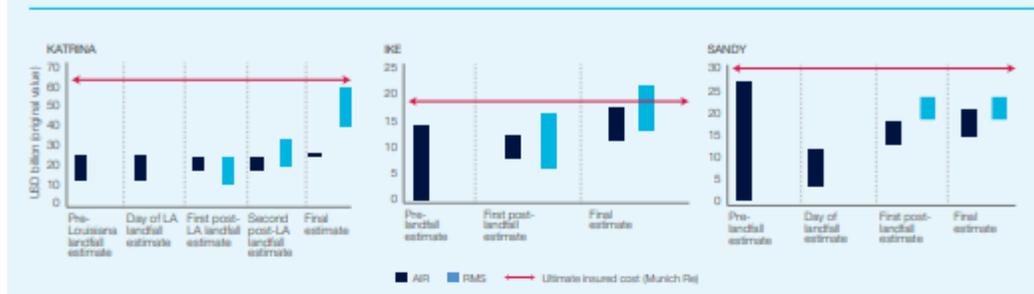
As alluded to earlier, this has important consequences in today's data-hungry world. With real-time loss information playing an increasingly crucial role in setting initial loss guidance, several carriers have been forced to make significant revisions to their own loss estimates as claims develop unexpectedly. Investor confidence and carriers' share prices can suffer in instances where expected losses develop adversely (as they did for most of the devastating storms in the recent past), fuelling unfavourable perceptions of modelling companies and other loss forecasters within the market. This, over time, has encouraged a general predisposition within the market to discount the bottom-end of ranges and expect losses to settle at, or above, the top.

HISTORICAL COMPARISONS

But are these perceptions justified? Breaking down industry loss estimates into groups of storms with similar characteristics reveals some interesting insights about model performance prior to 2017. Figure 6 shows that vendor models have performed relatively well for wind events that incurred moderate losses, regardless of landfall location. Results for hurricanes Charley (FL, 2004), Gustav (TX, 2008) and Irene (NC & NJ, 2011) suggest credible levels of accuracy (post-landfall) when loss components are anticipated and contained.

With real-time loss information playing an increasingly crucial role in setting initial loss guidance, several carriers have been forced to make significant revisions to their own loss estimates as claims develop unexpectedly.

Figure 7: Substandard Performance of Modelled Losses (Source: JLT Re, AIR, RMS, Munich Re)



Or, in other words, conventional hurricane events that do not assume super-cat characteristics are captured adequately by vendor catastrophe models, and this is reflected in the loss estimates provided for such events.

All three hurricanes had different intensities and landfall regions. Whilst Charley was a major hurricane when it came ashore along Florida's western coastline, Gustav was a category 2 storm when it made landfall in Texas (having moved through the Gulf of Mexico and caused damage to offshore oil assets) and Irene was a category 1 hurricane when it hit North Carolina. Each of these events generated insured losses of less than USD 10 billion, demonstrating that the market can expect modelled post-landfall estimates to be within a reasonable range of the fully developed figure for losses that are both wind driven and moderate in magnitude.

Breaking down industry loss estimates into groups of storms with similar characteristics reveals some interesting insights about model performance.

The models, however, have not performed as well for hurricane events where losses extend beyond wind into areas that are not modelled or well understood. Katrina, Ike and Sandy are three examples of such storms, and the evolutions of AIR's and RMS's modelled loss estimates for each are shown in Figure 7.

Despite a number of revisions being made in the days and weeks after Katrina's landfall, both AIR and RMS consistently underestimated the magnitude of the ultimate insured loss. This can mostly be explained by the flooding of New Orleans, a secondary consequence that virtually eclipsed the original catastrophe. Indeed, the models' limitations were laid bare by

the extent of the flood damage, as well as other non-modelled factors such as loss amplification (which includes demand surge and claims inflation) and wind versus flood disputes.

Such unique super-cat effects are extremely challenging to model and go a long way to explaining the huge divergence between AIR's and RMS's final Katrina estimates (which, unsurprisingly, is the largest of the entire sample in our study). AIR's much narrower range was in line with previous estimates but ultimately proved to be less than half of the ultimate insured loss. RMS, meanwhile, significantly increased its final projection, albeit with a wide margin for error (i.e. a USD 20 billion difference between the high and low end), and even this proved insufficient.

Ike and Sandy provide other, albeit less exaggerated, examples of loss underestimation around the time of landfall. Both storms had unforeseen attributes, which again helps to

account for the sub-par accuracy of the modelled loss estimates. Although neither event was classified as a major hurricane, they still packed a punch as Ike caused more damage inland than modellers expected and Sandy was largely a surge and flood event after it made landfall in New Jersey on an unusual trajectory.

All this highlights the inherent difficulties modelling companies face in predicting losses when tropical cyclones strike highly populated urban areas. These types of events often bring unforeseen (and often un-modelled) consequences that cause losses to spiral. The results for Katrina, Ike and Sandy show that catastrophe models have struggled to generate accurate loss ranges in such circumstances. Beyond these three storms, there have been other significant hurricanes, including Ivan and Wilma, where both AIR and RMS significantly underestimated the cost to the sector.

HIM: A NEW BENCHMARK?

On the face of it, the estimates released by the modelling companies in the days and weeks after HIM made landfall in 2017 seemed to reinforce market perceptions that catastrophe models cannot be relied on to predict accurately industry loss estimates. After all, the loss ranges were both vast and diverse. But whilst there is no denying that the accuracy of the modelled losses released in 2017 was mixed, closer analysis reveals that important differences emerged last year.

Figure 8 on page 14 shows the ranges released by AIR and RMS for Hurricane Irma. Despite the magnitude of the catastrophe (insured losses are currently expected to exceed USD 30 billion), neither AIR nor RMS underestimated the total and their post-landfall estimates remained largely consistent. In addition, whilst the loss estimates released by both modelling companies were initially deemed high, there is still significant uncertainty associated with Irma's loss and there is some evidence that claims development in the US may yet move Irma's ultimate insured cost into the lower end of AIR's and RMS's final estimates. Notwithstanding criticisms over the range of the estimates, this is a reasonable performance given the complexities associated with the event.

This initial consensus was short-lived, however, as Maria split opinion as never before (see Figure 9 on page 14). AIR's original top-end Maria estimate was nearly three times that of RMS and there was no overlap between its lower-end and RMS's top. The gulf stemmed in large part from differing judgements made over Maria's windfield size at landfall, ground-up exposures, repair costs and insurance coverages and terms (for business interruption especially) in Puerto Rico. Whilst RMS maintained its view, AIR substantially revised its estimate downwards as it altered assumptions around modelled wind speeds, insurance take-up rates in Puerto Rico and loss distributions across each line of business (industrial lines in particular).



Figure 8: Evolution of Modelling Companies' Market Loss Estimates for Hurricane Irma
(Source: JLT Re, AIR, RMS, Munich Re)

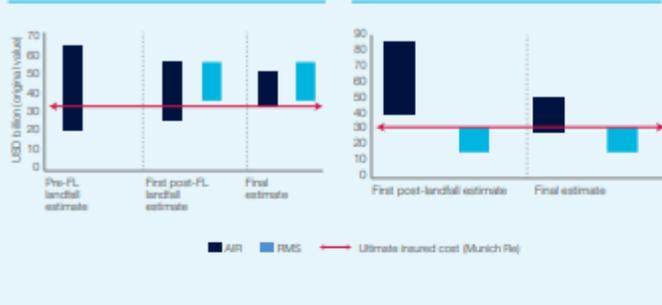


Figure 9: Evolution of Modelling Companies' Market Loss Estimates for Hurricane Maria
(Source: JLT Re, AIR, RMS, Munich Re)

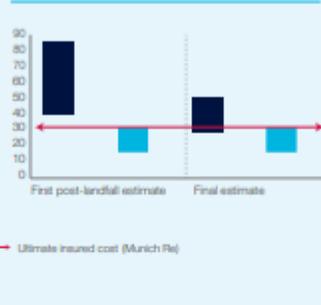


Figure 10: Complex Loss Profile of Hurricane Maria (Source: JLT Re, RMS)



The second, frequently overlooked by industry participants, including the media in particular, is the need for catastrophe modelling firms to balance any incentive of being first to market with accuracy. The requirements and expectations of real-time information will only increase and it is important that catastrophe modelling companies strengthen their authority in this area: accuracy needs to be the focus so that decision-makers can be confident in the numbers. Reducing core components of uncertainty in the real-time loss estimation process, particularly for hazard and exposure assessments, will augment accuracy and reduce the need for large ranges.

Unfortunately for catastrophe modelling firms, failures endure far longer in the memory than successes and a significant credibility gap remains, justified or not. Progress is being made (as supported by the results of our study) but perhaps the market can further assist the catastrophe modelling firms by refraining from the call for immediate estimates and waiting for a more considered view.

Post-Maria, it is evident that the increasing sophistication of windfield generation during and after the event, along with timely event reconnaissance trips to the most heavily impacted areas, influenced both the evolution of loss estimates and the range of uncertainty. Although the range of AIR's final estimate was subsequently narrowed to USD 21 billion (from USD 45 billion originally), it remains the largest in the entirety of this

study and raises questions about how large modelled market estimates can be, given a mid-point range of expectations, before they lose utility and credibility.

Two important points should not be lost in all of this, however. The first is that RMS deserves credit for the precision of its one and only loss estimate, especially given the high amount of uncertainty that was associated with Maria (see Figure 10).

The requirements and expectations of real-time information will only increase and it is important that catastrophe modelling companies strengthen their authority in this area: accuracy needs to be the focus so that decision-makers can be confident in the numbers.

SECTION 3: IN THE EYE OF THE STORM

Having assessed vendor market loss estimates for recent US hurricanes, it is clear that no catastrophe model is perfect. Given the multiple areas of uncertainty in determining the hazards, exposures and vulnerabilities during major events, vendor loss estimates are always likely to fall short of the precision levels desired by the market. With this being the case for hurricane risks, even greater variability can be expected for other natural hazards such as earthquakes, floods and convective storm outbreaks, as they are comparatively underdeveloped as modelled perils.

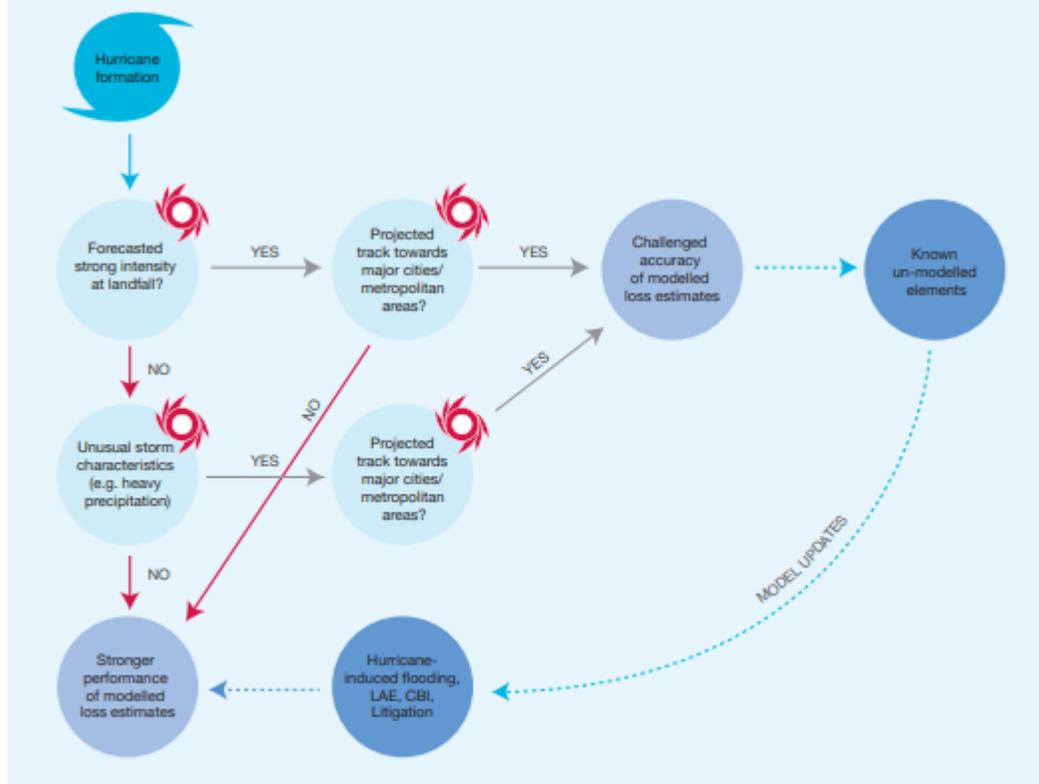
Challenged modelled loss accuracy for hurricane events is not an unexpected conclusion to emerge from the study and should not be interpreted as degrading the value of vendor modelling tools. After all, catastrophe models were not designed to predict the costs of individual events in real time and their primary purpose of assisting carriers in understanding and quantifying their risks is undisputed. The results are clear: whilst several carrier insolvencies followed Andrew (and Katrina to a lesser degree), billions of dollars in claims have been paid out post-HIM with no significant capital impairments.

A number of key conclusions emerge from this study, some, such as the importance of understanding differences between estimates, are more clear-cut than others. Having a range of views post-event can actually benefit carriers, brokers and investors as long as the important drivers are clearly communicated, particularly in situations where significant divergences occur.

Catastrophe modelling firms can assist the market further here by better communicating the levels of uncertainty contained within each estimate and providing more transparency around the various assumptions that are driving loss estimates. It is likewise incumbent on market participants to review rigorously, or even challenge, some of the more extreme loss estimates released by modelling firms. Scrutinising assumptions that can drive vastly different views of events (such as the physical parameters of the hazard or insurance take-up rates) is recommended best practice in establishing whether loss estimates pass initial tests of credibility.

Challenged modeled loss accuracy for hurricane events is not an unexpected conclusion to emerge from the study and should not be interpreted as degrading the value of vendor modeling tools.

Figure 11: Template for Gauging Accuracy of Modelled Industry Losses (Source: JLT Re)



This study also reveals important trends which can help the market gauge the likely accuracy of modelled loss estimates for hurricane events in the lead up to landfall, or immediately thereafter (see Figure 11). Analysis conducted for this report shows that hurricane losses which are both conventional (i.e. driven by wind/surge) and contained (i.e. less than USD 10 billion in total) are far more likely to be captured accurately by the vendor catastrophe models.

Over time, vendor firms will draw on lessons learned during such events to refine their models and incorporate a whole host of un-modelled perils.

Conversely, more complex hurricanes which often bring unforeseen and un-modelled consequences are far more challenging to predict. Not only are such events unlikely to be replicated

by the stochastic event sets initially used by catastrophe modelling firms, but any unusual storm characteristics are difficult to simulate even after landfall. The surge that caused the levees to fail in New Orleans after Katrina struck, the unusual trajectory of Superstorm Sandy or the record-breaking precipitation that inundated Houston with Hurricane Harvey are such examples.

All three of these storms saw vast differences in estimates between AIR and RMS due to un-modelled elements. In each case, un-modelled loss components accounted for a significant proportion (if not the majority) of the total cost. Ultimately, making real-time loss predictions for events that bring new loss phenomena is more art than science. This is reflected by the highly divergent views between the modelling companies.

Over time, however, vendor firms will draw on lessons learned during such events to refine their models and incorporate a whole host of un-modelled perils. Contributions from the academic and engineering communities will also continue to assist them in this area. Hurricane-induced flood and LAE are likely to be key areas of focus in the near term following HIM. Another theme that is starting to emerge from 2017 claims data, particularly for Irma, is the strong performance of newer construction and roofs in the highest wind zones. One possible implication for future model updates is that the building codes implemented and enforced, post the 2008 financial crisis, have performed even better than current modelling assessments. This may go some way to explaining why AIR's and RMS's estimates in 2017 broke the overriding trend of underestimating major losses and raises questions over whether recent model revisions (which were only first tested during HIM) may have overcorrected previous shortcomings.

Catastrophe modelling firms can assist the market by better communicating the levels of uncertainty contained within each estimate and providing more transparency around various assumptions.

Technological advancements will also drive future improvements to catastrophe models. Remote sensing on next generation satellites, as well as drone data, are already having an impact by facilitating the capture of more accurate satellite-derived wind speeds, improving post-event damage assessments (augmented by artificial intelligence detection methods) and enhancing the exposure calibration processes for higher resolution IEDs. Hurricane Maria was a stark example of how differing views on industry exposure can lead to disproportionate levels of variance between modelled estimates.

By leveraging increased skill in weather prediction, catastrophe modelling firms will soon be able to move away from pure stochastic track-driven estimates pre- (and immediately following) landfall and utilise real-time clustering methods to generate probabilistic scenarios. This will greatly enhance the windfield generation process and lead to a more robust statistical assessment of outcomes. Improved weather forecasting will also bring more tangible impacts by enabling further hurricane preparation and loss mitigation measures ahead of landfall.

Even with these advances, modelled loss estimates will no doubt continue to be the subject of scrutiny and scepticism in future years. And yet, their utility looks set to only grow as demand from carriers, brokers and investors for real-time loss information will only increase in today's data-hungry world. With peak hurricane season upon us, JLT Re's Analytics team is committed to providing differentiated real-time catastrophe reporting through its CATz blog to help clients understand and quantify the uncertainties associated with each event and any published modelled loss estimate. JLT Re's Cat Model Insight (CMI) function has also been created to assist clients with the model validation process by assessing various model components and identifying potential un-modelled elements of loss.

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8. Assignment 4, Module 1: III Facts and Figures: <https://www.iii.org/fact-statistic/facts-statistics-us-catastrophes>

Facts + Statistics: U.S. catastrophes

Natural catastrophes

Aon defines a catastrophe as a natural event that causes any of the following:

- \$25 million or more in insured property losses
- ten deaths
- 50 people injured
- 2,000 filed claims or homes and structures damaged.

Aon's natural catastrophe estimates include Puerto Rico and the U.S. Virgin Islands and include losses sustained by private insurers and government-sponsored programs such as the National Flood Insurance Program. They are subject to change as loss estimates are further developed.

Natural Catastrophe Losses In The United States By Peril, 2024 (1)

(\$ millions)

Peril	Number of events	Fatalities	Economic losses (2)	Insured losses (3)
Tropical cyclone	5	328	\$121,555	\$43,717
Severe convective storm	49	99	68,579	53,967
Wildfire, drought, heatwave	9	1,033	10,519	5,548
Winter weather	6	89	6,809	4,020
Flooding	12	27	10,189	5,323
Total	81	1,576	\$217,651	\$112,575



(1) Natural disasters that cause at least \$25 million in insured losses; or 10 deaths; or 50 people injured; or 2,000 filed claims or homes and structures damaged. Includes Puerto Rico and the U.S. Virgin Islands.

(2) Includes any direct physical damage or direct net loss business interruption costs.

(3) Includes losses sustained by private insurers and government-sponsored programs such as the National Flood Insurance Program. Subject to change as loss estimates are further developed. As of January 2025.

Source: Aon.

Natural Catastrophes By Quarter, 2024 (1)

(2024 \$ millions)

Quarter	Estimated Insured losses
1	\$18,680
2	36,587
3	35,186
4	22,377
Full year	\$112,830

(1) Natural disasters that cause at least \$25 million in insured losses; or 10 deaths; or 50 people injured; or 2,000 filed claims or homes and structures damaged. Includes Puerto Rico and the U.S. Virgin Islands. Includes losses sustained by private insurers and government-sponsored programs such as the National Flood Insurance Program. Subject to change as loss estimates are further developed. As of January 2025.

Source: Aon.

[View Archived Tables](#)

Estimated Insured Property Losses, U.S. Natural Catastrophes, 2015-2024 (1)

(\$ billions)

Year	In dollars when occurred	In 2024 dollars (2)
2015	\$23.0	\$30.7
2016	31.9	41.9
2017	131.0	168.1
2018	60.9	76.4
2019	39.2	48.5
2020	81.5	99.3
2021	93.3	108.7
2022	109.6	116.9
2023	80.0	82.9
2024	112.8	112.8

(1) Natural disasters that cause at least \$25 million in insured losses; or 10 deaths; or 50 people injured; or 2,000 filed claims or homes and structures damaged. Includes Puerto Rico and the U.S. Virgin Islands. Includes losses sustained by private insurers and government-sponsored programs such as the National Flood Insurance Program. Subject to change as loss estimates are further developed. As of January 2025. Adjusted for inflation by Aon using the U.S. Consumer Price Index.

Top 10 Costliest Natural Catastrophes, United States (1)

(\$ millions)

Rank	Year	Peril	Estimated insured property loss	
			Dollars when occurred	In 2024 dollars (2)
1	2005	Hurricane Katrina	\$65,000	\$104,471
2	2022	Hurricane Ian	54,000	57,231
3	2021	Hurricane Ida	36,000	41,540
4	2012	Hurricane Sandy	30,000	40,939
5	2017	Hurricane Harvey	30,000	38,571
6	2017	Hurricane Irma	30,050	38,432
7	2017	Hurricane Maria	29,511	37,743
8	1992	Hurricane Andrew	16,000	35,845
9	1994	Northridge Earthquake	15,300	33,035
10	2008	Hurricane Ike	18,200	26,259

(1) Natural disasters that cause at least \$25 million in insured losses; or 10 deaths; or 50 people injured; or 2,000 filed claims or homes and structures damaged. Includes Puerto Rico and the U.S. Virgin Islands.

Includes losses sustained by private insurers and government-sponsored programs such as the National Flood Insurance Program. Subject to change as loss estimates are further developed. As of January 2025.

(2) Adjusted for inflation by Aon using the U.S. Consumer Price Index.

Source: Aon.

9. Assignment 4, Module 1: Munich Re NatCat Information:

<https://www.catriskcredentials.org/wp-content/uploads/2019/04/NatCatService.pdf>



NatCatSERVICE

Relevant natural loss events in North America 1990 - 2017

28 June 2018

Munich RE 

Geographical overview

Relevant natural loss events
in North America 1990 - 2017

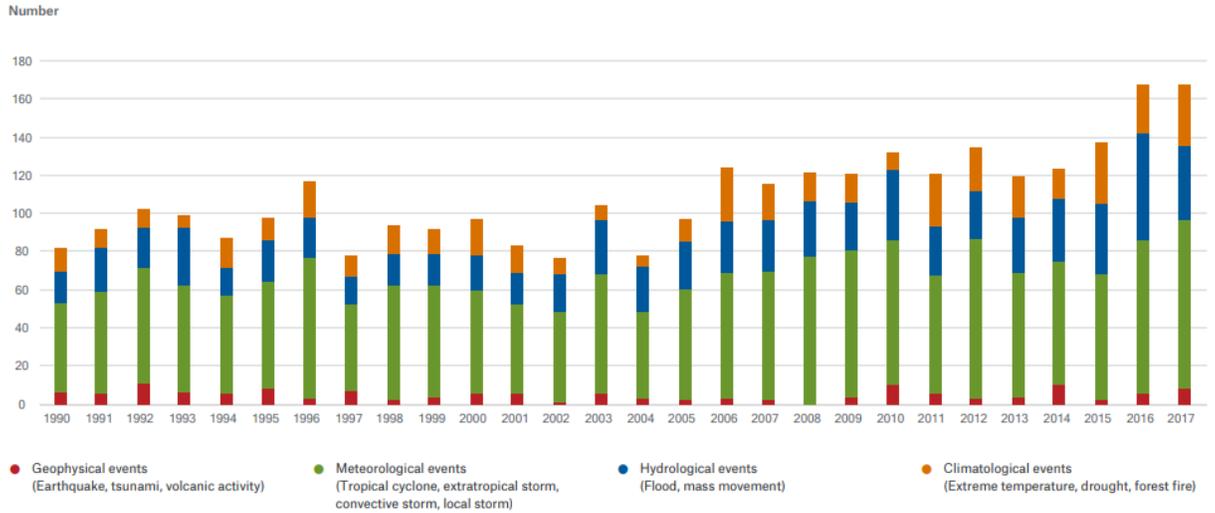


Source: Munich Re, NatCatSERVICE, 2018

- Small, medium and large loss events
 - Catastrophes
 - Geophysical events
(Earthquake, tsunami, volcanic activity)
 - Meteorological events
(Tropical cyclone, extratropical storm,
convective storm, local storm)
 - Hydrological events
(Flood, mass movement)
 - Climatological events
(Extreme temperature, drought, forest fire)
- 3,063** registered events

Number of events

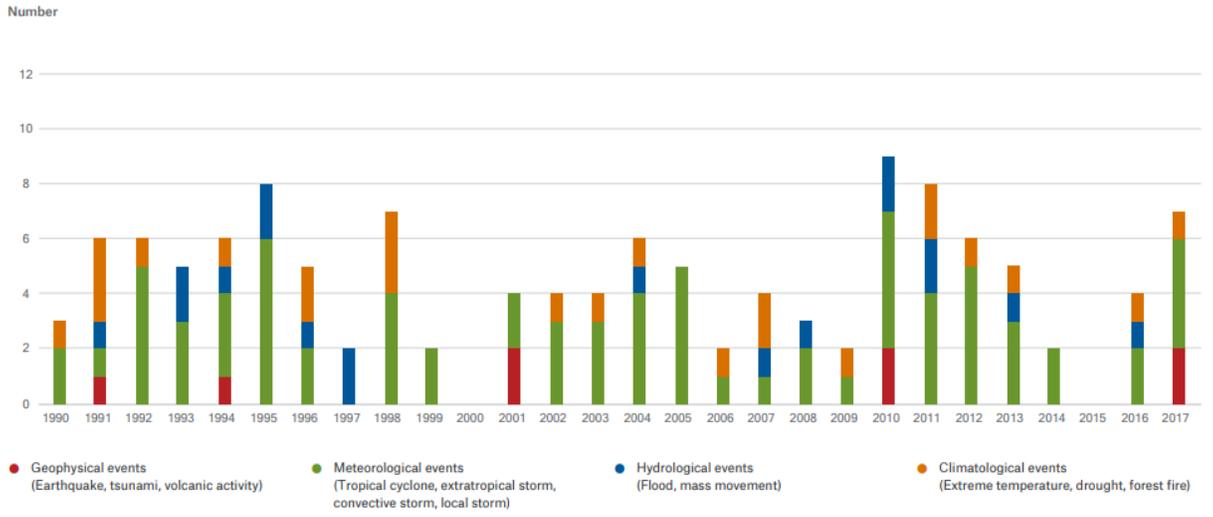
Relevant natural loss events
in North America 1990 - 2017



Accounted events have caused at least one fatality and/or produced normalised losses \geq US\$ 100k, 300k, 1m, or 3m (depending on the assigned World Bank income group of the affected country).

Number of events

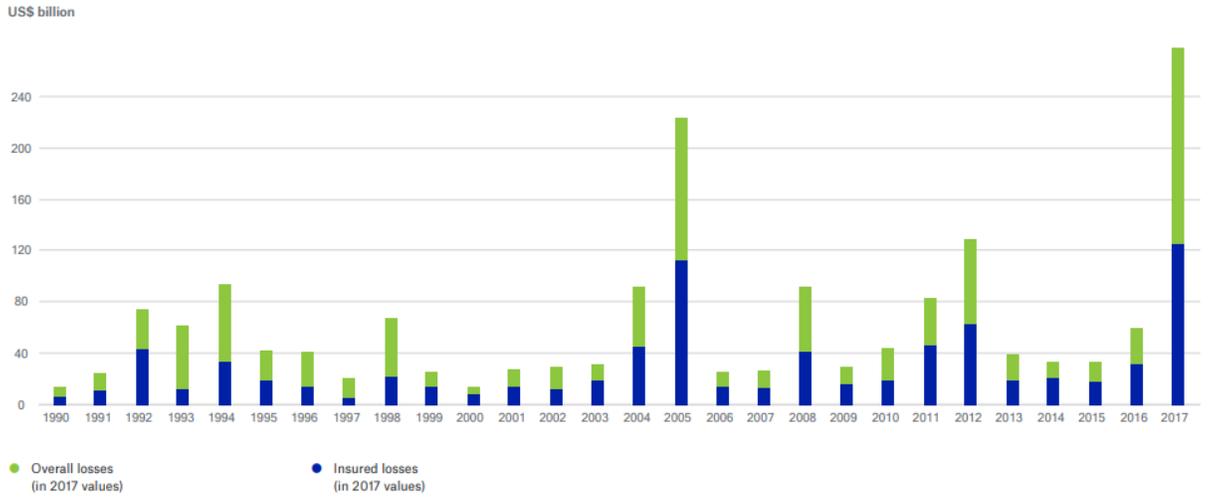
Catastrophic natural loss events
in North America 1990 - 2017



Accounted events have caused ≥ 1,000 fatalities and/or produced normalised losses ≥US\$ 100m, 300m, 1bn, or 3bn (depending on the assigned World Bank income group of the affected country).

Overall and insured losses in US\$

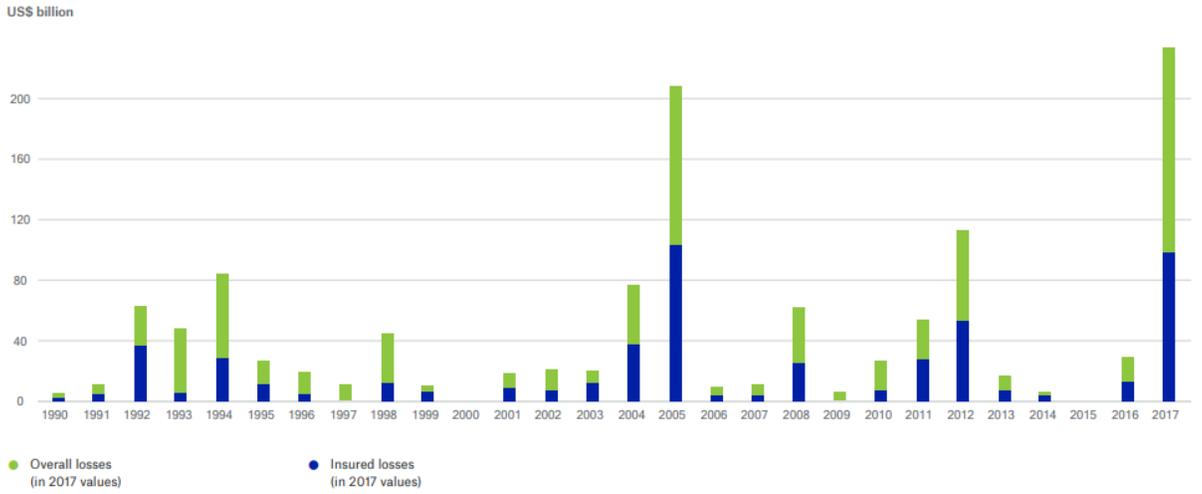
Relevant natural loss events
in North America 1990 - 2017



Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and US\$.

Overall and insured losses in US\$

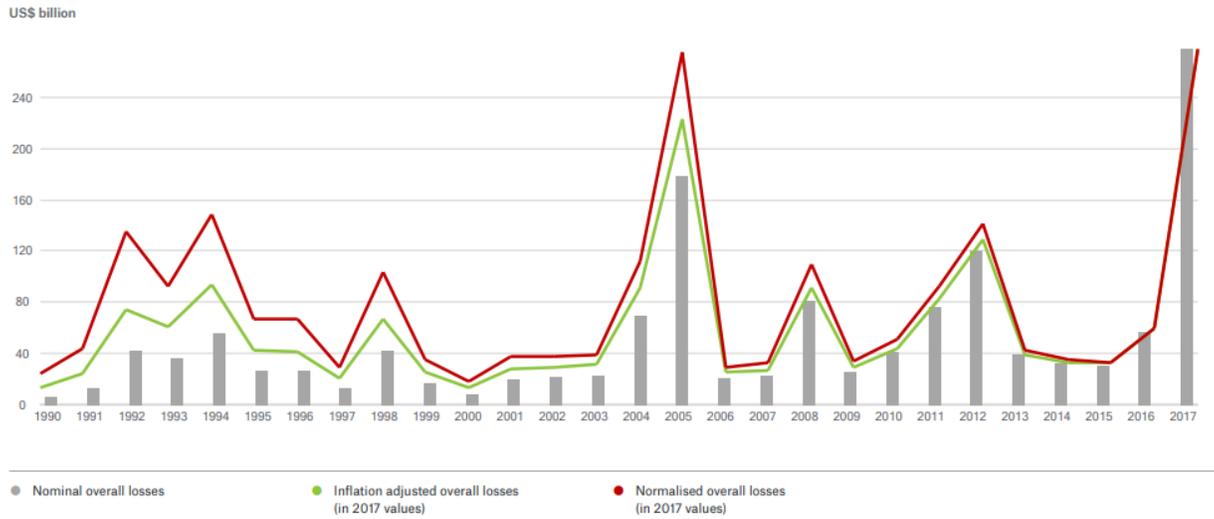
Catastrophic natural loss events
in North America 1990 - 2017



Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and US\$.

Overall losses in US\$: nominal, inflation adjusted, and normalised

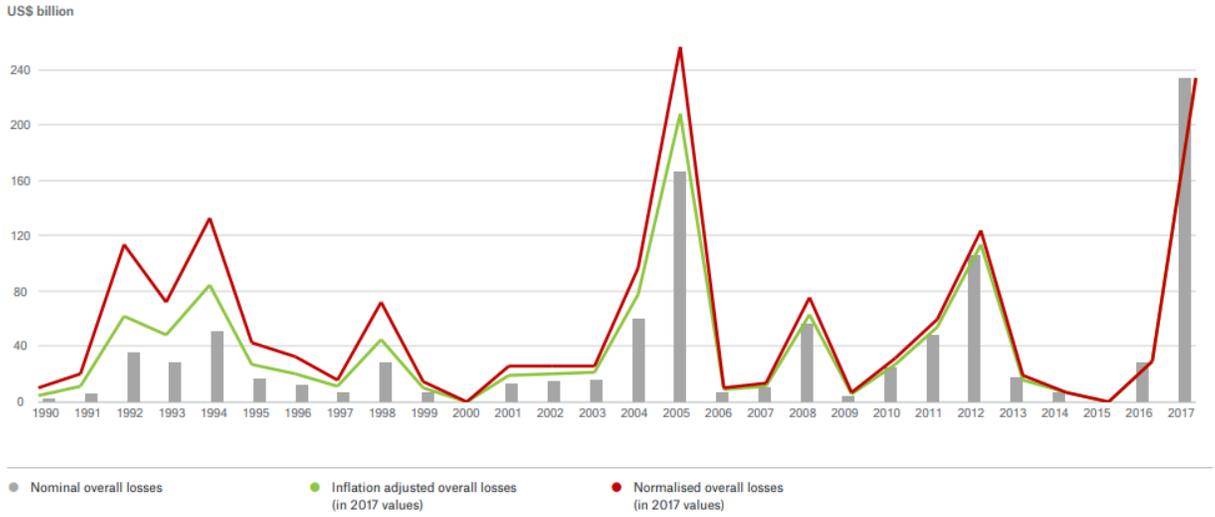
Relevant natural loss events
in North America 1990 - 2017



Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and US\$.
Normalization via local GDP developments measured in US\$.

Overall losses in US\$: nominal, inflation adjusted, and normalised

Catastrophic natural loss events
in North America 1990 - 2017



Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and US\$.
Normalization via local GDP developments measured in US\$.

Percentage distribution by event family

Relevant natural loss events
in North America 1990 – 2017

Number of events:
3,063



Overall losses:
US\$ 1,743bn



Fatalities :
202,898



Insured losses :
US\$ 811bn



- Geophysical events (Earthquake, tsunami, volcanic activity)
- Meteorological events (Tropical cyclone, extratropical storm, convective storm, local storm)
- Hydrological events (Flood, mass movement)
- Climatological events (Extreme temperature, drought, forest fire)

Accounted events have caused at least one fatality and/or produced normalised losses \geq US\$ 100k, 300k, 1m, or 3m (depending on the assigned World Bank income group of the affected country).

Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and US\$.

Percentage distribution by event family

Catastrophic natural loss events
in North America 1990 - 2017

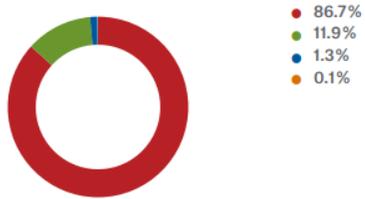
Number of events:
125



Overall losses:
US\$ 1,229bn



Fatalities :
185,040



Insured losses :
US\$ 522bn



- Geophysical events (Earthquake, tsunami, volcanic activity)
- Meteorological events (Tropical cyclone, extratropical storm, convective storm, local storm)
- Hydrological events (Flood, mass movement)
- Climatological events (Extreme temperature, drought, forest fire)

Accounted events have caused ≥ 1,000 fatalities and/or produced normalised losses ≥ US\$ 100m, 300m, 1bn, or 3bn (depending on the assigned World Bank income group of the affected country).

Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and US\$.

5 costliest events ordered by nominal overall losses

Relevant natural loss events in North America 1990 – 2017

Date	Event	Affected Area	Overall losses (US\$m, original values)	Insured losses (US\$m, original values)	Fatalities
25 - 30 Aug 2005	Hurricane Katrina, storm surge	United States: LA, New Orleans, Slidell, MS, Biloxi, Pascagoula, Waveland, Gulfport, Bay St. Louis, Hattiesburg, McComb, AL, FL	125,000	60,500	1,720
25 Aug - 1 Sep 2017	Hurricane Harvey, storm surge, flood	United States: TX, Harris County, Houston, Rockport, Refugio, Corpus Christi, Galveston, Crosby, LA, Lake Charles, Evangeline, AL, LA, MS, NC, TN, Nashville, Davidson County	95,000	30,000	88
23 - 31 Oct 2012	Hurricane Sandy, storm surge	United States, Cuba, Haiti, Bahamas, Canada, Jamaica, Dominican Republic, Puerto Rico	68,400	29,200	207
19 - 22 Sep 2017	Hurricane Maria, flood	Puerto Rico, Dominica, Virgin Islands, U.S., Guadeloupe, Dominican Republic, Martinique, Haiti	68,000	29,600	108
6 - 14 Sep 2017	Hurricane Irma, storm surge, flood	United States, Virgin Islands, U.S., Virgin Islands, British, Cuba, Saint Martin, Sint Maarten, Saint Barthelemy, Anguilla, Puerto Rico, Turks and Caicos Islands, Antigua and Barbuda, Bahamas, Bonaire, Sint Eustatius, Saba, Dominican Republic, Haiti, Saint Kitts and Nevis	57,200	28,900	128

5 costliest events ordered by nominal insured losses

Relevant natural loss events
in North America 1990 - 2017

Date	Event	Affected Area	Overall losses (US\$m, original values)	Insured losses (US\$m, original values)	Fatalities
25 - 30 Aug 2005	Hurricane Katrina, storm surge	United States: LA, New Orleans, Slidell, MS, Biloxi, Pascagoula, Waveland, Gulfport, Bay St. Louis, Hattiesburg, McComb, AL, FL	125,000	60,500	1,720
25 Aug - 1 Sep 2017	Hurricane Harvey, storm surge, flood	United States: TX, Harris County, Houston, Rockport, Refugio, Corpus Christi, Galveston, Crosby, LA, Lake Charles, Evangeline, AL, LA, MS, NC, TN, Nashville, Davidson County	95,000	30,000	88
19 - 22 Sep 2017	Hurricane Maria, flood	Puerto Rico, Dominica, Virgin Islands, U.S., Guadeloupe, Dominican Republic, Martinique, Haiti	68,000	29,600	108
23 - 31 Oct 2012	Hurricane Sandy, storm surge	United States, Cuba, Haiti, Bahamas, Canada, Jamaica, Dominican Republic, Puerto Rico	68,400	29,200	207
6 - 14 Sep 2017	Hurricane Irma, storm surge, flood	United States, Virgin Islands, U.S., Virgin Islands, British, Cuba, Saint Martin, Sint Maarten, Saint Barthelemy, Anguilla, Puerto Rico, Turks and Caicos Islands, Antigua and Barbuda, Bahamas, Bonaire, Sint Eustatius, Saba, Dominican Republic, Haiti, Saint Kitts and Nevis	57,200	28,900	128

5 deadliest events

Relevant natural loss events
in North America 1990 - 2017

Date	Event	Affected Area	Overall losses (US\$m, original values)	Insured losses (US\$m, original values)	Fatalities
12 Jan 2010	Earthquake	Haiti: Port-au-Prince, Petionville, Jacmel, Carrefour, Leogane, Petit Goave, Gressier	8,000	200	159,000
24 Oct - 8 Nov 1998	Hurricane Mitch, flood	Honduras, Nicaragua, El Salvador, Guatemala, United States, Belize, Jamaica, Mexico, Panama, Costa Rica	5,700	150	9,068
20 - 30 Sep 1998	Hurricane Georges	Puerto Rico, United States, Cuba, Dominican Republic, Saint Kitts and Nevis, Haiti, Antigua and Barbuda, Virgin Islands, U.S.	13,300	4,300	3,665
25 - 26 May 2004	Flood	Dominican Republic, Haiti			2,074
14 - 29 Sep 2004	Hurricane Jeanne, flood	United States, Bahamas, Dominican Republic, Puerto Rico, Virgin Islands, U.S., Haiti	9,200	5,000	1,844

5 costliest events ordered by inflation adjusted overall losses

Relevant natural loss events
in North America 1990 - 2017

Date	Event	Affected Area	Overall losses (US\$m, in 2017 values)	Insured losses (US\$m, in 2017 values)	Fatalities
25 - 30 Aug 2005	Hurricane Katrina, storm surge	United States: LA, New Orleans, Slidell, MS, Biloxi, Pascagoula, Waveland, Gulfport, Bay St. Louis, Hattiesburg, McComb, AL, FL	157,000	75,900	1,720
25 Aug - 1 Sep 2017	Hurricane Harvey, storm surge, flood	United States: TX, Harris County, Houston, Rockport, Refugio, Corpus Christi, Galveston, Crosby, LA, Lake Charles, Evangeline, AL, LA, MS, NC, TN, Nashville, Davidson County	95,000	30,000	88
23 - 31 Oct 2012	Hurricane Sandy, storm surge	United States, Cuba, Haiti, Bahamas, Canada, Jamaica, Dominican Republic, Puerto Rico	73,100	31,100	207
17 Jan 1994	Earthquake	United States: CA, Northridge, Los Angeles, San Fernando Valley, Ventura, Orange	72,800	25,300	61
19 - 22 Sep 2017	Hurricane Maria, flood	Puerto Rico, Dominica, Virgin Islands, U.S., Guadeloupe, Dominican Republic, Martinique, Haiti	68,000	29,600	108

5 costliest events ordered by inflation adjusted insured losses

Relevant natural loss events
in North America 1990 – 2017

Date	Event	Affected Area	Overall losses (US\$m, in 2017 values)	Insured losses (US\$m, in 2017 values)	Fatalities
25 - 30 Aug 2005	Hurricane Katrina, storm surge	United States: LA, New Orleans, Slidell, MS, Biloxi, Pascagoula, Waveland, Gulfport, Bay St. Louis, Hattiesburg, McComb, AL, FL	157,000	75,900	1,720
23 - 31 Oct 2012	Hurricane Sandy, storm surge	United States, Cuba, Haiti, Bahamas, Canada, Jamaica, Dominican Republic, Puerto Rico	73,100	31,100	207
25 Aug - 1 Sep 2017	Hurricane Harvey, storm surge, flood	United States: TX, Harris County, Houston, Rockport, Refugio, Corpus Christi, Galveston, Crosby, LA, Lake Charles, Evangeline, AL, LA, MS, NC, TN, Nashville, Davidson County	95,000	30,000	88
23 - 27 Aug 1992	Hurricane Andrew	United States, Bahamas	46,700	29,700	66
19 - 22 Sep 2017	Hurricane Maria, flood	Puerto Rico, Dominica, Virgin Islands, U.S., Guadeloupe, Dominican Republic, Martinique, Haiti	68,000	29,600	108

5 costliest events ordered by normalised overall losses

Relevant natural loss events
in North America 1990 - 2017

Date	Event	Affected Area	Overall losses (US\$m, in 2017 values)	Fatalities
25 - 30 Aug 2005	Hurricane Katrina, storm surge	United States: LA, New Orleans, Slidell, MS, Biloxi, Pascagoula, Waveland, Gulfport, Bay St. Louis, Hattiesburg, McComb, AL, FL	189,000	1,720
17 Jan 1994	Earthquake	United States: CA, Northridge, Los Angeles, San Fernando Valley, Ventura, Orange	112,000	61
25 Aug - 1 Sep 2017	Hurricane Harvey, storm surge, flood	United States: TX, Harris County, Houston, Rockport, Refugio, Corpus Christi, Galveston, Crosby, LA, Lake Charles, Evangeline, AL, LA, MS, NC, TN, Nashville, Davidson County	95,000	88
23 - 27 Aug 1992	Hurricane Andrew	United States, Bahamas	87,000	66
23 - 31 Oct 2012	Hurricane Sandy, storm surge	United States, Cuba, Haiti, Bahamas, Canada, Jamaica, Dominican Republic, Puerto Rico	79,400	207

Explanation for the interpretation of loss data statistics

Number statistics and loss thresholds

Number statistics are influenced by a constantly improved reporting of small-scale loss events over the time (*reporting bias*). There is a need to distinguish between **registered** and **relevant** loss events.

- **Registered loss events** are all events recorded by NatCatSERVICE. The range extends from *insignificant* to *catastrophic* loss events expressed in overall losses and / or fatalities. The reporting bias is particularly high for high frequency and low impact events.
- **Relevant loss events** exceed defined thresholds of *normalised* overall losses and/or fatalities. These events are considered in number statistics and trend analyses. Threshold values are:
 - Fatalities ≥ 1
 - Normalized overall loss \geq US\$ 100k, 300k, 1m, or 3m (depending on assigned World Bank income group of each affected country)
- **Type of data filtering is helpful for** reduction/elimination of reporting bias and for conclusions on changes in frequency of occurred loss events.

Explanation for the interpretation of loss data statistics

Inflation adjustment and normalization of NatCat loss data

Three ways of presenting loss data:

- Nominal losses: values as they originally occurred
- Inflation adjusted losses: accounting for changes in monetary equivalent
- Normalized losses: accounting for growth of values and assets

Inflation adjustment:

- Loss value in local currency is *adjusted to inflation* via the country's consumer price index (CPI) under consideration of exchange rate fluctuations between the local currency and the US\$.

Normalization:

- Loss value in US\$ is *normalized* via the development of locally resolved ($1^{\circ} \times 1^{\circ}$) nominal gross domestic product data in US\$ between year of occurrence and today.

Inflation adjusted loss data is helpful for...

- How high would a historic loss value be in today's money?

Normalized loss data is helpful for...

- What losses would a historic event cause when exposing today's values and assets?
- Conclusions on loss drivers like changes on the hazard side or effectivity of prevention measures

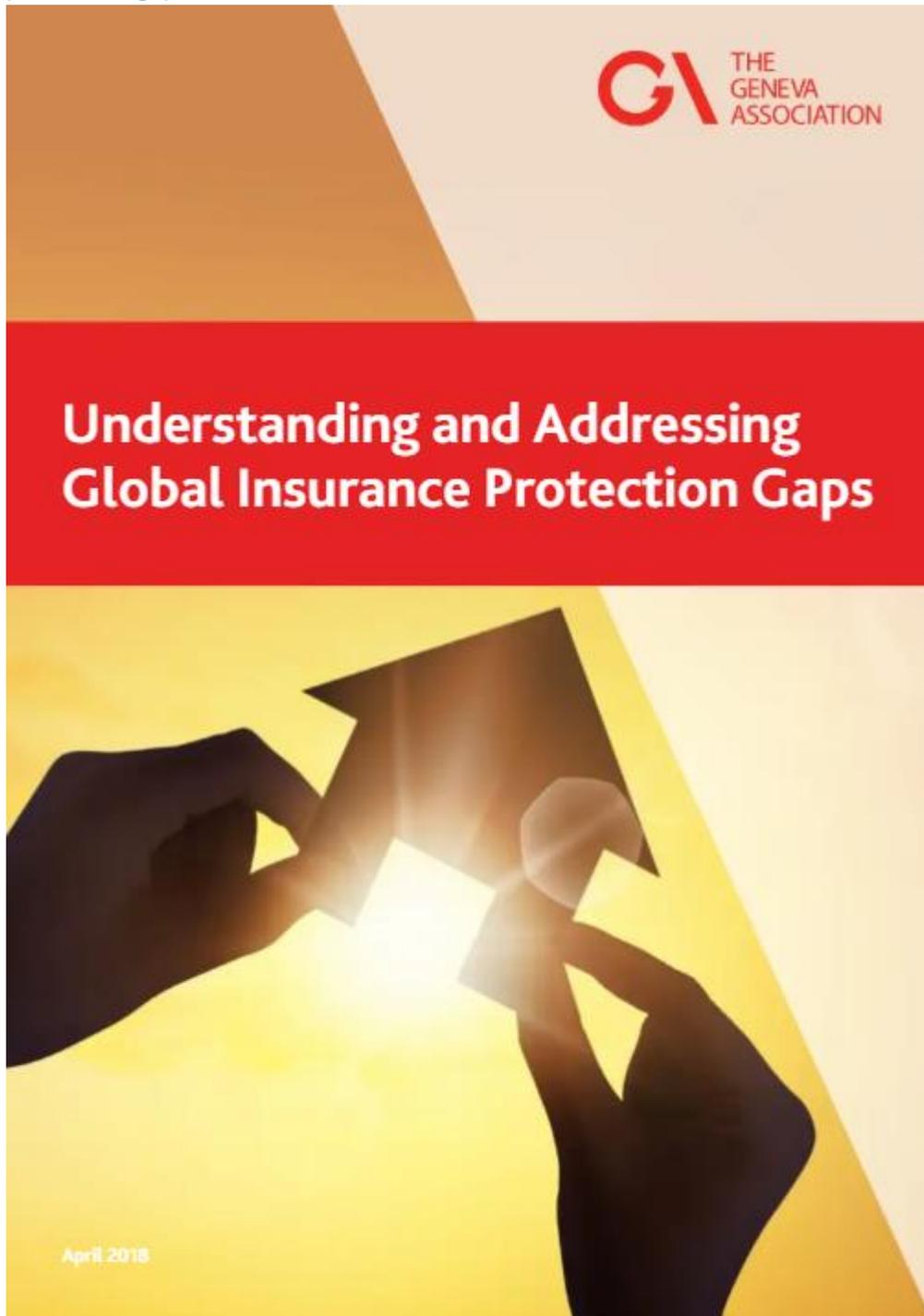
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10. Assignment 4, Module 2: Insurance Gaps:

<https://docslib.org/doc/10373577/understanding-and-addressing-global-insurance-protection-gaps>



The Geneva Association

The Geneva Association is the leading international insurance think tank for strategically important insurance and risk management issues. The Geneva Association identifies fundamental trends and strategic issues where insurance plays a substantial role or which influence the insurance sector. Through the development of research programmes, regular publications and the organisation of international meetings, The Geneva Association serves as a catalyst for progress in the understanding of risk and insurance matters and acts as an information creator and disseminator. It is the leading voice of the largest insurance groups worldwide in the dialogue with international institutions. In parallel, it advances—in economic and cultural terms—the development and application of risk management and the understanding of uncertainty in the modern economy.

The Geneva Association membership comprises a statutory maximum of 90 chief executive officers (CEOs) from the world's top insurance and reinsurance companies. It organises international expert networks and manages discussion platforms for senior insurance executives and specialists as well as policymakers, regulators and multilateral organisations.

Established in 1973, The Geneva Association, officially the 'International Association for the Study of Insurance Economics', is based in Zurich, Switzerland and is a non-profit organisation funded by its Members.



Understanding and Addressing Global Insurance Protection Gaps

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Contents

Acknowledgements	4
Foreword	5
1. Management summary	6
2. Size and nature of insurance protection gaps	9
2.1. Natural catastrophes	9
2.2. Cyber	14
2.3. Healthcare	16
2.4. Pensions	21
3. Root causes—A comparative analysis	25
3.1. The demand side	25
3.2. The supply side	29
4. Remedies—Towards a multi-stakeholder effort	32
4.1. The contribution of insurers	32
4.2. The role of governments	34
4.3. The role of public-private partnerships (PPPs)	36
5. Conclusions	38
6. References	39

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In addition, we would like to thank Petra Löw from Munich Re NatCatSERVICE for sharing historical data on natural catastrophe protection gaps globally and for different country income groups. Based on this data, we were able to perform genuinely original analyses.

Foreword



Anna Maria D'Hulster
Secretary General,
The Geneva Association

In November 2014, The Geneva Association published its maiden research report on 'The Global Insurance Protection Gap—Assessment and Recommendations'. This report offered a summary of major protection gaps in non-life and life insurance, their root causes as well as recommendations for potential remedies.

The topic's relevance is unabated. Risk exposures, driven by digitisation, urbanisation and climate change as well as value accumulation and concentration, tend to outgrow insurance premiums, leaving individuals, households, firms and the public sector alike underinsured. It is well documented that on average only one third of economic disaster losses are insured. In other areas too, from agriculture to term life, people buy less insurance than is economically beneficial. In addition, the digital transformation of modern economies creates a major gap between cyber risk exposure and available risk management and transfer options. The fact that cyber premiums account for less than one per mille of global insurance premiums speaks volumes.

The root causes and prevalence of insurance protection gaps vary widely across the globe, reflecting different stages of economic development as well as social, institutional and cultural peculiarities. Insurance protection gaps are most striking in developing and emerging markets where combined insurance premiums still fall significantly short of these countries' and regions' share in global GDP.

Against this backdrop, The Geneva Association offers an updated quantification of protection gaps in the areas of natural catastrophe, cyber, healthcare and pension risk. These areas were chosen due to the availability of relatively recent global data. In addition, we put forward a comparative taxonomy of root causes, distinguishing between high-, middle- and low-income countries in order to enhance the understanding of insurance protection gaps as a function of economic stages of development. Finally, we discuss potential remedies and contributions from insurers, governments and private-public partnerships. Insurers have a vital role to play in this mix of solutions—as well-capitalised risk absorbers, as facilitators of cost-efficient risk transfer and diversification, and as enablers of more risk-conscious behaviours.

We hope that this publication will encourage stakeholders to discuss insurance protection gaps and potential remedies in a more holistic way, with a clear view of commonalities and differences across various lines of business and country income groups.

1. Management summary

The most appropriate definition of insurance protection gaps is the difference between the amount of insurance that is economically beneficial and the amount of coverage actually purchased. This gap is smaller than the broader risk protection gap which describes the difference between total losses and insured losses. Defined as above, the insurance protection gap is hard to measure and subjective. Therefore we replace it by an indicator comparing covered loss to total economic loss. This figure, however, needs to be put into perspective, as a certain level of risk retention makes economic sense.

Protection gaps differ widely in terms of size, nature and dynamics, depending on the line of business and the general maturity of the insurance market. Historically, uninsured natural disaster losses were at the root of the protection gap discussion and they are still among those that make the headlines most frequently and spur the most intense debates.

No progress in shrinking the natural catastrophe protection gap in lower income countries

According to Munich Re, the natural catastrophe protection gap (uninsured losses as a share of total losses) has narrowed steadily over the past 30 years, from 78 per cent to 70 per cent, and from 0.3 per cent to 0.2 per cent of the world's GDP. Despite this gratifying global trend, the protection gap remains massive, with only about 30 per cent of catastrophe losses insured. In addition, this global trend masks huge differences between the various country income groups. Progress in terms of shrinking the gap has basically been limited to high- and upper middle-income countries, where the shortfalls decreased markedly by 12 and 11 percentage points to their current average levels of 55 per cent and 86 per cent respectively. Alarming, there was hardly any progress in lower middle- and lower-income countries, with protection gaps persisting in excess of 95 per cent. Those countries remain extremely vulnerable, with average annual catastrophe-induced GDP exceeding the global average by a significant multiple. Using a Monte Carlo simulation tool for a sample of 30 countries and extrapolating the results, Swiss Re projects the future protection gap at more than USD 150 billion p.a. or about 0.25 per cent of global GDP.

The cyber protection gap is estimated at about 90 per cent—in the face of major hurricane-like economic loss scenarios

The least researched protection gap is cyber risk. Estimating the cost of cyber incidents is challenging. Reported figures are likely to understate the extent of damage caused as affected institutions often have neither an incentive nor an obligation to disclose incidents. Some studies put the annual global economic cost of cyber incidents at around USD 400 billion, almost 0.5 per cent of global GDP and almost twice the average annual amount of natural disaster losses.

Current annual gross premiums for global cyber insurance are estimated at USD 3 to 3.5 billion, about 1.5 per mille of global non-life insurance premiums, according to Lloyd's. Swiss Re expects the global cyber insurance market to grow briskly to USD 18 billion by 2025; however, this would still be less than 1 per cent of the global non-life insurance market. A comparison of the current cumulative global damage from cyber incidents with today's cyber premiums generated by the insurance industry suggests that virtually all cyber losses remain uninsured and, from a macro perspective, insurance-based transfer of cyber risk still lacks any real relevance. Lloyd's recently attempted to quantify the cyber risk protection gap, based on modelled economic loss scenarios of up to USD 53 billion (i.e. equivalent to losses from a major hurricane) and protection gaps of about 90 per cent.

Healthcare—out-of-pocket expenses amount to about 2 per cent of global GDP

It is even more challenging to quantify the healthcare protection gap, primarily on account of the institutional and legal complexity of healthcare systems as well as the huge differences in the quality and availability of healthcare services. Out-of-pocket expenses (OOP), i.e. the share of the expenses that the insured must pay directly to the healthcare provider, without reimbursement by a third-party such as an insurer or the government, can serve as a very rough indicator of healthcare protection gaps. When people incur copayments or fees for healthcare services, the amount of such OOP expenses in relation to income can reach financially catastrophic proportions for the individual or the household.

World Health Organization research shows that catastrophic expenditure can occur in all countries at all stages of development. In most OECD countries, health systems and financial risk-pooling mechanisms have been developed over several decades. Nonetheless, even in these countries some households are threatened by catastrophic payments. In general, health systems that require lower OOP provide a higher level of protection to the poor against catastrophic spending—spending which remains low in countries where OOP represents less than 20 per cent of total national health expenditure.

The macroeconomic proportions of OOP are sizable. Across the various country income groups defined by the World Bank the GDP share of total national OOP ranges from 1.8 to 2.4 per cent. This ratio is just an illustration of the healthcare protection gap and could even be compared with the natural catastrophe protection gap's long-term annual average GDP share of 0.3 per cent globally. In light of rising levels of income per capita and unabated medical inflation, the healthcare protection gap is set to grow further.

Some estimates put the global pension savings gap at more than USD 100 trillion, about 1.5 times the world's GDP

As funding shortfalls are accumulated over time, the headline proportions of the 'pension savings gap' are even more staggering. It is defined as the difference between the present value of the yearly lifetime income needed to sustain a reasonable standard of living, and the actual amount that is saved for retirement plus the present value of pay-as-you-go (PAYG) benefits. Based on a target replacement rate of 70 per cent, defined as the percentage of a worker's pre-retirement income that is paid out by pension programmes on retirement, Aviva has quantified pension savings gaps for the European Union. The gaps show how much more people retiring between 2017 and 2057 would need to save each year to meet the 70 per cent target replacement rate level. The analysis suggests that European Union citizens may need to save an extra EUR 2 trillion p.a. to close the pension savings gap—equivalent to around 13 per cent of EU GDP in 2016.

In 2016, The Geneva Association estimated the global pension gap to be USD 41 trillion, after taking into account Pillar I (PAYG) entitlements. Excluding any Pillar I benefits, the gap amounts to more than USD 100 trillion.

The most recent estimate of current and projected future pension gaps was undertaken by the World Economic Forum. In 2015, the retirement savings gap for Australia, Canada, China, India, Japan, Netherlands, the U.K. and U.S., based on a 70 per cent income replacement target level, is estimated at around USD 70 trillion (including Pillar I benefits). This gap is roughly equal to 1.5 times the 2015 GDP of these countries. Extrapolating this ratio to the rest of the world would yield an illustrative global pensions savings gap of more than USD 110 trillion.

Why individuals and businesses buy less insurance than is economically beneficial

The reasons for insurance protection gaps lie with both demand- and supply-side factors affecting the demand for and the provision of insurance services. In addition, they vary for various stages of economic development.

On the demand-side, *affordability* remains a relevant obstacle primarily in developing and emerging insurance markets, as shown in this report. In addition, numerous empirical studies suggest that a lack of awareness, as a result of poor financial literacy or general education, plays an important role in explaining underinsurance, even in countries with higher levels of per-capita income.

Product appeal and service quality are of great importance, especially in advanced insurance markets, and they include the ease of buying insurance cover and the rising customer expectations in the wake of digitisation.

Policyholder trust in the context of insurance protection gaps is particularly relevant for developing and emerging markets, which are frequently characterised by relatively weak legal and regulatory systems for enforcing payment of valid claims.

Cultural and social factors can also help to understand insurance protection gaps, ranging from differences in risk aversion to factors attributed to religion, as shown by various empirical analyses focusing on low-income countries.

Behavioural biases are of more general relevance. More recently, behavioural factors have emerged as explanations for apparent demand anomalies in insurance. One example is less aversion, i.e. individuals being more sensitive to small

losses than large gains. In insurance, the premium is a certain and near-term expense, whereas the claim benefit is uncertain and distant and is therefore perceived as a potential loss.

However, insurance protection gaps do not only reflect demand-side issues. Equally important are insurance market imperfections that hold back insurance supply. Transaction costs are one of the most prominent examples. In non-life insurance, for example, about 30 cents of each dollar premium are generally absorbed by distribution and general administrative expenses. Even though it reflects its complexity, this fact dents the economic appeal of insurance, especially in low-income countries.

In addition, imperfect and asymmetric information is a long-standing feature of today's insurance markets. It can explain insurance protection gaps as it is set to lead to adverse selection, i.e. 'poor' risks being more likely to purchase cover. Another structural reason for inefficient insurance markets is moral hazard, i.e. the probability of a person assuming more risks because someone else is carrying the cost of those risks. Also, daunting accumulation scenarios such as in cyber insurance present so far unresolved challenges.

Furthermore, institutional parameters, such as the legal and regulatory environment, are major determinants of insurance supply. In many developing and emerging markets, the legal environment (e.g. a proper contract law) is still weak, and rules are frequently not enforceable. In addition to an effective legal framework, a sound regulatory framework is required to enable a stable insurance market and protect policyholders.

Last but not least, certain risks do not meet the most fundamental criteria of insurability and are considered uninsurable from a commercial viability point of view.

Effective remedies require a concerted effort

Any comprehensive and promising approach to narrowing insurance protection gaps requires a multi-stakeholder effort. The collaboration of private-sector insurers and local governments is of particular importance.

The optimal configuration of this multi-stakeholder mix depends on the maturity of insurance markets and the

specific nature of protection gaps. In advanced economies, there is a limited need but significant capacity for heavy government involvement, for example in the full absorption of natural catastrophe risks. In developing markets, the trend is one of low risk transfer and management capabilities in combination with massive protection gaps. In this case, governments may need to play a strong enabling and guiding role, albeit against the backdrop of limited fiscal leeway.

In general, governments can help improve the availability of retail and wholesale insurance by introducing compulsory schemes which create sufficiently large risk communities and risk pools.

In addition, many public sector entities are increasingly utilising *new forms of sovereign risk transfer* in order to relieve their balance sheets, especially from natural disaster losses. Countries in Africa, the Caribbean and the Pacific have always been particularly exposed to extreme weather events such as hurricanes, droughts and floods, but in recent years this exposure has grown further on the back of population growth, urbanisation dynamics, overexploitation of natural resources, environmental degradation and changing climate and weather patterns.

As a complement to improving risk transfer, protection gaps also need to be addressed through the *prevention and reduction of losses*. Government-sponsored building codes, for example, have proved essential for establishing and enforcing risk-reduction measures.

Also, in many advanced insurance markets, governments step in as insurers or reinsurers of last resort for certain risks which defy the most fundamental criteria of insurability. Under such circumstances *government backstop programmes* can facilitate private sector insurance solutions which at least could offer partial coverage, e.g. against catastrophic terrorism and, potentially, cyber security scenarios.

Having said all this, insurers have to step up their game. For example, irrespective of an economy's stage of development, *digital and mobile technologies* can go a long way in addressing protection gaps by simultaneously promoting affordability, awareness and product appeal. On the back of unprecedented data availability and quality, technology also facilitates the product innovation that is generally needed to expand risk pools. Technology might ultimately even help to expand the limits of insurability.

2. Size and nature of insurance protection gaps

2.1. Natural catastrophes

Defining the natural catastrophe protection gap

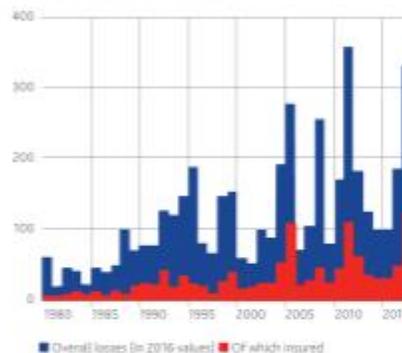
In property catastrophe insurance, the overall protection gap is generally referred to as the share of uninsured losses to total economic losses. The insurance protection gap, however, is smaller as the full insurance of all economic losses is neither desirable nor economically plausible. There are rational economic reasons for not fully insuring. Insureds usually retain some risks according to their risk appetite, risk bearing capability and cost-efficiency considerations. Individuals may use savings or credit lines as substitutes for insuring high-frequency/low-severity losses. In addition, Mossin (1968) suggests that it is not optimal to buy full insurance due to the transaction costs. Furthermore, insurers implement deductibles to mitigate moral hazard, translating into lower sums insured. Also, institutional factors such as extensive social security benefits reduce the need for individuals to take out private insurance. Therefore, the most appropriate definition of insurance protection gaps is the difference between the amount of insurance that is economically beneficial—taking into account some rational self-insurance or alternative ways of risk transfer—and the amount of coverage actually purchased.

For the purpose of this study we focus on the property catastrophe protection gap only and ignore general property risk, such as fire, water damage, burglary and business interruption.

Quantifying the natural property catastrophe protection gap

Figure 1 shows the difference between insured and economic losses since 1980. In absolute terms, according to the Munich Re NatCatSERVICE, the global catastrophe protection gap in the record catastrophe year of 2017 amounted to about USD 195 billion, or approximately 59 per cent of total economic losses of USD 330 billion, compared with the average value of about 70 per cent since 2000 (see also Figure 3).

Figure 1: Insured versus uninsured natural catastrophe losses, 1980-2017, in USD billion



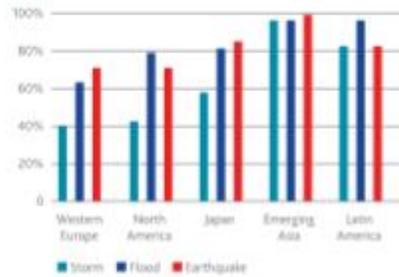
Source: Munich Re (2018)

A closer examination of the current protection gap by region and by peril

From 1980 to 2017, an estimated USD 4.6 trillion of economic losses were recorded globally as a result of natural disaster events. About USD 1.2 trillion were indemnified through insurance and approximately USD 3.4 trillion remained uninsured, according to the Munich Re NatCatSERVICE.

As revealed by Figure 2, the share of uninsured property catastrophe losses varies significantly by region and peril. In Emerging Asia, the protection gap exceeds 90 per cent for all three major perils (storms, floods and earthquakes). In Latin America, the protection gap is most pronounced for flood risk. In the mature markets of Western Europe, North America and Japan, storm risk is covered much more broadly than the other two perils (see Figure 2).

Figure 2: The average natural catastrophe protection gap by region and peril, 1980-2016



Source: Munich Re NatCatSERVICE

Figure 2 shows that the protection gap is a global phenomenon and not just a developing world issue. Coverage gaps are equally pronounced in many advanced economies. The April 2016 Kumamoto earthquakes in the Kyushu region of Japan, for example, caused economic losses of about USD 32 billion, with a protection gap of USD 25 billion. The insurance shortfall was even more dramatic in Italy, where the tremors that hit the central part of the country in August and October 2016 resulted in combined economic losses of USD 6 billion, of which a mere 3.4 per cent was insured (Munich Re (2018)). In the U.S. too, there are major pockets of underinsurance. For example, just over 10 per cent of homes in California have earthquake insurance. In addition, in 100-year U.S. floodplains, only about half of the homes are insured against floods (Kousky and Kunreuther (2017)).

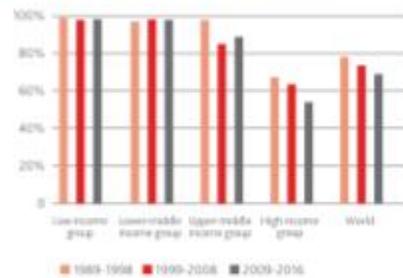
Economic vulnerability as a function of GDP per capita

Figure 3 is based on data from the Munich Re NatCatSERVICE. It illustrates the importance of distinguishing between high-, upper middle-, lower middle- and low-income countries when discussing natural catastrophe protection gaps. Globally, the gap has narrowed steadily over the past three decades from 78 to 70 per cent (based on 10-year moving averages). However, gratifying as this trend may be, it does mask huge differences between income groups in different countries. Progress, in terms of shrinking the gap, was

basically limited to high- and upper middle-income countries (with GDP per capita of more than USD 12,235; and between USD 3,956 to USD 12,235, respectively, as defined by the World Bank). These two country groups recorded protection gap reductions of 12 and 11 per cent, respectively. This major success story does warrant more dedicated research into its determinants, not least in order to derive lessons applicable to lower middle- and lower-income countries (with a GDP per capita of USD 1,006 to USD 3,955; and less than USD 1,006, respectively). In these countries there was no progress whatsoever, with protection gaps stuck at more than 95 per cent (see Figure 3).

These findings help to understand why global policy efforts in the areas of disaster risk reduction and mitigation focus on lower- and lower middle-income countries.

Figure 3: The natural catastrophe protection gap (uninsured losses as a share of total losses) for different country income groups, 10-year moving averages, 1989-2016

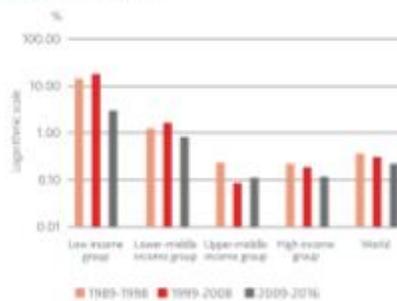


Source: Munich Re NatCatSERVICE

Figure 4 shows, on a logarithmic scale and based on 10-year moving averages, the share of uninsured disaster losses in GDP over the same period of time and for the same country income groups. Over the past three decades, the share of worldwide uninsured losses in global GDP has decreased from 0.31 to 0.19 per cent. For high-income countries, the share fell from 0.20 to 0.13 per cent. Upper middle-income countries show a reduction from 0.21 to 0.11 per cent. Lower middle-income countries display no clear trend, with shares hovering around 1 per cent,

indicating a significantly higher macro-economic relevance of uninsured losses compared to wealthier countries. This is particularly true for low-income countries, with average uninsured disaster losses amounting to around 15 per cent of GDP in the 1990s and 2000s before showing a reduction to about 3 per cent more recently, but this still shows an enormous degree of vulnerability as a result of underinsurance.

Figure 4: Uninsured natural catastrophe losses as a share of GDP for different country income groups, 10-year moving averages, 1989-2016



Source: Munich Re NatCatSERVICE

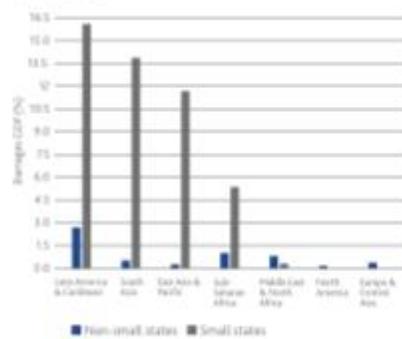
The IMF (2016) shows that small developing states are disproportionately vulnerable to natural disasters. The IMF membership includes 34 small developing states, categorised as countries with a population less than 1.5 million that are not advanced market economies or high-income oil exporting countries (as defined by the World Bank). About half of the group are lower or lower-middle income states.

Based on the most widely used database on natural disasters (EM-DAT), the IMF calculates that the economic cost of the average natural disaster between 1950 and 2014 was equivalent to nearly 13 per cent of GDP for small states compared to less than 1 per cent of GDP for larger states. Natural catastrophes are not only more costly but in some cases also more frequent in small states, partly reflecting their unfavourable location in the cyclone and hurricane belts on each side of the equator. In addition, if these countries fall into the low-income group, they generally lack the scale for the efficient implementation

of building codes and early warning/disaster response systems, for example.

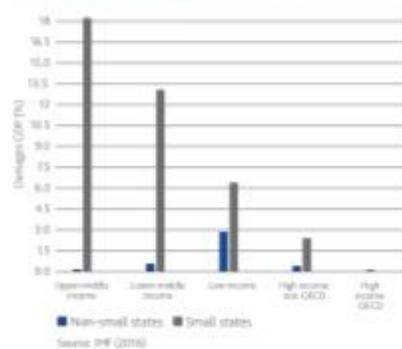
Latin America and the Caribbean display the highest level of vulnerability for both small and non-small states. From an income per capita perspective, upper middle-income small states and low income non-small states are most vulnerable (see figures 5 and 6).

Figure 5: Average impact of disasters (total losses as a share of GDP) by region, 1950-2014



Source: IMF (2016)

Figure 6: Average impact of disasters (total losses as a share of GDP) by income per capita, 1950-2004



Source: IMF (2016)

Projecting the natural catastrophe protection gap

Using a Monte Carlo simulation tool, Holzheu and Turner (2018) estimate expected losses for a sample of 30 countries, based on information on assets and risks by location.

As shown by Figure 7, the world's biggest economies—the U.S., China and Japan—have the largest expected (modelled) uninsured natural catastrophe risk in absolute USD terms. All three countries display large property values exposed to peak natural disaster risks such as earthquake, flood and tropical storm.

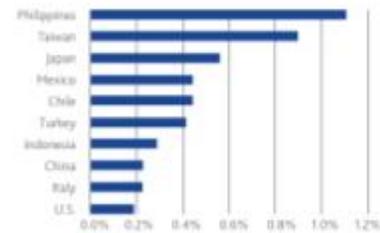
Figure 7: Expected insured and uninsured losses from natural catastrophes, in USD billion



Source: Holzheu and Turner (2018)

Holzheu and Turner also show that, as a percentage of GDP, Taiwan, Turkey and Chile stand to lose the most from earthquake risk, while Taiwan, the Philippines, Hong Kong and Mexico would be most severely affected by windstorm risk. Figure 8 summarises the combined scenarios for earthquake, flood and windstorm for the 10 most exposed countries of their sample. Generally speaking, emerging economies are more vulnerable to suffering from the disruptions caused by uninsured catastrophes. Among the mature markets, Japan stands out, reflecting a relatively low commercial insurance penetration (Swiss Re (2017b)). One reason for the limited take-up of commercial earthquake insurance in Japan is companies' high level of preparedness, e.g. through measures such as strengthening the resistance of buildings and establishing elaborate business continuity management processes. Therefore, the lack of commercial earthquake insurance cover is (somewhat) offset by effective pre-disaster risk mitigation and adaptation (The Geneva Association (2014), see also Section 4 for a discussion on the insurability of catastrophic risks and the way in which public-private partnerships could support the development of a commercial market for such risks in both developed and emerging markets).

Figure 8: Expected uninsured losses from natural catastrophes as a percentage of GDP



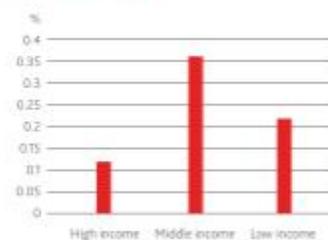
Source: Holzheu and Turner (2018)

Holzheu and Turner (2018) extrapolate these results to missing countries in proportion to their respective GDP. This extrapolation yields expected uninsured losses from catastrophes as an estimated USD 153 billion annually.

The authors acknowledge this estimate's shortcomings. It overestimates the protection gap since the modelled total economic losses include public infrastructure and commercial property where partial self-insurance exists. On the other hand, the projection tends to underestimate the overall protection gap since perils like hail, drought, tornadoes, mudslides and volcanoes are not included in the probabilistic models.

These findings are in line with those of Swiss Re (2015b), which also show expected natural catastrophe protection gaps by country income group. Middle-income countries display the highest relative protection gaps whereas high-income countries show the lowest, at just one third of the middle-income countries' relative exposure (see Figure 9).

Figure 9: Modelled natural catastrophe protection gaps by country income group¹



Source: Swiss Re (2015b)

The prospects for private property catastrophe insurance

Natural catastrophe protection gaps can place a significant burden on the public sector, for example as a result of lost public physical assets, the cost of emergency response measures and assistance to the affected population, foregone tax revenue and measures designed to mitigate the loss of uninsured private assets.

Against this backdrop, private sector insurance offers attractive financial, operational and information benefits

to public sector entities as well, such as guaranteed access to funds up to agreed limits, planning certainty as a result of annually budgeted premiums, no payback obligation as opposed to risk financing solutions, professional loss assessment for indemnity-based cover, fast payout under parametric schemes, and improved economic efficiency of resource allocation as insurance puts a price tag on risks (Baur (2016)).

Innovative approaches to product design may go a long way to increase the penetration of property catastrophe insurance. For example, coverage could be provided as an opt-out, where property owners in high-risk areas are automatically enrolled in insurance programmes unless they specifically decline to do so. Such nudging techniques have been successful elsewhere, for example in the area of employer-sponsored retirement plans (Thaler and Sunstein (2008)). Another related example is product bundling, which can reduce distribution and underwriting costs, for example in the area of mortgages. Some mortgage banks require borrowers to pay home insurance premiums alongside the mortgage payments (Holzheu and Turner (2018)).

In addition, digital and mobile distribution can leapfrog access to insurance in countries where no traditional distribution networks have developed up to now (Cole (2015)). In Sub-Saharan Africa, for example, the most effective partnerships have been between mobile operators and insurers. On that basis, microinsurance can provide low-income households with affordable insurance products. For property risks, many microinsurance programmes have used index-based insurance products for weather to cover crop damages (Barnett et al. (2008)).

Governments can also assist in improving the availability of risk transfer solutions to individuals and corporations by introducing compulsory insurance schemes or offering fiscal incentives. Such moves can be instrumental in creating sufficiently large risk communities. However, mandatory insurance schemes are rather infrequent in the property catastrophe space. A positive example is Turkey where residential buildings within municipal boundaries must have earthquake coverage through a

¹ The Swiss Re classification of countries differs from the World Bank's and is based on consumption per capita (greater than USD 25,000 for high-income countries, between USD 10,000 and USD 25,000 for middle-income countries and less than USD 10,000 for low-income countries).

private insurance company on behalf of the state-owned Turkish Catastrophe Insurance Pool (TCIP). Take-up rates are high as homeowners need earthquake coverage to access electricity or water services, obtain a mortgage, or receive rebuilding aid from the government if their homes are damaged in an earthquake.²

Generally speaking, disaster risk insurance penetration may also be affected by the type of post-disaster emergency financial aid system in place nationally or sub-nationally. In countries where such financial aid schemes are in place, residents may feel less incentivised to purchase disaster risk insurance. Therefore, disaster risk penetration needs to be looked at in the context of a broader national/sub-national disaster risk management system.

2.2. Cyber

Defining cyber risk

Cyber risk is arguably the biggest challenge facing modern digital economies. It can be defined as any risk emerging from the use of information and communications technology that compromises the confidentiality, availability or integrity of data or services. Its materialisation eventually leads to business disruption, [critical] infrastructure break down, and physical damage to humans and properties (The Geneva Association (2016b) and OECD (2017)). The notion of cyber risk encompasses a multitude of risk sources threatening the information and technology assets of firms, governments or individuals. The spectrum of risk includes identity theft, disclosure of sensitive information, and business interruption. Non-criminal sources such as power outages after a natural catastrophe as well as technical or human failure have to be distinguished from criminal sources (cybercrime), including physical attacks, hacker attacks and extortion.

Gauging the cost of cyber risk

Estimating the cost of cyber incidents is challenging. Reported figures are likely to understate the extent of damage caused as affected institutions often have neither an incentive nor an obligation to disclose

incidents. Some studies put the annual economic cost of cyber incidents at around USD 400 billion, about 0.5 per cent of global GDP (AGCS (2015), Graham (2017) and Lloyd's (2017a))—a figure well in excess of average annual economic costs associated with global natural disasters (see Section 2.1).

Quantifying the cyber gap

Most property insurance policies cover damage to physical assets only (even though business interruption is a steadily increasing part of commercial property covers) and often exclude cyber risk—which is generally the case with liability cover. While the policyholder assumes that cyber incidents are included, the insurer assumes the opposite. This ambiguity may cause major legal disputes and significant protection gaps, exacerbating more fundamental reasons such as a lack of insurability. According to AGCS (2015) fewer than 10 per cent of companies are thought to have purchased cyber insurance today.

Current annual gross premiums for global cyber insurance are around USD 3 to 3.5 billion, about 1.5 per mille of global non-life insurance premiums (Lloyd's (2017b)). Swiss Re expects the global cyber insurance market to grow briskly to USD 18 billion by 2025 (Swiss Re, 2015c), a figure which would still be considerably less than 1 per cent of the global non-life insurance market. The U.S. market is much more developed than its European counterpart, and according to OECD (2017), accounts for 90 per cent of the world total. One reason is the fact that several years ago the U.S. already introduced reporting requirements for cyber incidents as well as severe sanctions in case of non-compliance. The European Union will follow suit by June 2018 with the General Data Protection Regulation (GDPR) framework.

A comparison of the aggregate global damage from cyber incidents with cyber premiums generated by the insurance industry suggests that virtually all cyber losses remain uninsured, and from a macro perspective, insurance-based transfer of cyber risk still lacks any real relevance.

Lloyd's (2017b) attempts to quantify the cyber risk protection gap for two specific scenarios: a cloud service provider hack, leading to widespread service and business

² See sections 3 and 4 of this report for further analysis.

interruption; and a mass vulnerability attack, as a result of leaked information which is used by criminal parties to attack vulnerable businesses for financial gain.

These cyber event scenarios could lead to a wide range of potential economic losses. For the cloud service disruption scenario, estimated economic losses range from USD 4.6 billion for a large event to USD 53.1 billion for an extreme event; in the mass software vulnerability scenario, the economic losses range from USD 9.7 billion for a large event to USD 28.7 billion for an extreme event. However, economic losses could be much lower or higher than the average in these scenarios due to the uncertainty surrounding cyber aggregation and accumulation—a key reason why some (re)insurers question the insurability of cyber risk.

Only a small fraction of such losses would be indemnified by cyber insurers. For example, in the cloud services scenario, insured losses are estimated to range from USD 620 million for a large loss to USD 8.1 billion for an extreme loss. For the mass software vulnerability scenario, the insured losses would amount to USD 762 million (large loss) and USD 2.1 billion (extreme loss).

Under the cloud services scenario the cyber risk protection gap (uninsured losses as a share of total losses) would come in at 87 per cent for a large loss and 83 per cent for an extreme loss. The gap is even larger for the mass vulnerability scenario and is estimated to be around 93 per cent for both a large and an extreme loss event (see Figure 10).

Figure 10: Estimated coverage for modelled scenarios

Event	Overall losses		Insured losses		% Loss covered	
	Large loss	Extreme loss	Large loss	Extreme loss	Large loss	Extreme loss
Cyber CIP interruption	\$4.6bn	\$53.1bn	\$620m	\$8.1bn	13%	15%
Cyber mass vulnerability interruption	\$9.7bn	\$28.7bn	\$762m	\$2.05bn	7%	7%

Source: Lloyd's (2017c)

Based on current estimated global cyber insurance premiums of around USD 3 billion, it is apparent that a single cyber event has the potential to dramatically increase industry loss ratios by up to 250 per cent for extreme loss events, illustrating the catastrophe potential of the cyber risk class.

Overcoming challenges to insurability

Based on Berliner's (1982) seminal insurability criteria, Biener et al. (2015) shed light on the fundamental constraints facing cyber insurance. A first challenge to insurability is the lack of independence and predictability of cyber losses. As a result, risk pooling hits its limits. Exposures are largely unpredictable not only because of a lack of data (which is set to accumulate over time) but more fundamentally in light of the dynamics of cyber risks and the associated risk of change which complicates risk assessment.

A second insurability challenge in cyber insurance is asymmetric information. Adverse selection is almost inevitable as organisations that have experienced cyber incidents before are more likely to buy insurance. The lack of loss data impairs the risk classification of policyholders and in turn renders adverse selection even more acute.

Figure 11 illustrates the ‘vicious circle of cyber insurance’ as a result of missing data.

Figure 11: The vicious circle of cyber insurance



Source: Dierkes (2017)

The lack of historical data is arguably the most fundamental challenge and contributes to tight coverage limits in cyber insurance markets. Policies generally do not cover losses in excess of USD 500 million; they also come with exclusions such as losses from accessing unsecure websites or terrorism. In addition, some indirect effects of cyber incidents cannot be measured, and as a result they are not covered. An example is reputational damage and its impact on customer and investor sentiment.

As shown by Lloyd's (2017b), economic losses from cyber events have the potential to be as large as those caused by major hurricanes. Therefore, insurers need to think about cyber exposure in these terms and focus on aggregated cyber-related catastrophes and the potential tail risk associated with cyber coverage.

Despite the many challenges to the insurability of cyber risk, one should bear in mind that the cyber insurance market is still at an embryonic stage. As the market matures, risk pools and relevant data sets will expand. New players will grow the market's capacity. As competition intensifies, the rates are set to come down. In addition, policy wordings and product specifications will see more standardisation, with beneficial effects on both supply and demand. And, last but not least, the fundamental issue of insurability may be addressed by public-private partnerships in order to develop a robust commercial market for cyber risks.

2.3. Healthcare

The healthcare funding mix

Government provisions form the basis of most healthcare systems, especially in developing and emerging markets where private insurance plays a relatively small role. Such public healthcare services, provided free of charge or at subsidised cost, are funded through general taxes.

Social health insurance schemes are a different way of financing state-sponsored healthcare systems, being based on individual salary or tax and employer contributions. They are generally administered through government entities, they include deductibles to mitigate moral hazard and they may be both voluntary and mandatory.

Private health insurance plans are pre-paid, usually voluntary schemes which are operated by private insurance companies. Government influence can be substantial, for example through regulations and subsidies. One recent example is China, which has made health insurance premiums income tax deductible to the amount of RMB 2,400.

Finally, there is out-of-pocket spending on healthcare, using private household income and wealth. Its share in total healthcare expenses is a function of the economy's maturity and the specific institutional characteristics of the national healthcare system (Savedoff and Sekhri (2004)—see Figure 12).

Figure 12: Healthcare financing mechanisms



Source: Savitelli/Sakhi (2014)

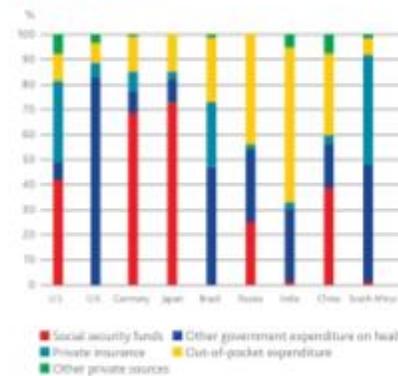
Defining the healthcare protection gap

In light of the institutional and legal complexity of healthcare systems, it is difficult to come up with a generally accepted definition of the healthcare protection gap. For people who are comfortable with the extent of (minimum) government-provided health and medical services there is no protection gap. Others may require additional services funded through social health insurance and private health insurance. In highly mature markets, some individuals seek healthcare services at an even higher standard (both in terms of quantity and quality) that they have to fund out of their own pockets, drawing on personal savings and assets. In many developing and emerging markets, however, out-of-pocket expenses play a dominant role because government and social insurance schemes provide only minimum coverage and private health insurance is at an embryonic stage. Having said this, such expenses can also be copayments, which governments mandate as a funding component and use as

a means to control the use of services. In addition, another relevant but virtually unquantifiable part of the healthcare protection gap is non-treatment or under-treatment due mostly to a lack of affordability and/or accessibility or an outright lack of supply and medical infrastructure, as indicated, for example, by very low numbers of doctors and hospital beds per 100,000 inhabitants.

Figure 13 illustrates the enormous differences in the healthcare funding mix, not only between mature and emerging markets but also within the respective country income groups.

Figure 13: Breakdown of national healthcare expenditure by source, 2014 data



Source: World Health Organization database (countries selected by The Geneva Association)

A specific approach to modelling the healthcare protection gap

According to a study published by Swiss Re in 2012, the healthcare protection gap in the Asia Pacific region could reach USD 197 billion in 2020.³ The research covers Australia, China, Hong Kong, India, Indonesia, Japan, Malaysia, the Philippines, Singapore, South Korea, Thailand, Taiwan and Vietnam. It found that government

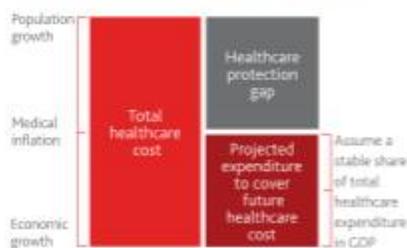
³ http://www.swissre.com/media/news_release/swissre_20121028_health_protection_gap_asia_pacific.html

provisions and out-of-pocket expenses are the two main funding sources of healthcare in the region, whereas private prepaid plans contributed less than 10 per cent of the total healthcare expenditure for all the markets covered in this report, with the exception of Taiwan which came in at 19 per cent.

The healthcare protection gap, according to Swiss Re, is defined as the difference between the level of healthcare costs which would be required to meet consumer needs—based on considerations including population growth, economic development and healthcare cost increases—versus the amount that would be available to cover those costs, assuming that society's total healthcare expenditure remained at a constant percentage of GDP (see Figure 14). This gap obviously evolves as it is influenced by many factors such as the introduction of new medicines and more people entering formal healthcare schemes.

The protection gap is based on projections of economic growth, medical inflation and population growth in the 13 individual markets covered. All three determinants suggest that healthcare expenses will account for a growing share of GDP, with the result that people and governments will need to increase their spending on healthcare.

Figure 14: Projecting the healthcare protection gap



Source: Adapted from Swiss Re (2012)

Out-of-pocket expenses (OOP) as a gauge for the healthcare protection gap

When people incur copayments or fees for healthcare services, the amount of such out-of-pocket expenses in relation to income can reach financially catastrophic

proportions for the individual or the household. Outsized expenditure can mean that people have to cut down on food and clothing or that they are unable to pay for their children's education. The World Health Organization suggests that OOP health expenditure be viewed as catastrophic whenever it is equal to or greater than 40 per cent of a household's non-subsistence income, i.e. income available after basic needs have been met. Therefore, OOP expenses can serve as a (necessarily imperfect) gauge for the healthcare protection gap.

OOP in mature economies frequently represent co-payments and non-catastrophic expenses that are not covered by insurance. Therefore, this measure is of limited value for determining underinsurance in high-income countries. In the U.S., for example, there is a mix of households that are protected with insurance cover (with increasing deductibles and copayments) against catastrophic expenses, while more than 10 per cent are completely uninsured and highly exposed to catastrophic expenses. The average OOP figure for the U.S. masks these differences.

In emerging economies, however, OOP mostly represents medical expenses for families without any insurance and therefore provides a more applicable gauge of underinsurance. Insurance or other funding would increase the utilisation of health services, leading to better health outcomes. However, analysing data for China, Li et al. (2012) show that expanding health insurance coverage does not always translate into improved health service coverage or better protection against (catastrophic) healthcare costs. If the depth (range of services covered by insurance) and height (extent to which costs are indemnified by insurers) are limited, the OOP remains high.

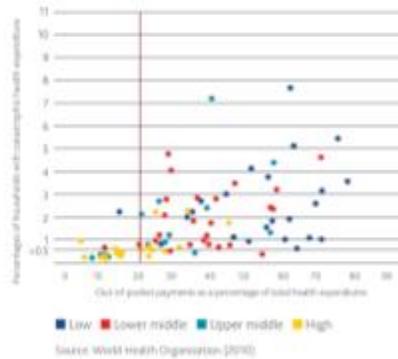
The most recent global analysis of catastrophic health expenditure is WHO (2010). The study identifies three factors driving catastrophic payments: (1) the availability of health services requiring OOP; (2) low household capacity to pay; and (3) a lack of prepayment mechanisms for risk pooling, e.g. funds collected through taxes and/or insurance contributions.

The research shows that catastrophic expenditure can occur in all countries at all stages of development. In most OECD countries, health systems and financial risk-pooling mechanisms have been developed over several

decades. Nonetheless, even in these countries some households are threatened by catastrophic payments.

In general, health systems that require lower OOP payments provide a higher level of protection to the poor against catastrophic spending. As suggested by Figure 15, catastrophic health expenditure remains low in countries where OOP represents less than 20 per cent of total national health expenditure.

Figure 15: Percentage of households incurring catastrophic health expenditure against OOP as a share of total health expenditure (2010 data)



The impact of these OOP payments for healthcare goes beyond catastrophic spending. Poor households may decide not to use services at all and are likely to sink even further into poverty due to the adverse effects of sickness on their earnings and general welfare (WHO (2005)).

Figure 16: Share of out-of-pocket expenses in total healthcare expenditure: Low-income economies (2014 data)

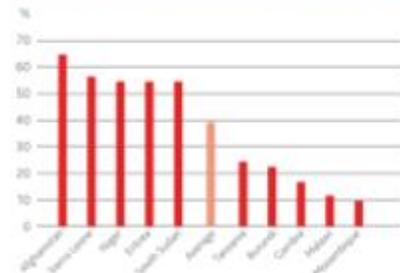


Figure 17: Share of out-of-pocket expenses in total healthcare expenditure: Lower-middle income economies (2014 data)

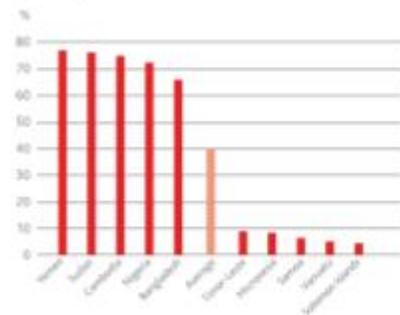
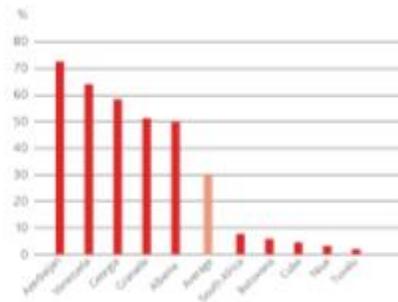
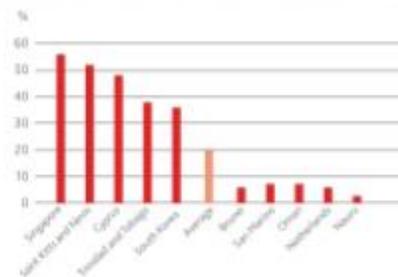


Figure 18: Share of out-of-pocket expenses in total healthcare expenditure: Upper-middle income economies (2014 data)



Source: World Health Organization database, The Geneva Association

Figure 19: Share of out-of-pocket expenses in total healthcare expenditure: High-income economies (2014 data)



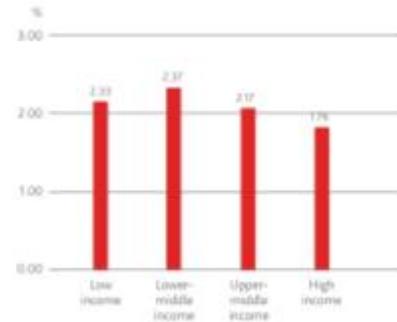
Source: World Health Organization database, The Geneva Association

However, especially in high-income countries the share of OOP needs to be considered in combination with the overall efficiency of the healthcare system. For example, while Singapore shows a higher share of OOP than other comparable high-income countries, its total healthcare

expenses to GDP ratio is smaller and the ultimate medical outcome superior. One can also argue that, at least close to the moment of their introduction, some new diagnosis and treatment techniques can only be utilised through OOP. In addition, as mentioned before, copayments can be mandated by governments as a funding component and a means of controlling the use of healthcare services.

Figure 20 illustrates the macroeconomic proportions of OOP. Across the various country income groups the GDP share of OOP ranges from 1.8 to 2.4 per cent—about seven times the average for historical natural catastrophe protection gaps (see Figure 9).

Figure 20: Out-of-pocket healthcare expenses as a share of GDP (2014 data)



Source: World Health Organization database, The Geneva Association

Prospects for private health insurance as a key element of the future funding mix

Healthcare costs are expected to continue rising faster than gross domestic product and consumer price inflation. Key reasons include:

- Cost escalation as a result of medical innovation and the increasing use of new technologies in medicine and treatments

- Healthcare being highly labour-intensive with lower rates of productivity growth compared to other sectors of the economy
- Economic growth and rising incomes in emerging markets which will translate into additional demand for healthcare services
- Population growth and ageing which will require a broader healthcare infrastructure and increase the financial burden from healthcare services, and
- Urbanisation and its drawbacks such as less healthy lifestyles, the (re)emergence of communicable diseases and detrimental levels of air pollution (Swiss Re (2015a)).

In combination with rising concerns about fiscal sustainability, private health insurance is set to play a bigger role. It offers individuals and households the option to pay for healthcare through regular premiums into prepaid plans and to reap the benefits of risk pooling whilst reducing the spectre of crippling healthcare expenses.

2.4. Pensions

Defining the pension gap

The 'pension gap' is defined as the difference between the present value of the yearly lifetime income needed to sustain a reasonable standard of living and the actual amount that is saved for retirement plus the present value of pay-as-you-go (PAYG) contributions over a 40-year period (The Geneva Association (2016a)). Obviously, the pension gap is conceptually different from other protection gaps as it concerns the cumulative adequacy of household savings which are a function of many non-insurance related factors such as the level of interest rates. For this reason, the phenomenon is also frequently referred to as the pension/savings gap.

Quantifying the pension gap

Pensions are generally a social type of insurance provided through a public mechanism, usually a PAYG scheme where today's workers pay for the retirement benefits of today's pensioners. In almost all countries, these

schemes are complemented by privately managed occupational and individual voluntary pension pillars. In many cases, insurance companies manage these schemes and assume longevity risks from governments and employers who still offer defined-benefit pension schemes (with guaranteed levels of retirement income) and from individuals who proactively seek to ensure the adequacy of their future retirement income. The shift towards non-public schemes is primarily a result of the increasing unsustainability of public schemes as people live longer and have fewer children.

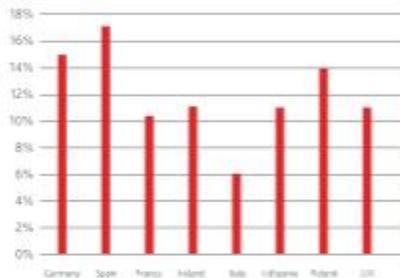
In most countries, both developed and developing, there is a widening pension gap, measured by the extent to which pension levels fall short of an appropriate replacement rate that would ensure the continuation of the accustomed standard of living during retirement. Demographics are generally the main cause for pensions protection gaps. Changes in the old-age dependency ratio (which measures the number of elderly people as a share of those of working age) challenge most pension systems across the globe.

Based on a target replacement rate, defined as the percentage of a worker's pre-retirement income that is paid out by a pension programme on retirement, of 70 per cent (as recommended by the OECD), Aviva (2016) has quantified pension savings gaps for the European Union. The gaps show how much more the people retiring between 2017 and 2057 would need to save each year to meet the 70 per cent replacement rate level. The analysis suggests that European Union citizens may need to save an extra EUR 2 trillion a year to close the pension/savings gap that is equivalent to around 13 per cent of EU GDP in 2016 (Figure 21).

As a percentage of GDP, Spain currently faces the biggest shortfall of 17 per cent. Italy's gap at 6 per cent is the lowest, but the country's generous state pension may not be sustainable in the future.

Another interesting finding of this research is that no single policy measure will be able to close the gap. Even radical measures that are almost inconceivable from a political perspective, such as increasing the retirement age by five or 10 years, would only reduce the gap by a quarter or by a half, respectively.

Figure 21: Annual pension/savings gap as a percentage of 2016 GDP

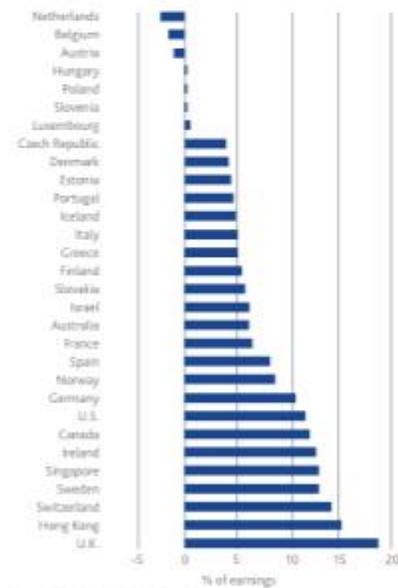


Source: Axa (2016)

This analysis is based on comprehensive OECD data published biennially. It offers detailed information on net replacement rates, i.e. the after-tax level of pension benefits in retirement from mandatory public and private pension schemes relative to after-tax earnings when working. Drawing on this data and a number of assumptions, ILC-UK (2017) calculates savings gaps for 30 different countries and regions. These gaps illustrate how much an average individual entering the workforce today might need to save in order to achieve a replacement rate at the recommended level of 70 per cent. For countries with positive gaps, individuals will have less income in retirement than they require for an adequate lifestyle. Therefore, they need to save more, retire later or rely on more generous government support. According to ILC-UK, the average earner in 27 out of 30 countries and regions will face an income shortfall in retirement using the benchmark 70 per cent net replacement rate (excluding voluntary savings). The U.K. performs worst, showing a savings gap of 18 per cent of annual income. This amount would have to be saved each year to ensure an adequate income in retirement. In contrast, the Netherlands is a prominent example of a country benefitting from having both a public pension component and a mandatory or quasi-mandatory pension saving component. The country is not projected to have any retirement income shortfall for average earners (see Figure 22).

Having said this, the pension challenge goes beyond insufficient retirement savings. For example, even if retirement savings are sufficient, the challenge (especially for defined-contribution plan participants who have to bear the investment risk associated with their retirement savings) is to properly convert retirement savings into steady and reliable retirement income. One common mistake is to withdraw assets too quickly, which leaves individuals exposed to longevity risk.

Figure 22: Pension adequacy gap (based on mandatory (Pillars I and II) retirement schemes, excluding voluntary savings) as a percentage of earnings



Source: ILC-UK, based on OECD (2015)

The Geneva Association (2016a), based on Marin (2013), estimates the global pension gap at USD 41 trillion, after taking into account Pillar I (PAYG) entitlements. Marin had estimated the global pension gap at USD 100 trillion (or about 140 per cent of GDP) excluding any Pillar I benefits, using GDP and old-age dependency ratios (the number of elderly people as a share of those of working age) to project the amounts needed for retirement and then deducting estimated savings in pension funds. Marin assumes a 5 per cent discount rate and a 60 per cent replacement ratio. While Pillar I significantly reduces the gap, it cannot fill it in its entirety.

Another recent estimate of current (2015) and projected future (2050) pension gaps was undertaken by WEF (2017). The calculations assume that, generally, retirement needs will be met by a combination of income from three sources: (1) government-provided Pillar I pension, (2) employer-based Pillar II pension and (3) voluntary individual savings. The authors compare the aggregate level of savings to the expected average annual retirement income needs as well as life expectancies. The study targets eight countries with data available and the largest established pension systems or populations (Australia, Canada, China, India, Japan, Netherlands, the U.K. and U.S.).

The retirement savings gap in 2015, based on a 70 per cent income replacement target level for these eight countries is estimated at around USD 70 trillion, including Pillar I benefits, with the largest deficit being in the U.S. This gap is roughly equal to 1.5 times the 2015 GDP for the countries under investigation. Extrapolating this ratio to the rest of the world would yield an illustrative global pension/savings gap of more than USD 110 trillion.

According to the study, over 75 per cent of the 2015 USD 70 trillion pension gap is attributable to unfunded government-provided Pillar I pensions and pensions promised to public employees; 24 per cent of the gap is the result of deficient individual savings. The underfunding of corporate (defined-benefits) pension plans only accounts for about 1 per cent of the total gap.

The prospects for private life and pension insurance

Both governments and employers are increasingly shifting longevity and market/savings risks to individuals, for example, through reduced public pension schemes and the transition from defined-benefit to defined-contribution schemes in corporate retirement plans. This trend has widened pension protection gaps. Ultimately, such gaps can impose a severe additional financial burden on society as the number of individuals who outlive their assets and are thrown into poverty will probably increase.

Against this backdrop, the commercial potential for life insurers is as vast as their responsibility vis-à-vis society to make a meaningful contribution to risk mitigation and live up to insurers' claimed relevance. The insurance industry needs to explore innovative approaches to developing a more effective proposition for the challenge of the rising longevity risk facing society. A starting point would be to offer individuals easier access to simpler products with lower fees, for example deferred annuities that must annuitise at a certain age, as opposed to existing complex annuities with guaranteed withdrawal benefits or guaranteed income benefits, products that may not be affordable to the lower-income segments of society. In addition, the insurance industry, in conjunction with trade groups, associations and educators, could play a significantly bigger role in designing and delivering financial literacy education (The Geneva Association (2016a)).

However, public and private-sector decision-makers need to bear in mind that longevity risk has two components—the 'individual' and the 'aggregate'. Individual longevity risk arises because it is impossible to know when a particular individual will die. Individual longevity risk can be managed through risk pooling, which is performed by the government, pension funds and/or insurers that sell annuities.

Aggregate longevity risk, on the other hand, reflects the uncertainty of how long an entire population cohort will live. Historically, experts have consistently underestimated life expectancy. This systematic component of longevity risk cannot be mitigated through diversification by age groups or geography as certain mortality improvements due to medical breakthroughs, for example, will affect the entire population. Aggregate longevity risk is substantial and therefore a concern for the future of all pension systems.

Therefore, policy recommendations go beyond the insurance industry: closing the pension gap requires the involvement of both the public and the private sector. The current parameters and conditions surrounding pension systems such as retirement age, mandatory contribution rates, investment restrictions, the degree of competitiveness for pension fund administrators, incentives to save voluntarily and the degree of economic informality can all be adjusted in order to close the pension gap. Life insurance products, long-term savings plans and annuities offered by the insurance industry can also be embedded in pension systems to protect individuals against mortality and longevity risks and to complement existing pension schemes.

3. Root causes—A comparative analysis

It is neither feasible nor desirable that all economic costs of calamity are insured. However, there is a level at which individuals, households and firms buy less insurance than is economically beneficial. The reasons for such insurance protection gaps lie with both demand- and supply-side factors affecting the demand for and the provision of insurance services. In addition, they vary for various stages of per capita income and economic development. Along these two dimensions, the following section will explore the root causes of underinsurance across all lines of business covered by this study.

3.1. The demand side

In the following we discuss six specific demand-side obstacles to the take-up of insurance (for a general overview, see Eling et al. (2014) and Swiss Re (2017c)).

Affordability

According to standard economic theory, the price of a normal good is inversely related to demand for that good or service. Evidence from mature markets (Marquis et al. (2004)) shows a price elasticity of demand for insurance of 0.2 to 0.4 (i.e. if the price increases by 10 per cent, demand will decline by 2 to 4 per cent). Also, disposable income (and the income elasticity of insurance demand) is a major demand-side factor for explaining insurance purchases and insurance protection gaps (see, for example, Millo (2014)). In this context, the wealth distribution structure matters too as a broader middle class is set to have a positive effect on insurance demand (Feyen et al. (2011)). In addition, transaction costs can adversely impact (perceived) affordability (Baicker et al. (2012) discuss low take-up rates of public health insurance in the U.S. in the context of transaction costs). Global consumer surveys suggest that about half of insurance buyers base their final purchasing decisions on price. This price-driven buying behaviour is bound to result in major coverage gaps (EY (2014); in homeowner insurance this behaviour is particularly common (59 per cent), followed by motor (57 per cent) and life insurance (50 per cent)).

Figure 23: Top reasons for closing or replacing an insurance policy

	Global life	Global auto	Global home
Cost/terms	50%	57%	59%
Policy benefits/coverage	47%	42%	48%
Recommended by broker, friends	38%	28%	39%
Frequency/relevance of communication	28%	16%	34%
Level of service	28%	26%	31%
Policy did not align to my life circumstances	26%	14%	26%
Research I conducted	25%	20%	30%
Experienced personal/family milestones	24%	11%	25%
Brand reputation	24%	17%	29%
Did not like the way claim was handled	22%	18%	26%
Customer loyalty benefits	20%	17%	26%

Source: EY (2014)

Not surprisingly, the relevance of affordability is even more acute in developing and emerging markets, where household budget constraints may require reduced consumption in other areas in order to be able to afford insurance premiums. The price sensitivity of insurance demand is, therefore, significantly more pronounced. According to Cole et al. (2013), the price elasticity of rainfall insurance demand in India is between 1.04 and 1.16. However, overall take-up rates of microinsurance may remain low even if prices are reduced. Even when prices are significantly below the actuarially fair level, Cole et al. (2013) show that fewer than half of households purchase rainfall insurance. Mobarak and Rosentzweig (2012) find that that a 50 per cent price reduction relative to the actuarial price, increases the probability of take-up by 17.6 percentage points, indicating a price elasticity of 0.44.

Awareness

The existing empirical evidence on mature insurance markets (for example Cappelletti et al. (2013)) suggests a positive relationship between financial literacy and insurance demand. Similarly, most of the empirical studies on developed economies show the same for education and insurance demand (e.g. Li et al. (2007)).

Besides deficits in financial literacy and general education, specific gaps in risk awareness play an important role in explaining underinsurance. This is particularly relevant for low-probability events. For example, research on individual behaviour during Hurricane Sandy in New York in 2012 showed that only one third of homeowners who owned removable storm shutters actually put them up (Meyer et al. (2014)).

In addition, even though there is evidence that insurance demand increases in the wake of natural disaster events, this effect vanishes over time as the memory of the loss event fades or as new residents who do not have prior disaster awareness move into disaster-prone areas (Gallagher (2014)).

As far as developing markets are concerned, Cole et al. (2013) find that insurance demand is higher among households with higher levels of financial literacy. Gimé et al. (2008) suggest that a lack of product understanding is the second most relevant reason for not purchasing insurance, following affordability. However, other studies

(for example Clarke and Kalani (2012)) find no impact of financial literacy on insurance demand.

Appeal and quality of product/service

The perceived quality and appeal of the insurance offering is an important determinant of purchasing decisions. For example, Costa and Garcia (2003) show that the quality of care matters significantly to health insurance take-up. According to their analysis, in Spain the quality of service (e.g. long waiting lists) explains the low demand for public healthcare.

In developing countries, there is similar evidence. De Allegri et al. (2006), for example, suggest that the number of enrolments in community-based health insurance in rural West Africa is closely linked to the quality of the health centre.

In a broader sense, surveys suggest that ease of purchase is also an important factor in insurance buying behaviour. According to EY (2014), service and experiential factors, such as "easy to understand, clear communications" and "being easy to deal with," are among the most relevant drivers of insurance purchasing decisions and are almost as important as price and scope of coverage. If insurance as an abstract and intangible concept is not properly "sold", coverage gaps seem set to arise.

Trust

It is undisputed that trust, i.e. an individual's bet on a third party's future contingent actions, is an indispensable ingredient of the insurance business. Insurers are in the "business of trust". They sell contingent promises to pay, more often than not at a distant and unspecified point in the future, e.g. in life insurance. From a policyholder's perspective, the insurer's willingness and ability to fulfil these promises cannot be assessed until a claim has been filed and settled. The insurer's performance is only incompletely observable at the time of signing an insurance policy. Information asymmetries make it difficult for the policyholder to instantly judge and assess the value of an insurer's promise to pay. Where this is possible, the overall reputation and performance of an insurance company, as well as a robust legal and regulatory framework, are instrumental in generating trust with policyholders (Schanz (2009)).

In addition, collective policyholder trust in insurers can be eroded by exogenous factors. One example is the protracted environment of ultra-low interest rates which has dented confidence levels in some mature life and health insurance markets.

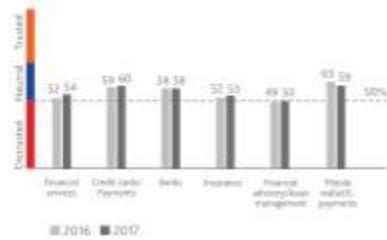
Global surveys show that financial services in general and insurance in particular suffer from a severe public trust gap compared to industries such as energy, consumer goods, food and technology (see figures 24 and 25).

Figure 24: Levels of trust by industry (percentage of people who trust each industry)



Source: Edelman (2017)

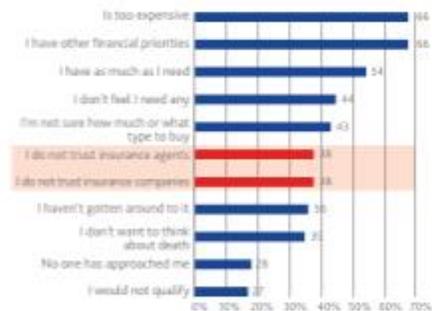
Figure 25: Levels of trust by financial services subsector



Source: Edelman (2017)

Figure 26 reveals that a lack of trust in insurance carriers and distribution channels is an important reason behind protection gaps, even in mature insurance markets.

Figure 26: Mistrust as a top reason behind the life insurance protection gap in the U.S.



Source: Roper (2017), IPIRA (2017)

Trust issues in the context of insurance protection gaps are particularly relevant for developing and emerging markets, which are frequently characterised by relatively weak legal and regulatory systems for enforcing payment of valid claims (see Outreville (2013) and Cole et al. (2013)). Based on qualitative responses, Giné et al. (2008) find that trust in the insurance provider is a key determinant of rainfall insurance demand in India, for example. Cole et al. (2013) discovered that Indian household insurance demand is 36 per cent higher when there is a recommended and trusted insurance educator involved in the purchasing process.

Cultural and social factors

Cultural and social peculiarities can also help to understand insurance protection gaps. For example, Basaza et al. (2008), in their study on community health insurance in Uganda, find that pre-payment before illness was seen as "inviting disease".

As far as the link between risk aversion and insurance demand is concerned, most empirical findings are either counter-intuitive or inconclusive. In contrast with economic theory and consistent observations in mature economies, studies in microinsurance markets show a negative relationship between risk aversion and insurance demand. Giné et al. (2008) and Cole et al. (2013), for example, find that more risk-averse households are less likely to purchase insurance. One interpretation suggests that households view insurance as risky as a result of price uncertainty in agricultural insurance (Kouame and Komenan (2012)) or the possibility of non-performance (basis risk) associated with parametric rainfall insurance in India (Clarke (2011)). As shown by Outreville (2013), empirical evidence on the relationship between risk aversion and insurance demand in developed markets is ambiguous.

In addition, various studies explore and test the effects of religion on risk attitudes in insurance markets. Eisenhauer and Halek (1999) find only a small effect on risk aversion. Others such as Noussair et al. (2012) establish more robust results in terms of a positive relationship between the number of religious people and levels of risk aversion. For Islamic countries, several cross-country studies find a negative correlation between (non-Takaful) insurance demand and religious beliefs/affiliation, e.g. Beck and Webb (2003).

Behavioural biases

With the rise of behavioural economics, seemingly irrational and inconsistent patterns of human behaviour are increasingly looked at as a possible explanation of why individuals, households and firms buy less insurance cover than is economically beneficial to them.

According to insurance theory, people benefit from incurring a small cost (the premium) to obtain protection against an event that could cause significant financial losses but that has a low probability of occurrence. If insurance can be produced with relatively small transaction costs, i.e. if it can be reasonably priced, a risk-averse individual should prefer a smaller but certain premium to taking the chance of experiencing a large loss. If properly designed and priced, insurance policies also offer incentives through premium discounts for those who mitigate their risk (Kunreuther and Pauly (2013)).

However, there is considerable empirical evidence that many consumers do not take advantage of insurance protection against losses of property and health, even if the insurance premium is subsidised or below the actuarial level, and do not invest in efficient loss reduction measures. In both cases they fail to behave in ways that would not only benefit them personally but might also enhance social welfare.

Historically, these phenomena have been explained through information asymmetries and search costs (The Geneva Association (2016c)). More recently, however, behavioural factors have emerged as contributing to such demand anomalies. One example is loss aversion, i.e. individuals are more sensitive to small losses than large gains. In insurance, the premium is a certain and near-term expense, whereas the claim benefit is uncertain and distant and is therefore perceived as a potential loss. Another example is mental accounting: individuals mentally allocate their planned expenditures into different accounts so that they feel constrained in spending on other activities. In insurance, people often refrain from premium payment commitments because they do not have a risk protection account in their mental model or because they have already exhausted the account through other commitments.

A final example is the status quo bias: individuals are reluctant to depart from the status quo, even though it

might be beneficial to do so. This matters particularly for low-income households. Since insurance is a relatively new product category for them, they tend to resist insurance commitments and instead cling to current risk-coping mechanisms such as informal savings (Kutreuther and Pauly (2013)).

3.2. The supply side

Insurance protection gaps do not only reflect demand-side issues. Equally important are insurance market imperfections that hold back insurance supply. In the following subsection we focus on four specific supply-side driven reasons for underinsurance.

Transaction costs

The cost of producing insurance cover is currently one of the most intensely debated industry topics, not least in light of technological innovation and the prospect of disruption by more cost-efficient ways of providing insurance cover (The Geneva Association (2016c)). In non-life insurance, for example, about 30 cents of each premium dollar are generally absorbed by distribution and general administrative expenses. Even though it reflects its complexity, this fact dents the economic appeal of insurance. As early as 1965 Lees and Rice (p. 143) noted: "In practice, insurance is not costless: sellers incur costs of time and trouble and expense for advice (...). Specifically, the transaction costs to the individual of completing and filing application and claims forms, paying premiums, keeping records, etc., as well as possible costs of obtaining information, may be of sufficient magnitude to make insurance policies against certain losses not worthwhile."

More recently, the relevance of the time and effort required for policy purchase/renewal and claim filing was discussed by De Bock and Gelade (2012). Thornton et al. (2010) identify these as important reasons for choosing not to enrol in health insurance, even when it is subsidised. Allowing workers to sign up directly at their place of employment, rather than miss a day of work due to the process, led to a 30 per cent increase in the take-up rate.

Based on Coase (1937), Lees and Rice (1965) even see an analogy between households and firms. Coase found that if market-based transactions were too costly they would be 'internalised' and take place within firms. Similarly, households (or more likely peer and risk retention groups) would opt to (partially) self-insure if insurance is associated with significant transaction costs.

Adverse selection and moral hazard

Imperfect information is a prominent feature of today's insurance markets and may explain insurance protection gaps (see the seminal work of Rothschild and Stiglitz (1976) on the economics of imperfect information in insurance). Insurers and policyholders operate in a space where the characteristics of the services exchanged are not fully known to at least one of the parties. Under such conditions, high-risk individuals cause an externality as the low-risk customers are worse off than they would be in their absence. This is a particular challenge in health insurance which could actually be exacerbated by medical advancements based on technology (e.g. increasingly inexpensive genetic tests).

One of the most influential academic works on the consequences of information asymmetry is Akerlof (1970). Taking the market for used cars as an example, he shows that if buyers cannot distinguish between a high-quality car (a 'peach') and a 'lemon', they will only be willing to pay a price for a car that averages the value of a 'peach' and a 'lemon'. As a result, sellers will only enter the market if they hold 'lemons', whilst 'peaches' will no longer be offered. This form of adverse selection, with high-quality cars no longer on offer, ultimately leads to a market failure. The notion of 'lemons' and 'peaches' can be applied to insurance markets ('poor' versus 'good' risks). Therefore, if the insurer prices its business on the average loss probability of the entire pool of insureds, those with the highest risk will be the most likely to purchase coverage, and as a result the insurer is set to lose money.

Arrow (1963) also found that risks were traded and transferred incompletely in real-world markets. One of the reasons he identified was moral hazard, i.e. the probability of a person assuming more risks because someone else carries the costs of those risks. This leads to an increase in the loss probability caused by the behaviour of the policyholder.

Institutional obstacles and shortcomings

Institutional parameters such as the legal and regulatory environment are major determinants of insurance supply. In many developing and emerging markets the legal environment (e.g. a proper contract law) is weak and rules are frequently not enforceable. In addition to an effective legal framework, a sound regulatory framework is required to enable a stable insurance market and protect policyholders.

In low- and lower middle-income countries in particular, immature regulatory frameworks are a major obstacle to insurance market development. A lack of solvency margins, not to mention risk-based solvency rules, insufficient minimum capital requirements and a general lack of cohesion, transparency, consultation and implementation are frequently observed regulatory deficiencies. In addition, excessive approval requirements could discourage product innovation (The Geneva Association (2014)).

Rudimentary or insufficiently enforced frameworks are clearly not conducive to risk-based pricing, adequate risk retention, product innovation and the overall resilience and stability of insurance markets. Under such circumstances, corporate defaults and mis-selling scandals, for example, are more likely, potentially shaking customer confidence in the industry as a whole—a particularly severe threat in nascent markets.

A general reliance on government aid as a substitute for insurance is another explanation for insurance protection gaps. Governments have historically played an important role in post-event disaster relief, for instance, in countries as different as China, Italy, Japan and Turkey most losses arising from natural disasters have traditionally been covered by the government on a post-event basis (Swiss Re (2015b)). Under such circumstances, private-sector risk transfer solutions face a crowding out. In the context of the U.S. National Flood Insurance Program, Kousky et al. (2013) find that an increase in average aid grants reduces average insurance coverage by more than the amount of aid.

The same crowding-out effect can arise from informal risk-sharing mechanisms, especially in developing countries.

For example, Jowett (2003), based on an analysis of health insurance markets in Vietnam, suggests that strong informal networks may crowd out insurance solutions.

In today's mature markets, social security systems based on the concept of mutuality can be viewed as "the closest relative to informal risk-sharing strategies" (Eling et al. (2014), p. 248). By providing protection against health, disability and mortality risks, social security is expected to have a negative impact on insurance demand (Outreville (2013)). One example is the provision of Long-Term Care (LTC) by the Japanese government which almost completely crowds out private LTC insurance. The empirical findings, however, are contradictory (Zietz (2003)). Some studies suggest a positive relationship (Browne and Kim (1993)) whereas others establish a negative link (Lewis (1989)).

Limits to insurability

Occasionally, the insurance industry is faced with events that test the limits of insurability. The destruction of the World Trade Centre on 11 September 2001 is probably the most prominent example. Prior to this event, the scale of losses from terrorist acts was comparable to other property losses, and therefore terrorism was rarely excluded from property policies. A more recent challenge is the insurability of cyber risk. Based on a broad empirical analysis and recent literature, Biener et al. (2015) examine this topic, based on the fundamental set of criteria introduced by Berliner (1982). They identify distinct characteristics of cyber risks compared to other operational risks and shed light on significant challenges associated with highly interrelated losses, lack of data, and severe information asymmetries. These challenges hinder the development of an effective cyber insurance market.

Against this backdrop, it is obvious that when assessing risks, any insurer or reinsurer must carefully take into consideration the fundamental principles of insurability (Berliner (1982)). Ignoring these constraints would ultimately undermine the (re)insurer's solvency and jeopardise the ability to honour obligations.

Randomness is the first relevant criterion: The time and location of an insured event must be unpredictable, and the occurrence itself must be independent of the will of the

insured. Second, the frequency and severity of claimable events must be quantifiable within reasonable confidence limits. In many developing markets this is a particular challenge given the paucity of data and actuarial know-how which forces insurers to add high uncertainty loadings, undermining the product's value proposition. Third, the premium rate must be economically viable, covering the insurer's expected cost of acquiring and administering the business as well as claims costs. In addition, the price must allow for an appropriate return on the capital allocated to the risk, a return which meets shareholder's return requirements. As such, insurability is not entirely a supply-side issue but also relates to the affordability of premiums.

Figure 27 summarises the various root causes of protection gaps and illustrates their respective main (but not exhaustive) relevance by country group, based on a review of the cited empirical references and our own assessment.

Figure 27: The root causes of insurance protection gaps—main areas of relevance



Source: The Geneva Association

4. Remedies—Towards a multi-stakeholder effort

Any effective approach to narrowing insurance protection gaps requires a multi-stakeholder effort. The collaboration of private-sector insurers and governments is of particular importance and is the focus of this chapter. In addition, employers have an important potential role to play, for example by enrolling the workforce in income protection insurance schemes as part of their employment contract, by providing employees with ongoing financial education and training to enable them to make informed choices to protect themselves, and by promoting and incentivising healthy lifestyles (Zurich (2017)).

The optimal configuration of this multi-stakeholder mix depends on the maturity of insurance markets and the specific nature of protection gaps. Certain tasks require private-sector leadership whereas others are considered to be in governments' realm of responsibilities. A third category of challenges needs equal partnerships between both sectors.

In developed countries, there is a limited need for heavy government involvement, such as the full absorption of natural catastrophe risks. This is likely to be different in markets where there is a combination of low risk transfer and management capabilities, and massive protection gaps (see Section 2.1). Here, governments may need to take on a strong enabling and guiding role, subject to their fiscal capacity to do so.

Generally speaking, the public sector is essential to designing and providing the legal and regulatory framework that underpins any well-functioning private insurance sector, whose primary task is to develop cost-efficient and attractive risk transfer solutions.

4.1. The contribution of insurers

Embracing technology

Irrespective of a country's GDP per capita, digital and mobile technologies can go a long way in addressing protection gaps. First, the affordability of insurance improves as its 'production cost' decreases significantly. Digitisation enables massive cost savings in all relevant areas: claims and claims settlement, acquisition and administration. As a result, individuals and households but also corporations are likely to revisit their approach to self-retention and may transfer more risk to professional carriers.

At the same time, social media and mobile tools of communication enable quantum leaps in public awareness of insurance and its cost-benefit characteristics, as well as main product features. In conjunction with improved affordability, increased levels of awareness are expected to be a powerful catalyst for higher insurance penetration, particularly in developing markets. Having said this, access to digital media in low-income countries remains a serious challenge, especially for women and elderly persons.

Last but not least, digitisation comes with enormous advances in customer experience. Hassle-free and more regular communication, combined with a more favourably perceived cost-benefit ratio of more tailored and individualised insurance products could significantly enhance the appeal of insurance, the lack of which is also an important reason for protection gaps in advanced economies (The Geneva Association (2016c)).

Generally speaking, digital and mobile technologies can leapfrog access to insurance in countries with no existing traditional distribution channels (Cole (2015)). Mobile microinsurance has been successfully sold through partnerships primarily with mobile network operators but also through pharmacies and agricultural input companies. The critical success factors include a trusted brand reputation, payment collection capabilities and frequent customer interactions enabling the cost-efficient collection of small premium amounts.

Driving product extensions and innovation

Insurers are not renowned for innovation. This record can explain various protection gaps, primarily in mature markets. Residential earthquake risk, for instance, is generally uninsured, partly because of the behavioural factors discussed in Section 3.1. Therefore, much of the world's residential earthquake risk exposure is ultimately borne by mortgage providers such as banks. Providing lenders with tailored earthquake coverage is a commercial opportunity for insurers and helps narrow the natural catastrophe insurance gap (Swiss Re (2015b)).

Alternatively, and this is another area of opportunity for product bundling, some mortgage lenders require their borrowers to pay home insurance through an escrow system alongside the mortgage payments. This approach reduces transaction costs and puts the insurance

purchase-renewal process in the bigger context of cost of housing. From their panel data analysis Holzheu and Turner (2018) find a strong correlation between mortgage and insurance penetration.

A related concept is 'nudging' which has received widespread attention following the award of the 2017 Nobel Prize in economics to Richard Thaler. Applied to insurance, coverage may be provided as an opt-out. Homeowners in high-risk zones would be required to carry insurance unless they specifically decline it. Such techniques have been successfully implemented elsewhere, for example for enrolment into employer-sponsored retirement plans (Thaler and Sunstein (2008))

Another example of product innovation is cyber insurance. For instance, in April 2017, Willis Towers Watson, in collaboration with AIG, introduced CyFly, an innovative and flexible insurance solution specifically tailored to cover cyber exposure affecting the airline industry. The product extends airlines' business interruption cover to third party service providers—a regular exclusion under 'off-the-shelf' cyber insurance policies. Further, business interruption is not limited to IT service providers alone but also includes non-technology providers such as global distribution systems, baggage processing, aircraft maintenance, fuelling and catering and airport security.⁴

Promoting microinsurance

Microinsurance provides low-income, vulnerable households with affordable insurance products. Due to the low premiums, key microinsurance features such as product design, distribution channel and claim settlement processes differ significantly from traditional insurance. Microinsurance generally offers small amounts of coverage and premiums per person. Distribution frequently relies on existing networks, sometimes bundling insurance with other products. Claims handling expenses are minimised by involving local communities in order to influence individual risk behaviour, improve verification, enhance product understanding and foster trust (Cole et al. (2013) and Giné et al. (2008)). Crop covers are frequently based

on weather indices which reduces underwriting and claims processing costs (Barnett et al. (2008)).

Life insurance, however, is the most popular microinsurance product in emerging markets. It usually comes in the form of microcredit life insurance which covers the outstanding balance of a loan on the death of a borrower. Such policies protect the portfolios of banks and, indirectly, facilitate consumer access to financial services.

According to Aon (2015) 263 million people worldwide are covered by some form of microinsurance. Although this is up sharply from 78 million people in 2005, the coverage ratio still falls significantly short of its potential of several billion potential policyholders. Coverage ratios remain low, with only 4 to 8 per cent of the eligible population currently insured. Global microinsurance premiums are currently estimated to amount to USD 2.2 billion, less than one per mille of the global insurance market.

Developing Takaful insurance

Conventional insurance may contain elements that are incompatible with Islamic principles. For this reason, Takaful insurance, which is compliant with Sharia law, was developed. Under such policies, policyholder and shareholder funds are separated, and a Sharia-compliant investment strategy is pursued. As a rapidly growing business, Takaful has arguably helped to overcome objections against insurance that are rooted in Islamic law. On the back of double-digit growth rates, the global Takaful market in 2015 was estimated to generate premiums of about USD 15 billion (see Figure 28). At a 77 per cent share the Gulf countries dominate, especially with non-life products, as growth on the life side is held back by generous government provisions. In Asia, on the other hand, life insurance accounts for the biggest chunk of Takaful business, benefitting from a stringent regulatory framework, favourable demographics, and a growing middle class. In terms of major country markets, Saudi Arabia and Malaysia alone generate three quarters of global Takaful premiums (Milliman (2017)).

⁴ <https://www.willistowerswatson.com/en/press/2017/04/Willis-Towers-Watson-launches-innovative-new-cyber-product-for-global-airlines>

Figure 2B: The global Takaful insurance market



Source: Mubarrak (2017)

Note: In some Takaful markets, "gross written contribution" (GWC) is more commonly used than "gross written premium" (GWP).

4.2. The role of governments

Mandating risk communities

In certain situations, governments can help improve the availability and affordability of retail and wholesale insurance by introducing compulsory schemes which create sufficiently large risk communities and risk pools. In addition, mandatory schemes can mitigate adverse selection by standardising premium rates across risk types, enabling the cross-subsidisation of higher-risk policyholders with the premiums from lower-risk policyholders. Such schemes can be accompanied by premium subsidies for low-income households (Kousky and Kunreuther (2014) and Kunreuther (2015)).

Compulsory insurance is universally used but almost exclusively as part of social security schemes covering

health, old age and unemployment, or as compulsory (motor) liability insurance. In property insurance, however, mandatory regimes are rare (Swiss Re (2015b)).

In some developing markets, such as India and the Philippines, crop insurance is compulsory for farmers who seek loans from banks or other financial institutions. Loan-linked insurance can be used as collateral by farmers (Holzheu and Turner (2018)).

Providing public insurance programmes

Many public sector entities are increasingly utilising new forms of risk transfer, especially for natural disaster losses, in order to relieve their balance-sheets.

Countries in Africa, the Caribbean and the Pacific have always been particularly exposed to extreme weather

events such as hurricanes, droughts and floods, but in recent years this exposure has grown further on the back of population growth, urbanisation dynamics, overexploitation of natural resources, environmental degradation and changing climate and weather patterns.

Partially building on mature markets' experience with public and private-public pooling schemes, some of these vulnerable countries, supported by development agencies and donors, have joined forces by pooling their scant financial resources in regional risk-sharing vehicles. The best known examples are the Caribbean Catastrophe Risk Insurance Facility (CCRIF) established in 2007, the African Risk Capacity (ARC) set up in 2012, and the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) launched in 2016. In exchange for an annual premium, these facilities offer participating countries limited parametric payouts designed to cope with the immediate aftermath of major disasters. The payouts cover public expenditures for disaster-related emergency and relief measures only, rather than large-scale reconstruction measures. The maximum payout per country is capped at USD 100 million for CCRIF and USD 30 million for ARC.

Another example is Mexico. The country issued its first sovereign catastrophe bond with the assistance of the World Bank in 2009. The objective was to take some of the likely costs of earthquake and hurricane damage off the government's balance-sheet and into the capital markets, thereby reducing its fiscal vulnerability to future disasters. The most recent bonds, issued by the World Bank Group's multilateral development bank and facilitated by the International Bank for Reconstruction and Development (IBRD) has recently proven its usefulness in the aftermath of the Chiapas earthquake in September 2017, as a result of which the Mexican government is expecting to receive a payout of USD 150 million.

Promoting risk mitigation

As a complement to improving risk transfer, protection gaps also need to be addressed through the prevention and reduction of losses. Government-sponsored building codes, for example, are essential to establishing and enforcing risk reduction measures. According to Deryugina (2013), stricter building codes reduce the fiscal burden on the U.S. federal government in the aftermath of

hurricanes. Governments can also effectively discourage development of high-risk areas through zoning.

The insurance industry can encourage the public sector to take risk-mitigating measures. Insurers will only insure against floods in the presence of properly enforced flood prevention measures. By the same token, insurers will not provide fire insurance in the absence of fire brigades. A particularly interesting example is flood-prone Northern Queensland in Australia where insurer Suncorp has successfully encouraged municipal governments to build levees in order to reduce disaster losses. In some municipalities, following the completion of levees, average insurance premiums dropped massively, with some homeowners experiencing decreases of up to 80 per cent (Swiss Re (2015b)).

For most weather-related and other natural catastrophe risks, the private sector has the data and expertise to allow robust modeling—a key enabler of insurance coverage. When the private market can ultimately provide coverage, the public sector should focus on facilitating the availability and affordability of insurance schemes as well as creating a conducive framework for risk reduction and mitigation.

Addressing limits to insurability

In many countries, governments step in as insurers or reinsurers of last resort for certain risks which defy the most fundamental criteria of insurability. Under such circumstances, government backstop programs can facilitate private-sector insurance solutions which at least offer partial coverage. Terrorism for catastrophic scenarios is an example. As human acts without a regular historical pattern terrorism risk is inherently ambiguous and unpredictable.

The spectrum of terrorism insurance arrangements is broad. On the one hand, there is Israel which has historically faced high costs of terrorism, providing complete government coverage with no private sector involvement. At the other end of the spectrum, Germany has established Exremus, a private insurance company jointly owned by leading German (re)insurers. Exremus insures terror risks above EUR 25 million and is endowed with a government backstop to cover aggregate losses in excess of EUR 2 billion (Kunreuter and Michel-Karjan (2004), Swiss Re (2015b)).

Other public sector funded insurance programmes focus on increasing consumer affordability and access rather than on market efficiency. Examples include the U.S. National Flood Insurance Program, the California Earthquake Authority, or state-based windstorm pools such as Citizens Property Insurance in Florida.

4.3. The role of public-private partnerships (PPPs)

PPPs are of particular use in emerging markets as a means of leveraging existing public sector infrastructure to enable wider distribution, to roll out products more quickly and to achieve benefits from pooling and diversification. For example, insurance penetration can increase rapidly if governments require borrowers from public sector banks to purchase insurance as a prerequisite to loans. In addition, through PPPs government-subsidised insurance programmes can promote insurance penetration. For example in India, crop insurance has grown rapidly in recent years. The government PPP scheme Pradhan Mantri Fasal Bima Yojana (PMFBY) made crop insurance the third largest non-life insurance segment in 2016. Since inception, the scheme has provided protection for many farmers and has generated substantial premium volumes for insurers (Swiss Re (2017c)).

But in mature insurance markets as well, PPPs have an important role to play. In the context of the U.S., Kunreuther (2015) shows that PPPs can encourage investment in protective measures prior to a disaster, deal with affordability issues and provide coverage for catastrophic risks. Risk-based insurance premiums are essential for providing signals to individuals and businesses regarding the hazards they face and for enabling insurers to lower premiums if steps have been taken to reduce risk. Public interventions (e.g. subsidies linked to loss reduction measures) can enable this beneficial mechanism to work even for those who cannot afford insurance.

Figure 29 summarises the remedies discussed and illustrates their respective main (not exhaustive) relevance by country group, based on a review of the cited empirical references and our own assessment.

Figure 29: Remedies to insurance protection gaps—main areas of relevance

	Frontier markets	Emerging markets	Mature markets
 Insurers		Technology	
		Product innovation	
	Microinsurance		
	Takaful insurance		
 Governments		Risk mitigation	
	Public insurance		
	Mandatory schemes		
			Reckless provider
 PPP		Subsidised programmes	

Source: The Geneva Association

5. Conclusions

This report proposes three main conclusions: first, when assessing the relevance and value contribution of insurance to society, what really matters is the adequacy of cover judged against its effectiveness in relieving insureds (and ultimately society at large) from severe or even unbearable financial hardship. Due to its normative character, “adequacy of cover” usually escapes quantification. Therefore, in this publication general risk protection gaps are used as a gauge of societal exposure and the potential contribution of insurance to mitigating it. Genuine insurance protection gaps, as opposed to general protection gaps, are very difficult to quantify. The former describe the gap between the amount of insurance that is economically and socially beneficial and the amount of insurance actually purchased. This notion is fundamentally different from the simple gap between economic and insured losses.

Second, while protection gaps in the areas of natural disasters and pensions are well researched and widely covered by stakeholder debates, this is not necessarily the case for healthcare and cyber risks, even though the proportions of the respective protection shortfall are even more dramatic than in the area of natural catastrophes (based on uninsured losses as a share of economic cyber losses and the GDP share of OOP expenses, respectively). More research, commercial and public policy efforts need to be deployed in these highly relevant segments of the societal risk landscape. Arguably, cyber, as a genuinely global risk, presents the insurance industry with a fundamental strategic challenge that could even prove to be existential. The product suite and risk appetite of insurers increasingly fall short of the pace at which the digital economy of the future is emerging. Pessimists contend that insurers are set to lose their relevance to society if they fail to make more meaningful contributions to the protection of the virtual space of economies and societies. The health protection gap too is bound to widen in light of rising customer expectations and unabated medical inflation.

Third, our research demonstrates the importance of carefully distinguishing between developing (*frontier*), emerging and mature markets when exploring the scope and root causes of protection gaps as well as potential remedies. It is striking to note, for example, that progress in narrowing natural catastrophe protection gaps has largely remained confined to advanced economies. In addition, the potential for OOP healthcare expenses to reach catastrophic dimensions is particularly pronounced in low- and lower middle-income countries. Against this backdrop, it is absolutely plausible that international policy efforts designed to address protection gaps generally focus on developing and emerging economies.

A diligent differentiation according to stages of economic development is also crucial when analysing the root causes of protection gaps which can range from attitudinal, economic and cultural reasons to supply-side factors such as institutional shortcomings and a fundamental lack of insurability. The configuration of root causes is the basis for designing remedies and determining the most promising ‘split of responsibilities’ between insurers, governments and other stakeholders. As it is imperative to address both demand- and supply side-issues holistically and simultaneously, a joint stakeholder effort in combination with a perspective that cuts across lines of business and geographical silos appears to be a necessary condition for effectively narrowing protection gaps.

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11. Assignment 4, Module 2: Insurance Protection Gap (2):

<https://www.insurancejournal.com/news/international/2018/01/17/477266.htm>

Insurance Protection Gap Is Growing Global Problem; Swiss Re, RenRe & WTW Comment

By L.S. Howard | January 17, 2018

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Article

The insurance protection gap. It's a phrase that will be increasingly heard over the coming years – because it is getting bigger. The protection gap is the difference between insured losses and total economic losses. The protection gap, or those uninsured losses, is a global problem and affects emerging nations and developed countries alike.



The problem, emphasize insurance executives, is that properties and economies with high insurance penetration recover much more quickly after a natural disaster than properties that rely on governments for their recovery.

Swiss Re estimates that the global protection gap for weather-related risks is at least \$180 billion. It's a huge figure and a huge challenge because the solutions potentially exist, but they are not being used, said Christian Mumenthaler, group CEO of Swiss Re, who spoke on a panel on underinsurance at the reinsurance Rendez-Vous de Septembre (RVS).



Christian Mumenthaler

"This protection gap exists everywhere," he said, pointing to new risks such as cyber, drones and new technologies.

"It also exists in life and health on a very big scale," he affirmed. "There are a lot of products that could protect families if someone dies, for example, and aren't that expensive, but people don't buy them—so there is a big, big life and health protection gap."

Hurricane Harvey, which hit Texas at the end of August and early September, provides another powerful example of the protection gap. With economic losses estimated by RMS to be in the range of \$70 billion to \$90 billion, its insured losses, mostly from flood, were estimated by the catastrophe modeler to be just a fraction of that: \$25 billion to \$35 billion. (These were the latest figures available from RMS at the time of this writing in December.)

Insurance Creates Quicker Economic Recovery

There is plenty of evidence that if the economic loss from a natural catastrophe has a higher percentage that's insured, "then the economic recovery is quicker, the human deprivation is lower and the cost to the taxpayer is lower," said Stephen Catlin, special adviser to XL Group CEO Mike McGavick.

Before his retirement, Catlin was XL's deputy chairman. He currently is chairman of the Insurance Development Forum (IDF), which aims to reduce the insurance protection gap in emerging nations.

Catlin, who moderated the RVS panel, pointed to the example of New Zealand—where two-thirds of the nation's property owners were covered by insurance. As a result of this high insurance penetration, New Zealand recovered more quickly from its devastating earthquakes in 2010/2011, he said.

Common Problem with Different Causes

Mumenthaler said the situations that create protection gaps vary across the globe.

As an example, in many western countries, there are available and affordable insurance solutions to protect against natural catastrophes, but people don't buy them, he said.

Italy's October 2016 earthquakes revealed that only 1 or 2 percent of the households were covered. However, Mumenthaler said, the 1 percent who had insurance received their check and have rebuilt their houses, while the rest, who were helped by government, are still waiting.

The Italian Civil Protection Agency estimates the economic losses from the October earthquake series at €16.5 billion (\$19.2 billion). PERILS, the independent Zurich-based organization that provides industrywide catastrophe insurance data, estimates the earthquakes had insured losses of €208 million (\$241.6 million), which means that just 1.3 percent of the overall economic loss was insured.

And for California, the situation is the same.

"They know there are going to be earthquakes in California," Mumenthaler said. "They have always existed, and yet only 12 percent of the people who have a fire policy have earthquake cover, so it's a huge gap."

He said the least amount of progress has been made in closing the protection gap in western economies, which is "a bit depressing for our industry."

Aon Benfield's "Reinsurance Market Outlook," published in January 2018, said, natural catastrophe events continue to highlight the protection gap existing even in developed markets.

"The proportion of total losses covered by insurance is estimated at only 40 percent in 2017, despite the relatively high insurance penetration rate prevailing in the U.S.," said the report.

Aon Benfield noted the insurance recovery ratio in the U.S. in 2017 was estimated at 47 percent, which is below the 17-year average of 54 percent, due to the relatively high proportion of losses caused by flooding, particularly during Hurricane Harvey.

Emerging Nations

On the other hand, the industry and initiatives like the IDF have had more success in closing the protection gap in emerging nations where even when insurance exists, people can't afford it.

"There I'm more encouraged. Over the last 10 years, a lot of us have been engaging with governments...to find new solutions," Mumenthaler said, admitting, however, that it's a long process.

"If you approach governments for the first time, they will have a lot of prejudices about the insurance industry. They have a lot of frustrating stories," he said.

"But as you explain what you do, and you get people to get more comfortable about what we do, we've had a lot of successes across the world, including very poor countries like Kenya, Malawi, Vietnam, etc., where hundreds of thousands of people have been covered through schemes that were sponsored by [Swiss Re and other companies] and sometimes brokered by the big brokers," Mumenthaler continued.

Technology is helping a lot with insurance penetration, he affirmed.

"You cannot have huge costs in these instances, so new technologies like satellite imagery actually help to determine when to pay, without having tens of thousands of claims adjusters running around," he said.

As an example, the technology that exists in Kenya where people can have money transferred using their phones actually is a very efficient way to transfer the funds after an event, he said. "To a certain extent, some of the most digital value chains I've seen in insurance have happened in other countries like Kenya."

There has been progress made, but it's not enough for companies to work on their own, as Swiss Re has for about a decade.

When the idea for the IDF was formed, he said, Swiss Re supported the project because a huge part of IDF is sharing knowledge and education. "This is where we need all the resources from the industry," he said.

"IDF has made great progress," Mumenthaler said, adding that IDF representatives know how to talk to governments.

"I was particularly pleased that the United Nations and the World Bank joined this because I think it's critical that we bridge the gap of understanding and mutual trust..."

Lack of Models

One of the big challenges to bringing natural disaster insurance into emerging nations is the lack of models and data to support the models, which Ian Branagan is trying to address as co-chair of the risk modeling and mapping working group of the IDF. In his day job, Branagan is senior vice president and group chief risk officer at Renaissance Re.



Ian Branagan

During his talk at the RVS, he discussed extending risk modeling capabilities to the most vulnerable countries in the world.

The absence of models and data to support the models in the developing world is the key issue of the slower development of resiliency and disaster risk financing in those countries, Branagan said.

The absence of these models is partially due to the fact that historically, both in the private sector and the public sector, development of models to understand natural hazards has been done on a demand-led way, he explained.

“In the insurance industry, that’s typically if there’s an existing or foreseeable, reasonable economic opportunity of some sort. This is true not just across natural hazards. This is true across many perils, such as cyber,” he added.

On the other hand, in the public sector, demand typically follows an event, Branagan noted. “All too often, when bad things happen, the risk understanding and the risk tools and the models to be able to provide preparedness and financing aren’t there when they’re needed.”

For example, he said, in the developing world, there are huge swaths of Asia and Africa where there is information about hazard, which is sometimes higher quality and sometimes lower quality, “but there often is almost zero information about the exposure and about the overlay of hazard and exposure to generate risk.”

As a result, his IDF risk modeling and mapping group has come up with a plan to solve the absence of models in some developing regions by moving away from the demand-led approach. (He explained that the group is composed of about 50-60 individuals from academia, the private and public sectors, commercial modeling companies, and a host of others.)

If the public and private sector really want to develop models in a more efficient, effective and speedy manner, then a collaborative strategic modeling agenda should be created and funded, Branagan continued.

“What that means is selecting a suite of countries for which a collaborative effort will be employed to develop out the underlying hazard, exposure and risk models, building capabilities for understanding risk in the region,” he said. “It will enormously speed up the process and create much greater efficiency to bring disaster risk financing to those regions.”

While there is still an enormous amount to do, Branagan said, “there is enough effort and money already being spent to significantly make a dent in the provision of risk models and risk data in the developing world.”

Addressing Misunderstandings

In his presentation at the RVS, Rowan Douglas, CEO Capital Science & Policy, Willis Towers Watson, said that IDF is helping to address the “deep misunderstandings” that exist about the insurance industry’s appetite for risk.

“If you talk to the wider world outside...our industry, they would assume that the industry is quite scared of risk,” Douglas said, explaining that many people assume the growth of risk in the last 25 years, due to climate change and population and economic growth, “is something that actually puts off our industry.”



Rowan Douglas

Governments and international institutions, such as the World Bank and the United Nations, have commonly thought the insurance industry has an aversion to risk when in reality it seeks more risk transfer opportunities and more risk diversification, explained David Simmons, managing director, Capital, Science & Policy Practice, Willis Towers Watson, who works closely with Douglas and the IDF. (Simmons provided his comments by email.)



David C. Simmons

As a result of these misapprehensions, the IDF frequently has to explain that “our industry feels fundamentally quite comfortable with those risks,” especially natural catastrophe risks, said Douglas during his presentation.

That’s not to say that everything is insurable, but it’s not the risks that are the major challenge to the insurance industry. The major challenge is lack of demand, he added.

The industry needs to stimulate the generation of demand for insurance by creating the right mechanisms to enable people to consume risks either individually or collectively, which is being helped by the IDF and other risk facilities seeking to bridge the protection gap, he said.

Douglas noted that the industry itself also needs education to appreciate that significant business opportunities exist from sustainable development goals or the Paris climate agreement adaptation mechanism.

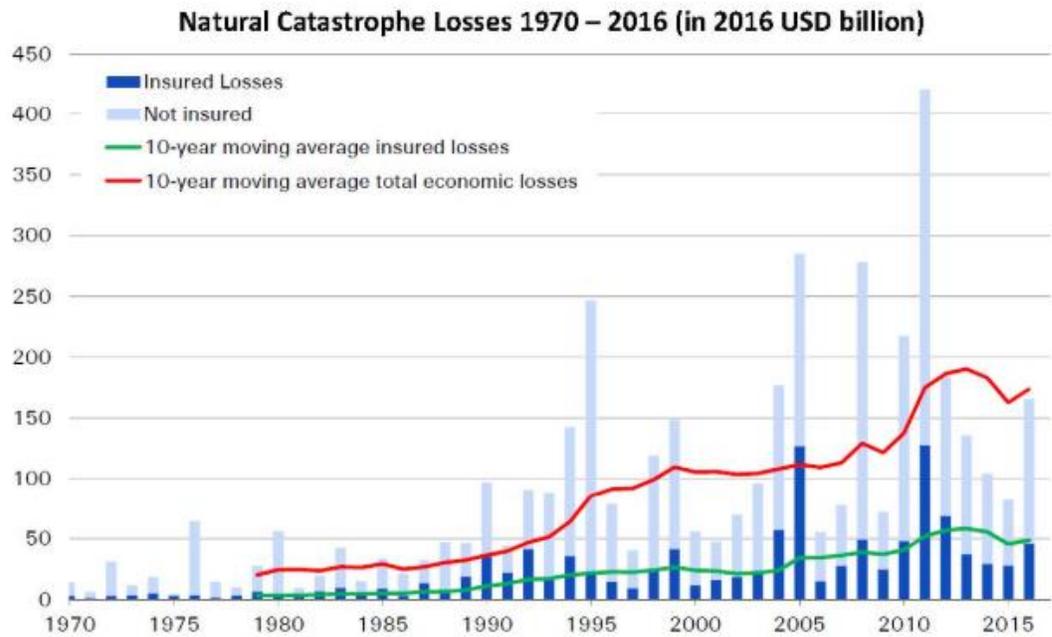
The need to understand risks that society faces “implicitly means that we need to quantify and manage that risk,” explained Simmons. “Insurance helps to mitigate the impact of natural disasters, while insurance-led modeling in risk understanding drives better risk management and response.”

During his speech, Douglas said, “Some people say to me, ‘Why are we involved with poverty reduction?’ I say, ‘It depends on how you look at it.’”

He explained that providing people in developing or emerging countries with insurance against the shocks of major natural disasters is a mechanism for relieving and hopefully alleviating poverty—often multigenerational poverty—from natural disasters.

“Governments aren’t supporting people to have insurance for insurance’s sake. It’s to protect people from poverty,” Douglas noted.

Confronting Global Underinsurance amid Heightened Global Risks



Source: Swiss Re Economic Research & Consulting and Cat Perils

12. Assignment 4, Module 3: Continental US Landfall Frequency:

<https://journals.ametsoc.org/view/journals/bams/99/7/bams-d-17-0184.1.xml>

ARTICLES

CONTINENTAL U.S. HURRICANE LANDFALL FREQUENCY AND ASSOCIATED DAMAGE

Observations and Future Risks

PHILIP J. KLOTZBACH, STEVEN G. BOWEN, ROGER PIELKE JR., AND MICHAEL BELL

While neither U.S. landfalling hurricane frequency nor intensity shows a significant trend since 1900, growth in coastal population and wealth have led to increasing hurricane-related damage along the U.S. coastline.

Among weather-related disasters, landfalling tropical cyclones (TCs) are a leading cause of economic damage in the continental United States (CONUS) and globally (www.aonbenfield.com/catastropheinsight). The very active and destructive 2017 Atlantic hurricane season resulted in an excess of \$125 billion in damage in the CONUS (Aon Benfield 2018). Landfalling TCs also accounted for 8 of the top 10 costliest U.S. insured losses from natural disaster events according to Aon Benfield through 2017. CONUS

landfalling hurricane damage has risen dramatically since the start of the twentieth century after adjusting historical losses for inflation (Pielke et al. 2008). However, because property and wealth exposed to hurricane impact accumulate in exposed coastal locations, inflation adjustments alone cannot entirely capture the increased potential for losses if those same storms were to impact at today's levels of development.

Several studies have examined trends in CONUS hurricane losses since 1900 by normalizing historical damage to modern-day values by adjusting for inflation, population, and various individual wealth metrics, as well as other factors (Pielke and Landsea 1998; Pielke et al. 2008; Schmidt et al. 2010; Nordhaus 2010; Bouwer and Wouter Botzen 2011; Neumayer and Barthel 2011; Barthel and Neumayer 2012). These studies have typically shown no significant trend in CONUS landfalling normalized damage once societal change is considered (Pielke et al. 2008). This result is expected, as landfalling CONUS hurricanes have not increased in frequency or intensity from 1900 through 2017 (as shown below), meaning that an unbiased normalized loss record

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would be expected to show the same (lack of) trend. Independent climate and economic data indicate that the primary source of the increase in damage caused by hurricanes in recent decades is due to increases in exposure along the U.S. East and Gulf Coasts (Pielke et al. 2008; Bouwer and Wouter Botzen 2011).

This manuscript has three primary themes. Following a discussion of data sources, we examine trends in both CONUS landfalling hurricanes and CONUS normalized damage from 1900 to 2017. We then reexamine the relationship between El Niño–Southern Oscillation (ENSO) and CONUS landfalling hurricanes (Bove et al. 1998; Klotzbach 2011) along with the relationship with associated normalized damage (Pielke and Landsea 1998). This section also updates the impact that the phase of the Atlantic multidecadal oscillation (AMO)¹ has on CONUS landfalling hurricanes and damage (Landsea et al. 1999). The manuscript then examines potential future CONUS landfalling hurricane damage through analyses of current and projected trends in coastal exposure and finishes with a discussion and conclusions.

DATA AND METHODOLOGY. CONUS hurricane landfall data are extracted from the Atlantic Oceanographic and Meteorological Laboratory’s (AOML) website for the periods 1900–60 and 1983–2016 (www.aoml.noaa.gov/hrd/hurdat/UShurrs_detailed.html). For the period 1961–82 for which the National Hurricane Center’s (NHC) “best track” hurricane database (HURDAT2) reanalysis project (Landsea and Franklin 2013) is not yet complete, we calculated hurricane landfall locations directly from hurricane tracks plotted from HURDAT2 with landfall intensities constrained to be the same Saffir–Simpson category as listed on the AOML website (www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html). Landfall locations and intensities for the 2017 Atlantic hurricane season were taken from NHC operational advisories. Multiple landfalls by an individual TC were counted separately as long as they traveled over the open ocean for at least 100 miles between their individual landfalls. In the case of 2017, all three CONUS hurricanes (Harvey, Irma, and Nate) made multiple landfalls, but the second landfall was less than 100 miles from the first

one; consequently, each storm was counted once in this analysis.

Base damage adjusted for inflation and normalized damage estimates for historical CONUS landfalling TCs were taken from the ICAT Damage Estimator (www.icatdamageestimator.com/), which is based on Pielke et al. (2008). Damage values in the ICAT database through 2016 were adjusted to 2017 dollars using the methodology of Pielke et al. (2008). The 2017 damage total was taken from individual storm estimates determined by Aon Benfield (2018).

The definition of ENSO events used here is the August–October-averaged oceanic Niño index (ONI). The ONI is the official index used by the National Oceanic and Atmospheric Administration (NOAA) to define ENSO events. We calculate the ONI from the NOAA Extended Reconstructed SST, version 4 (Huang et al. 2015). The August–October ONI is defined to be the August–October average of Niño-3.4 (5°S–5°N, 170°–120°W; Bamston et al. 1997) sea surface temperature (SST) anomalies calculated from 30-yr centered base periods updated every 5 years. Any August–October-averaged ONI greater than 0.5°C was classified as El Niño, an anomaly less than –0.5°C was classified as La Niña, and all other seasons were classified as ENSO neutral. Using this metric, 29 years were classified as El Niño, 29 years were classified as La Niña, and the remaining 60 years were classified as ENSO neutral.

Our definition of the AMO-classified seasons used the same approach as in Klotzbach and Gray (2008), whereby 1900–25 and 1970–94 were classified as negative AMO periods, and 1926–69 and 1995–2017 were classified as positive AMO periods. There is considerable uncertainty as to whether the Atlantic has in recent years reverted to a negative AMO phase (Klotzbach et al. 2015), but given the very active 2017 Atlantic hurricane season that has just occurred, we prefer to extend the positive AMO phase through to the present, recognizing that such a classification remains provisional. However, the results displayed for the AMO throughout the manuscript would not show significant differences were the 2013–17 period to be reclassified as a negative AMO phase.²

Statistical significance for trends in both landfall frequency and normalized damage were evaluated using a *t* test. All statistical significance tests must

¹ We note that there remains vigorous scientific discussion as to the origins of the AMO, with some arguing that the Atlantic meridional overturning circulation is the primary driver (Grossmann and Klotzbach 2009; Yan et al. 2017), while others argue that sulfate aerosol (Booth et al. 2012) or stochastic midlatitude atmospheric forcing plays a greater role (Clement et al. 2015).

² For example, the average positive (negative) AMO number of CONUS landfalling hurricanes per year is 1.94 (1.53) when treating 2013–17 as a continuation of a positive AMO phase, while the average number is 2.00 (1.50) when treating 2013–17 as a new negative AMO phase.

exceed the 5% level to be considered significant. For the remainder of the document, significant and insignificant trends refer to those that exceeded and failed to exceed the 5% level, respectively. Each year was counted as an individual degree of freedom, since there is little autocorrelation between one year's Atlantic hurricane activity (correlation coefficient $r = 0.11$) or damage ($r = 0.22$) and that experienced the following year. Monte Carlo simulations were conducted to determine the differences in mean and median values between climate modes and CONUS hurricane landfalls and damage. A total of 1,000 random time series with the same number of years as the climate mode being investigated were drawn from the full 118-yr dataset. For example, in the cases of both El Niño and La Niña, 1,000 time series, each 29-yr time series of the full 118-yr time series was drawn. If the observed value was either greater than the 95th percentile or less than the 5th percentile of the randomly drawn values, then the difference from the mean value of all seasons was said to be significant at the 5% level. However, such simple statistics should be interpreted with caution, as climate variables may or may not exhibit stationarity, and the textbook notion of observations serving as a sample from a population may not accurately represent out-of-sample climate processes (Saunders et al. 2017).

TRENDS IN CONUS LANDFALLING HURRICANES AND NORMALIZED HURRICANE DAMAGE. We begin by examining the long-term trend in CONUS landfalling hurricanes

and damage since the start of the twentieth century. Inflation-adjusted CONUS hurricane losses show a significant increasing trend since 1900 (Fig. 1). However, there is an insignificant trend in CONUS landfalling hurricanes from 1900 to 2017 (Fig. 2a). When we examine only hurricanes that made landfall at major hurricane strength (Saffir–Simpson categories 3–5) (1-min sustained winds ≥ 96 kt; $1 \text{ kt} = 0.51 \text{ m s}^{-1}$), which are responsible for greater than 80% of all normalized tropical cyclone-related damage (Pielke and Landsea 1998), we find a similar insignificant trend (Fig. 2b). We therefore conclude that the large increase in observed hurricane-associated inflation-adjusted CONUS damage (Pielke et al. 2008) is primarily due to increases in exposure as opposed to increasing frequency or intensity of hurricanes making CONUS landfall.

We next employ the same methodology used in Pielke et al. (2008) to examine trends in CONUS hurricane damage since 1900 normalized to 2017 values, noting that there is currently an effort underway by Pielke and colleagues to comprehensively update Pielke et al. (2008). The long-term normalized hurricane damage record also shows no significant trend. One of the most notable items is the extreme year-to-year variability in the time series (Fig. 3). For example, the most damaging normalized CONUS landfalling hurricane is the Miami (Florida) hurricane of 1926, which is estimated to result in $> \$210$ billion in damage were it to occur in 2017. If the normalization is unbiased, then no significant trend in CONUS normalized hurricane damage since 1900

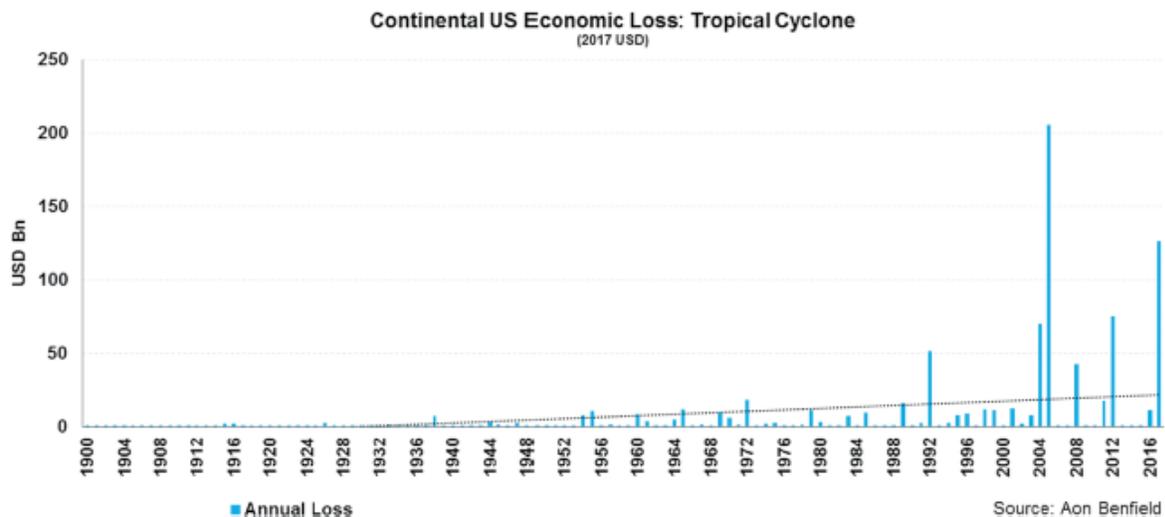


FIG. 1. CONUS total inflation-adjusted economic losses from TC landfalls (1900–2017). The dotted line represents the linear trend over the period. The p value for the linear trend is < 0.01 , indicating that the trend is significant.

is expected, which is consistent with no significant trend in landfalling hurricanes or major hurricanes.

The fact that both climate trends and normalization trends show no significant increases or decreases provides an indication that the normalization methodology is, in aggregate, unbiased.³ In other words, the adjustments to economic data result in a time

series with statistical properties that correspond with those of the climate time series, as would be expected from an unbiased normalization. Climate data provide an independent check on the normalization time series.

RELATIONSHIPS BETWEEN LARGE-SCALE CLIMATE MODES AND CONUS LANDFALLING TROPICAL CYCLONE FREQUENCY AND DAMAGE. ENSO.

We next examine how ENSO is related to the frequency and intensity of CONUS landfalling hurricanes. About 1.75 times as many hurricanes make CONUS landfall in La Niña seasons compared with El Niño seasons (Fig. 4a), although Jagger and Elsner (2006) found that the strongest storms making CONUS landfall occur in El Niño seasons. We find similar ENSO-related modulation in both Florida and East Coast landfalls as well as Gulf Coast landfalls. The La Niña-to-El Niño ratio is slightly larger for all hurricane landfalls than for major hurricane landfalls (Fig. 4b), which is also in keeping with prior research (Bove et al. 1998; Klotzbach 2011), although we note that the increase in hurricane landfalls observed in La Niña seasons from that observed in all seasons does not meet the 5% significance level. The stronger modulation of stronger hurricane activity is in keeping with physical reasoning, since more conducive environments are necessary to sustain major hurricane intensity as opposed to category 1–2 hurricane intensity. Gray (1984) documented that vertical wind shear in the Caribbean and farther east into the tropical Atlantic increased in El Niño seasons, creating conditions that were detrimental for TC formation and intensification. Tang and Neelin (2004) showed that El Niño also increases upper-tropospheric temperatures in the tropical Atlantic, thereby stabilizing the air column and suppressing deep

³ It is of course possible that there are numerous biases that are insignificant or cancel out each other.

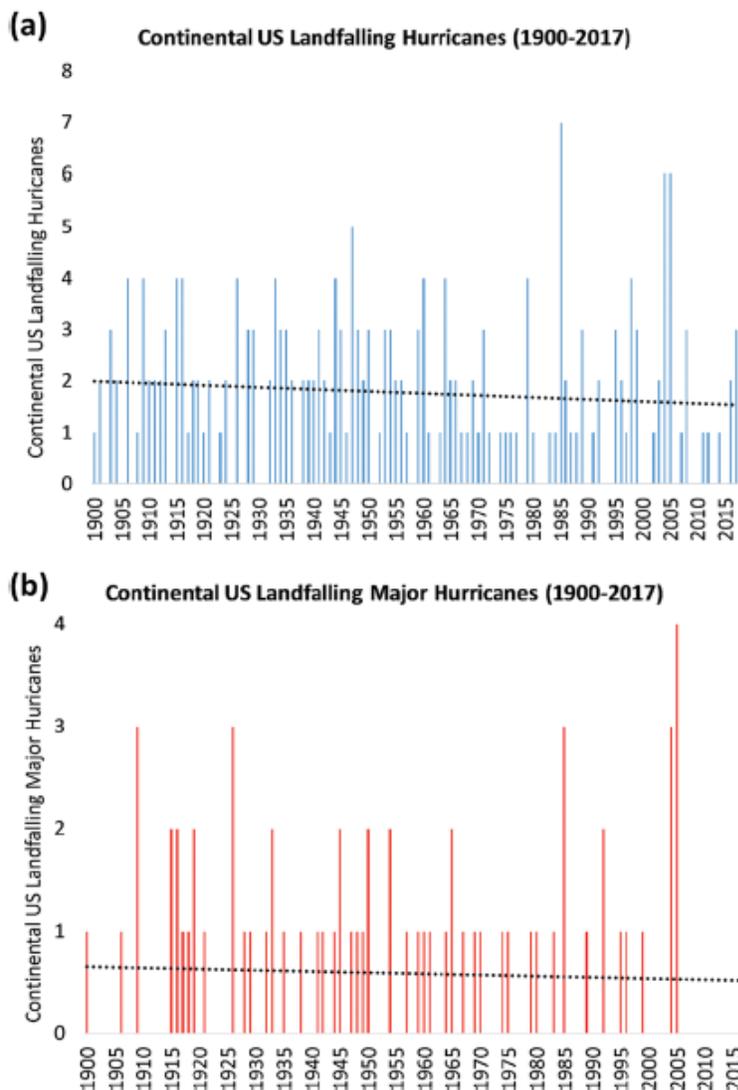


FIG. 2. (a) CONUS landfalling hurricanes by year from 1900 to 2017, and (b) CONUS landfalling major hurricanes by year from 1900 to 2017. The dotted lines represent linear trends over the period. The *p* values for the linear trends are 0.33 for landfalling hurricanes and 0.61 for landfalling major hurricanes, indicating that neither of these trends are significant.

convection. El Niño has also been shown to be associated with a weaker subtropical high, promoting the recurvature of TCs and reducing the frequency of CONUS hurricane landfall (Colbert and Soden 2012).

CONUS normalized hurricane damage shows a large increase in La Niña seasons compared with El Niño seasons, with neutral ENSO conditions having larger median damage than El Niño seasons but less than La Niña seasons (Fig. 5a). Normalized damage in El Niño seasons is significantly less than the median damage incurred in all seasons, while the observed median damage in La Niña seasons is significantly more than the median damage incurred in all seasons. The reduction in normalized damage in El Niño seasons and the increase in normalized damage in La Niña seasons are significant for Florida and the East Coast. The significance level of the reduction for Gulf Coast damage in El Niño is unable to be determined precisely, as ~25% of all Monte Carlo simulations for Gulf Coast damage returned a median damage of \$0. Note that the combined Florida and East Coast and Gulf Coast median damage values do not sum to the CONUS total in Fig. 5, since median values are being plotted (as opposed to mean values).

Since 1900, a total of 37 years have had over \$10 billion in normalized damage. Only four of those years were classified as El Niño seasons: 1965, 1969, 1972, and 2004. Two of these seasons (1969 and 2004) would qualify as weak El Niño seasons using the current operational definition of NOAA for ENSO strength, as their ONI values were $<1^{\circ}\text{C}$. Both 1965 and 1972 would qualify as strong El Niño seasons. As would be expected given the volatile nature of the normalized damage time series, the standard deviation of the damage is much larger than the median value (Fig. 5b). These conclusions are consistent with those of Pielke and Landsea (1999) using 21 years of additional data.

AMO. Our focus now turns to the AMO (Goldenberg et al. 2001) and its relationship with CONUS hurricane landfall frequency. Klotzbach and Gray (2008) demonstrated a significant modulation in both

Continental US Landfalling Hurricane Normalized Total Economic Damage (1900-2017)

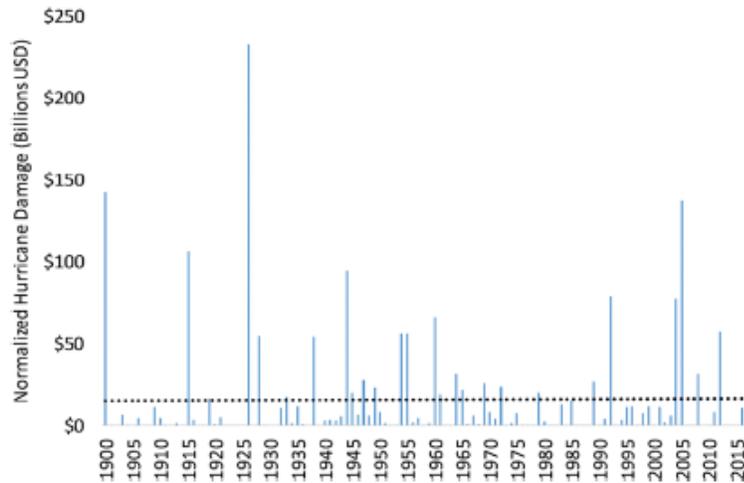


FIG. 3. Normalized CONUS landfalling hurricane damage from 1900 to 2017. The dotted line represents the linear trend in CONUS hurricane normalized damage during the period of record. The p value for the linear trend is 0.86, indicating that the trend is not significant.

basinwide and Florida and East Coast landfalling hurricane frequency. We find similar results, with a significant increase in both CONUS and Florida and East Coast landfalling hurricanes in positive AMO phases (Fig. 6a) and a significant decrease in negative AMO phases from the average of all hurricane seasons. Little signal is observed for hurricanes making landfall along the Gulf Coast. This is likely due to different formation mechanisms for Florida and the East Coast versus Gulf Coast systems. Hurricanes making landfall in Florida and along the East Coast often form from Cape Verde hurricanes or develop in the Caribbean, which are areas where the AMO plays a significant role (Klotzbach and Gray 2008) (Fig. 7). Hurricanes making landfall along the Gulf Coast can form from these mechanisms but can also form in either the Bay of Campeche or in the Gulf of Mexico. TCs forming in the Gulf of Mexico or in the subtropical Atlantic are not as significantly modulated by the AMO (Goldenberg et al. 2001).

When examining CONUS major hurricane landfalls, we find a significant modulation between positive and negative AMO phases for Florida and East Coast landfalls, while we continue to find very little difference for the Gulf Coast (Fig. 6b). The difference in CONUS landfalls between AMO phases also is not statistically significant. Median U.S. normalized hurricane damage shows statistically significant modulations by the AMO, with ~9 times

as much median damage in a positive AMO season compared with a negative AMO season (Fig. 8a). The difference is also significant for Florida and the East Coast, with over \$800 million in median damage for Florida and the East Coast in a positive AMO compared with \$69 million in a negative AMO. While the differences in median damage are considerable for the Gulf Coast as well (\$105 million for positive AMO vs \$4 million for negative AMO), these differences are not statistically significant. As was the case

with ENSO, the standard deviation of year-to-year normalized damage by AMO phase is quite large, indicating the high levels of volatility in the normalized damage time series (Fig. 8b).

BACKGROUND FACTORS FOR CONUS LANDFALLING HURRICANE DAMAGE.

Population and housing. With the historical hurricane landfall and financial cost trends established, the focus can now shift toward the future and what

trends may be experienced in the decades to come given observed socioeconomic and demographic shifts. Of particular interest to many sectors—including local, state, and federal government agencies, as well as the insurance industry—is the continued pattern of population increases along coasts, and in turn greater exposures to hurricanes.

Decadal data from the U.S. Census Bureau from 1900 to 2010 show that the population of the United States grew from 132 million to 309 million, equal to an annual growth rate of 2.8%. However, when breaking the country into six distinct regions (Atlantic, Gulf Coast, noncoastal South, Midwest, West, coastal West) (Fig. 9a), there are vastly different annual growth rates and total counts of residents since 1940 across each of these regions (Fig. 9b). This is particularly true during the past ~50 years. Partial decadal census data from 2010 to 2016 show a continuation of these trends, with the U.S. population now estimated at 323 million.

From 1970 to 2016, regional annual rates of growth were as follows:

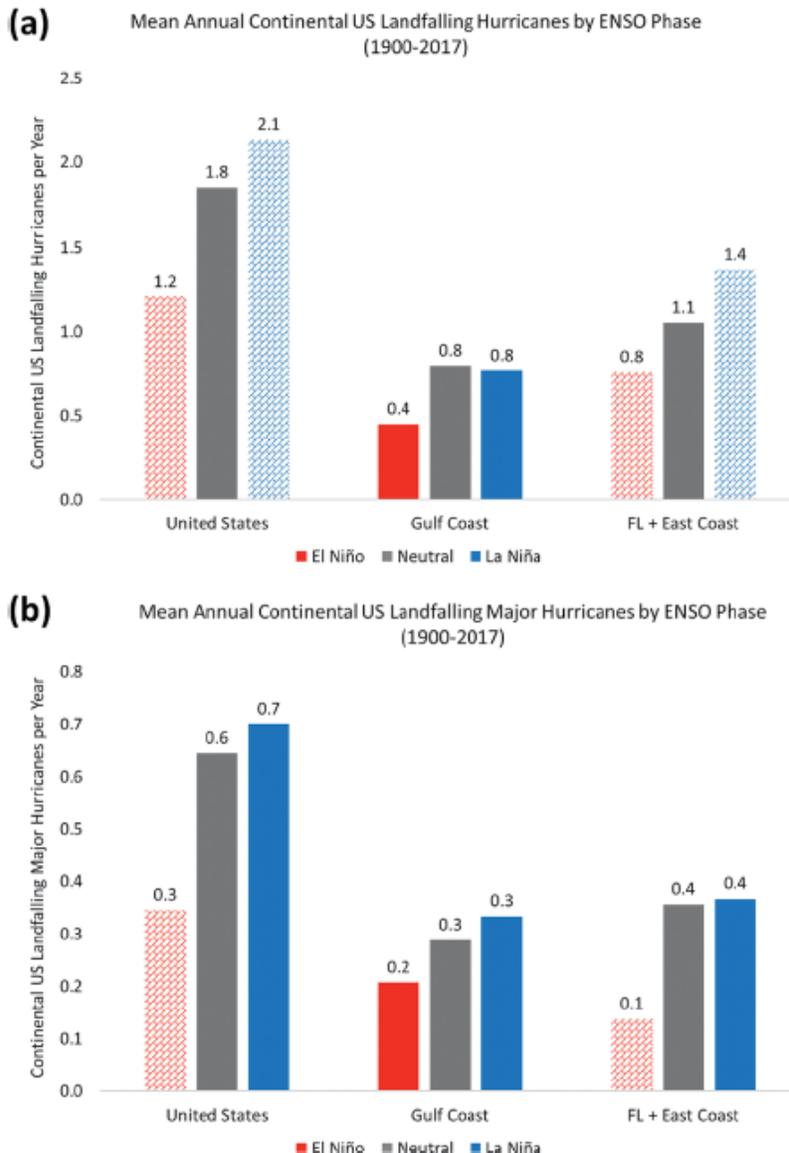


FIG. 4. (a) Mean annual CONUS landfalling hurricanes by ENSO phase from 1900 to 2017, and (b) mean annual CONUS landfalling major hurricanes by ENSO phase from 1900 to 2017. Differences that are significant at the 5% level are plotted with diagonal hatching.

West, 3.9%; Gulf Coast, 2.7%; coastal West, 2.1%; noncoastal South, 1.2%; Atlantic, 0.8%; and Midwest, 0.4%. The national growth rate was 1.3%. When breaking down the data into raw totals, during the 47 years from 1970 to 2016, the actual population increase was as follows: Gulf Coast, +33.7 million; Atlantic, +26.5 million; coastal West, +25.1 million; West, +16.7 million; Midwest, +11.4 million; and noncoastal South, +6.4 million. This indicates that over 60 million more people are now living in states directly exposed to TC landfall than in 1970.

In the years since the last official decadal census in 2010, an even more pronounced trend of coastal growth has occurred, as some of the greatest rates of population growth were found in particularly vulnerable hurricane landfall locations. Of the top 20 fastest-growing counties from 2010 to 2016, 13 were in hurricane-prone states, including 12 in either Florida or Texas (Table 1). While much of the growth is occurring in ocean-bordering counties, which are most prone to high-impact damage at the point of TC landfall, a significant portion of growth is found in areas farther inland. This means that there is an increased risk of exposed inland population and property to be impacted by hurricanes in their weakening or posttropical phases. Recent examples such as Hurricane Irma (2017), Hurricane Sandy (2012), and Hurricane Ike (2008) highlighted damage from high winds, prolonged rainfall and flooding, and severe convective storms that were recorded well inland from the initial landfall location.

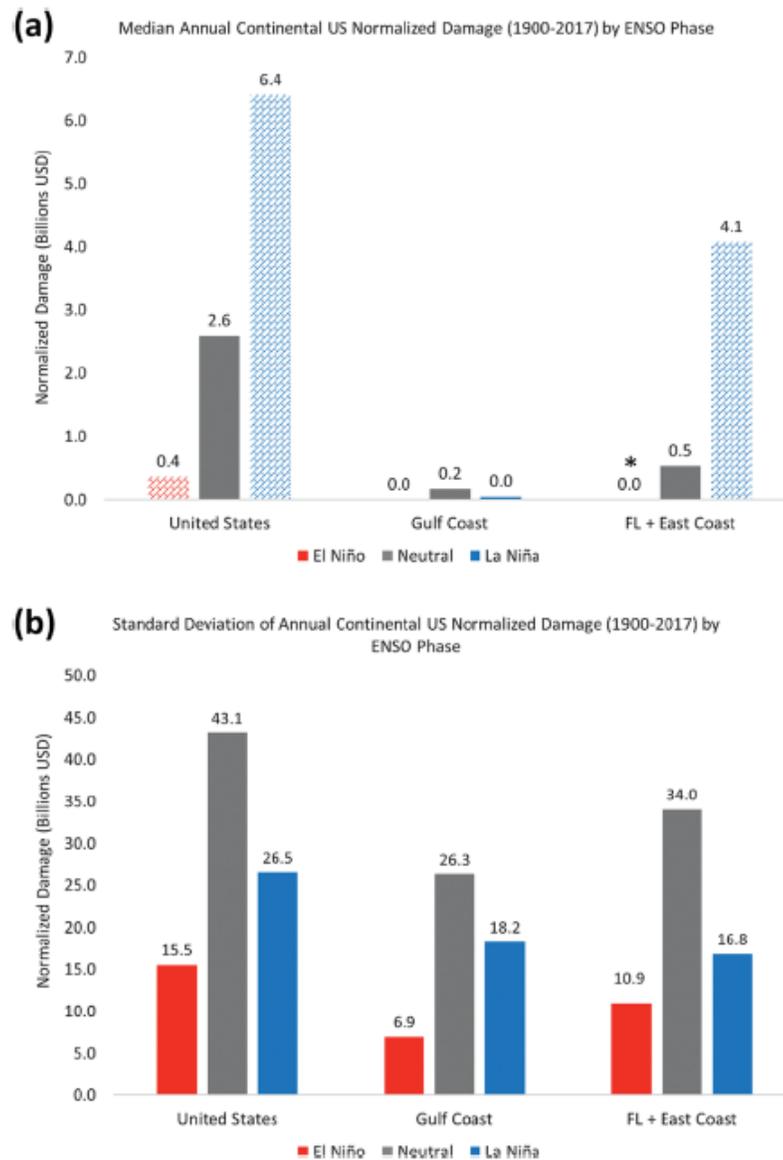


FIG. 5. (a) Median and (b) standard deviation of annual CONUS normalized hurricane damage by ENSO phase. Differences in the median that are significant at the 5% level are plotted with diagonal hatching. The asterisk in (a) above the El Niño bar in the Florida and East Coast column indicates that this difference is significant at the 5% level (the hatching would not display since the value is so small).

Unsurprisingly, the growth in population has directly correlated to an accelerated rate of exposure⁴ increase in these same areas. Further analysis using housing count data from the U.S. Census Bureau

⁴ For this exercise, an *exposure* is defined as any public, residential, and commercial building or other physical structure, as well as the wealth that it contains.

shows that annual national housing units grew from 37 million (1940; first year of data collection) to 136 million (2016). This corresponds to a national average annual growth rate of 3.5% during the 77-yr period.

Similar to the trends seen with population, there has been a wide spread of housing unit growth rate and aggregated count among the six identified regions since 1970 (Fig. 10). The regional annual rate of housing count growth was as follows: West, 5.5%; Gulf Coast, 3.8%; coastal West, 2.4%; noncoastal

South, 2.2%; Atlantic 1.6%; and Midwest, 1.3%. The national rate during this time was 2.1%. The higher rate of growth for housing count versus population suggests that more people have bought multiple properties during this time, increasing the volume and scope of exposure. In addition, U.S. Census Bureau data show a slow decline in the average number of people per household from 3.14 in 1970 to 2.53 in 2016, providing another possible explanation for the increase in housing units.

Further studies have shown that household composition and structure has also continued to evolve over time. For instance, the number of households identified as “family” in U.S. Census Bureau surveys conducted between 1940 and 2010 has shown a decrease from 90% to 66%, while “nonfamily” households increased from 10% to 34% (Jacobson et al. 2012).

When breaking down the data into raw totals, from 1970 to 2016, the actual regional housing unit increase was as follows: Atlantic, +18.1 million; Gulf Coast, +16.3 million; Midwest, +11.0 million; coastal West, +9.9 million; West, +7.7 million; and noncoastal South, +4.0 million. Most strikingly, the two most vulnerable regions for hurricane landfall—Atlantic and Gulf Coast—combined for over 34 million new homes, or 51% of all new housing units during this time.

One final metric regarding housing units examined here is the actual size of single-family homes. Since the U.S. Census Bureau first started collecting data on single-family home size, the average home has grown from 1,660 square feet (1973) to 2,640 square feet (2016) ($1 \text{ ft}^2 \approx 0.09 \text{ m}^2$), or by

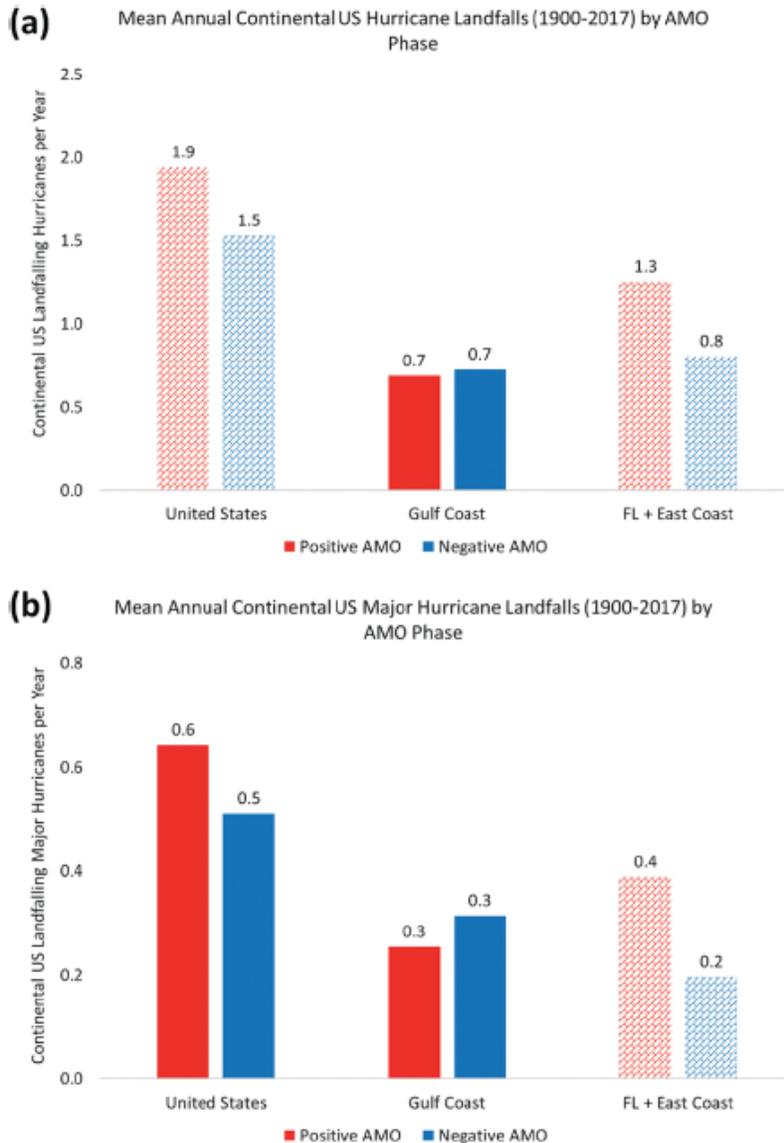


FIG. 6. (a) Mean annual CONUS landfalling hurricanes by AMO phase from 1900 to 2017, and (b) mean annual CONUS landfalling major hurricanes by AMO phase from 1900 to 2017. Differences that are significant at the 5% level are plotted with diagonal hatching.

59%. The two regions, as defined by the U.S. Census Bureau, that have noted the greatest growth in size are the Northeast and South (Fig. 11). Larger homes often require greater cost and more material to build. When a hurricane makes landfall, the combined costs to rebuild or fix a home—plus higher costs often associated with demand surge at construction and home retail sectors—often enhance the final damage bill beyond a home's original value.

An important point regarding housing unit exposure and financial losses in TC-prone areas is the quality of construction and efficiency of building codes. Damage assessments conducted by one of this paper's authors (S. Bowen) following Hurricanes

Harvey, Irma, and Maria in 2017 found that structures either built to modernized code and/or with proper elevation in areas identified in the most current Federal Emergency Management Agency (FEMA) flood zones often reported minimal damage. In Texas, the worst flood damage from Harvey often occurred to older-built structures constructed at ground level; while in Florida, structures built prior to current stringent codes developed after Hurricane Andrew (1992) performed much more poorly in areas where Irma's radius of maximum winds occurred. Many other studies have delved more deeply into the positive impact of improved building codes over time with respect to hurricane-force

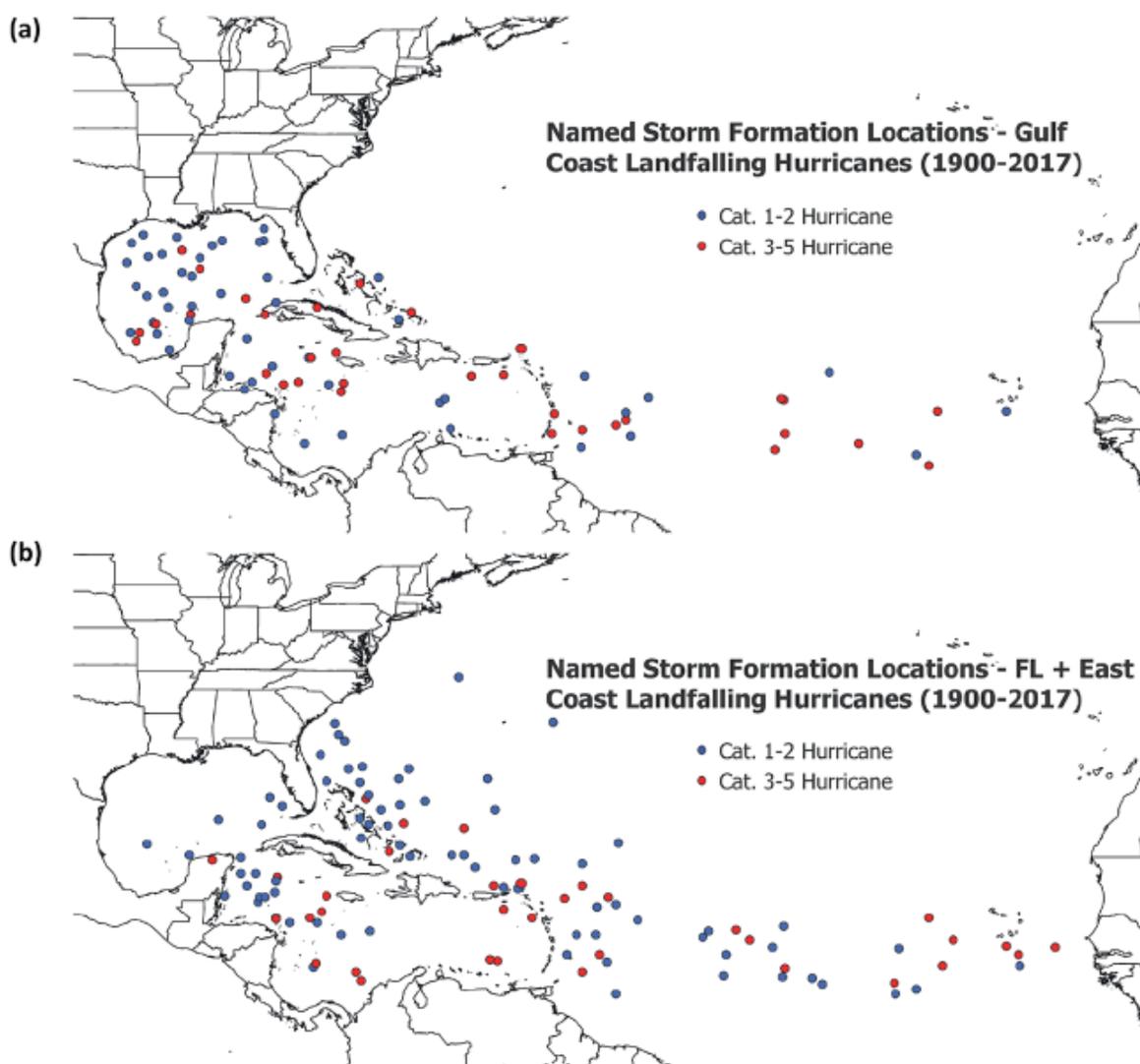


FIG. 7. (a) Named-storm formation location for all Gulf Coast landfalling hurricanes from 1900 to 2017, and (b) named-storm formation location for all Florida and East Coast landfalling hurricanes from 1900 to 2017.

winds, notably in Florida (Done et al. 2017). Simply put, when homes and structures are built properly to recommended modernized guidelines in TC-prone or flood-risk areas, the magnitude of damage can be reduced. Future work with academia and private sector groups will prove critical to continued improvements in future building codes and their enforcement. One particular private sector group

conducting such studies, the Insurance Institute for Business and Home Safety (IBHS), is an insurance industry organization that focuses entirely on independent scientific research and whose mission statement includes to “identify and promote the most effective ways to strengthen homes, businesses and communities against natural disasters and other causes of loss” (<https://disastersafety.org/about/>).⁵

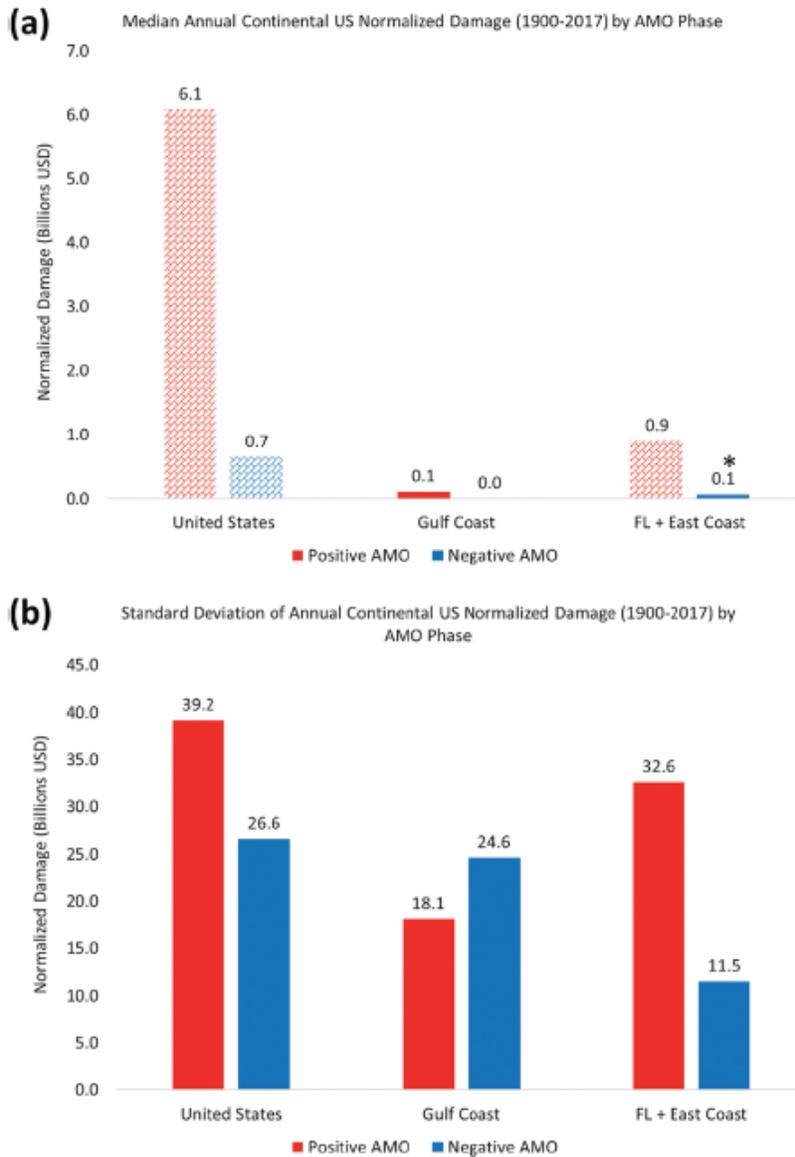


FIG. 8. (a) Median and (b) standard deviation of annual CONUS normalized hurricane damage by AMO phase. Differences that are significant at the 5% level are plotted with diagonal hatching. The asterisk in (a) above the negative AMO bar in the Florida and East Coast column indicates that this difference is significant at the 5% level (the hatching would not display since the value is so small).

Wealth. Another data metric highlighting the expectation of greater future TC-related catastrophe losses is the general increase in wealth. Using available data from the U.S. Bureau of Economic Analysis (BEA; 1980–2016), nationwide gross domestic product (GDP) has trended upward at an annual average of 2.8%. Using the “real” inflation-adjusted BEA dataset, with losses indexed/chained to 2009 dollars, the BEA cites GDP growth from \$6.1 trillion (1987) to \$16.3 trillion (2016). Index/chained datasets help provide a more accurate picture of the economy and better capture changes in spending patterns and prices (Landefeld et al. 2003). Similar to population count and exposure growth, the increases in GDP are more pronounced in certain states and regions of the country. For this study we are particularly interested in the performance of GDP

⁵ IBHS, headquartered in Tampa, Florida, has an entire research center in Richburg, South Carolina, dedicated to testing residential and commercial construction materials, practices, and systems.

growth since the start of the most recent positive AMO phase in 1995 (Fig. 12).

The breakout of regional growth during the 22-yr time frame included the coastal West at +3.3%, the Gulf Coast at +3.2%, the West at +3.1%, the Atlantic at +2.5%, noncoastal South at +2.5%, and the Midwest at +2.0%. The national average was 2.7%. When focusing specifically on three states historically prone to landfall events, we find that the annual rate of growth is higher than the U.S.

average: Texas, +4.0%; North Carolina, +2.9%; and Florida, 2.8%. This further supports the claim that the accelerated economic growth in these states would additionally lead to more expensive damage and rebuilding costs. The population, housing, and wealth dataset analyses put into strong context the current and future TC risk and are essential data points for the many public and private agencies that are responsible for warning, protecting, and assisting in recovery.

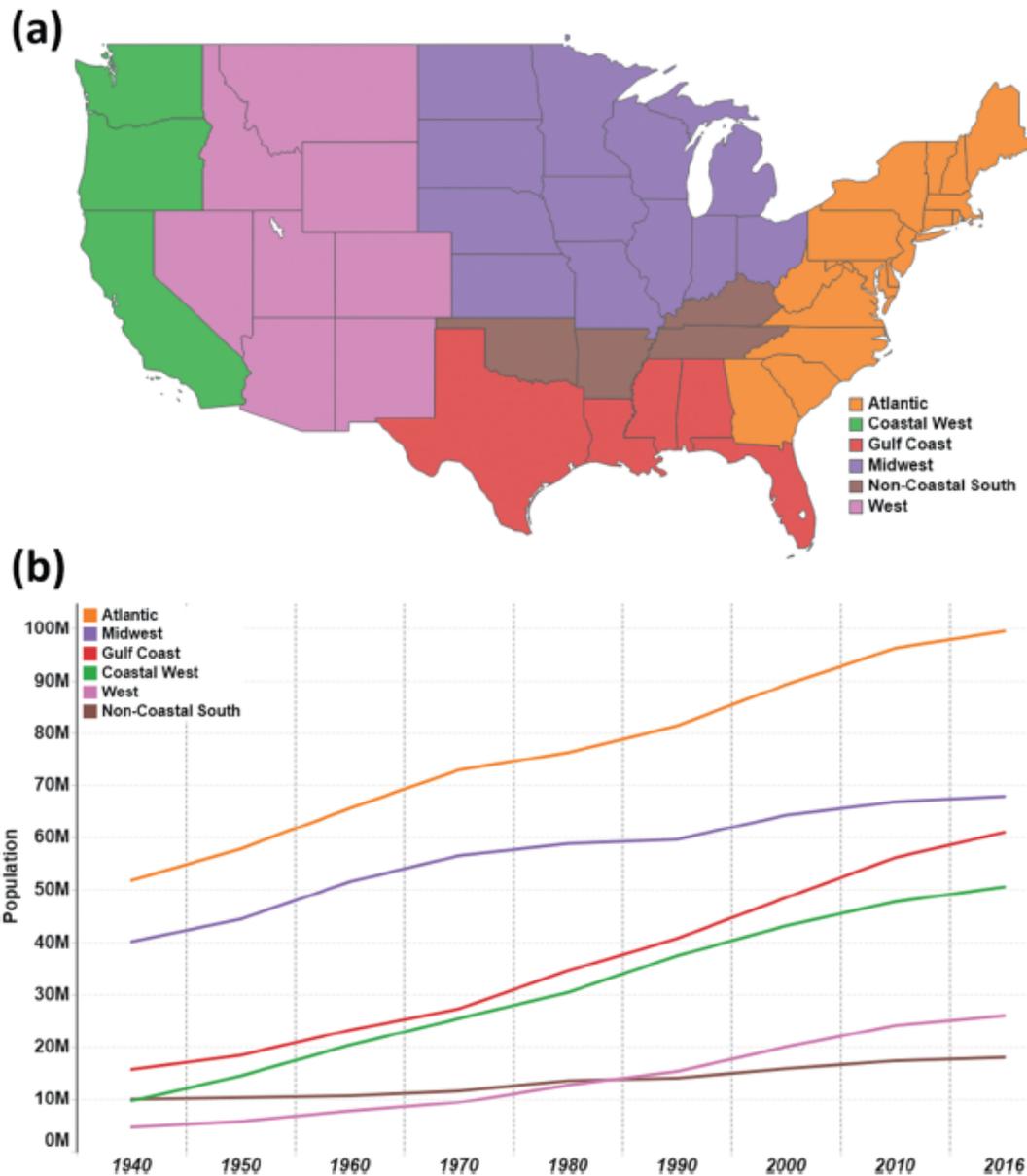


FIG. 9. (a) CONUS map showing six regions as defined in this manuscript and (b) CONUS decadal population by region (1940–2016).

TABLE 1. Top 20 U.S. counties in terms of population growth from 2010 to 2016. Boldface counties are in states that are prone to hurricane impacts.

Rank	County	State	2010	2011	2012	2013	2014	2015	2016	Absolute change	Relative change (%)
1	Harris	Texas	4,108,308	4,179,717	4,259,206	4,346,883	4,441,928	4,533,341	4,589,928	481,620	10.35
2	Maricopa	Arizona	3,825,616	3,870,806	3,942,959	4,011,219	4,083,931	4,161,637	4,242,997	417,381	8.78
3	Los Angeles	California	9,825,473	9,888,476	9,953,555	10,015,436	10,066,615	10,112,255	10,137,915	312,442	2.92
4	San Diego	California	3,104,346	3,140,692	3,181,513	3,218,419	3,258,856	3,290,245	3,317,749	213,403	5.99
5	King	Washington	1,937,786	1,972,444	2,008,763	2,045,874	2,078,886	2,114,256	2,149,970	212,184	9.11
6	Bexar	Texas	1,723,006	1,755,342	1,788,530	1,822,056	1,858,749	1,895,482	1,928,680	205,674	10.01
7	Miami-Dade	Florida	2,507,362	2,573,361	2,607,979	2,641,273	2,667,299	2,692,593	2,712,945	205,583	7.39
8	Dallas	Texas	2,372,450	2,407,305	2,452,421	2,479,810	2,512,281	2,545,775	2,574,984	202,534	7.31
9	Clark	Nevada	1,953,216	1,966,295	1,995,815	2,025,096	2,064,899	2,109,289	2,155,664	202,448	7.99
10	Tarrant	Texas	1,817,687	1,848,347	1,882,352	1,912,501	1,944,512	1,981,410	2,016,872	199,185	9.01
11	Riverside	California	2,202,226	2,236,146	2,264,919	2,291,452	2,322,455	2,352,892	2,387,741	185,515	6.84
12	Travis	Texas	1,030,569	1,061,858	1,096,122	1,120,948	1,149,668	1,174,818	1,199,323	168,754	14.00
13	Orange	Florida	1,148,716	1,169,806	1,202,048	1,225,366	1,253,631	1,284,864	1,314,367	165,651	11.85
14	Broward	Florida	1,753,125	1,787,889	1,816,552	1,840,051	1,865,385	1,887,281	1,909,632	156,507	7.65
15	Orange	California	3,017,647	3,053,884	3,084,935	3,112,576	3,134,438	3,156,573	3,172,532	154,885	4.60
16	Collin	Texas	788,741	814,607	837,229	858,098	885,175	913,079	939,585	150,844	15.76
17	Fort Bend	Texas	590,433	606,962	625,796	653,252	684,646	713,849	741,237	150,804	20.90
18	Hillsborough	Florida	1,233,839	1,271,205	1,281,677	1,293,189	1,317,116	1,347,077	1,376,238	142,399	9.18
19	Wake	North Carolina	906,949	929,208	952,296	973,920	997,897	1,021,974	1,046,791	139,842	12.68
20	Denton	Texas	666,736	685,376	707,475	728,282	752,820	778,491	806,180	139,444	16.76

Insurance. Beyond analyzing the overall economic cost of TCs in the United States, another important measure that helps explain the growth of exposure, population, and wealth are the claims paid by public and private insurance entities. Insured losses are the portion of economic damage that is covered by insurance. A public insured loss is identified as a claim paid via the Federal Emergency Management Agency's National Flood Insurance Program (NFIP) or the U.S. Department of Agriculture's Risk Management Agency crop insurance program. Private insured losses are claims paid directly by corporate for-profit entities.

Losses resulting from TC damage did not become significant for the insurance industry in the United States until the 1950s (Fig. 13). This coincided with the first introduction of homeowners insurance in September 1950 by the Insurance Company of North America in which a singular policy would protect against "loss caused by fire, theft, lightning, wind, explosion, hail, riot, vehicle damage, vandalism and smoke" (*Los Angeles Times*, 31 October 1954). Hurricanes Carol and Hazel—both of which led to notable damage across the Northeast and mid-Atlantic—combined to cause \$258 million in nominal insurance payouts in 1954 (\$2.3 billion

in 2017 when adjusted for inflation). TC landfalls often drive growth in property and casualty insurance take-up rates, defined as the percentage of eligible people or properties in which active insurance policies are held and premiums as homeowners and businesses recognize the need to protect themselves should disaster strike.

In the next several decades, numerous significant hurricane landfalls, such as Betsy (1965), Hugo (1989), Andrew (1992), and the 2004 and 2005 hurricane seasons, all led to greater public and private insurance industry response to the peril. Hurricane Betsy caused extensive damage in Louisiana and was thought to be the first nominal billion-dollar

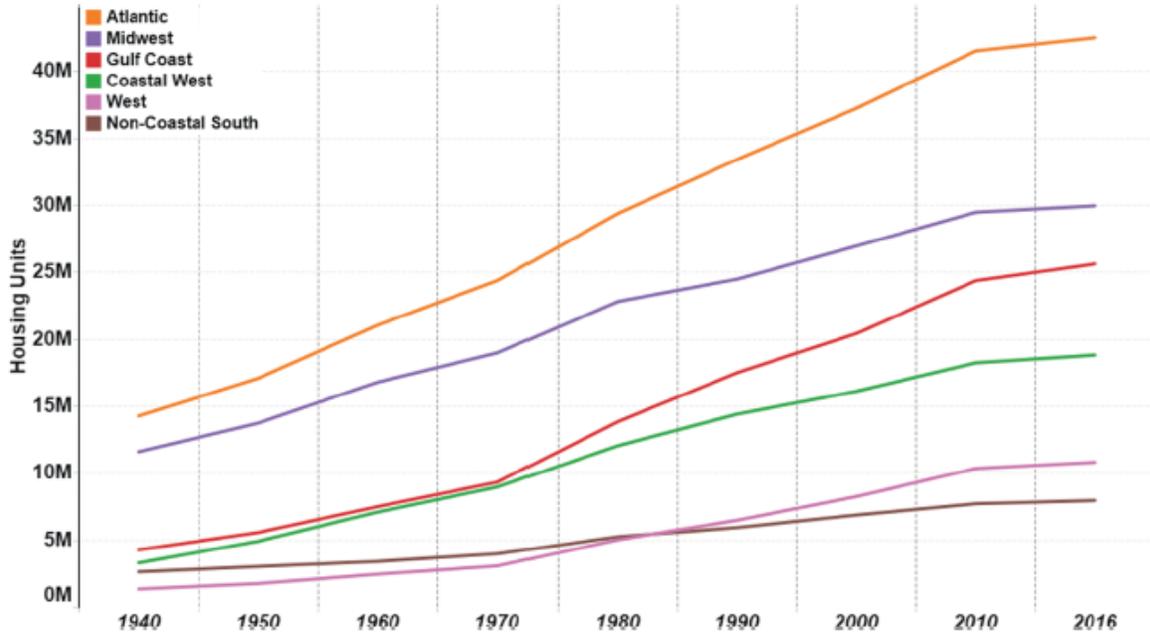


Fig. 10. CONUS decadal housing unit count (in millions) by region (1940–2016).

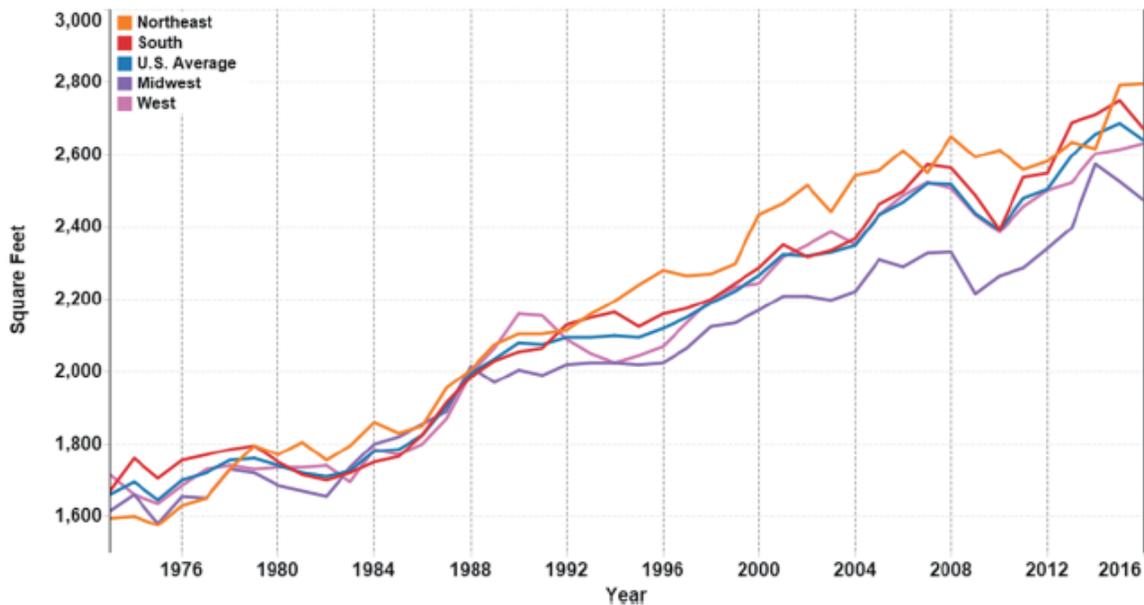


Fig. 11. Average size of a CONUS single-family home by region as defined by the U.S. Census Bureau (1973–2016).

TC event in the United States— earning the name “Billion-Dollar Betsy” (Sugg 1966). Much of the damage was caused by coastal and inland flood inundation. At the time no defined flood insurance program existed, and since private insurers viewed floods as too risky, the federal government established the NFIP to provide an alternative to disaster assistance to meet the escalating costs of home, building, and content repairs (FEMA 2002). It was often considered by the public that wind was the primary threat from hurricanes, but Betsy helped change the narrative. Andrew, in particular, changed how the private insurance industry market viewed hurricane risk, especially in the state of Florida. Some of the profound changes that Andrew made for the insurance industry included more carefully assessed and managed coastal exposure, greater use of global reinsurance capital (*reinsurance* can be simply defined as insurance for insurance companies), major growth in the sophistication and usage of catastrophe modeling, and increased focus on modernized and enforced building codes (McChristian 2012).

At the end of 2016, there were roughly 5.1 million NFIP active policies in place in the United States, the fewest number since 2005. By the start of the 2017 Atlantic hurricane season, that total had dipped slightly below 5.0 million. Historically, there was a gradual rise in policies from the late 1970s to the late 2000s following notable hurricane landfalls (Fig. 14a). With an extended stretch of lessened hurricane landfalls [and no major (category 3+) hurricane landfalls in more than a decade] (Hall and Hereid 2015), there was a steady drop in national NFIP coverage as well as total insured value

(TIV) (Fig. 14b) prior to the 2017 season. State-level data from FEMA indicates that the number of NFIP policies often increase following major events. Following the 2004 and 2005 seasons, the number of NFIP “earned contract counts” in Florida increased from 1.28 million in 2004 to a peak of 1.51 million in 2007—that number dropped to under 1.25 million by 2016.

With costly coastal exposures continuing to increase along the Gulf Coast and East Coast, this enhances the risk of greater spikes in catastrophe loss on an economic basis when the next hurricanes come ashore. For NFIP, flood payout spikes coincide with hurricane landfalls (Fig. 14c).

With more housing units and fewer NFIP policies in place, this leads to the likelihood of a greater portion of the economic cost not being covered by insurance during future events. A large portion of hurricane damage is often flood related, and in the case of Hurricane Harvey (2017), only 30% of that storm’s impacts—estimated \$100 billion economic loss—were covered by insurance given high coastal and inland flood inundation throughout southeast Texas (Aon Benfield 2018). Less than 20% of homeowners in Harris County in Texas had active NFIP policies in place at the time of landfall, and given Harvey’s remarkable flood footprint, much of the damage occurred in areas outside of the demarcated 100- or 500-yr flood zones.⁶ To put recent NFIP trends into

⁶ To view address-level FEMA flood-zone mapping, visit the FEMA Flood Map Service Center website (<https://msc.fema.gov/portal/search>).

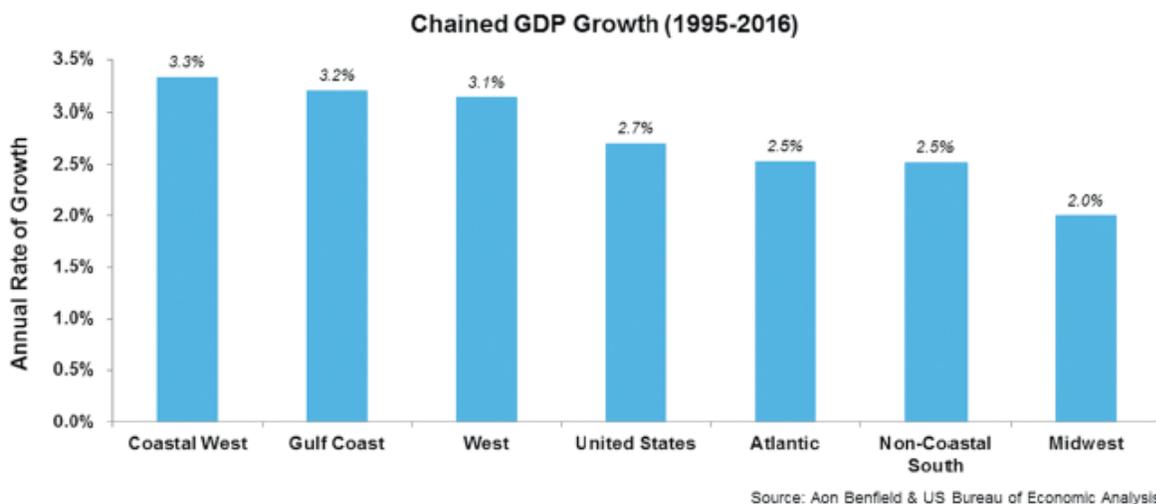


Fig. 12. Real GDP growth by region (1995–2016).

perspective, we use the state of Florida as an example. At the end of 2011, Florida had active NFIP policies in place with a total insured value of \$471 billion. By the middle of 2017, a decline in active policies also coincided with TIV dropping to \$422 billion despite hundreds of thousands of new single-family homes being built during that time. Table 2 provides regional breakouts of 2017 NFIP policies and TIV.

Using data as of early 2017, 14 of the top 20 states receiving the greatest amount of NFIP payouts are found in ocean-bordering states prone to hurricane landfall (Fig. 15). For greater context, the five Gulf Coast states have received more than 60% (or \$34.5 billion) of all nominal NFIP payouts. The payouts are somewhat unsurprising given that more than 84%—or nearly 4.2 million—of all NFIP policies currently in place are found in the Gulf Coast and

Atlantic regions. The TIV of these active policies in the Gulf Coast and Atlantic regions covers \$1.05 trillion (85%) in residential and commercial property assets. Whether fully insured or not, this further highlights the growing risk in these states given the tremendous aggregated value of properties located in hurricane-prone locations.

These data strongly suggest that the combination of increased population, greater exposure, the quality of building construction, and further modifications of building codes have played—and will continue to play—a significant role in rising damage associated with TCs in the CONUS. Any increase in landfalling TC frequency or intensity (e.g., Knutson et al. 2010; Walsh et al. 2015) would expectedly combine with these socioeconomic and demographic factors to cause even greater losses.

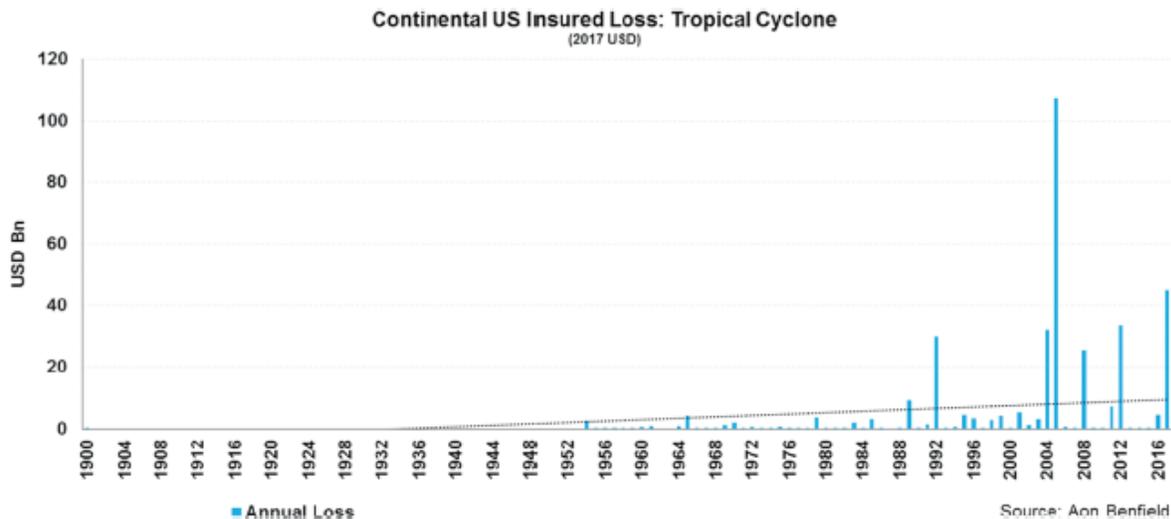


FIG. 13. CONUS total inflation-adjusted insured losses from TC landfalls (1900–2017). The dotted line represents the linear trend over the period. The *p* value for the linear trend is <0.01, indicating that the trend is significant.

TABLE 2. NFIP policies in place by U.S. region, the percentage of total NFIP policies in each U.S. region, the TIV of NFIP policies by U.S. region, and the percentage of TIV of NFIP policies by U.S. region.				
Region	Policies per region	NFIP policies (%)	TIV per region (billion of dollars)	TIV (%)
Atlantic	1,231,707	25.0	310	25.2
Coastal west	310,757	6.3	86	7.0
Gulf Coast	2,925,909	59.4	737	59.9
Midwest	210,513	4.3	42	3.4
Noncoastal south	80,969	1.6	17	1.3
West	160,696	3.3	38	3.1
Other U.S. territories	6,918	0.1	1	0.1
Total	4,927,469	100	1,023	100

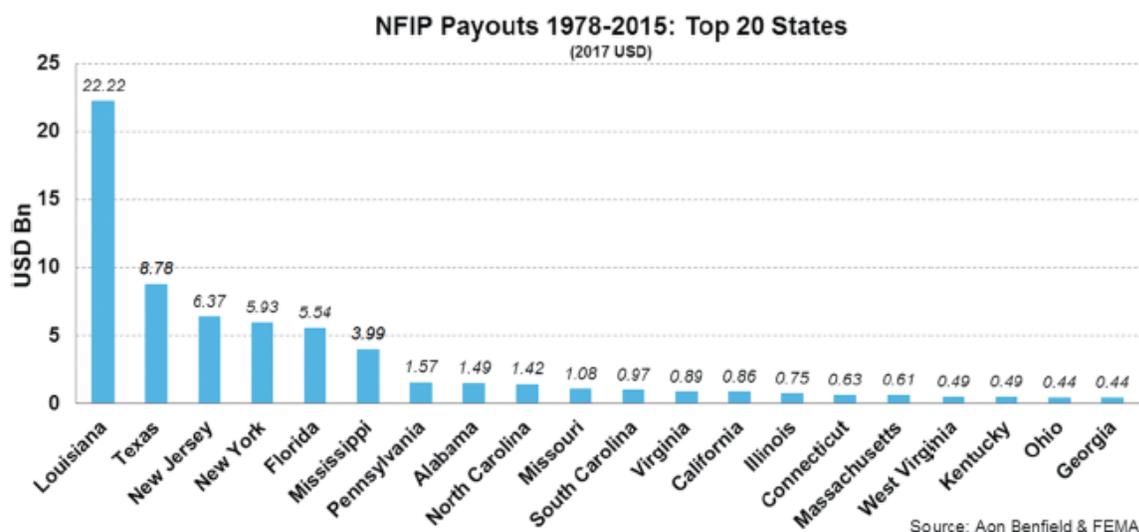


FIG. 15. Top 20 states for NFIP payouts (1978–2015; inflation adjusted to 2017 dollars).

DISCUSSION AND CONCLUSIONS. We have investigated trends in CONUS hurricane activity since 1900 and found no significant trends in landfalling hurricanes, major hurricanes, or normalized damage consistent with what has been found in previous studies. CONUS landfalling hurricane activity is, however, influenced by El Niño–Southern Oscillation on the interannual time scale and by the Atlantic multidecadal oscillation on the multidecadal time scale.

Despite a lack of trend in observed CONUS landfalling hurricane activity since 1900, large increases in inflation-adjusted hurricane-related damage have been observed, especially since the middle part of the twentieth century. We demonstrate that this increase in damage is strongly due to societal factors, namely, increases in population and wealth along the U.S. Gulf and East Coasts.

These findings have practical significance. Prior to the very active and costly 2017 season, the CONUS enjoyed an 11-yr major-hurricane drought (Hall and Hereid 2015; Hart et al. 2016), and during this period there were sizable growth patterns in coastal population, vulnerable coastal exposures, housing size, and nominal wealth in the most hurricane-prone areas of the country.

When the major-hurricane drought came to an end in 2017, Texas and Florida recorded aggregated economic damage losses in excess of \$125 billion. In total, economic damage in CONUS during the 2017 season was among the costliest ever recorded on a nominal, inflation-adjusted, and normalized basis. It is further

expected that future catastrophe losses resulting from landfalling storms will be even more financially significant for local, state, and federal government agencies, and the insurance industry if proper steps are not taken to reduce the current vulnerabilities of property and other exposures. The conclusion of greater future losses stands regardless of any changes in future hurricane frequency or intensity associated with changes in the climate behavior of hurricanes. Even if the frequency of future hurricanes were to lessen, even one storm in an otherwise quiet year can result in unprecedented damage (e.g., Hurricane Andrew in 1992).

Losses from future hurricanes have significant potential to dwarf those of the past based on societal change alone. Event losses will be even greater with potential increases in storm intensity (Knutson et al. 2010; Walsh et al. 2015) as well as flood-related impacts associated with an accelerated rate of sea level rise (Mousavi et al. 2011) and/or increased amounts of rainfall (Emanuel 2017). This highlights the continued importance of modernized and consistent building codes across hurricane-prone states, updated flood maps, and improved coastal and inland infrastructure given assumed impacts in the future.

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13. Assignment 4, Module 3: IBHS Building Codes: <https://ibhs.org/building-codes/>



Building codes are laws that set minimum requirements for the design and construction of buildings, historically focused on life-safety. Building codes define what your building should withstand from a variety of external forces like wind, rain, hail and wildfire, but also help safeguard people from other internal hazards such as fire and electrical malfunctions.

Building codes are developed through a consensus process administered by the International Code Council (ICC), which develops, among other codes, the International Residential Code (IRC), International Building Code (IBC), and International Wildland Urban Interface Code (IWUI Code). IBHS has been deeply engaged in this process for decades—our research and insights have contributed to significant code advancements since 2000.

Lawmakers and government officials can adopt or tailor the code to their state, county or city's needs. No new state has adopted a building code since 2008. In the absence of statewide codes, local jurisdictions must try to fill the gap, but they do not always have the resources to succeed. IBHS research can affect a better outcome that leads to a more resilient tomorrow.

Modern building codes, when adopted and enforced, work!

They save lives, reduce property damage, reduce disruption in our lives, and strengthen the resiliency of our communities. IBHS strongly supports:

- Statewide adoption of building codes
- Local enforcement of the codes
- Training and licensing of building officials, builders, and contractors

WIND AND WIND-DRIVEN RAIN

ANALYSIS:

- [Rating the States](#) evaluates the 18 states along the Atlantic and Gulf coasts, all vulnerable to catastrophic hurricanes, based on building code adoption, enforcement, and contractor licensing.
- [Survey of Coastal Texas Building Codes Executive Summary](#) surveyed this vulnerable region of Texas with no building code protection to understand building code adoption and enforcement at the local jurisdiction level.
- [IBHS & CoreLogic Building Codes and Mortgage Delinquency Study](#) demonstrates the financial value of building codes to individuals and the financial industry. Modern building codes reduce the expected spike in mortgage delinquency rates following hurricanes by 50 percent.
- [Increasing Wind Safety Standards for Manufactured Housing](#) identifies a pathway to strengthen the resilience of manufactured housing through changes to the Federal Manufactured Home Construction and Safety Standards (HUD Code).

TOOLS:

- [FORTIFIED](#) is a beyond-code construction method backed by decades of research, that a roofing contractor or builder can use to further protect a home, multifamily or commercial structure against severe weather. Once a home or building has been built or retrofitted to this standard, a certificate is issued that can be distributed to their insurer.
- The beyond-code [Coastal Construction Code Supplement](#) and [Inland Construction Code Supplement](#), developed by IBHS and [Smart Home America](#), bridge the gap between existing I Codes and the IBHS FORTIFIED technical standard.

WILDFIRE

ANALYSIS:

- [Construction Costs for a Wildfire-resistant Home 2022](#). This report compares the costs for constructing three different versions of a wildfire-resistant home in California.
- [Building a Wildfire-Resistant Home: Codes and Costs](#) – Cost Roughly Same as a Typical Home. Analysis: Expense Should Not Be a Barrier to Constructing Safer Homes. Learn about codes and costs. (2018 Headwaters Research Report)

TOOLS:

- [Wildfire Prepared Home](#) is a beyond-code, research-based mitigation and designation program designed for homeowners to meaningfully reduce wildfire risk to protect their home. Once a home has been built or retrofitted to this standard, a certificate is issued that can be distributed to their insurer.
- [WUI Model Ordinance](#) provides a model ordinance addressing construction and defensible space requirements with three levels of increasing resilience to wildfire.

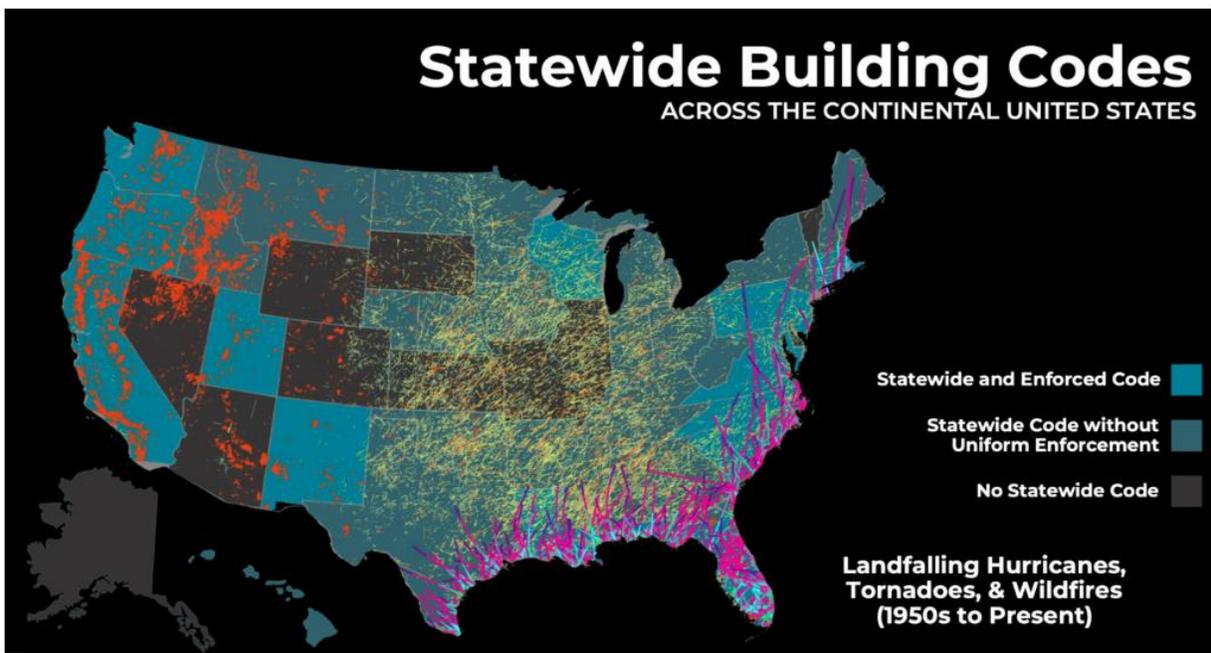
WINTER

ANALYSIS:

- [IBHS, ISO & VERISK Ice Dam & Building Codes Study](#) helps to determine if you're protected.

OTHER RESOURCES

- [FEMA- Building Codes Toolkit for Homeowners and Occupants](#) Help homeowners learn about building codes and how they can make a home more resilient against natural hazards.
- [FEMA- Nationwide Building Code Adoption Tracking](#) Tracks current building code adoption status for state, local, tribal and territorial governments (SLTTs).
- [FLASH- Inspect to Protect](#) Find the local building codes adopted in your area.
- [IBHS Code Development Activities](#) See our contributions to updating building codes based on our research.
- [IBHS Building Codes & Standards White Paper](#) lays out the history of the modern code era, and the importance of building codes across different perils. There is an advancement in resilience but continued resistance to adoption and enforcement.



15. Assignment 4, Module 3: Rating the States: https://ibhs.org/wp-content/uploads/member_docs/Rating-the-States-2018_IBHS.pdf



RATING THE STATES: 2018

*An Assessment of Residential Building Code and Enforcement Systems
for Life Safety and Property Protection in Hurricane-Prone Regions*

ATLANTIC AND GULF COAST STATES
MARCH 2018

The 2018 Edition

The Insurance Institute for Business & Home Safety (IBHS) is a nonprofit organization, supported by property insurers and reinsurers, that conducts scientific research to identify and promote effective actions to strengthen homes, businesses, and communities against natural disasters and other causes of loss. As part of this mission, IBHS provides technical guidance to inform and improve model building codes, advocates for timely adoption of national model building codes and standards, and encourages uniform enforcement of these codes.

The importance of strong, well-enforced building codes was clearly demonstrated in 2017. Over a two-month period from August through late September, three devastating hurricanes (Harvey, Irma, and Maria) each caused more than \$1 billion in damages, and collectively affected 25 million Americans, or almost 8 percent of the U.S. population, according to the Federal Emergency Management Agency (FEMA).¹

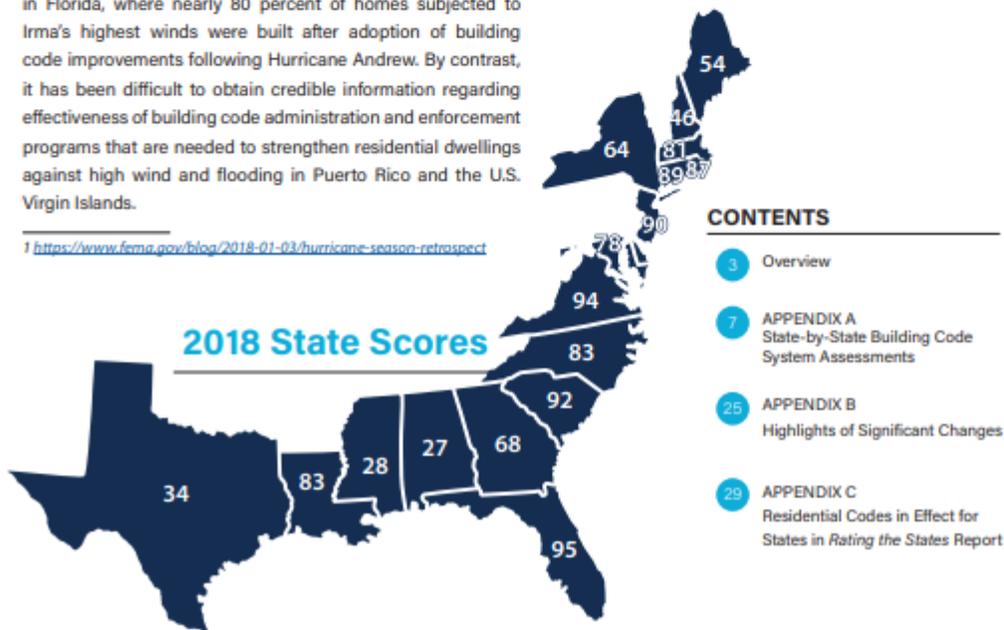
While no single meteorological, physical, or economic attribute is responsible for the damage caused by these events, evidence shows that strong, well-enforced building codes reduce loss and facilitate recovery. This was most apparent in Florida, where nearly 80 percent of homes subjected to Irma's highest winds were built after adoption of building code improvements following Hurricane Andrew. By contrast, it has been difficult to obtain credible information regarding effectiveness of building code administration and enforcement programs that are needed to strengthen residential dwellings against high wind and flooding in Puerto Rico and the U.S. Virgin Islands.

¹ <https://www.fema.gov/blog/2018-01-03/hurricane-season-retrospect>

This is the third *Rating the States* report produced by IBHS to assess elements of code enforcement and administration and contractor licensing in the 18 states most vulnerable to catastrophic hurricanes along the Atlantic Coast and the Gulf of Mexico. Each state has been assigned a score on a 0-100 point scale. Additionally, this report highlights some recent legislative/regulatory developments—both positive and negative—and includes information about building code programs in the U.S. territories of Puerto Rico and the Virgin Islands damaged by Hurricanes Maria and Irma.

This report is intended to:

- Focus public attention on the need for effective statewide building codes.
- Underscore the importance of code administration and enforcement.
- Ensure required performance standards are incorporated into construction of residential dwellings.
- Note whether states require licensing of building officials and construction contractors.
- Highlight steps states can take to improve their building code systems, providing better protection for their citizens and communities.



2018 AND 2015 STATE SCORES

STATE	2018 SCORE (NEW)	2015 SCORE
FLORIDA	95	94
VIRGINIA	94	95
SOUTH CAROLINA	92	92
NEW JERSEY	90	89
CONNECTICUT	89	88
RHODE ISLAND	87	87
NORTH CAROLINA	83	84
LOUISIANA	83	82
MASSACHUSETTS	81	79
MARYLAND	78	78
GEORGIA	68	69
NEW YORK	64	56
MAINE	54	55
NEW HAMPSHIRE	46	48
TEXAS	34	36
MISSISSIPPI	28	28
ALABAMA	27	26
DELAWARE	17	17

The Importance of Mitigation and Resilience

According to the National Oceanic and Atmospheric Administration (NOAA), 2017 was the most costly year on record for weather-related disasters in the U.S., with damages totaling approximately \$306 billion. These events underscore the importance of mitigation for reducing property loss. Particularly relevant to this report, the catastrophic Hurricanes Harvey, Irma, and Maria affected millions of Americans. Preliminary post-storm investigations indicate that homes along the path of Hurricane Irma that were built to strong, modern building codes in Florida sustained less damage than weaker structures built to pre-Hurricane Andrew provisions.

New research confirms the value of investing in property loss mitigation. According to a report by the National Institute of Building Sciences (NIBS), [Natural Hazard Mitigation Saves: 2017 Interim Report](#), society saves \$6 for every \$1 spent through federal mitigation grants, and \$4 for every \$1 in private sector investments that exceed select provisions in model building codes. A follow-up study on the economic benefits of model building codes is forthcoming.

As is evident once again in this newest IBHS *Rating the States* report, residential building code adoption and enforcement practices vary among states (with even greater variation in states that are not featured here). A list of current codes for each state is available at DisasterSafety.org/ibhs-public-policy/building-codes.

Following Hurricane Sandy, a comprehensive federal report² called on states to use the most current building codes to “ensure that buildings and other structures incorporate the latest science, advances in technology and lessons learned.” That admonition is even more compelling in the wake of Harvey, Irma, and Maria precisely because the building code is an active, evolving document. The application of the codes in the field reflects new knowledge and new standards of practice that have evolved from lessons learned; accordingly, their adoption and enforcement should be a priority in all communities across the U.S.

The Value of Building Codes

Building codes are regulatory standards designed to protect the health, safety, and general welfare of the public. They also ensure the soundness of buildings and their electrical, plumbing, and mechanical systems. Building codes are intended, first and foremost, to prevent deaths and reduce injuries, as well as to reduce economic losses from a wide range of hazards. However, damage reduction that results from the adoption and enforcement of building codes helps to keep people in their homes and businesses following a natural or man-made disaster, reduces the need for public and private disaster aid, and preserves natural resources and the built environment.

For example, a study conducted by IBHS following Hurricane Charley³ in 2004 found that improvements to the codes adopted in 1996 and enforced in Florida resulted in a 60 percent reduction in residential property damage frequency (number of claims) and a 42 percent reduction in damage severity (cost of claims).

Additional benefits of strong, uniform, well-enforced statewide codes include the following:

- Giving residents a sense of security about the safety and soundness of their buildings.
- Offering protection to first responders during and after fires and other disaster events.
- Promoting a level, predictable playing field for designers, builders, and suppliers.
- Allowing for economies of scale in production and building.
- Reflecting recent design and technology innovation, often incorporating newly identified best practices and cost efficiencies.
- Reducing the amount of solid waste in landfills produced by homes that are damaged or destroyed during disasters.

² Hurricane Sandy Rebuilding Strategy Report: <http://portal.hud.gov/hudportal/documents/hudidoc/?id=HS8rebuildingStrategy.pdf>

³ Hurricane Charley Report: www.DisasterSafety.org/hurricane/hurricane-charley

Overview of the Building Code Process

While building codes apply to a wide range of buildings and address both safety and energy efficiency, the adoption and enforcement of safety codes for residential buildings is especially important because registered design professionals (such as engineers and architects) are less likely to be involved in residential design than in commercial construction. The focus of this report, therefore, is on the model building code developed by the International Code Council (ICC) known as the *International Residential Code*[®] (IRC).

In the U.S., building codes are adopted and enforced at the state and local levels. Rather than developing their own unique building codes from scratch, most jurisdictions base

their codes on the ICC model codes, allowing for state and local amendments as appropriate (see the model codes in effect in the 18 states reviewed in this report in Appendix C). The IRC and other model codes are developed through a public, national consensus process that provides for input and participation from a wide range of stakeholders, including state and local officials, designers, builders, contractors, insurers, and product manufacturers.

The IRC is updated on a three-year schedule; the most recently released version is the 2018 edition. As of December 31, 2017, the most recent IRC adopted by states and local jurisdictions is the 2015 edition.

Methodology and Numeric Scores

IBHS evaluated 47 data points to assess the effectiveness of the states' residential building code adoption and enforcement programs. This assessment covered important factors such as a state's current residential building code, the processes in effect to ensure universality of code application without weakening amendments, state and local level enforcement, and licensing and education of building officials, contractors, and subcontractors who implement building code provisions. A complete description of the factors included in the model is provided in Appendix B.

This report is intended to help provide a roadmap states can follow to improve their system of residential-related building regulations by following best practices. It is not intended for use in insurance underwriting or rating, or for regulatory purposes.

This report looks at state-level performance as a whole and provides a relative standing for each state. After identifying data points in each category, IBHS constructed a model that weighs the activities and/or processes associated with each element as follows:

- **50 percent** of the total score is allotted to statewide adoption and enforcement of building codes.
- **25 percent** is allotted to state-adopted requirements for building official certification, training, and continuing education.
- **25 percent** relates to state regulations for on-site implementation and proficiency, as demonstrated by contractor and subcontractor registration, licensing, and continuing education.

While this numerical scoring is relatively simple, it recognizes that building codes are the focal point of an effective state regulatory life safety and property protection system. Within each of the three main model components, there are several subcategories: whether statewide building codes can be amended at the local level; certification requirements for building officials; and the specific construction trades covered by licensing requirements. Points were assigned to these subcategories based on their relative importance to building safety and integrity, with an emphasis on wind hazard protection requirements of the building code.

NOTE: Appendices A and B describe the states and the model in more detail.

States received points based on IBHS research relating to a set of questions seeking to gauge the statutory and regulatory environment in three categories and associated subcategories identified. Points were allotted when the answer to a given question was consistent with promotion of safer residential construction. No points were allotted if the answer to a given question was inconsistent with the promotion of safer construction. No negative points were allotted.

As a result, possible scores range from 0 to 100, with 0 as the weakest and 100 as the strongest score. Actual scores ranged from 17 to 95. The complete list of states in order of highest to lowest scores follows. By examining the detailed assessment elements, policymakers and other interested parties can find a clear roadmap to strengthen their residential building code system and improve their standing in this report.

Results in Brief

During this assessment, no state achieved a perfect rating based on the IBHS 100-point scale. Several states received high scores including Florida (95 points), Virginia (94 points), South Carolina (92 points), and New Jersey (90 points). Other states that performed well were Connecticut (89 points), Rhode Island (87 points), North Carolina (83 points), Louisiana (83 points), Massachusetts (81 points), and Maryland (78 points). While all of these states have uniform statewide residential building codes and enforcement processes, some unfortunately have taken actions that may weaken their codes in the future, as described later in this report.

The states that received below 70 points (Georgia, New York, Maine, New Hampshire, Texas, Mississippi, Alabama, and Delaware) have no mandatory statewide codes. That said, there are some jurisdictions within these states that have strong code adoption and/or enforcement programs, and have made improvements since the original *Rating the States* report. Under the "State-by-State Building Code System Assessment" part of this report, additional meaningful steps have been identified that could be implemented by these states to improve their statewide code adoption and enforcement programs.

APPENDIX A

State-by-State Building Code System Assessments

Florida



BUILDING CODE ADOPTION

Florida continues to be a leader in building code safety. The 6th Edition (2017) of the *Florida Building Code - Residential* (FBCR), which is based on the 2015 edition of the IRC, became effective December 31, 2017. In 2017, the State of Florida enacted legislation that makes major changes to the process the state employs to adopt building codes in the future. Under the new law, the Florida Building Commission (Commission) will update future editions of the code using the existing FBCR as the base text, with all existing Florida-specific requirements carried forward. The Commission will then consider technical amendments to the code in two phases. See **Highlights of Significant Changes** for further discussion of this legislation.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Florida has a mandated program for building official certification and training. The program requires individuals to take code-specific courses prior to taking a certification/licensing exam, but a combination of experience and education can qualify candidates as well. The state has a one- and two-family dwelling inspector certification category, which is limited to residential dwelling inspections.
LICENSING OF CONTRACTORS	The state requires licensing of general, plumbing, mechanical, electrical, and roofing contractors. The contractor licenses require passing examinations along with continuing education in every category. Mechanisms are in place enabling the state to discipline a contractor for violations or noncompliance with the code.
KEY AREAS FOR IMPROVEMENT	The lack of requirement for continuing education of building officials specific to the residential code to maintain certification and/or a license is one area that could be improved. Also, in the future it will be necessary to pay close attention to the new code development process to ensure important improvements to the IRC are not bypassed as the state places greater emphasis on the FBCR.

Virginia



BUILDING CODE ADOPTION

Virginia is currently enforcing the 2012 edition of the IRC. However, the commonwealth is in the process of updating the *Virginia Uniform Statewide Building Code* to the 2015 editions of the *ICC International Codes (I-Codes)*, which would potentially be effective in 2018. The process—which entails a review of the Virginia Base Code document and correlation with updates in the 2015 IRC—has been completed and, after a comment period and public hearing, the final regulations will be published in the Virginia Register; pending any petitions received during the 30-day comment period, it will become effective.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Virginia requires certification and training for its building officials. On-the-job training prior to sitting for examination for certification is permitted. While in training, the inspectors receive supervision; upon completion of on-the-job training and the examination, inspectors receive the official construction trade recognition. A mechanism for consumers to file complaints related to building code enforcement is available in Virginia. The rules permit the authority to apply disciplinary actions, which also can be applied at the local level.
LICENSING OF CONTRACTORS	Virginia issues licenses for general, plumbing, mechanical, electrical, and roofing contractors. However, general and roofing contractors are not required to complete continuing education to renew licenses.
KEY AREAS FOR IMPROVEMENT	Virginia has an exemplary code adoption and enforcement program. The addition of continuing education requirements for general and roofing contractors can further enhance the commonwealth's model statewide code adoption and enforcement program.

South Carolina



BUILDING CODE ADOPTION

South Carolina's residential building code is based on the 2015 edition of the IRC with South Carolina modifications. The design wind speed maps have been amended to align the wind contour lines with physical boundaries such as streets, highways, streams, rivers, and lakes. The state also redrew boundaries for seismic design categories based on a state-sponsored study conducted by The Citadel. Proposed legislation in South Carolina sought to lengthen the cycle of code adoption from three to six years, which if approved would have placed the state adoption cycle behind the model code update cycle. The proposed bill did not advance during the 2017 legislative session; however, reintroduction is expected in 2018.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	The state requires registration, certification, and licensing for all building officials. A nonrenewable two-year provisional license is issued to code enforcement officials who are undergoing training for certification required by the state. The state, under a new rule, requires that the chief code enforcement officer/building official must at least be certified in one trade category before hire; however, he/she would be granted a period of one year to obtain the remaining code certification categories. South Carolina has continuing education requirements for building officials.
LICENSING OF CONTRACTORS	The state requires licensing of general, plumbing, mechanical, electrical, and roofing contractors, but does not mandate continuing education for renewal of licenses in any category.
KEY AREAS FOR IMPROVEMENT	South Carolina's on-schedule code adoption process has helped position it among the top three states with the best building code systems in this report. However, passage of any legislation that could place the state code adoption cycle behind the model code adoption cycle could negatively affect the state's rating. Also, a meaningful change for the state would be to require continuing education for licensed contractors.

New Jersey



BUILDING CODE ADOPTION

The state has adopted and is currently enforcing the 2015 edition of the IRC, without any modification or weakening of the code requirements.

As a result of devastating flooding caused by storm surge from Hurricane Sandy in October 2012, the state adopted FEMA's updated Advisory Base Flood Elevation maps as the rebuilding standard for the state—a change that has enhanced property protection in the state, not only from coastal storm surge but also from riverine flooding.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	New Jersey has a state program for building official certification and training with continuing education requirements that is modeled after the certification program administered by the ICC.
LICENSING OF CONTRACTORS	The state requires registration for homebuilders; however, an exam is not required for obtaining a license and there is no continuing education requirement for renewal. Similarly, registered roofing contractors are not required to take an exam, or complete any continuing education. In contrast, the state has a good system in place for licensing and continuing education of electrical, mechanical, and plumbing contractors.
KEY AREAS FOR IMPROVEMENT	The state would benefit from continuing education for building officials specifically dealing with the residential code.

Connecticut



BUILDING CODE ADOPTION

The state is currently enforcing the 2012 edition of the IRC and as of December 2017, was in the process of updating to the 2015 edition of the code. The Connecticut Division of Construction Services has been developing initiatives to improve resilience of the residential dwellings in the state, focusing in particular on properties located in coastal areas at risk for high wind, flooding, and storm surge.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	The state has a program for certifying building officials. The program requires education classes prior to becoming certified as a residential code inspector.
LICENSING OF CONTRACTORS	Although Connecticut requires licensing for all construction trades, only electrical and plumbing contractors are required to take continuing education to maintain their licenses. The state has a system for consumers to file complaints against licensed contractors and may institute disciplinary action as appropriate.
KEY AREAS FOR IMPROVEMENT	The state should consider requiring continuing education for all contractors.

Rhode Island



BUILDING CODE ADOPTION

The state is currently enforcing the 2012 edition of the IRC with Rhode Island State amendments. The Rhode Island code still contains a deficiency that was highlighted in prior editions of the IBHS *Rating the States* report. Specifically, Section R301.2.1.1 of the code has been modified to allow buildings to be designed as partially enclosed in windborne debris regions in lieu of protecting glazed openings. Although such a design methodology results in a building designed for generally higher wind loads, it increases the likelihood that wind-driven rain could enter a home in the event windows and glazed areas are broken during a storm, which is a concern. The partially enclosed building design was eliminated long ago as an option in the IRC. Also, the state-published prescriptive method for high-wind design (i.e., Appendix AA of *Rhode Island State Building Code, SBC-2*) has several weak provisions for roof truss-to-wall connections, as well as design and anchorage of shear walls.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Rhode Island has a program for building official certification and licensing and includes code-specified training courses prior to certification. The state also has requirements for continuing education of its building officials.
LICENSING OF CONTRACTORS	In Rhode Island, general and roofing contractors are required to be registered, and the state issues licenses for plumbing, mechanical, and electrical contractors. However, only electrical and plumbing contractors are required to complete continuing education classes to renew licenses. Roofing contractors are required to be registered and are governed by a licensing board.
KEY AREAS FOR IMPROVEMENT	The state should consider updating the residential statewide code based on the latest edition of the IRC. Another meaningful step would be to eliminate the option to design a building as partially enclosed in lieu of protecting glazed openings from the state amendments applicable to coastal zones, and to reevaluate some of the recommendations in Appendix AA of SBC-2 for high-wind design areas.

North Carolina



BUILDING CODE ADOPTION

The state is currently enforcing the 2009 edition of the IRC with *North Carolina Building Code* amendments. There are no significant changes in the state amendments since last published (2012–2017). In 2015, the North Carolina Building Code Council deleted the requirement in the 2009 IRC that anchorage for wood structural panels used for opening protection in windborne debris regions be permanently installed on the building. This amendment makes it less likely that wood structural panel opening protections will be adequately anchored in coastal windborne debris regions of the state. In 2013, North Carolina changed the adoption cycle of the state residential code from three years to six years. As a result, the North Carolina Building Code Council does not intend to update the statewide residential building code until 2018. This change means the state residential code will always be one or two cycles behind the latest national model codes.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	The state has a program for building official certification/licensing and includes code-specific training courses prior to certification with continuing education requirements.
LICENSING OF CONTRACTORS	Licenses are required for general, plumbing, mechanical, and electrical contractors in North Carolina. However, except for electrical contractors, trades are not required to complete continuing education classes to renew licenses. There are no licensing requirements for roofing contractors.
KEY AREAS FOR IMPROVEMENT	North Carolina needs to reinstate regular updates of the state residential code and ensure that statewide requirements are consistently updated based on national model codes and standards published by the ICC every three years. Other meaningful changes the state should take include requiring continuing education for plumbing and mechanical contractors, as well as instituting licensing requirements for roofing contractors.

Louisiana



BUILDING CODE ADOPTION

In June 2017, the Louisiana governor issued Executive Order 17-14 suspending adoption of the 2015 editions of the I-Codes until June 1, 2018. However, this order was rescinded in December 2017. Accordingly, the Louisiana State Uniform Code Council voted to adopt the 2015 edition of the IRC and the *National Electrical Code*[®] (NEC), effective February 1, 2018. Adoption of the 2015 edition of the IRC removes the deficiency that resulted from an Emergency Declaration in 2013 that weakened the wind design provisions of the residential building code by not adopting the appropriate "trigger" for high-wind design in the 2012 edition of the IRC.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Louisiana has a state program that requires building official certification; however, no mandatory code education classes are included in the certification process.
LICENSING OF CONTRACTORS	The state requires licensing of general, plumbing, mechanical, electrical, and roofing contractors, with continuing education for renewal of licenses for general and plumbing contractors. The electrical, mechanical, and roofing contractors are not required to take continuing education classes.
KEY AREAS FOR IMPROVEMENT	The state may want to require continuing education classes for electrical and mechanical contractors as a part of its licensing requirements.

Massachusetts



BUILDING CODE ADOPTION

In 2017, the Commonwealth of Massachusetts adopted the ninth edition of the statewide building code based on the 2015 IRC. While this move is positive overall, the now-current Massachusetts building code—either through error or a simple failure to update—has amendments to wind design requirements and exposure category classifications that are below specifications for high wind and coastal areas.

Specifically, Massachusetts-specified amendments regarding wind design requirements in the 2015 IRC are based on ASCE 7-05 (*Minimum Design Loads for Buildings and Other Structures*) and use ASD-level wind speeds (V_{ASD}). However, the design wind speeds in the 2015 IRC and its referenced standards such as *Wood Frame Construction Manual* (WFCM) are strength-level wind speeds (V_{SL}) consistent with ASCE 7-10.

Also, parts of Cape Cod and portions of Southeastern Massachusetts where design wind speeds are 140 mph may be considered Exposure Category C (open terrain) or Exposure Category D (coastal exposure). However, the state amendments classify all coastal areas as Exposure Category B, which applies only to urban/suburban areas where many buildings and structures are closely spaced.

On a positive note, new residential townhouses constructed in Massachusetts are required to be equipped with automatic fire sprinkler systems.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Although there is a program for building official certification, it does not require individuals to complete training classes prior to the certification exam. Also, the commonwealth does not require a continuing education program specifically related to the residential dwelling code.
LICENSING OF CONTRACTORS	Massachusetts requires licensing of general, plumbing, electrical, and roofing contractors along with continuing education requirements. However, no licensing is required to perform heating, ventilation, and air conditioning work for lower than ten-ton HVAC units, which are almost always used in one- and two-family dwellings subject to IRC requirements.
KEY AREAS FOR IMPROVEMENT	To avoid confusion, the Massachusetts-amended design wind speeds for coastal and high-wind areas need to be specified in strength-level values (V_{SL}) aligned with ASCE 7-10. Also, the commonwealth should consider including the 140 mph Exposure C High-Wind Guide for areas that need to be classified as Exposure C, and should require design in accordance with the WFCM or ASCE 7 for areas classified as Exposure Category D.

Maryland



BUILDING CODE ADOPTION

Maryland was one of the first states that adopted the 2015 edition of the IRC as a part of *Maryland Building Performance Standards*, which is the designated code for enforcement throughout the state. Local jurisdictions may modify provisions of the *Maryland Building Performance Standards*—except for wind design requirements; however, through amendments, they can address conditions specific to the local jurisdiction's needs. The state strives to be recognized as a leader in life and public safety by requiring automatic residential fire sprinklers in all new residential dwellings.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Maryland does not license inspectors separately for residential construction, or require completion of code training classes prior to certification. Nor does it have a mechanism for the public to file complaints against inspectors.
LICENSING OF CONTRACTORS	The state requires licensing of general, plumbing, mechanical, electrical, and roofing contractors with continuing education required only for electrical contractors.
KEY AREAS FOR IMPROVEMENT	While the Maryland Office of Code Administration provides a voluntary training program for building officials throughout the state, mandating certification and licensing for residential inspectors would further reinforce Maryland's commitment to an even stronger building and safety code program. Such a program would improve the capabilities of the code enforcement personnel, improve the uniformity of enforcement, and help elevate their recognition as professionals throughout the state.

Georgia



BUILDING CODE ADOPTION

The state is currently enforcing the 2012 edition of the IRC, with state amendments consistent with the major provisions of the model code, except that the requirements for automatic residential fire sprinklers are optional in new one- and two-family dwellings and townhouses. In Georgia, the decision to enforce the code is left up to local jurisdictions.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Georgia has a program for certification of building officials, but does not require code classes prior to certification. Their program requires continuing education but there is no mechanism for taking disciplinary action against an inspector by the state.
LICENSING OF CONTRACTORS	General contractors, plumbing, mechanical, and electrical contractors are required to be licensed in Georgia. Exams and continuing education are a part of licensing programs. There are no licensing requirements for roofing contractors.
KEY AREAS FOR IMPROVEMENT	To strengthen its building code system, Georgia should make adoption and enforcement of the statewide code by all jurisdictions throughout the state mandatory.

New York



BUILDING CODE ADOPTION

In 2017, the state adopted the 2015 edition of the IRC along with the 2016 supplement as the *New York State Uniform Code* for residential construction. The *New York State Uniform Code* requires that any single-family dwelling or a townhouse over two stories in height be equipped with an automatic fire sprinkler system conforming to the NFPA 13D standard.

The New York City building regulatory system remains exempt from the New York State requirements. In the aftermath of Hurricane Sandy, the New York City Department of Buildings took major positive steps in updating and strengthening their building codes, especially for wind and wind-driven rain resistance. Additionally, based on the recommendations of FEMA's Mitigation Assessment Team, the city made several improvements to its building code consistent with FEMA's NFIP requirements. The October 1, 2014 amendments brought the *New York City Building Code* in line with the 2009 edition of the *International Building Code* (IBC) with city-specific residential code requirements.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	New York State has a mandated program for certification of building officials including code classes prior to certification. However, its program does not require that continuing education be specifically on the residential code.
LICENSING OF CONTRACTORS	The state does not require licensing of general, plumbing, mechanical, electrical, or roofing contractors and leaves the decision of whether to require regulations for licensing of construction trade contractors to local jurisdictions.
KEY AREAS FOR IMPROVEMENT	New York State should consider adopting a state-mandated certification and licensing program for construction trade contractors.

Maine



BUILDING CODE ADOPTION

There have been no significant changes in the *Maine Uniform Building Code* since the last published edition of the *Rating the States* report. The state is still on the 2009 edition of the IRC. Based on the latest information obtained from the Maine Office of Community Development, Bureau of the Building Codes, the state is currently in the rule-making process to adopt the 2015 edition of the IRC; however, as of December 31, 2017, the adoption process was not completed. A major weakness in state regulations allows municipalities with fewer than 4,000 people to choose not to have or enforce a building code.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Maine has a program for certifying building officials, but does not require code-specific education courses prior to certification. The state requires continuing education, but it is a minimal requirement of nine hours every six years. The state has a certification category for residential construction inspectors, but there is no process for filing complaints or disciplinary action against inspectors.
LICENSING OF CONTRACTORS	The state requires licensing for plumbing and electrical contractors, but not for other trades. Plumbing and electrical contractors are required to take an exam prior to licensing and they are subject to disciplinary action. Electrical contractors are required to obtain continuing education for license renewal.
KEY AREAS FOR IMPROVEMENT	Maine's long delay in code adoption is an area of concern. Considering the model residential code is updated every three years, the state should consider regular adoption and enforcement of the IRC, and require all municipalities throughout the state, regardless of population size, to adopt and enforce the <i>Maine Uniform Building Code</i> .

New Hampshire



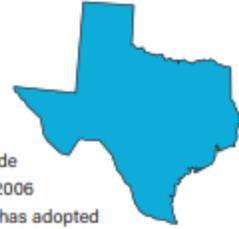
BUILDING CODE ADOPTION

New Hampshire is still enforcing the 2009 edition of the IRC. The state is working to update the residential building code to the 2015 edition of the IRC. Adoption and enforcement of the residential code, however, is not mandatory throughout the state; rather, it is at the discretion of the local jurisdictions.

A bill signed by the governor on June 26, 2017, permits removal and replacement of arc-fault circuit interrupter (AFCI) devices with non-AFCI devices from electrical circuits that demonstrate repetitive tripping. This action constitutes a weakening of the electrical safety requirements of the NEC.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	New Hampshire has no statewide program to license building officials.
LICENSING OF CONTRACTORS	Contractor licensing is required for plumbing and electrical contractors, but not for other trades. Plumbing and electrical contractors are required to take an exam prior to licensing, are subject to disciplinary action, and are required to take continuing education classes.
KEY AREAS FOR IMPROVEMENT	New Hampshire should consider mandatory enforcement of the statewide residential code and establish a building official certification and licensing program throughout the state.

Texas



BUILDING CODE ADOPTION

Texas does not require mandatory adoption and enforcement of its residential building code throughout the state. However, the law states that municipalities may adopt and enforce the 2006 IRC as a minimum residential construction code. In addition, the Texas Department of Insurance has adopted windstorm building standards that homes must meet to obtain windstorm and hail insurance from the Texas Windstorm Insurance Association (TWIA), the state wind catastrophe pool.

In 2017, the legislature in Texas enacted a law that requires builders to provide an inspection report to the county—in unincorporated areas of certain counties—indicating that the construction complies with the building code. In accordance with this law, failure to provide an inspection documentation to the county could result in prosecution of the builder.

Post-event investigations by teams that consisted of IBHS staff and other stakeholders revealed that several jurisdictions struck by high winds in the primary landfall locations of Hurricane Harvey (August 2017, Category 4) had adopted more recent editions of the IRC (2012 or 2015). In general, it was observed that there was limited wind damage to construction built to newer building codes; however, damage due to the amount of rain accumulated from Harvey and catastrophic flooding was extensive around Houston and coastal bayous of Southeast Texas.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Texas has no statewide program to license building officials.
LICENSING OF CONTRACTORS	The state requires licensing for plumbing, mechanical, and electrical contractors, and contractors are required to take continuing education classes for license renewal.
KEY AREAS FOR IMPROVEMENT	<p>Hurricane Harvey and other events during the past have demonstrated that Texas is vulnerable to a wide range of natural disasters including hurricanes, flooding, wildfires, hail, and severe convective storms. Adoption of a mandatory statewide code system throughout the state would help establish uniformity in enforcement and application of the code provisions, and reduce losses in areas that have not adopted building codes.</p> <p>The extensive damage and loss of life that resulted from Hurricane Harvey—one of the costliest hurricanes on record, inflicting nearly \$200 billion in damage to Houston and surrounding areas—necessitates stringent control of future land development and residential building construction, especially in flood-prone areas.</p>

Mississippi



BUILDING CODE ADOPTION

There have been no significant changes in the state code adoption since the last published edition of the *Rating the States* report. Mississippi took an important step forward in 2014 by adopting a building code law that governs construction of most residential buildings in the state. The law allows municipalities to adopt one of the last three effective IRC editions. However, municipalities could opt out of the requirements for adoption and enforcement within 120 days of the effective date (i.e., November 30, 2014). Based on previous data available to IBHS, it appears that approximately 90 percent of the population within Mississippi's municipalities lives in areas that have not opted out of the building code law. However, approximately 50 percent of the state's population lives in unincorporated areas, which are governed by the respective county board of supervisors. To this date, data associated with these unincorporated areas has not been available, so it is not possible to fully determine what percentage of the entire state's population is covered by a building code law.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Mississippi has no statewide program to license building officials. However, the state has allocated funding for training of building officials and inspectors through local governments.
LICENSING OF CONTRACTORS	General contractors are the only trade required to obtain a license and continuing education is required. Also, the state has a mechanism to register complaints from the public and discipline contractors, if needed.
KEY AREAS FOR IMPROVEMENT	Establishment of a State Construction Code Council with the primary function of administering (i.e., reviewing, adopting, maintaining, and providing guidance for staff qualification/certification and training, as well as direction for contractors) up-to-date codes throughout the state would be highly beneficial in promoting the Mississippi statewide building code program.

Alabama



BUILDING CODE ADOPTION

Alabama does not have a mandatory statewide building code system. The state Department of Economic and Community Affairs (ADECA) updated the *Alabama Energy and Residential Codes (AERC)* to the 2015 edition of the IRC for voluntary adoption by jurisdictions in the state. Although the energy portion of the code is mandatory at the local level, local jurisdictions are permitted to continue enforcing the residential code edition they had already adopted. The law requires that if a jurisdiction has not previously adopted a residential building code and decides to adopt one, they must now adopt the AERC codes. It should be noted that enforcement aspects of the AERC are not clearly defined in the rule and/or can be considered nonexistent.

On a more positive note, several coastal communities within the state are to be applauded for adopting and enforcing strong code programs.

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Alabama has no statewide program to license building officials.
LICENSING OF CONTRACTORS	The state requires licensing for general, plumbing, mechanical, and electrical contractors, but not for roofing contractors. Mechanical and electrical contractors are required to obtain continuing education for license renewal.
KEY AREAS FOR IMPROVEMENT	Over the last several years, Alabama has experienced repetitive devastating inland tornadoes and storms, and was in the potential path of Hurricanes Harvey, Irma, and Nate in 2017. Adoption of a modern mandatory statewide residential code throughout the state would help establish uniformity in enforcement and application of the important code provisions. Further, it would reduce losses to life and property in the event of severe storms, to which the state is highly vulnerable.

Delaware



BUILDING CODE ADOPTION

Delaware does not have a statewide residential building code, except for a plumbing code, which is based on the 2015 edition of the *International Plumbing Code*® (IPC).

CERTIFICATION AND EDUCATION OF BUILDING OFFICIALS	Delaware has no statewide program to license building officials.
LICENSING OF CONTRACTORS	Delaware requires licensing for plumbing, mechanical, and electrical contractors, while general and roofing contractors are not licensed. Electrical contractors are required to obtain continuing education for license renewal.
KEY AREAS FOR IMPROVEMENT	Delaware should consider adoption and enforcement of a model statewide residential code system throughout the state and a program to license building officials and construction trade contractors.

U.S. Virgin Islands

Based on the information available from public resources, the territory of the U.S. Virgin Islands has adopted the 2003 IRC for residential one- and two-family dwelling construction. Title 29 (Public Planning and Development), Chapter 5 (Building Code) of the U.S. Virgin Islands' laws requires a minimum design wind speed of 145 mph (ASD-level wind speed consistent with ASCE 7-05 or earlier editions) for buildings throughout the territory. The laws have provisions for permit requirements as well as inspections of construction work by representatives of the territory's building commissioner.

In early September 2017, prior to striking the mainland U.S., Hurricane Irma made landfall in the U.S. Virgin Islands as a Category 5 storm. Irma caused significant and catastrophic damage on the island, leaving many buildings totally or partially destroyed. Power outages resulting from

Hurricane Irma hampered post-hurricane repair and reconstruction operations. The findings from the FEMA mitigation assessment team that visited the territory in December 2017 should identify systemic deficiencies observed in construction techniques throughout the territory and could provide mitigation strategies for improving the resilience of future construction. The update of the territory's building codes based on the latest U.S. model building codes and standards should be emphasized as well.

Puerto Rico

Puerto Rico has adopted the 2011 Puerto Rico Building Code (PRBC), which is based on the 2009 edition of the IRC. The Office of Permit Management is tasked with implementation of the PRBC. As evidenced by Category 4 Hurricane Maria in September 2017, Puerto Rico is vulnerable to high wind speeds that fall outside the prescriptive standards of the IRC. As such, to reduce wind damage, higher-level design and construction standards are needed to address the increased wind speeds. Examples of what is referenced in the Puerto Rico residential code include design of the building wind loads based on the IBC, ICC *Standard for Residential Construction in High-Wind Regions* (ICC 600) and designs based on ASCE 7. IBHS was not able to determine the extent to which these standards are being applied throughout Puerto Rico while developing this report.

The only amendment in Division III of the PRBC, which specifically governs residential construction, is to Section R301.2.1.2 regarding protection of openings (i.e., windborne debris protection). This section has been modified to include requirements in the 2015 edition of the IRC with respect to standards for testing of garage doors with glazing, predrilling requirements of the protective panels, and use of corrosion-resistant fasteners to secure the panels over openings. Tested and certified storm shutter systems are also included as alternatives to wood structural panels for protection of openings from windborne debris.

Appendix R in the PRBC provides alternate structural provisions—reinforced concrete structural design as well as masonry construction based on a wind speed of 145 mph (3-second gust) as defined in ASCE 7-05—for one- and two-story buildings, which also covers residential construction. However, based on Section R102.5 of the PRBC, this appendix is not mandatory. The code has provisions for permit requirements as well as inspections

of construction work by representatives of the territory's municipalities. It needs to be emphasized that Puerto Rico is also located in a high seismic activity zone and is consequently vulnerable to seismic forces as well. Accordingly, the designs should factor in seismic vulnerabilities.

Puerto Rico permitting laws require sign-off by licensed professionals for all construction; however, there is evidence of what is referred to as informal construction or construction without a permit throughout the territory.

The extent of damage to buildings in Puerto Rico during Hurricanes Maria and Irma in 2017 was widespread and devastating. In general, preliminary investigations revealed that most light-frame construction—which includes residential dwellings—performed poorly and there were significant property losses. On a more positive note, reinforced concrete structures performed well. There was evidence of widespread damage to building envelope systems (i.e., roof covering, windows and doors, and deteriorated shutters), regardless of light-frame or reinforced concrete construction. Flood damage, which includes coastal erosion, storm surge and riverine damage, was extensive. It should also be noted that widespread power losses and damage to power generation and distribution systems resulting from Maria and Irma have been a significant roadblock to post-hurricane repair and reconstruction efforts in the territory.

The findings from the FEMA mitigation assessment team that visited the territory in December 2017, should provide a better picture of how the residential building stock performed during the massive hurricane forces, and of the systemic deficiencies observed in construction methods and code enforcement throughout the territory. The report could provide mitigation strategies for improving the resilience of future construction in Puerto Rico.

APPENDIX B

Highlights of Significant Changes

The numeric scores in this report are important in understanding how states are addressing the key components of an effective building code system: adoption and updating of mandatory statewide codes; proper enforcement of building code requirements by building officials; and licensing of contractors and subcontractors who are responsible for complying with building code requirements. Beyond the changes reflected in these scores, the following three states took actions that could affect their current or future building code adoption processes.

Florida

Hurricane Irma demonstrated the effectiveness of Florida's strong, up-to-date, mandatory statewide code in reducing wind damage. Timely adoption of the sixth edition of the FBCR in 2017 further illustrates the state's commitment to maintaining the latest modern codes and standards for residential construction. Against this backdrop, there has been considerable controversy surrounding a new 2017 law that changed the process the state employs to adopt building codes in the future. Prior to the new legislation, the Florida Building Commission (Commission) used the IRC model code as the base code for developing the FBCR with any statutory requirements merged into the base code.

Under the new law, the Commission will update future editions of the code using the existing FBCR as the base text with all Florida-specific requirements carried forward. The Commission will then consider technical amendments to the code in two phases. During the first phase, the Commission will consider for approval all amendments to the IRC that were approved for the 2018 IRC and any other nationally recognized code. During the second phase, the Commission will consider for approval any new Florida-specific amendments that are proposed. The new legislation requires the Commission to adopt, at a minimum, any updates to the IRC or any other code necessary to maintain eligibility for federal funding and discounts from the National Flood Insurance Program (NFIP), FEMA, and the U.S. Department of Housing and Urban Development (HUD).

The new legislation also provides the authority for the Commission to change the threshold voting requirement—for the Technical Advisory Committees and the Commission—to approve technical amendments from a three-quarters to two-thirds majority (Note: the Technical Advisory Committees provide recommendations on code changes to the Commission). While the voting threshold for the Technical Advisory Committees has been reduced to a two-thirds majority, the Commission opted to maintain the three-fourths majority for approval of code changes by the Commission.

Supporters of the new process argue that using the existing edition of the FBCR as the base is a more commonsense approach than starting with an ICC model residential code that was designed for broad adoption across the country in states that have different risks from those in Florida, especially with regard to high wind and water intrusion. They also note that the legislation specifically prohibits the FBCR from weakening any wind resistance or water intrusion standards and requirements, the two greatest concerns regarding hurricanes to which the state is especially vulnerable. Also, the bill explicitly requires the Commission to adopt updates that preserve federal funding or discounts linked to minimum building code requirements, such as those required for participation in the NFIP, eligibility for hazard mitigation assistance and grants, and so forth.

That said, there also was strong opposition to the bill by many stakeholders, who voiced concerns that the bill could weaken the FBCR or undermine advances made in triennial updates of the model building codes. Critics also suggested that 25 years after Hurricane Andrew, which resulted in adoption of strong Florida statewide codes, memories are fading and the proposed changes to the code adoption process are dangerous.

Regardless of whether the FBCR or the IRC is used as the base text for updating building codes in Florida, in the past, the state has utilized a combined approach that is consistent with the most recent national model codes and standards while adding in stronger wind and water intrusion protections. Just as the previous approach required careful attention to make sure that older provisions of the FBCR were carried forward, advocates of building safety will need to stay engaged in the new process to make sure that important advancements and requirements in published editions of the model codes and standards are added to future editions of the FBCR.

Louisiana

In June 2017, the Louisiana governor issued an Executive Order suspending adoption of the 2015 editions of the I-Codes and the NEC. This delay continued a problem in Louisiana's building code resulting from a 2013 Emergency Declaration that weakened the wind design provisions of the residential building code by reducing the area of the state where specific wind design and windborne debris protection was required. After extensive efforts by many stakeholders and supporters of the up-to-date codes, Governor Edwards rescinded the executive order, allowing adoption of the 2015 codes to proceed. The Louisiana State Uniform Construction Code Council subsequently voted to adopt the codes and Louisiana amendments, effective February 2018.

Although the statewide code is now a well-established and important component of the state's improved hurricane defense system, regulatory actions over the past several years directly threaten progress made in a state that is especially vulnerable to hurricanes and flooding.

New York

After many years with a residential building code that was based on the 2006 IRC, New York State finally adopted the 2015 edition of the IRC in 2017. The *New York State Uniform Residential Code* is now in conformance with one of the latest editions of the IRC. The update also eliminated provisions that weakened opening protection requirements in the IRC, thereby improving protections in windborne debris regions. The new code also requires any single-family dwelling or a townhouse over two stories in height above grade to be equipped with automatic fire sprinkler systems; this is one of the stronger fire sprinkler requirements in the states covered by this report.

APPENDIX C

Residential Codes in Effect for States in Rating the States Report

FLORIDA	2015 <i>International Residential Code</i> [®] with state amendments
VIRGINIA	2012 <i>International Residential Code</i> [®] with state amendments
SOUTH CAROLINA	2015 <i>International Residential Code</i> [®] with state amendments
NEW JERSEY	2015 <i>International Residential Code</i> [®] with state amendments
CONNECTICUT	2012 <i>International Residential Code</i> [®] with state amendments
RHODE ISLAND	2012 <i>International Residential Code</i> [®] with state amendments
NORTH CAROLINA	2009 <i>International Residential Code</i> [®] with state amendments
LOUISIANA	2015 <i>International Residential Code</i> [®] with state amendments
MASSACHUSETTS	2015 <i>International Residential Code</i> [®] with state amendments
MARYLAND	2015 <i>International Residential Code</i> [®] with state amendments
GEORGIA	2012 <i>International Residential Code</i> [®] with state amendments, if code is to be adopted at a local level
NEW YORK	2015 <i>International Residential Code</i> [®] with state amendments, except New York City which adopted 2009 <i>International Building Code</i> [®] with residential construction provisions
MAINE	2009 <i>International Residential Code</i> [®] with state amendments; municipalities with populations less than 4,000 may opt out
NEW HAMPSHIRE	2009 <i>International Residential Code</i> [®] with state amendments, but local enforcement not mandatory
TEXAS	No mandatory statewide code; the 2006 <i>International Residential Code</i> [®] is optional
MISSISSIPPI	One of the latest three editions of the <i>International Residential Code</i> [®] ; a number of counties and municipalities have opted out
ALABAMA	No mandatory statewide code; jurisdiction may continue with any code editions currently being enforced; however, if a code is to be adopted at local level for the first time, it shall be the 2015 IRC
DELAWARE	No mandatory statewide residential code

16. Assignment 4, Module 3: FEMA Building Codes: <https://www.fema.gov/emergency-managers/risk-management/earthquake/seismic-building-codes>

Seismic Building Codes

 English

There is an often-repeated saying, "earthquakes don't kill people, buildings do." Although you can't control the seismic hazard in the community where you live or work, you can influence the most important factor in saving lives and reducing losses from an earthquake: the adoption and enforcement of up-to-date building codes.



Unreinforced Masonry Risk Reduction Report

Unreinforced masonry was a common building material throughout Utah until the 1970s. Published by FEMA and the state of Utah, this report provides local communities with a strategy to significantly reduce the earthquake risk posed by these buildings.

Download the Report 

What Are Building Codes?

Building codes are sets of regulations governing the design, construction, alteration and maintenance of structures. They specify the minimum requirements to adequately safeguard the health, safety and welfare of building occupants.

Rather than create and maintain their own codes, most states and local jurisdictions adopt the model building codes maintained by the [International Code Council \(ICC\)](#). The ICC's family of International Codes includes:

- **International Building Code (IBC):** Applies to almost all types of new buildings
- **International Residential Code (IRC):** Applies to new one- and two-family dwellings and townhouses of not more than three stories in height
- **International Existing Building Code (IEBC):** Applies to the alteration, repair, addition or change in occupancy of existing structures. The ICC publishes new editions of the International Codes every three years and many states and localities have adopted them since the first editions were issued in 2000. In 2000, the three regionally-based model code organizations (BOCA National Code, SBCCI Standard Code and ICBO Uniform Code) combined together to form the ICC.

What Are Seismic Codes?

Some provisions within the IBC, IRC and IEBC are intended to ensure that structures can adequately resist seismic forces during earthquakes. These seismic provisions represent the best available guidance on how structures should be designed and constructed to limit seismic risk.

Changes or additions to the seismic provisions come from many different sources, including new research results and documentation of performance in past earthquakes. A primary resource is the [2020 NEHRP Provisions Edition Volume I](#) and [Volume II](#). FEMA's companion document [Earthquake Resistant Design Concepts \(FEMA P-749\)](#) provides a nontechnical background explanation.

Adoption of the model codes is uneven across and within states, even in areas with high levels of seismic hazard. Some states and local jurisdictions have adopted the codes but have made amendments or exclusions relating to the seismic provisions.

Other jurisdictions have been slow to adopt the latest code editions. Unless your community has adopted the latest model building code, including its seismic provisions, new structures in your community will probably not provide the current minimum level of protection from earthquake hazards to you and others who use them.

How Are The Codes Enforced?

Adopting the latest building codes is only part of the solution. Codes must also be effectively enforced to ensure that buildings and their occupants benefit from advances in seismic provisions in the model codes. For the most part, code enforcement is the responsibility of local government building officials who review design plans, inspect construction work and issue building and occupancy permits.

What About Older Buildings?



Damage to older, reinforced concrete building in the 1994 Northridge Earthquake. © 1994 by Peter W. Clark and Regents of the University of California.

Except in certain circumstances, such as when a building is significantly renovated or altered or there is a change in its use that triggers the IBC or IEBC, the code requirements for existing buildings are those that were in effect when the structure was designed and constructed.

Your community probably has many older structures that are not protected against earthquakes. This is because buildings are often used for decades before being replaced or substantially altered.

These existing buildings are the single biggest contributor to seismic risk in the United States today.

Can We Make These Buildings Safe?

It's possible to make these buildings more resistant to earthquakes through seismic retrofitting. When dealing with a population of buildings, the first step is to perform a quick survey using [Rapid Visual Screening of Buildings for Potential Seismic Hazards \(FEMA 154\)](#). The next step is to evaluate the building using [Seismic Evaluation of Existing Buildings \(ASCE/SEI 31-03\)](#). If the evaluation shows that retrofitting is needed, this should be done using [Seismic Rehabilitation of Existing Buildings \(ASCE/SEI 41-06\)](#). This standard, which is referenced in the IEBC, is based on [Prestandard and Commentary for the Seismic Rehabilitation of Buildings \(FEMA 356\)](#). The FEMA publication [Techniques for the Seismic Rehabilitation of Existing Buildings \(FEMA 547\)](#) provides an extensive description of retrofit techniques for strengthening the structural elements of buildings.

Seismic retrofitting of a building must also include steps to better protect non-structural components (suspended ceilings, non-load-bearing walls and utility systems) and building contents (furnishings, supplies, inventory and equipment). [Reducing the Risks of Non-Structural Earthquake Damage \(FEMA E-74\)](#) was recently updated and is an excellent resource for information on mitigating risk to non-structural components and contents.

Certain types of buildings, such as unreinforced masonry structures, have performed poorly in past earthquakes and are known to be particularly hazardous. Some local governments in high-hazard areas have enacted ordinances mandating that owners evaluate and retrofit these buildings. In most jurisdictions, however, seismic retrofitting remains voluntary.

How Important Is Seismic Retrofitting ?

Seismic retrofitting of vulnerable structures is critical to reducing risk. It is important for protecting the lives and assets of building occupants and the continuity of their work. On the whole, communities with more retrofitted structures can recover from earthquakes more rapidly.

If you live or work in retrofitted structures, you're less likely to be injured during an earthquake. After the earthquake, you're also more likely to have a home and a job to which you can quickly return.

Businesses that use retrofitted buildings are more likely to survive damaging earthquakes and to sustain shorter business interruptions and fewer inventory losses.

FEMA's [QuakeSmart](#) program helps businesses identify and address their seismic risks through retrofitting and other earthquake mitigation activities.

Conclusions

There is no more important factor in reducing a community's risk from an earthquake than the adoption and enforcement of up-to-date building codes. Evaluating older buildings and retrofitting structural and non-structural components also are critical steps. To survive and remain resilient, communities should also strengthen their core infrastructure and critical facilities so that these can withstand an earthquake or other disaster and continue to provide essential services.

17. Assignment 5, Module 1: ASOP 23: https://actuarialstandardsboard.org/wp-content/uploads/2014/07/asop023_097.pdf



ACTUARIAL STANDARDS BOARD

**Actuarial Standard
of Practice
No. 23**

Data Quality

Revised Edition

**Developed by the
General Committee of the
Actuarial Standards Board and
Applies to All Practice Areas**

**Adopted by the
Actuarial Standards Board
December 2004**

(Doc. No. 097)

ASOP No. 23—December 2004

TABLE OF CONTENTS

Transmittal Memorandum	iv
STANDARD OF PRACTICE	
Section 1. Purpose, Scope, Cross References, and Effective Date	1
1.1 Purpose	1
1.2 Scope	1
1.3 Cross References	1
1.4 Effective Date	2
Section 2. Definitions	2
2.1 Appropriate Data	2
2.2 Audit	2
2.3 Comprehensive Data	2
2.4 Data	2
2.5 Data Element	2
2.6 Practical	2
2.7 Review	2
Section 3. Analysis of Issues and Recommended Practices	3
3.1 Overview	3
3.2 Selection of Data	3
3.3 Reliance on Data Supplied by Others	3
3.4 Reliance on Other Information Relevant to the Use of Data	4
3.5 Review of Data	4
3.6 Limitation of the Actuary's Responsibility	5
3.7 Use of Data	5
3.8 Documentation	5
Section 4. Communications and Disclosures	6
4.1 Disclosure	6
4.2 Prescribed Statement of Actuarial Opinion	7
4.3 Deviation from Standard	7

ASOP No. 23—December 2004

APPENDIXES

Appendix 1—Background and Current Practices	8
Background	8
Current Practices	8
Appendix 2—Comments on the Exposure Draft and Committee Responses	9

ASOP No. 23—December 2004

December 2004

TO: Members of Actuarial Organizations Governed by the Standards of Practice of the Actuarial Standards Board and Other Persons Interested in Data Quality

FROM: Actuarial Standards Board (ASB)

SUBJ: Actuarial Standard of Practice (ASOP) No. 23

This booklet contains the final version of a revision of ASOP No. 23, *Data Quality*.

Background

The ASB originally adopted ASOP No. 23, *Data Quality* (Doc. No. 044), in 1993. The previous ASOP was prepared by the Data Quality Task Force of the Specialty Committee of the ASB. The General Committee has prepared this revision of ASOP No. 23 to be consistent with the current ASOP format, to reflect current, generally accepted practice with respect to data quality, and to provide guidance concerning other information relevant to the use of data.

Exposure Draft

The exposure draft of this ASOP was approved for exposure in October 2003 with a comment deadline of March 31, 2004. Twenty-eight comment letters were received and considered in developing the final standard. A summary of the substantive issues contained in the exposure draft comment letters and the General Committee's responses are provided in appendix 2.

The most significant changes from the exposure draft were as follows:

1. Section 1.2, Scope, has been clarified to indicate that if this standard establishes requirements in addition to those imposed by law, the actuary should satisfy the requirements of both the standard and the law.
2. When data are supplied by others, section 3.3 clarifies that the actuary should follow the guidance of section 3.5, Review of Data, before relying on such data. This means that the actuary should review the data for reasonableness and consistency unless, in the actuary's professional judgment, such a review is not necessary or not practical.

ASOP No. 23—December 2004

3. Similarly, section 3.4, *Reliance on Other Information Relevant to the Use of Data*, allows reliance on such information, but now does so “unless it is or becomes apparent to the actuary during the time of the assignment that the information contains material errors or is otherwise unreliable.”
4. The standard clarifies that section 3.5, *Review of Data*, applies whether the actuary prepared the data or received the data from a third party. The section also suggests that, in doing the review of the data, the actuary attempt to determine the definition of each data element used in the analysis. A definition of “review” has been added to section 2, pointing out that this is an informal examination of the obvious characteristics of the data.
5. The sentence that appeared in the previous ASOP No. 23 but was removed from the exposure draft of this revision, which stated that the actuary is not expected to “develop additional data compilations solely for the purpose of searching for questionable or inconsistent data,” was reinserted in section 3.6, *Limitation of the Actuary’s Responsibility*.
6. Section (c) of 3.7, *Use of Data*, was expanded to apply to results that are highly uncertain, in addition to those that have a material bias. Appropriate disclosure is required in section 4.1 if the actuary decides to complete the assignment in such circumstances.
7. The committee clarified section 3.8 by explicitly requiring the actuary to document any material defects in the data, in keeping with the requirements of ASOP No. 41, *Actuarial Communications*.

The General Committee thanks everyone who took the time to contribute comments on the exposure draft.

The ASB voted in December 2004 to adopt this standard.

ASOP No. 23—December 2004

General Committee of the ASB

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ASOP No. 23—December 2004

ACTUARIAL STANDARD OF PRACTICE NO. 23

DATA QUALITY

STANDARD OF PRACTICE

Section 1. Purpose, Scope, Cross References, and Effective Date

- 1.1 Purpose—The purpose of this actuarial standard of practice (ASOP) is to give guidance to the actuary in the following:
- a. selecting the data that underlie the actuarial work product;
 - b. relying on data supplied by others;
 - c. reviewing data;
 - d. using data; and
 - e. making appropriate disclosures with regard to data quality.
- 1.2 Scope—This standard applies to actuaries when providing professional actuarial services in all practice areas. Other actuarial standards of practice may contain additional considerations related to data quality that are applicable to particular areas of practice or types of actuarial assignment.

This standard does not require the actuary to audit data.

If this standard establishes requirements in addition to those imposed by applicable law, regulation, or other binding authority, the actuary should satisfy the requirements of both the applicable law and the standard. To the extent applicable law conflicts with this standard, compliance with such applicable law shall not be deemed a deviation from this standard, provided the actuary discloses that the actuarial assignment was performed in accordance with the requirements of such applicable law.

- 1.3 Cross References—When this standard refers to the provisions of other documents, the reference includes the referenced documents as they may be amended or restated in the future, and any successor to them, by whatever name called. If any amended or restated document differs materially from the originally referenced document, the actuary should consider the guidance in this standard to the extent it is applicable and appropriate.

ASOP No. 23—December 2004

- 1.4 Effective Date—This standard will be effective for any actuarial work product for which data were provided to or developed by the actuary on or after May 1, 2005. In all cases, this standard will be effective for any actuarial work product commenced on or after July 1, 2006.

Section 2. Definitions

The terms below are defined for use in this actuarial standard of practice.

- 2.1 Appropriate Data—For purposes of data quality, data are appropriate if they are suitable for the intended purpose of an analysis and relevant to the system or process being analyzed.
- 2.2 Audit—To conduct a formal and systematic examination of a set of data for the purpose of testing its accuracy, using techniques commonly employed by audit professionals.
- 2.3 Comprehensive Data—For purposes of data quality, data obtained from inventory or sampling methods are comprehensive if they contain sufficient data elements or records needed for the analysis.
- 2.4 Data—For purposes of this standard, the term refers to numerical, census, or classification information and not to general or qualitative information. Assumptions are not data, but data are commonly used in the development of actuarial assumptions.
- 2.5 Data Element—An item of information, such as date of birth or risk classification.
- 2.6 Practical—Realistic in approach during the time of the assignment, given the purpose and nature of the assignment and any constraints, including cost and time considerations.
- 2.7 Review—An informal examination of the obvious characteristics of the selected data to determine if such data appear reasonable and consistent for purposes of the assignment. A review is not an audit of data.

ASOP No. 23—December 2004

Section 3. Analysis of Issues and Recommended Practices

- 3.1 **Overview**—Data that are completely accurate, appropriate, and comprehensive are frequently not available. The actuary should use available data that, in the actuary's professional judgment, allow the actuary to perform the desired analysis. However, if material data limitations are known to the actuary, the actuary should disclose those limitations and their implications. The following sections discuss such considerations in more detail.
- 3.2 **Selection of Data**—In undertaking an analysis, the actuary should consider what data to use. The actuary should consider the scope of the assignment and the intended use of the analysis being performed in order to determine the nature of the data needed and the number of alternative data sets or data sources, if any, to be considered. The actuary should do the following:
- a. consider the data elements that are desired and possible alternative data elements; and
 - b. select the data with due consideration of the following:
 1. appropriateness for the intended purpose of the analysis, including whether the data are sufficiently current;
 2. reasonableness and comprehensiveness of the necessary data elements, with particular attention to internal and external consistency;
 3. any known, material limitations of the data;
 4. the cost and feasibility of obtaining alternative data, including the ability to obtain the information in a reasonable time frame;
 5. the benefit to be gained from an alternative data set or data source as balanced against its availability and the time and cost to collect and compile it; and
 6. sampling methods, if used to collect the data.
- 3.3 **Reliance on Data Supplied by Others**—In most situations, the data are provided to the actuary by others. The accuracy and comprehensiveness of data supplied by others are the responsibility of those who supply the data. The actuary may rely on data supplied by others, subject to the guidance in section 3.5. In doing so, the actuary should disclose such reliance in an appropriate actuarial communication.

ASOP No. 23—December 2004

- 3.4 **Reliance on Other Information Relevant to the Use of Data**—In many situations, the actuary is provided with other information relevant to the appropriate use of data, such as contract provisions, plan documents, and reinsurance treaties. The validity and comprehensiveness of such information are the responsibility of those who supply such information. The actuary may rely on such information supplied by another, unless it is or becomes apparent to the actuary during the time of the assignment that the information contains material errors or is otherwise unreliable. The actuary should disclose reliance on information provided by another in an appropriate actuarial communication.
- 3.5 **Review of Data**—A review of data may not always reveal existing defects. Nevertheless, whether the actuary prepared the data or received the data from others, the actuary should review the data for reasonableness and consistency, unless, in the actuary's professional judgment, such review is not necessary or not practical. In exercising such professional judgment, the actuary should take into account the extent of any checking, verification, or auditing that has already been performed on the data, the purpose and nature of the assignment, and relevant constraints.

When determining the nature and extent of such a review, the actuary should consider the following:

- a. **Data Definitions**—The actuary should make a reasonable effort to determine the definition of each data element used in the analysis, as described in section 3.2.
- b. **Identify Questionable Data Values**—The actuary should review the data used directly in the actuary's analysis for the purpose of identifying data values that are materially questionable or relationships that are materially inconsistent. If the actuary believes questionable or inconsistent data values could have a material effect on the analysis, the actuary should consider further steps, when practical, to improve the quality of the data.
- c. **Review of Prior Data**—If similar work has been previously performed for the same or recent periods, the actuary should consider reviewing the current data for consistency with the data used in the prior analysis. If the actuary does not have the prior data, the actuary should consider requesting the prior data.

If, in the actuary's professional judgment, it is not appropriate to perform a review of the data, the actuary should disclose that the actuary has not done such a review and should disclose any resulting limitation on the use of the actuarial work product.

ASOP No. 23—December 2004

- 3.6 **Limitation of the Actuary's Responsibility**—The actuary is not required to do any of the following:
- a. determine whether data or other information supplied by others are falsified or intentionally misleading;
 - b. develop additional data compilations solely for the purpose of searching for questionable or inconsistent data; or
 - c. audit the data.
- 3.7 **Use of Data**—Because data that are completely accurate, appropriate, and comprehensive are frequently not available, the actuary should make a professional judgment about which of the following is applicable:
- a. the data are of sufficient quality to perform the analysis;
 - b. the data require enhancement before the analysis can be performed, and it is practical to obtain additional or corrected data that will allow the analysis to be performed;
 - c. judgmental adjustments or assumptions can be applied to the data that allow the actuary to perform the analysis. If the actuary judges that the use of the data, even with adjustments and assumptions applied, may cause the results to be highly uncertain or contain a material bias, the actuary may choose to complete the assignment, but should disclose the potential existence of the uncertainty or bias, and, if reasonably determinable, their nature and potential magnitude;
 - d. if the actuary believes that the data are likely to contain material defects, the actuary should determine, if practical, the nature and extent of any checking, verification, or auditing that may have been performed on the data. Then, if, in the actuary's professional judgment, a more extensive review is needed, the actuary should arrange for such a review prior to completing the assignment; or
 - e. if, in the actuary's professional judgment, the data are so inadequate that the data cannot be used to satisfy the purpose of the analysis, then the actuary should obtain different data or decline to complete the assignment.
- 3.8 **Documentation**—The actuary should comply with the requirements of ASOP No. 41, *Actuarial Communications*, regarding the preparation and retention of the documentation. In addition, the actuary's documentation should include the following:

ASOP No. 23—December 2004

- a. the process the actuary followed to evaluate the data, including the review or consideration of prior data;
- b. a description of any material defects the actuary believes are in the data;
- c. a description of any adjustments or modifications made to the data, other than routine corrections made by reference to source documents, including the rationale for any such adjustments or modifications; and
- d. any other documentation necessary to comply with the disclosure requirements of section 4.1.

Section 4. Communications and Disclosures

- 4.1 **Disclosure**—When issuing communications under this standard, the actuary should refer to ASOP No. 41. In addition, the actuary should disclose the following items:
- a. the source(s) of the data;
 - b. whether the actuary reviewed the data and, if not, any resulting limitations on the use of the actuarial work product;
 - c. the extent of the actuary's reliance on data and other information relevant to the use of data supplied by others;
 - d. any material judgmental adjustments or assumptions that the actuary applied to the data, or are known by the actuary to have been applied to the data, to allow the actuary to perform the analysis;
 - e. any limitations on the use of the actuarial work product due to uncertainty about the quality of the data;
 - f. any unresolved concerns the actuary may have about the data that could have a material effect on the actuarial work product;
 - g. (1) the existence of results that are highly uncertain or have a potentially material bias of which the actuary is aware due to the quality of the data; and (2) the nature and potential magnitude of such uncertainty or bias, if they can be reasonably determined; and
 - h. any conflicts that arose from complying with applicable law, regulation, or other binding authority.

ASOP No. 23—December 2004

- 4.2 **Prescribed Statement of Actuarial Opinion**—This ASOP does not require a prescribed statement of actuarial opinion (PSAO) as described in the *Qualification Standards for Prescribed Statements of Actuarial Opinion* promulgated by the American Academy of Actuaries. However, law, regulation, or accounting requirements may also apply to an actuarial communication prepared under this standard, and as a result, such actuarial communication may be a PSAO.
- 4.3 **Deviation from Standard**—The actuary must be prepared to justify to the actuarial profession's disciplinary bodies, or to explain to a principal, another actuary, or other intended users of the actuary's work, the use of any procedures that depart materially from those set forth in this standard. If a conflict exists between this standard and applicable law or regulation, compliance with applicable law or regulation is not considered to be a deviation from this standard.

ASOP No. 23—December 2004

Appendix 1

Background and Current Practices

Note: The following appendix is provided for informational purposes, but is not part of the standard of practice.

Background

An actuarial analysis is based upon an analysis of data, along with practical knowledge of the field of practice and training in actuarial theory, which together enable the actuary to interpret the results of calculations. Throughout the analytic process, data play an important role. The accuracy and validity of the actuarial analysis are dependent on, among other things, the quality of the data used. Hence, an actuarial standard of practice concerning data quality is appropriate.

Data frequently contain errors, are not fully complete, and are not precisely appropriate for the intended analysis. Actuaries deal with these limitations, the majority of which are non-critical. However, actuaries are often called upon to perform actuarial services in situations where data limitations may be critical. Actuaries use professional judgment when determining whether and how to refine data or make modifications within the analysis.

Current Practices

Actuaries use informed judgment to determine what kinds of data are appropriate for a particular analysis. It is important that the data used are relevant to the system or process being analyzed.

Persons or organizations responsible for generating, collecting, or publishing data may apply different standards of quality assurance, ranging from straightforward compilation of figures to extensive verification. Actuaries, in turn, deal with the question of the quality of data underlying their work products in a variety of ways and with varying levels of review or checking.

Actuaries are called upon to provide analyses for a broad range of uses, from limited distribution within an organization to public exposure.

Important aspects of data utilization include documentation and disclosure of (1) the sources of data; (2) review of data; (3) material biases resulting from data used by the actuary; (4) adjustments or corrections made to the data; and (5) the extent of reliance on data supplied by others. Typically, actuaries do not audit data.

ASOP No. 23—December 2004

APPENDIX 2

Comments on the Exposure Draft and Committee Responses

The exposure draft of this revision of ASOP No. 23, *Data Quality*, was issued in October 2003 with a comment deadline of March 31, 2004. Twenty-eight comment letters were received, some of which were submitted on behalf of multiple commentators, such as by firms or committees. For purposes of this appendix, the term “commentator” may refer to more than one person associated with a particular comment letter. The General Committee carefully considered all comments received. Summarized below are the significant issues and questions contained in the comment letters and the committee’s responses. Unless otherwise noted, the section numbers and titles used below refer to those in the exposure draft.

GENERAL COMMENTS	
Several commentators suggested various editorial changes in addition to those addressed specifically below. The committee implemented such suggestions if they enhanced clarity and did not alter the intent of the section.	
In the transmittal memorandum of the exposure draft, the committee asked readers to comment on whether the exposure draft clarified the previous standard. Most commentators believed that the revisions did clarify the standard, and others had suggestions that are addressed in the following responses.	
Comment	One commentator suggested that the standard should address issues concerning how results vary when using data with different time horizons.
Response	The committee believed that issue was more about credibility than data quality and made no change in the standard.
Comment	A commentator believed that the standard should also provide guidance on privacy, confidentiality, and distribution of the actuarial report.
Response	The committee believed such issues were beyond the scope of this standard. ASOP No. 41, <i>Actuarial Communications</i> , provides guidance with respect to actuarial reports.
Comment	One commentator recommended expanding the title of the standard to add “Actuaries’ Responsibilities in Selecting, Reviewing, and Using Data.”
Response	The committee believed that this was unnecessary, because section 1.1, Purpose, identifies the specific professional services discussed in the standard.
Comment	A commentator suggested that, since it is common for actuaries to extract their own data for use in their analyses, the standard should more clearly indicate the actuary’s responsibility to review data that the actuary has independently created.
Response	The committee agreed and revised section 3.5, Review of Data, in response.
Comment	One commentator thought that the actuary should be required to disclose and resolve material differences between prior and current period data.
Response	The committee believed that the actuary should be satisfied that the current data are appropriate and should disclose other concerns related to data quality in accordance with section 4.1(g) (now 4.1(f)). The reconciliation of data from one period to the next is beyond the scope of this standard.

ASOP No. 23—December 2004

SECTION 1. PURPOSE, SCOPE, CROSS REFERENCES, AND EFFECTIVE DATE	
Section 1.2, Scope	
Comment	One commentator objected to not requiring the actuary to audit the data, while several others supported the statement in the standard that audits are not required.
Response	The committee believed that the actuary should generally be required to review, but not audit the data, and left this scope limitation unchanged.
Comment	Several commentators recognized that the actuary must comply with law, regulation, or other binding authority, but disagreed that the actuary should disclose such a conflict.
Response	The committee disagreed and retained the disclosure requirement, consistent with other standards. In response to another comment, the committee also added a sentence clarifying that the actuary must comply with both the standard and the law when the standard has more extensive requirements than the law. Finally, the wording of this section was modified to clarify that the standard applied only to professional "actuarial" services.
Section 1.4, Effective Date	
Comment	A commentator pointed out that it is common in some practice areas to use a significant amount of data collected in prior years and then perform the current analysis after the latest data have been added to the database or using relevant current data. The commentator believed that the prior data should be subject only to requirements in effect when the data were originally collected and not be subject to any new requirements in the standard.
Response	The committee discussed this point and made no change to this section, because it believed that other sections of the standard gave sufficient guidance to the actuary regarding the extent to which the actuary should review the data, including consideration of practicality and materiality.
SECTION 2. DEFINITIONS	
Some commentators suggested adding definitions of other terms. In most cases, the committee did not believe that was necessary. However, it did add a definition of "review," as suggested by one commentator, to clarify that a review is less formal than an audit and does not verify the accuracy of data, but merely consists of observing its obvious characteristics and abnormalities.	
Section 2.1, Appropriate (now Appropriate Data)	
Comment	Several commentators suggested adding the word "data" to the title of this section.
Response	The committee agreed and added "data" here and in the title of section 2.3.
Comment	One commentator suggested deleting the phrase "relevant to the system or process being analyzed."
Response	The committee thought the existing language was necessary and sufficiently clear and made no change.
Section 2.2, Audit	
Comment	Some editorial suggestions were made to improve the definition.
Response	The committee adopted some of the suggestions, adding "for the purpose of testing its accuracy" and removing "or review," because that latter term is now defined and differentiated from an audit.
Section 2.3, Comprehensive (now Comprehensive Data)	
Comment	A commentator recommended that "sufficient data elements" be used in this definition in place of "each data element."
Response	The committee agreed that this was more appropriate wording and made the change.
Comment	One commentator suggested adding a discussion of inventory or sampling methods.
Response	The committee did not see the need for such a discussion.

ASOP No. 23—December 2004

Section 2.4, Data	
Comment	A commentator pointed out that actuaries often use data contained in reports prepared by other professionals and suggested that such data be covered by this definition.
Response	The committee made no change to this definition, because sections 3.3 and 3.4 address reliance on data and other information supplied by others.
Comment	One commentator suggested expanding the definition to indicate that sometimes assumptions are used to develop certain data elements.
Response	The committee did not believe such an expansion was necessary. The use of assumptions to perform such analyses is referenced in section 3.7(c).
Section 2.6, Practical	
Comment	A number of comments were received on the inclusion of the defined term "practical" in response to the committee's request in the transmittal letter of the exposure draft. Some commentators thought the definition was unnecessary, and some offered suggestions for further improvement.
Response	Because the concept of practicality is an important consideration in this standard in aiding an actuary to make professional judgments regarding selection of data, and whether and to what extent to review the data, among other things, the committee strongly believed that a definition of this term should be included.
Comment	One commentator pointed out that use of hindsight would be inappropriate in determining what was practical.
Response	The committee agreed and added "during the time of the assignment" to the definition.
Comment	One commentator wanted to add guidance on considerations for evaluating materiality.
Response	The committee believed that materiality is a subjective concept that depends on the actuary's professional judgment, and that it was beyond the scope of this standard to define or provide guidance on materiality.
SECTION 3. ANALYSIS OF ISSUES AND RECOMMENDED PRACTICES	
Section 3.1, Overview	
Comment	One commentator pointed out that some assignments do, in fact, require perfect data, and that the standard should recognize this.
Response	The committee disagreed that the standard should be written to address specific situations that would require more diligent treatment. Sections 3.2 and 3.5 state that consideration should be given to the purpose and nature of the assignment.
Section 3.2, Selection of Data	
Comment	One commentator wanted to clarify the language relating to "review."
Response	The committee decided to delete reference to "review" in this section as it is thoroughly covered in section 3.5.

ASOP No. 23—December 2004

Comment	One commentator believed that section 3.2(b)(5) should be eliminated or at least restricted to alternate data sources reasonably known to the actuary.
Response	The committee believed this guidance is important and, in view of the comment, carefully considered the wording again and revised the wording to clarify that the actuary is provided adequate leeway to consider the benefits of seeking alternative data sources versus the effort necessary to get them.
Comment	One commentator suggested that the terms "data sets" and "data sources" should be consistent here and in section 3.2(b)(5).
Response	The committee agreed and made changes to accomplish this.
Comment	One commentator believed "subject to the limitations presented by the actuary's reliance on others..." should be added to clarify how this section relates to sections 3.3 and 3.4.
Response	The committee believed that the guidance for selection of data should not depend on whether or not the actuary needs to rely on others to supply the data and did not believe such an addition was necessary or appropriate.
Comment	One commentator suggested deleting "relative availability" and adding "time and" in front of the word "cost" in section 3.2(b)(5).
Response	The committee did drop "relative" and did add "time and."
Section 3.3, Reliance on Data Supplied by Others	
Comment	One commentator supported the concept of what was labeled "blind reliance." A couple of commentators were uncertain as to whether the implication of such reliance was appropriate and consistent with sections 3.1 or 3.5. Several others commented that such reliance was inappropriate.
Response	After much discussion and careful consideration, the committee ultimately agreed that additional clarity was needed. Accordingly, the committee added the phrase "subject to the guidance in section 3.5," and that section provides that the actuary should review the data for reasonableness and consistency unless, in the actuary's professional judgment, it is not practical or not necessary to do so.
Section 3.4, Reliance on Other Information Relevant to the Use of Data	
Comment	Two commentators were uncomfortable with the implication of absolute reliance in this section, believing that it could conflict with the guidance in other sections of the ASOP by setting a different standard.
Response	The committee believed a lower standard was appropriate but agreed that the actuary should not proceed with the analysis based on information that is known by the actuary to be suspect. Accordingly, the committee added the phrase "unless it is or becomes apparent to the actuary during the time of the assignment that the information contains material errors or is otherwise unreliable."
Comment	Two commentators thought that "or summaries of such documents" should be specifically added to the list.
Response	Because the list provides examples only, the committee believed that this added language was not needed.
Section 3.5, Review of Data	
Comment	Several commentators questioned the meaning of the word "appropriate."
Response	The committee deleted the word "appropriate" where it might be confusing.
Comment	Several commentators questioned whether it was always necessary to review prior data and suggested adding the word "consider" in section 3.5(a) regarding review of prior data.
Response	The committee agreed and incorporated this wording change in what is now section 3.5(c).

ASOP No. 23—December 2004

Comment	One commentator believed that a new section on the time period of the data should be added.
Response	The committee believed this was sufficiently covered in section 3.2(b)(1).
Comment	Two commentators were unclear if this section applied to data received from others.
Response	The committee clarified that it does apply and that the actuary should review for reasonableness and consistency “unless, in the actuary’s professional judgment, such review is not necessary or not practical.”
Comment	One commentator suggested adding a new consideration: “Data Definitions—The actuary should make a reasonable effort to determine the definition of each data element provided.”
Response	The committee agreed and added what is now section 3.5(a).
Comment	One commentator interpreted section 3.5(b) as requiring a datum-by-datum review and a datum-by-datum correction process, thereby precluding any type of sampling procedure.
Response	The committee disagreed with this interpretation. Section 3.2 specifically allows for sampling procedures. Based on the definition of “review,” the committee believed guidance for the actuary to look for obvious errors or inconsistencies that may materially affect the analysis was appropriate.
Section 3.6. Limitation of the Actuary’s Responsibility	
Comment	Several commentators responded to a question requesting comments about whether it was appropriate to delete the following language from section 5.3(a) of the previous ASOP No. 23: “The actuary is not required to develop additional data compilations solely for the purpose of searching for questionable or inconsistent data.” While a couple of commentators believed the deletion was appropriate, most believed that the language should be put back into the revision.
Response	The committee agreed with the majority and reinserted what is now section 3.6(b).
Comment	Several comments suggested eliminating the word “intentionally” inaccurate.
Response	The committee disagreed and left this wording, because just removing the word “intentionally” would weaken the standard by implying that the actuary is relieved of any responsibility for inaccurate data, whether intentional or not. However, after lengthy discussions the committee revised the section by amending the wording of what is now section 3.6(a), in addition to reinserting section 3.6(b).
Section 3.7. Use of Data	
Comment	One commentator suggested clarifying section (d) to apply when material defects are likely, not just possibilities.
Response	The committee agreed and added the words “are likely to” to this subsection.
Comment	One commentator suggested changing the word “should” to “must,” eliminating the words “when practical,” and specifying that this disclosure should be in the summary level presentation of the results.
Response	The committee disagreed and left the wording as is.
Comment	Two commentators suggested changing the wording in the opening paragraph to clarify that data are rarely completely accurate, appropriate, and comprehensive.
Response	The committee agreed and changed the wording in the opening paragraph.

ASOP No. 23—December 2004

Comment	One commentator suggested that section 3.7 could be viewed to be in conflict with section 4.1, Disclosure.
Response	The committee disagreed that there would be a conflict. If the actuary believes there is a material defect in the data, the actuary can still perform the assignment and make the disclosures in section 4.1.
Comment	One commentator suggested removing the words "if practical" from section (d).
Response	The committee disagreed and left this wording.
Comment	One commentator suggested defining a process for what to do if material defects have been found or are known to exist in the data.
Response	The committee prepared this section to provide guidance to the actuary in discriminating between different types of situations. The committee believed that sections (d) and (e) provided adequate guidance in this respect.
Comment	One commentator suggested removing the first sentence of this section since all items in this section are based on the premise that the actuary is aware of data deficiencies.
Response	The committee revised the first paragraph of section 3.7 to clarify that the actuary should decide which of the circumstances in sections (a)–(e) apply, even if the actuary is not necessarily aware of material defects in the data.
Comment	One commentator suggested removing the first sentence from section (d).
Response	The committee disagreed and left the first sentence.
Comment	One commentator suggested that this section provides only two alternatives for inadequate data.
Response	The committee disagrees and refers the commentator to the four alternatives contained in sections (b)–(e). The committee also added a consideration in section (c) to address results that may be highly uncertain.
Section 3.8, Documentation	
Comment	One commentator suggested adding a section requiring a description of any material defects the actuary believes are in the data and the review conducted by the actuary on this data.
Response	The committee agreed in respect of material defects and added appropriate wording to section 3.8(b).
Comment	Two commentators suggested eliminating the first sentence since it was confusing.
Response	The committee agreed with this commentator and eliminated the first sentence of this section.
Comment	One commentator suggested changing the wording of section (b) by replacing it with "whether the actuary reviewed the data as contemplated by section 3.5 and, if so, the scope of the review."
Response	The committee agreed that additional clarity was needed and revised the entire section 3.8.
Comment	One commentator suggested changing the wording of section (c) by inserting the words "if reasonably estimable, the" before "effect."
Response	The committee agreed that this language could be too burdensome and revised the language in section (c).

ASOP No. 23—December 2004

Comment	One commentator suggested adding words to this section similar to those in the disclosure section pertaining to a description of the insufficiencies or issues with the data that may have an impact on the results.
Response	The committee revised section 3.8, adding sections (b) and (d) to deal with this issue.
Comment	One commentator suggested that this section is not needed as long as the disclosure section exists.
Response	The committee believed there is a need for this section, because this section applies to the work papers of the actuary and not the disclosure that goes along with a work product. In addition, some items that should be documented need not be disclosed.
Comment	Numerous commentators suggested changes to section (b).
Response	The committee agreed with these commentators and reworded section (b) with consequential changes to section (a).
SECTION 4. COMMUNICATIONS AND DISCLOSURES	
Section 4.1. Disclosure	
Comment	One commentator suggested that the standard does not appear to require disclosure of the actuary's unresolved concerns, particularly in the case of an actuarial opinion, regarding data that could have a material effect on the actuarial work product.
Response	Section (g) (now (f)) requires the actuary to disclose any unresolved concerns the actuary may have about the data. That disclosure is required in an appropriate actuarial communication, regardless of whether it is an actuarial opinion.
Comment	One commentator suggested adding the words "to the principal" after "following items" to clarify to whom the disclosure is to be made and also wanted to add the words "if other than the principal" to item (a).
Response	The committee did not concur with this commentator.
Comment	Several commentators believed that section (b) was unclear or unnecessary.
Response	The committee deleted section (b).
Comment	One commentator suggested changing the wording in section (c) (now (b)) to reflect the fact that the standard seems to mandate that actuaries almost always review data. Another commentator believed that section (c) (now (b)) should read, "the extent of the actuary's review of the data" rather than "whether the actuary reviewed the data."
Response	The committee very carefully considered this issue and revised what is now section (b) to require, where no review was performed, disclosure of any resulting limitations on the use of the actuarial work product.
Comment	Two commentators suggested adding "material" before "judgmental adjustments" in section (e) (now section (d)).
Response	The committee agreed and made this change.

ASOP No. 23—December 2004

Comment	One commentator believed that section (f) (now (e)) would be clearer if it ended after the phrase “work product.”
Response	The committee revised the language to omit reference to “not sufficiently reviewed,” thereby including situations where the actuary did not review the data as well as situations where the actuary did review the data but is uncertain about the data.
Comment	One commentator believed that section (g) (now (f)) was unnecessary because it was covered by section (h) (now (g)). The commentator believed it was burdensome for the actuary to disclose concerns that would not have a material effect.
Response	The committee disagreed and believed that both sections are needed to fully describe required disclosure because they cover different situations. However, the committee did agree that only “unresolved concerns the actuary may have about the data that could have a material effect...” are required to be disclosed, and the wording of these two sections incorporates the word “material” to support this.
Comment	One commentator believed that section (g) (now (f)) could conflict with section 3.7, which does not contain an option for producing a work product with adequate disclosure if there is a material effect in the data.
Response	The committee did not believe there was a conflict, but revised section 3.7(c) to clarify that the actuary may produce a work product even if the data (after judgmental adjustments or assumptions have been applied) may produce results that “are highly uncertain or contain a material bias” as long as this is disclosed.
APPENDIX (now Appendix 1)	
Current Practices	
Comment	One commentator suggested inserting the words “important aspects of data utilization include such” in the last paragraph of this section as well as deleting the words “of such items” after the word “disclosure” in this same section. The commentator also suggested deleting the word “the” after “reliance on” and deleting the words “are important aspects of utilization of data” in the last paragraph of this section.
Response	The committee agreed with the general thrust of these comments and made appropriate changes.
Comment	One commentator suggested removing the words “complete and independent verification of the data” in the second paragraph of this section. The commentator went on to suggest that actuaries deal with the quality of data in a variety of ways and “with varying levels of review or checking.”
Response	The committee agreed with this commentator and changed the wording as suggested.

18. Assignment 5, Module 1: ASOP 38: https://www.actuarialstandardsboard.org/wp-content/uploads/2014/02/asop038_155.pdf



ACTUARIAL STANDARDS BOARD

**Actuarial Standard
of Practice
No. 38**

**Using Models Outside the Actuary's Area of Expertise
(Property and Casualty)**

**Developed by the
Task Force on Complex Models of the
Casualty Committee of the
Actuarial Standards Board**

**Adopted by the
Actuarial Standards Board
June 2000**

Updated for Deviation Language Effective May 1, 2011

(Doc. No. 155)

ASOP No. 38—June 2000

TABLE OF CONTENTS

Transmittal Memorandum	iv
------------------------	----

STANDARD OF PRACTICE

Section 1. Purpose, Scope, Cross References, and Effective Date	1
1.1 Purpose	1
1.2 Scope	1
1.3 Cross References	1
1.4 Effective Date	1
Section 2. Definitions	2
2.1 Expert	2
2.2 Model	2
Section 3. Analysis of Issues and Recommended Practices	2
3.1 Introduction	2
3.2 Appropriate Reliance on Experts	2
3.3 Understanding of the Model	3
3.3.1 Model Components	3
3.3.2 User Input	3
3.3.3 Model Output	3
3.4 Appropriateness of the Model for the Intended Application	3
3.5 Appropriate Validation	4
3.5.1 User Input	4
3.5.2 Model Output	4
3.6 Appropriate Use of the Model	4
3.7 Reliance on Model Evaluation by Another Actuary	4
Section 4. Communications and Disclosures	5
4.1 Documentation	5
4.2 Proprietary Information	5
4.3 Disclosures	5

APPENDIXES

Appendix 1—Background and Current Practices	6
Background	6
Current Practices	7
Appendix 2—Comments on the Second Exposure Draft and Task Force Responses	8

ASOP No. 38—June 2000

June 2000

TO: Members of Actuarial Organizations Governed by the Standards of Practice of the Actuarial Standards Board and Other Persons Interested in the Use of Models Outside the Actuary's Area of Expertise in Property and Casualty Insurance

FROM: Actuarial Standards Board (ASB)

SUBJ: Actuarial Standard of Practice (ASOP) No. 38.

This booklet contains the final version of ASOP No. 38, *Using Models Outside the Actuary's Area of Expertise (Property and Casualty)*.

Background

The Casualty Practice Council of the American Academy of Actuaries requested that the ASB consider drafting an actuarial standard of practice concerning the use of complex models. In submitting to the ASB its proposal for a new ASOP, the council expressed concern over the use of catastrophe models when estimating catastrophe costs. Catastrophe models are developed by groups of scientists, engineers, and actuaries working together to simulate catastrophic events. While most actuaries conceptually agree that catastrophe models may provide more realistic measures of catastrophic risk than those provided by analyzing the latest twenty to fifty years of catastrophe losses, most actuaries are not experts in many of the underpinnings of these models.

Of course, catastrophe models are not the only models with which actuaries work. Actuaries also may utilize interest rate models, investment return models, credit scoring models, asbestos and pollution models, and dynamic financial analysis models, to name a few. The standard would not apply to models that incorporate specialized knowledge within the actuary's own area of expertise, since working with these components is part of the normal actuarial effort and is covered by other ASOPs.

In order to feel comfortable with relying on models that incorporate specialized knowledge outside the actuary's area of expertise, actuaries seek guidance in defining their *duty of care* in understanding and relying upon these models. This was another reason for the development of the standard, and why the ASB created the Task Force on Complex Models, under its Casualty Committee, to initiate the project.

The task force intended that the standard should define the guidelines that an actuary should follow when working with models outside of the actuary's own area of expertise. In providing such guidance, the standard makes it clear that an actuary may rely upon a model evaluation by another actuary who has performed his or her evaluation in accordance with this standard, and

ASOP No. 38—June 2000

that the standard is not intended to discourage the use of new methodologies in advancement of the profession.

First Exposure Draft

The first draft of a proposed standard, titled *The Use of Models with Nonactuarial Components*, was exposed for review in a document dated May 1998. As originally proposed in this first exposure draft, the standard would have applied to models in all areas of actuarial practice. In response to the fifty-two comment letters and forty-two comment postcards received, the scope of the standard was narrowed to apply only to property and casualty practice. In addition, the standard was refocused to apply to models that incorporate specialized knowledge outside the actuary's own area of expertise. Each actuary must determine what this boundary means to him or her. The title of the standard was changed accordingly. The significant issues and questions contained in the comment letters on the first exposure draft as well as the task force's responses to them are summarized in appendix 2 of the second exposure draft titled *Using Models Outside the Actuary's Area of Expertise (Property and Casualty)* dated September 1999.

Second Exposure Draft

The second draft of the standard was exposed for review in a document dated September 1999, with a comment deadline of March 1, 2000. Ten comment letters were received. The task force considered the issues and questions raised in these letters and made some editorial changes to the text, but no substantive changes were necessary. For a summary of the issues contained in these ten comment letters and the task force's responses, please see appendix 2.

The Task Force on Complex Models and the Casualty Committee thank everyone who took the time to contribute comments and suggestions on both exposure drafts.

The Casualty Committee would like to thank Godfrey Perrott and Kurt Reichle for their assistance in the initial drafting of this standard.

The ASB voted in June 2000 to adopt this standard.

ASOP No. 38—June 2000

Task Force on Complex Models of the Casualty Committee

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ASOP No. 38—June 2000

ACTUARIAL STANDARD OF PRACTICE NO. 38

**USING MODELS OUTSIDE THE ACTUARY'S AREA OF EXPERTISE
(PROPERTY AND CASUALTY)**

STANDARD OF PRACTICE

Section 1. Purpose, Scope, Cross References, and Effective Date

- 1.1 **Purpose**—The purpose of this standard is to provide guidance to the actuary in using models that incorporate specialized knowledge outside of the actuary's own area of expertise when developing an actuarial work product. This guidance addresses the actuary's obligation to review the model and make appropriate disclosures.
- 1.2 **Scope**—This standard applies to actuaries who use models that incorporate specialized knowledge outside of the actuary's own area of expertise when performing professional services in connection with property and casualty insurance coverages (including risk financing systems, such as self-insurance and securitization products, that provide similar coverages). This standard applies to the use of all models whether or not they are proprietary in nature.

If the actuary departs from the guidance set forth in this standard in order to comply with applicable law (statutes, regulations, and other legally binding authority), or for any other reason the actuary deems appropriate, the actuary should refer to section 4.
- 1.3 **Cross References**—When this standard refers to the provisions of other documents, the reference includes the referenced documents as they may be amended or restated in the future, and any successor to them, by whatever name called. If any amended or restated document differs materially from the originally referenced document, the actuary should consider the guidance in this standard to the extent it is applicable and appropriate.
- 1.4 **Effective Date**—This standard will be effective for work performed on or after December 15, 2000.

ASOP No. 38—June 2000

Section 2. Definitions

The terms below are defined for use in this actuarial standard of practice.

- 2.1 Expert—One who is qualified by knowledge, skill, experience, training, or education to render an opinion concerning the matter at hand.
- 2.2 Model—An information structure, such as a set of mathematical equations, logic, or algorithms, that is used to represent the behavior of specified phenomena.

Section 3. Analysis of Issues and Recommended Practices

- 3.1 Introduction—In performing actuarial work, an actuary may find it appropriate to use models that incorporate specialized knowledge outside of the actuary's own area of expertise. When using such a model, the actuary should do all of the following:
 - a. determine appropriate reliance on experts;
 - b. have a basic understanding of the model;
 - c. evaluate whether the model is appropriate for the intended application;
 - d. determine that appropriate validation has occurred; and
 - e. determine the appropriate use of the model.

The actuary's level of effort in understanding and evaluating a model should be consistent with the intended use of the model and its materiality to the results of the actuarial analysis.

- 3.2 Appropriate Reliance on Experts—An actuary may rely on experts concerning those aspects of a model that are outside of the actuary's own area of expertise. The experts relied upon may either be the experts who provided the model or other experts. In determining the appropriate level of reliance, the actuary should consider the following:
 - a. whether the individual or individuals upon whom the actuary is relying are experts in the applicable field;
 - b. the extent to which the model has been reviewed or opined on by experts in the applicable field, including any known significant differences of opinion among experts concerning aspects of the model that could be material to the actuary's use of the model; and

ASOP No. 38—June 2000

- c. whether there are standards that apply to the model or to the testing or validation of the model, and whether the model has been certified as having met such standards.
- 3.3 **Understanding of the Model**—The actuary should be reasonably familiar with the basic components of the model and understand both the user input and the model output, as discussed below.
- 3.3.1 **Model Components**—The actuary should be reasonably familiar with the basic components of the model and have a basic understanding of how such components interrelate within the model. In addition, the actuary should identify which fields of expertise were used in developing or updating the model, and should make a reasonable effort to determine if the model is based on generally accepted practices within the applicable fields of expertise. The actuary should also be reasonably familiar with how the model was tested or validated and the level of independent expert review and testing.
 - 3.3.2 **User Input**—Certain user input may be required to produce model output for the specific application. The actuary should understand the user input that is required to produce the model output. This understanding includes the level of detail required in the user input to produce results that are consistent with the intended use of the model.
 - 3.3.3 **Model Output**—The actuary should determine that the model output is consistent with the actuary’s intended use of the model.
- 3.4 **Appropriateness of the Model for the Intended Application**—The actuary should evaluate whether the model is appropriate for the particular actuarial analysis, and consider limitations of the model, modifications to the model, and the assumptions needed in order to apply the model output.

Some additional considerations include the following:

- a. **Applicability of Historical Data**—To the extent historical data are used in the development of the model or the establishment of model parameters, the actuary should consider the adequacy of the historical data in representing the range of reasonably expected outcomes consistent with current knowledge about the phenomena being analyzed.
- b. **Developments in Relevant Fields**—The actuary should make a reasonable effort to be aware of significant developments in relevant fields of expertise. The

ASOP No. 38—June 2000

actuary should evaluate whether such developments are likely to materially affect the current actuarial analysis.

- 3.5 Appropriate Validation—The actuary should evaluate the user input and the reasonableness of the model output, as discussed below.
- 3.5.1 User Input—With respect to the quality and availability of the user input data to be used in the model, the actuary should refer to ASOP No. 23, *Data Quality*.
- 3.5.2 Model Output—In view of the intended use of the model, the actuary should examine the model output for reasonableness, considering factors such as the following:
- a. the results derived from alternate models or methods, where available and appropriate;
 - b. how historical observations, if applicable, compare to results produced by the model;
 - c. the consistency and reasonableness of relationships among various output results; and
 - d. the sensitivity of the model output to variations in the user input and model assumptions.
- 3.6 Appropriate Use of the Model—Having completed the analysis described in sections 3.2–3.5 above, the actuary should use his or her professional judgment to determine whether it is appropriate to use the model results, subject to any appropriate adjustments. The actuary should disclose any such adjustments in accordance with section 4.3.
- 3.7 Reliance on Model Evaluation by Another Actuary—The actuary may rely on another actuary who has, for a particular model, conducted some or all of the evaluations and processes described in this standard. However, the relying actuary should be satisfied that the other actuary’s evaluation was performed in accordance with this standard and is appropriate for the intended application. The actuary should document the extent of such reliance in accordance with section 4.1.

ASOP No. 38—June 2000

Section 4. Communications and Disclosures

- 4.1 **Documentation**—This standard requires documentation whether or not a legal or regulatory requirement exists. The actuary should maintain appropriate documentation on the evaluation of the model and the use of the model output in the analysis. Documentation should demonstrate how the actuary has met the requirements of sections 3.2–3.7 above.
- 4.2 **Proprietary Information**—If the model has proprietary aspects or contains proprietary information, the actuary should document the steps taken to comply with this standard in light of the proprietary aspects or information.
- 4.3 **Disclosures**—In communicating the results of actuarial work using a model that incorporates specialized knowledge outside of the actuary’s own area of expertise, the actuary should disclose the model(s) used and any adjustments made to the model results as described in section 3.6.

In addition, the actuary should include the following, as applicable, in an actuarial communication:

- a. the disclosure in ASOP No. 41, *Actuarial Communications*, section 4.2, if any material assumption or method was prescribed by applicable law (statutes, regulations, and other legally binding authority);
- b. the disclosure in ASOP No. 41, section 4.3, if the actuary states reliance on other sources and thereby disclaims responsibility for any material assumption or method selected by a party other than the actuary; and
- c. the disclosure in ASOP No. 41, section 4.4, if, in the actuary’s professional judgment, the actuary has otherwise deviated materially from the guidance of this ASOP.

ASOP No. 38—June 2000

Appendix 1

Background and Current Practices

Note: This appendix is provided for informational purposes, but is not part of the standard of practice.

Background

Actuaries have always used models. Most of the models used by actuaries are developed using expertise that is common to actuaries, and their use by actuaries is addressed by existing standards of practice and statements of principles.

However, actuaries have also used models that contain components that are outside the actuary's own area of expertise. For example, certain catastrophe models, interest rate models, dynamic financial analysis models, credit scoring models, and pollution models contain components that are outside the expertise of many of the actuaries who use them. Although in retrospect the use of models may have posed the need for a specific standard of practice, it was not until recently, as actuaries grappled with the financial issues surrounding various natural catastrophes, that the need for such a standard was recognized and acted on by the Actuarial Standards Board.

Specifically, Hurricane Andrew in 1992 and the Northridge Earthquake in 1994 led actuaries involved in evaluating hurricane and earthquake exposures to recognize the severe inadequacy of the traditional, empirical actuarial methods used for ratemaking for these exposures. In recognition of the need to replace these methods, many actuaries began using stochastic computer simulation models for their actuarial analysis of hurricane and earthquake exposure. Computer simulation models had been commonly used for some time by actuaries and others for the purpose of evaluating probable maximum loss but had not been widely used for ratemaking.

Computer simulation models are now widely used by actuaries for calculating expected losses due to hurricane and earthquake perils. The accuracy of these models is heavily dependent on the accuracy of meteorological, seismological, or engineering assumptions, areas clearly outside the expertise of most actuaries.

Because models sometimes contain components that incorporate specialized knowledge outside the actuary's own area of expertise, this raises the question as to what is required of an actuary before he or she makes use of model output in his or her actuarial analysis. This standard addresses such requirements. Although the development of this standard originated with the problem of providing accurate actuarial analysis of hurricane and earthquake exposure, the standard applies to *any model*

ASOP No. 38—June 2000

that incorporates specialized knowledge outside the actuary's own area of expertise used in connection with property and casualty insurance coverages.

Current Practices

The use of output from models is an evolving area of actuarial theory and practice. To date, current practices have been governed by the former *Guides and Interpretative Opinions as to Professional Conduct*, and their successor documents, the Code of Professional Conduct and the *Qualification Standards for Prescribed Statements of Actuarial Opinion*. Practices have varied according to individual interpretations of the *Guides* and the Code.

ASOP No. 38—June 2000

Appendix 2

Comments on the Second Exposure Draft and Task Force Responses

The second exposure draft of this actuarial standard of practice (ASOP) was exposed for review in September 1999, with a comment deadline of March 1, 2000. Ten letters of comment were received on the second exposure draft. Summarized below are the significant issues and questions contained in the comment letters, printed in roman type. The task force's responses appear in **boldface**.

General Observations

Two basic concerns were raised as general observations. One commentator believed the phrase "outside an actuary's area of expertise" was not clear enough to define when the standard applies and when it doesn't. An actuary has some training in econometric techniques but may not be familiar with state of the art methods and protocols. Are econometric models outside the actuary's area of expertise or not? Does the standard apply?

The task force believes this example clearly shows the need for this standard. Actuaries performing professional services must determine if they are qualified to practice in that area. As such, they are making a determination of their area of expertise and if using models should then determine if this standard applies. Since the situation will differ for every individual actuary, the task force believes the ASOP can not be made more specific and no changes were made.

The other commentator making a general observation questioned if the ASOP applies when "commercial models" such as @Risk, BestFit, and Evolver are used. The commentator asked "is it not enough to know that these are commercially available products...and have general acceptance as tools...without contacting the vendor to ask questions about the fields of expertise used to develop these models?"

This standard applies when using any model outside the actuary's area of expertise. The extent of the effort applied will be dependent on the individual circumstances and application of each model. The task force does not believe an unreasonable effort is required on the part of the actuary to apply this standard to the use of "commercial models." In fact, the task force believes that in most cases, the actuary is probably already complying with the standard with perhaps the exception of the documentation requirement.

ASOP No. 38—June 2000

Section 1. Purpose, Scope, Cross References, and Effective Date

Section 1.2, Scope—Some commentators questioned the application of the standard to health companies and some forms of health coverages. They implied the standard should define property and casualty. **The ASOP does not apply to companies but rather to actuaries “performing professional services in connection with property and casualty insurance coverages.” The task force does not believe a definition of property and casualty is possible since it is not static and will tend to change over time. Actuaries will have to determine if the work they are doing is “in connection with property and casualty insurance coverages.”**

One commentator questioned the intent of the phrase “if a conflict exists between this standard and applicable law.” If a regulator requires something that is not either a regulation or a law, does this fall under section 4.5, Deviation from Standard [clause] or is it exempt because of the conflict clause? **The task force believes this depends on the individual circumstances of the situation and made no changes to the text.**

Section 3. Analysis of Issues and Recommended Practices

Section 3.1, Introduction—One commentator believed the use of the word “basic” in section 3.1(b) sets too high of a standard and suggested replacing it with “general.” **The task force discussed this issue and determined that the requirement to have a basic understanding of the model is appropriate. No change was made.**

Section 3.2, Appropriate Reliance on Experts—Some commentators were concerned with this section. One believed it was confusing and did not provide the actuary with sufficient guidance, others believed it was unreasonable to expect the actuary to know “the extent to which significant differences of opinion exist among experts....” **The task force reviewed the suggested changes from these commentators and made two changes to this section. A sentence was added to clarify that “experts relied upon may either be the experts who provided the model or other experts.” Secondly, the reference to “differences of opinion among experts” was deleted as a separate item and included with section 3.2 (b), “the extent to which the model has been reviewed or opined on by experts in the applicable field.”**

Section 3.3, Understanding of the Model—Some commentators believed the requirement in section 3.3.1, Model Components, stating “The actuary should be aware of the extent to which the model is based on contested or new theory” is unnecessary. They believed it was duplicative since the actuary is required in section 3.2(b) to consider “whether the model has been reviewed or opined on by expert....” and consider “the extent to which significant differences of opinion

ASOP No. 38—June 2000

exist.” **The task force agrees that the language in section 3.2 provides sufficient guidance and deleted the sentence**

from section 3.3.1 that read, “The actuary should be aware of the extent to which the model is based on contested or new theory.”

Section 3.4, Appropriateness of the Model for the Intended Application—In section 3.4(b), a few commentators believed it was unreasonable to expect the actuary to “[make a reasonable effort to] be aware of significant developments in relevant fields of expertise.” **The task force disagrees with this concern and made no changes to the text.**

Section 3.5, Appropriate Validation—Section 3.5.2, Model Output, provides a list of items to consider when checking the model output for reasonableness. One commentator believed the list was not necessary as it implies that the actuary must perform all checks on the list. **The task force believes the list of examples provides valuable guidance with regard to the intent of the statement. The task force modified the introductory language to clarify that the list of examples is illustrative. The actuary, however, is not relieved from the duty to check for reasonableness.**

In section 3.5.2(d), one commentator expressed concern that considering “the sensitivity of the model output to variations in the assumptions” was too broad of a requirement. **The task force revised the section to narrow the scope of the sensitivity consideration to “variations in the user input and model assumptions.”**

Section 4. Communications and Disclosures

Section 4.1, Documentation—One commentator was confused by the intent of the documentation requirement. **The task force clarified that the “documentation should demonstrate how the actuary met the requirements of sections 3.2–3.7.”**

Section 4.2, Proprietary Information—One commentator offered alternative language for this section to clarify the intent. **The task force shortened the wording without changing the intent or meaning of the section.**

Section 4.3, Disclosure—**To clarify the disclosure requirement, wording was added to this section specifying that the actuary should disclose the model(s) used and any adjustments made to the model results as described in section 3.6.**

19. Assignment 5, Module 1: ASOP 39: https://actuarialstandardsboard.org/wp-content/uploads/2014/07/asop039_072.pdf



ACTUARIAL STANDARDS BOARD

**Actuarial Standard
of Practice
No. 39**

**Treatment of Catastrophe Losses in
Property/Casualty Insurance Ratemaking**

**Developed by the
Subcommittee on Ratemaking of the
Casualty Committee of the
Actuarial Standards Board**

**Adopted by the
Actuarial Standards Board
June 2000**

(Doc. No. 072)

ASOP No. 39—June 2000

TABLE OF CONTENTS

Transmittal Memorandum	iii
------------------------	-----

STANDARD OF PRACTICE

Section 1. Purpose, Scope, Cross References, and Effective Date	1
1.1 Purpose	1
1.2 Scope	1
1.3 Cross References	1
1.4 Effective Date	1
Section 2. Definitions	2
2.1 Catastrophe	2
2.2 Catastrophe Ratemaking Procedures	2
2.3 Contagion	2
2.4 Demand Surge	2
Section 3. Analysis of Issues and Recommended Practices	2
3.1 Identification of Catastrophe Perils or Events	2
3.2 Identification of Catastrophe Losses	2
3.3 The Use of Data in Determining a Provision for Catastrophe Losses	3
3.3.1 Use of Historical Insurance Data	3
3.3.2 Use of Noninsurance Data and Models	4
3.4 Using a Provision for Catastrophe Losses	5
3.5 Loss Adjustment Expenses	5
Section 4. Communications and Disclosures	5
4.1 Conflict with Law or Regulation mentation and Disclosure	5
4.2 Documentation and Disclosure	5
4.3 Prescribed Statement of Actuarial Opinion	6
4.4 Deviation from Standard	6

APPENDIXES

Appendix 1—Background and Current Practices	7
Background	7
Current Practices	8
Appendix 2—Comments on the 1999 Exposure Draft and Subcommittee Responses	10

ASOP No. 39—June 2000

June 2000

TO: Members of Actuarial Organizations Governed by the Standards of Practice of the Actuarial Standards Board and Other Persons Interested in the Treatment of Catastrophe Losses in Property/Casualty Insurance Ratemaking

FROM: Actuarial Standards Board (ASB)

SUBJ: Actuarial Standard of Practice (ASOP) No. 39

This booklet contains the final version of Actuarial Standard of Practice No. 39, *Treatment of Catastrophe Losses in Property/Casualty Insurance Ratemaking*.

Background

Many property/casualty insurance products are, by their nature, subject to large aggregate losses resulting from relatively infrequent events or natural phenomena, i.e., from catastrophes. These losses can cause extreme volatility in historical insurance data and generally require separate and different treatment from other losses in ratemaking methodologies. Historically, the most common method was to calculate the ratio of actual catastrophe losses to noncatastrophe losses over a longer experience period, and apply that ratio to expected noncatastrophe losses in the ratemaking formula.

In 1992 and 1994, two events occurred that changed the actuarial profession's view of catastrophe losses. The Hurricane Andrew and Northridge Earthquake catastrophes clearly demonstrated the limitations of relying exclusively on historical insurance data in estimating the financial impact of potential future events. In addition, property/casualty insurers (including self-insurers) and their actuaries began to focus on the impact that large individual events or sequences of events could have on the insurers' solvency, cash flow, and earnings.

This actuarial standard of practice is intended to provide guidance to actuaries in evaluating catastrophe exposure and in determining a provision for catastrophe losses and loss adjustment expenses in property/casualty insurance ratemaking.

Exposure Draft

This standard was exposed for review in February 1999, with a comment deadline of June 15, 1999. Fourteen comment letters were received. The Subcommittee on Ratemaking reviewed all the comments carefully, and many of the suggestions were incorporated in the final standard. In particular, the subcommittee did the following: (1) revised the title and the scope of the standard to more explicitly recognize that the standard applied to ratemaking; (2) revised the text to

ASOP No. 39—June 2000

indicate that the actuary was estimating a catastrophe provision not estimating actual catastrophe losses; and (3) more explicitly recognized that, in the end, the procedure that the actuary uses must reflect the expected frequency and severity distribution of catastrophes, as well as the anticipated class, coverage, geographic and other relevant exposure distributions. For a summary of the substantive issues contained in these fourteen comment letters and the task force's responses, please see appendix 2.

The subcommittee and Casualty Committee thank all those who commented on the exposure draft.

The subcommittee also thanks former member Robert W. Gossrow for his contributions during the development of this proposed ASOP.

The ASB voted in June 2000 to adopt this standard.

Subcommittee on Ratemaking of the Casualty Committee

Patrick B. Woods, Chairperson

Mark S. Allaben	R. Michael Lamb
Charles H. Boucek	Marc B. Pearl
Frederick F. Cripe	Jonathan White
Gregory L. Hayward	Paul E. Wulterkens

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ASOP No. 39—June 2000

ACTUARIAL STANDARD OF PRACTICE NO. 39

**TREATMENT OF CATASTROPHE LOSSES IN
PROPERTY/CASUALTY INSURANCE RATEMAKING**

STANDARD OF PRACTICE

Section 1. Purpose, Scope, Cross References, and Effective Date

1.1 Purpose—The *Statement of Principles Regarding Property and Casualty Insurance Ratemaking* of the Casualty Actuarial Society states that consideration should be given to the impact of catastrophes and that procedures should be developed to include an allowance for catastrophe exposure in the rate. The purpose of this actuarial standard of practice (ASOP) is to provide guidance to actuaries in evaluating catastrophe exposure and in determining a provision for catastrophe losses and loss adjustment expenses in property/casualty insurance ratemaking.

1.2 Scope—This standard provides guidance to actuaries when performing professional services in connection with ratemaking for property/casualty insurance coverages including property/casualty risk financing systems, such as self-insurance or securitization products, which provide similar coverage.

If a conflict exists between this standard and applicable law or regulation, the actuary should comply with the requirements of the law or regulation and make the disclosures specified in section 4.1 of this ASOP. Compliance with applicable law or regulation is not considered to be a deviation from this standard.

1.3 Cross References—When this standard refers to the provisions of other documents, the reference includes the referenced document as it may be amended or restated in the future, and any successor to it, by whatever name called. If the amended or restated document differs materially from the originally referenced document, the actuary should consider the guidance in this standard to the extent it is applicable and appropriate.

1.4 Effective Date—This standard will be effective for work performed on or after December 15, 2000.

ASOP No. 39—June 2000

Section 2. Definitions

The definitions below are defined for use in this actuarial standard of practice.

- 2.1 Catastrophe—A relatively infrequent event or phenomenon that produces unusually large aggregate losses.
- 2.2 Catastrophe Ratemaking Procedures—Ratemaking procedures that adjust for the impact of catastrophe losses in the experience data and determine a provision for catastrophe losses and loss adjustment expenses.
- 2.3 Contagion—A lack of independence between the occurrence of losses among different entities.
- 2.4 Demand Surge—A sudden and usually temporary increase in the cost of materials, services, and labor due to the increased demand for them following a catastrophe.

Section 3. Analysis of Issues and Recommended Practices

In evaluating catastrophe exposure and in determining a provision for catastrophe losses and loss adjustment expenses in property/casualty insurance ratemaking, the actuary should be guided by the following sections.

- 3.1 Identification of Catastrophe Perils or Events—The actuary should take reasonable steps to identify the perils or events that have the potential to generate catastrophe losses that differ materially from the expected aggregate losses or the expected distribution of losses. These perils or events have at least one of the following characteristics:
 - a. The Potential to Display Contagion—Examples of perils that display contagion include windstorms, earth movement, and freezing.
 - b. Infrequent Occurrence—Some events that occur infrequently have the potential to produce losses that can significantly distort the historical experience. An example of such an event is an explosion that results in the release of toxic material. If the experience data contain such events, using this experience data without adjustment may overstate the catastrophe provision in the rates. If the experience data do not contain such events, using this experience data without adjustment may understate the catastrophe provision in the rates.
- 3.2 Identification of Catastrophe Losses—The actuary should identify, where practicable, the catastrophe losses in the historical insurance data. In doing so, the actuary should consider how accurately the catastrophe losses can be identified, and the extent to which they may have a material impact on the results of the analysis.

ASOP No. 39—June 2000

- 3.3 The Use of Data in Determining a Provision for Catastrophe Losses—The actuary may use historical insurance data and noninsurance data, as described in sections 3.3.1 and 3.3.2 below.
- 3.3.1 Use of Historical Insurance Data—The actuary should consider the following when using data available from insurance sources:
- a. Evaluating Historical Insurance Data—The actuary should consider comparing historical insurance data to noninsurance data to determine the extent to which the available historical insurance data are fully representative of the long-term frequency and severity of the perils or events identified in section 3.1 that produced the catastrophe losses. Thus, in determining a provision for catastrophe losses, the actuary should consider the sensitivity of the provision to changes in the historical insurance data relating to the following: (1) the frequency of catastrophes; (2) the severity of catastrophes; and (3) the geographic location of catastrophes.
 - b. The Applicability of Historical Insurance Data—The actuary should consider the applicability of historical insurance data for the insured coverage. This includes determining (1) whether catastrophe losses are likely to differ significantly among elements of the rate structure, such as construction type and location; (2) whether such differences should be reflected in the ratemaking procedures; and (3) how to reflect such differences, taking into account both homogeneity and the volume of data. In addition, the actuary should consider whether there is a sufficient number of years of comparable, compatible historical insurance data.
 - c. Adjustments to Historical Insurance Data to Reflect Future Conditions—The actuary should consider making adjustments to the historical insurance data to reflect conditions likely to prevail during the period in which the rate will be in effect. Such adjustments should take into account the impact of changes in the exposure to loss, including coverage differences, the underlying portfolio of insured risks, building codes and the enforcement of these codes, and building practices; population shifts; costs; and demand surge during both the historical period and the period for which the rate will be in effect. These considerations become more important when a longer experience period is used because they can have a greater effect over longer time periods.
 - d. Stability of Outcomes Based on Historical Insurance Data—The actuary should consider the extent to which the provision for catastrophe losses would change if the catastrophe ratemaking procedure were to be carried out using different historical experience periods. If, in the actuary's judgment, the procedure is too sensitive to the inclusion or exclusion of an

ASOP No. 39—June 2000

individual catastrophe or sets of years, the actuary should consider modifying the procedure to reduce the sensitivity.

- e. **Differing Trends in Loss Data**—Historical insurance data used to determine a provision for catastrophe losses will often extend over much longer time periods than data used in most other ratemaking procedures; thus, the effect of small differences in annual trend rates will be magnified. The actuary should consider the potential for catastrophe losses to trend at a rate materially different than the noncatastrophe losses and reflect such differences in the ratemaking process as appropriate.
- f. **Consistent Definition of a Catastrophe**—In utilizing a catastrophe ratemaking procedure, the actuary often uses two sets of historical insurance data. The first set may be comprised of data from the ratemaking experience period from which the catastrophe losses have been removed. The second set may contain longer term experience for catastrophe losses. Collecting a greater volume of data for this second data set may be accomplished in various ways, such as by using a greater number of relevant years or by using relevant data for a broader segment of business.

The actuary should consider the catastrophe definition pertaining to, and the catastrophe potential in, both of these data sets to ensure that the definitions are not materially inconsistent. Specific areas to consider are consistency of the thresholds used to determine catastrophe losses and consistency in identifying specific catastrophes.

3.3.2 **Use of Noninsurance Data and Models**—If, after considering the items contained in section 3.3.1(a–f), the actuary believes that the available historical insurance data do not sufficiently represent the exposure to catastrophe losses, the actuary should consider doing one of the following:

- 1. use noninsurance data to adjust the historical insurance data;
- 2. use noninsurance data (including models based thereon) as input to ratemaking procedures; or
- 3. use models based on a combination of historical insurance data and noninsurance data.

The actuary should be satisfied that the resulting ratemaking procedures appropriately reflect the expected frequency and severity distribution of catastrophes, as well as anticipated class, coverage, geographic, and other relevant exposure distributions.

ASOP No. 39—June 2000

- 3.4 Using a Provision for Catastrophe Losses—In ratemaking, actuaries generally use historical data or modeled losses to form the basis for determining future cost estimates. The presence or absence of catastrophes in any historical data used to form future cost estimates can create biases that diminish the appropriateness of using that data as the basis for future cost estimates. The actuary should address such biases by adjusting the historical data used to form future cost estimates and determining a provision for catastrophe losses (after consideration of the issues and practices found in sections 3.1–3.3).

The actuary may employ other considerations and methods to adjust for catastrophes associated with casualty coverages. For example, such adjustments may include limiting losses in the underlying data and using increased limits factors or excess loss factors based on industry data or other sources, or adjusting for legislative changes, legal decisions, changes in the distribution of policy limits, and coverage provisions. In addition, other adjustments, such as supplementing state-specific data with countrywide data or company-specific data with industry information, may be appropriate.

- 3.5 Loss Adjustment Expenses—The actuary should be aware that the relationship of loss adjustment expense to incurred loss can be significantly different for catastrophe losses and for noncatastrophe losses. In some cases, the historical relationships of overall loss adjustment expense to overall incurred losses may produce inappropriate loss adjustment expense estimates for catastrophe losses. Similarly, the historical relationship of overall loss adjustment expense to overall incurred losses may produce inappropriate loss adjustment expense estimates for noncatastrophe losses if the historical period was impacted by catastrophe losses. The actuary should modify the loss adjustment expense procedure where necessary to develop a reasonable estimate of prospective loss adjustment expense for both catastrophe and non-catastrophe losses.

Section 4. Communications and Disclosures

- 4.1 Conflict with Law or Regulation—If a law or regulation conflicts with the provisions of this standard, the actuary should develop a rate in accordance with the law or regulation, and disclose any material difference between the rate so developed and the actuarially-determined rate to the client or employer.
- 4.2 Documentation and Disclosure—The actuary should be guided by the provisions of ASOP No. 9, *Documentation and Disclosure in Property and Casualty Insurance Ratemaking, Loss Reserving, and Valuations*. If the actuarial work product includes mathematical modeling developed by someone other than the actuary, the documentation should include the source of the model and how the model was used in the analysis. In addition, if the model is outside the actuary's area of expertise, the actuary should be guided by the documentation and disclosure requirements of ASOP No. 38, *Using Models Outside the Actuary's Area of Expertise*.

ASOP No. 39—June 2000

- 4.3 Prescribed Statement of Actuarial Opinion—This ASOP does not require a prescribed statement of actuarial opinion (PSAO) as described in the *Qualification Standards for Prescribed Statements of Actuarial Opinion* promulgated by the American Academy of Actuaries. However, law, regulation, or accounting requirements may also apply to an actuarial communication prepared under this standard, and as a result, such actuarial communication may be a PSAO.
- 4.4 Deviation from Standard—An actuary must be prepared to justify the use of any procedures that depart materially from those set forth in this standard and must include, in any actuarial communication disclosing the results of the procedures, an appropriate statement with respect to the nature, rationale, and effect of such departures.

ASOP No. 39—June 2000

Appendix 1

Background and Current Practices

Note: This appendix is provided for informational purposes, but is not part of the standard of practice.

Background

Historical Procedures—Prior to Hurricanes Hugo and Andrew, the predominant ratemaking procedures used to determine a catastrophe provision involved calculating the long-term ratio of such losses to noncatastrophe losses over a twenty- to thirty-year span. Catastrophes were identified either by some industry-dollar or loss-ratio threshold, and typically represented weather-related perils such as hurricanes, tornadoes, or snow storms. Other physical catastrophes such as floods and earthquakes were usually covered by separate policies designed to specifically include such perils. A provision for casualty-related catastrophes was typically not included separately in the rates, but was implicitly included with the contingency provision.

Issues—In the late 1980s and early 1990s, catastrophes produced record levels of damage, and it became evident that adjustments to historical ratemaking procedures were necessary. Hurricanes Hugo, Andrew, and Iniki produced aggregate losses exceeding previously expected possibilities. These huge losses brought to light other issues such as population shifts, non-adherence to building codes, and exposure concentration, none of which had been addressed previously. In addition, the occurrence of earthquakes in both San Francisco and Northridge, and a major flood in the Midwest during this period heightened the need for development of improved ratemaking procedures for these perils. Finally, catastrophes that had not been contemplated previously, such as the World Trade Center bombing and the Oakland Hills fires, raised other questions concerning how to provide for such losses in the rate.

In addressing these issues, catastrophe models, which previously were used by companies to determine their probable maximum loss under various scenarios, were adjusted for use in ratemaking. However, since these models were often multidisciplinary in nature or proprietary, it was often difficult to (1) ascertain the underlying assumptions of the model, and (2) obtain regulatory approval of rates based on these models.

Other issues have also emerged, making assessment of catastrophe exposure even more difficult. Examples of such issues include coverage changes, such as the greater use of guaranteed replacement cost on homeowner policies or the use of separate wind deductibles; the emergence of state-run catastrophe funds; and the availability of catastrophe options.

ASOP No. 39—June 2000

Current Practices

Subsequent to Hurricanes Hugo and Andrew, numerous enhancements and alternatives have been developed that improve on the traditional, long-term catastrophe ratemaking procedure.

One procedure uses the traditional excess wind approach but supplements or replaces the historical insurance data with hypothetical losses from an infrequent event (for example, a fifty-year event) as calculated by a catastrophe simulation model. Historical events of greater severity than the modeled fifty-year event are eliminated. Separate excess factors are calculated from the historical insurance data and for a hypothetical year constructed to include the modeled fifty-year event. The excess factor is calculated as a weighted average of those two separate factors.

A second procedure involves loading catastrophe reinsurance costs into the rate calculation. With this procedure, the rates are initially calculated using losses net of the catastrophe reinsurance. The company's overall catastrophe reinsurance costs are allocated to state and line, and those allocated costs are added to the calculated rate net of reinsurance.

A third procedure separates catastrophes into hurricane and nonhurricane components and treats each separately. This enables the actuary to focus on the particular difficulties, low frequency and high severity, in estimating hurricane losses. One specific procedure that is used for nonhurricane catastrophes is to relate catastrophe losses to amount of insurance years. A long-term ratio of catastrophe losses to amount of insurance years is calculated and used to load the ratemaking experience period for expected catastrophe losses. This procedure has also been used for hurricanes, using noninsurance data such as long-term hurricane frequencies to adjust the historical insurance data.

A fourth procedure that has been used for nonhurricane catastrophes is based on frequency. With this procedure, daily frequencies are calculated over a long period and each day is ranked using that frequency. A set percentage of days with the highest frequencies is considered excess. The losses incurred on those excess days are compared to the losses incurred on all other days in order to calculate an excess factor.

In considering earthquakes and hurricanes, the predominant approach currently used to calculate expected catastrophe losses is computer simulation models. These models make extensive use of noninsurance data to estimate the overall frequency of these events, as well as the frequency of the key defining characteristics of these events. Based on these estimated frequencies, a large number of catastrophes are simulated across a broad geographic area. For each simulated catastrophe, the model translates the event or phenomenon into a specific "hazard" parameter, such as wind speed or ground shaking, at all locations impacted by the event. Based on engineering analysis and prior catastrophe losses, the hazard parameter is translated into a damage ratio, i.e., ratio of losses to amount of insurance. These damage ratios are applied to the current or projected amounts of insurance and, when adjusted by the estimated frequencies of the specific catastrophes, produce the expected catastrophe losses.

Since our knowledge of catastrophes is not complete and is still evolving, computer simulation models are also evolving. The expected catastrophe losses calculated from these models can be

ASOP No. 39—June 2000

subject to significant variation, since different models (i.e., both models from different developers and different versions of models from the same developer) will obviously provide different answers.

All of these procedures may or may not be supplemented with a risk load calculated in accordance with ASOP No. 30, *Treatment of Profit and Contingency Provisions and the Cost of Capital in Property/Casualty Insurance Ratemaking*.

ASOP No. 39—June 2000

Appendix 2

Comments on the 1999 Exposure Draft and Subcommittee Responses

The exposure draft of this actuarial standard of practice (ASOP)—formerly titled *Treatment of Catastrophe Losses in Property/Casualty Insurance*—was issued in February 1999, with a comment deadline of June 15, 1999. Fourteen comment letters were received. The Subcommittee on Ratemaking carefully considered all comments received. Summarized below are the significant issues and questions contained in the comment letters, printed in roman type. The subcommittee's responses are printed in **boldface**.

General Comments

One commentator notes that, in the end, the definition of a catastrophe is driven by frequency. High frequency loss processes should produce credible estimates of future losses without adjustment. Low frequency events do not provide these estimates and adjustments are needed. **The subcommittee disagrees and believes that the most important facts are that the event or phenomenon not only should be relatively infrequent but should also produce unusually large aggregate losses.**

Two commentators suggested that the title of the standard should be *Treatment of Catastrophe Losses in Property/Casualty Insurance Ratemaking*. **The subcommittee agreed and changed the title.**

Two commentators believed that the standard too often specified what the actuary *should* do, suggesting the use of *may* as more appropriate. **The subcommittee disagrees, since the standard generally is specifying what the actuary needs to consider. The standard does not say the actuary needs to do something after the consideration if the item has no material impact on the results. In performing this work, the actuary needs to consider all items that may materially impact or bias the results.**

One commentator noted that the standard permits the actuary to rely on the work of nonactuaries without proper review and disclosure, particularly as it pertains to models developed by others. **The subcommittee disagrees that an actuary can rely on the work of a nonactuary without review and disclosure. The subcommittee prepared this standard fully aware of ASOP No. 38, *Using Models Outside the Actuary's Area of Expertise (Property and Casualty)*, which was being exposed concurrently.**

One commentator suggested that the definitions and explanations should be phrased more in statistical terms whenever possible. **The subcommittee believes that, given the wide variation in available methodologies, a statistically-based definition would too narrowly restrict current acceptable practices.**

ASOP No. 39—June 2000

Another commentator suggested that the term *procedures* should be replaced by *models*. **The subcommittee believes that *procedures* is appropriate, particularly since *models*, in this case, could be too narrowly read to mean computer models.**

One commentator stated that the standard does nothing to help an actuary who uses a computer model to develop estimated catastrophe losses and is challenged by individuals who refuse to accept the validity of these models. **The subcommittee disagrees. The standard provides the analytical steps that the actuary should follow in examining the available data. Based on the analysis, the actuary can determine and demonstrate to others whether the data need to be supplemented by additional data or, alternatively, whether models that consider various sources of data should be used.**

Transmittal Memorandum

The transmittal memorandum of the exposure draft asked readers to address several key questions. One question asked, “Is the application of the standard to casualty (i.e., nonproperty) insurance appropriate, and has the subject been addressed adequately?” One commentator stated that catastrophes should be limited to first party coverages, particularly since the considerations listed in 3.3.1 and 3.3.2 were property related in nature. The commentator also noted that the methodologies referenced were predominantly for property coverages. The commentator did suggest, that if the standard were to apply to casualty coverages, it would need to include considerations such as limiting losses to basic limits; using excess loss factors; adjusting for changes in limits, coverages, or reinsurance; and supplementing state data with countrywide data. **The subcommittee intends that the requirements of this ASOP should also apply to casualty catastrophe losses when such a catastrophe is identified. The subcommittee has included the suggested language for casualty catastrophes in section 3.4.**

The subcommittee also drew its readers’ attention to several provisions in particular: section 2.1, Catastrophe; section 3.1, Identification of Catastrophe Perils or Events; section 3.3.2, Use of Noninsurance Data; and section 4.1, Conflict with Law or Regulation. Please see those sections below for discussion of any pertinent readers’ comments and subcommittee responses.

Section 1. Purpose, Scope, and Effective Date

Section 1.1, Purpose—One commentator stated that no guidance has been given regarding a unique or separate loss adjustment expense for catastrophe. The commentator suggested that the standard delete reference to loss adjustment expenses or provide explicit guidance on this aspect. **The subcommittee agreed and added section 3.5, Loss Adjustment Expenses, to address the issues surrounding loss adjustment expenses.**

Section 1.2, Scope—One commentator noted that the purpose section specifically makes reference to insurance ratemaking, but the scope section says that the standard applies to many more professional services. The commentator asked, “Does this standard apply to those entities cited in the scope section, only when they are related to property/casualty ratemaking?” **The**

ASOP No. 39—June 2000

standard has been retitled to specify that it applies to property/casualty insurance ratemaking. The services referred to for risk financing systems, such as self-insurance and securitization products, are considered to be ratemaking when estimates for future costs are being determined.

Section 2. Definitions

Section 2.1, Catastrophe—One commentator believed that the definition of catastrophe should relate to how the event or phenomenon violated the general insurance ratemaking model assumption of independent events. **The subcommittee believes that the use of a qualitative definition is more broadly applicable and useful in terms of current accepted practices.**

Another commentator believed that the phrase “or natural phenomenon” should be removed, as the phrase “relatively infrequent events” included natural and manmade phenomena. **The subcommittee agreed and deleted the word “natural” from the definition.**

Another commentator believed that “relatively” should modify high amounts, instead of infrequent events. **The subcommittee believes that it is more important to emphasize the frequency aspects of the definition as opposed to the amount of loss dollars.**

Another commentator stated that serious damage to a very large risk would be considered a catastrophe according to the definition. In the commentator’s view, this did not seem appropriate since a large number of claims might not have resulted. **The subcommittee does not believe that the event needs to produce a large number of claims in order for it to be defined as a catastrophe.**

One commentator believed that the definition need not include the adjective “insured” to modify losses. **The subcommittee agrees and removed it.**

Another commentator suggested the definition eliminate the phrase, “the potential to” produce, as an event either is or is not a catastrophe. **The subcommittee agreed and eliminated the phrase “the potential to” in the definition.**

Section 2.2, Catastrophe Ratemaking Procedures—One commentator believed that the use of the term “adjust” was defensive in nature and that the definition should be something like “to provide a better expected value estimate than could be developed with the limited actual history.” **The subcommittee believes that the original definition is more descriptive of the actual practices in use, while still being consistent with the more theoretical expression of the commentator.**

Another commentator expressed the concern that the current use of the word “adjust” would limit the ability of the actuary to consider any method that includes supplementing or credibility-weighting the losses. **The subcommittee believes that the current wording does not limit the ability of the actuary to use any techniques that, in the opinion of the actuary, produce appropriate estimates of catastrophes losses.**

ASOP No. 39—June 2000

Two commentators suggested editorial changes in the definition to clarify the timing of the catastrophe losses. **The subcommittee agreed with the suggestions and revised the definition.**

Section 2.3, Contagion—One commentator expressed the concern that some casualty catastrophes may result in claims against a single entity. **The subcommittee is aware of this issue and believes that the standard addresses the issue by providing guidance in section 3.4.**

Section 2.4, Demand Surge—Several commentators suggested editorial changes to sharpen the definition. **The subcommittee changed the definition to reflect the fact that demand surge is a sudden and temporary increase, not only in material and labor but also in services.**

Section 3. Analysis of Issues and Recommended Practices

Section 3.1, Identification of Catastrophe Perils or Events—Several commentators expressed concern about the original language, which seemed to require the actuary to identify all perils or events that might have the potential to generate insured catastrophe losses. **The subcommittee agreed and revised the language to include the idea that the actuary should take reasonable steps to identify the perils or events that would generate material losses.** Another commentator believed that it was appropriate to add a condition of suddenness, either in the discovery or occurrence of loss to the list of characteristics. **The subcommittee did not think that any additional characteristics were needed.**

Some commentators suggested clarifications to section 3.1(b). One commentator suggested replacing the last two sentences with the phrase “the presence or absence of such events in the experience period may result in materially different perceptions of future loss estimates.” **While the subcommittee agrees that the original two sentences were awkward, the revision retains the parallel treatment because the subcommittee believes that a more explicit explanation of the impacts is appropriate.** Another commentator suggested that *infrequent occurrence* should be defined in terms like the frequency of the event over a longer time period than the experience period. **The subcommittee concluded that it was important for the actuary to be able to evaluate the materiality of the loss and frequency of events relative to the long term in the context of the methodology being used.**

Section 3.2, Identification of Catastrophe Losses—Two commentators suggested that the language should be clarified to indicate that the actuary may not be able to identify the catastrophe losses in all the historical data used. **The subcommittee agreed and modified this section to reflect such a possible limitation.** Another commentator believed that the standard provided no guidance to the actuary as to how to identify catastrophe losses in the historical insurance data. **The subcommittee believes that the perils insured and the events covered provide sufficient guidance for the identification of catastrophe losses.**

Section 3.3, The Use of Data in Determining a Provision for Catastrophe Losses—The subcommittee made an editorial revision to the order of the items (a), (b), (c) and (d). Item (d)

ASOP No. 39—June 2000

was placed first and relabeled as (a) to emphasize the importance of the frequency component of historical data in making use of the historical data in determining a provision for catastrophe losses. One commentator noted that computer simulations are not data. **The subcommittee agreed and revised this section.** Another commentator believed that sections 3.3.1(b) and 3.3.1(a), and 3.3.1(c) and 3.3.1(e), could be combined. **The subcommittee notes that 3.3.1(b) refers to a comparison over time within the set of insurance data, whereas 3.3.1(a) addresses a comparison of the insurance data to external sources. With regard to 3.3.1(c) and 3.3.1(e), the subcommittee believes that 3.3.1(c) refers to the distribution of the exposure to loss in the experience period, compared to the prospective period, whereas 3.3.1(e) refers to possible differing trends in the costs by peril over the available period.**

Two commentators noted that the language in section 3.3.1(a) created an obligation that may not be possible to satisfy in all cases. **The subcommittee agreed and revised this section to say that the actuary should consider comparing historical insurance data to noninsurance data.** Another commentator noted that this section implies that one uses historical data only if the data give comparable results to modeling, since use of modeling will give the full spectrum of loss distribution. **The subcommittee notes that this section is alerting the actuary to be sure that he or she believes that the data underlying his or her procedure sufficiently reflect the long-term frequency and severity of events producing insured catastrophe losses. If the actuary does not believe that the data are sufficient, section 3.3.2 states that the actuary should consider using a modeling procedure.**

In section 3.3.1(b), one commentator suggested changing the language to say “whether catastrophe losses are likely to differ significantly among elements.” **The subcommittee agreed and made the change.**

In section 3.3.1(c), one commentator suggested the use of a bullet-point list to highlight the importance of each element, particularly items related to coverage, such as limits, co-insurance, deductibles, etc. **The subcommittee agrees that it is important to highlight aspects of coverage and has explicitly mentioned changes in coverage as a consideration.**

In section 3.3.1(d), one commentator believed that if the indicated rate change is sensitive to the number of years in the historical experience period, then one should not use the historical period at all. The commentator believed that this section implies one would modify the current procedure, not switch to using computer simulation. **The subcommittee disagrees. In fact, the subcommittee views modifying procedures to include adopting computer simulation models.**

In section 3.3.1(e), one commentator noted that the section should be revised to say “when noncatastrophe losses are expected to change at a rate materially different from that for catastrophe losses.” **The subcommittee agreed with this and revised the text to cover the potential aspects as referring to past and future time periods.**

Another commentator stated that the phrase “most catastrophe ratemaking procedures” should be revised to “traditional catastrophe ratemaking procedures,” since generally the standard is

ASOP No. 39—June 2000

referring to procedures that have existed in the past. **The subcommittee revised this section to remove the reference to any specific type of procedure.**

One commentator suggested several editorial changes for section 3.3.1(f) that generalized the section as well as broadened the suggested conditions for increasing the amount of data in the second set. **The subcommittee agreed with this comment and revised the text.**

Two commentators suggested that the term “consistent” be replaced by “not materially inconsistent.” **The subcommittee agreed with this suggestion and made the revision.** Another commentator suggested that the last sentence should be revised to remove the word “dollar” and changing the “or” to “and.” **The subcommittee agreed and revised the text.**

Section 3.3.2, Use of Noninsurance Data—One commentator suggested that the standard is giving the false impression that one should adjust past insurance data for all catastrophe perils. This commentator suggests that the adjustments are impossible to do adequately, giving false hope that meaningful results can be obtained. The commentator suggested that the standard be restructured to separate the treatment of catastrophes, such as hurricanes and earthquakes, from all others. **The subcommittee disagrees with these comments. The standard provides the actuary with a framework for evaluating the usability of the available data and developing appropriate catastrophe treatments. The standard identifies the issues for the actuary and gives sufficient freedom for the actuary to demonstrate the appropriateness of the resolution of the issues.**

The exposure draft contained sections 3.3.2(a) and (b). The revisions made as a result of comments received combined parts (a) and (b). All responses to comments received in this section refer to the original section references.

In section 3.3.2(a), one commentator suggested the addition of the phrase “and other relevant.” **The subcommittee agreed with this suggestion.** The same commentator suggested that the section be modified to say “expected” frequency and catastrophes “for the current or prospective periods.” **The subcommittee disagreed as the expected frequency and severity of catastrophes was felt to be sufficiently descriptive.**

In section 3.3.2(b), two commentators believed the section implied that the actuary was capable of making decisions on when the historical insurance data best capture the range of frequency and severity of catastrophes. **The subcommittee recognizes that an actuary may not know these facts without consultation with outside experts. The subcommittee believes that the actuary could become aware of the issues by referring to such experts, and make intelligent decisions about the representativeness of the data.**

One commentator suggested that in section 3.3.2(b) the phrase “if the results of the simulation” was inappropriate. The commentator’s point was that the process—not the results—was most important here. **The subcommittee agreed and has deleted any reference to results of the simulation and has focused the actuary on addressing the appropriateness of the procedures used.**

ASOP No. 39—June 2000

Section 3.4, Using a Provision for Estimated Catastrophe Losses—One commentator believed that the section demanded that the actuary *always* replace the actual data with estimated data, and suggested that the phrase “should adjust” be changed to “may consider adjusting.” **The subcommittee disagrees and believes that if the actuary has biased data, the actuary needs to estimate what the values should be excluding the bias.**

Section 4. Communications and Disclosures

Section 4.1, Conflict with Law or Regulation—Several commentators felt that the requirement that the actuary disclose material differences between the rate developed in accordance with law or regulation and the actuarially-determined rate was unnecessarily burdensome. One commentator suggested that this disclosure burden was unique among all ASOPs. **The subcommittee believes that the potential range of differences could be so large that disclosing the difference to the client or employer would be necessary. The subcommittee also notes that this same requirement exists in ASOP No. 30, *Treatment of Profit and Contingency Provisions and the Cost of Capital in Property/Casualty Insurance Ratemaking.***

20. Assignment 5, Module 1: ASOP 41: https://www.actuarialstandardsboard.org/wp-content/uploads/2014/02/asop041_120.pdf



ACTUARIAL STANDARDS BOARD

**Actuarial Standard
of Practice
No. 41**

Actuarial Communications

Revised Edition

**Developed by the
General Committee of the
Actuarial Standards Board**

**Adopted by the
Actuarial Standards Board
December 2010**

(Doc. No. 120)

TABLE OF CONTENTS

Transmittal Memorandum	iv
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STANDARD OF PRACTICE

Section 1. Purpose, Scope, Cross References, and Effective Date	1
1.1 Purpose	1
1.2 Scope	1
1.3 Cross References	1
1.4 Effective Date	1
Section 2. Definitions	2
2.1 Actuarial Communication	2
2.2 Actuarial Document	2
2.3 Actuarial Finding	2
2.4 Actuarial Report	2
2.5 Actuarial Services	2
2.6 Deviation	2
2.7 Intended User	2
2.8 Oral Communication	2
2.9 Other User	2
2.10 Principal	2
Section 3. Analysis of Issues and Recommended Practices	3
3.1 Requirements for Actuarial Communications	3
3.1.1 Form and Content	3
3.1.2 Clarity	3
3.1.3 Timing of Communication	3
3.1.4 Identification of Responsible Actuary	3
3.2 Actuarial Report	3
3.3 Specific Circumstances	4
3.4 Disclosures Within an Actuarial Report	4
3.4.1 Uncertainty or Risk	4
3.4.2 Conflict of Interest	4
3.4.3 Reliance on Other Sources for Data and Other Information	4
3.4.4 Responsibility for Assumptions and Methods	4
3.4.5 Information Date of Report	5
3.4.6 Subsequent Events	5
3.5 Explanation of Material Differences	6
3.6 Oral Communications	6
3.7 Responsibility to Other Users	6
3.8 Retention of Other Materials	6
Section 4. Communications and Disclosures	7

ASOP No. 41—December 2010

4.1 Disclosures in any Actuarial Communication	7
4.1.1 Identification of Responsible Actuary	7
4.1.2 Identification of Actuarial Documents	7
4.1.3 Disclosures in Actuarial Reports	7
4.2 Certain Assumptions or Methods Prescribed by Law	8
4.3 Responsibility for Assumptions and Methods	8
4.4 Deviation from the Guidance of an ASOP	9

APPENDIXES

Appendix 1—Background and Current Practices	10
Background	10
Current Practices	10
Appendix 2—Comments on the Second Exposure Draft and Responses	12

ASOP No. 41—December 2010

December 2010

TO: Members of Actuarial Organizations Governed by the Standards of Practice of the Actuarial Standards Board and Other Persons Interested in Actuarial Communications

FROM: Actuarial Standards Board (ASB)

SUBJ: Actuarial Standard of Practice (ASOP) No. 41

This document contains the final version of the revision of ASOP No. 41, *Actuarial Communications*.

Background

The current version of ASOP No. 41 has been in effect for eight years, and applies to all U.S. actuaries in all areas of practice. During that time, the ASB has received comments regarding a lack of clarity in the document and confusion in respect to its wording and structural arrangement. One of the ASB's priorities is to make sure that all ASOPs are clear and unambiguous.

First Exposure Draft

In September 2008, the ASB approved the first exposure draft of a revised ASOP No. 41 with a comment deadline of December 31, 2008. Twenty-three comment letters were received. Most had multiple comments, many of which were substantive. The majority of commentators were supportive of the effort to revise this ASOP, and most comments were positive in nature, but some indicated that the first draft needed significant revision.

In September 2008, the ASB also adopted "Revision of Deviation Language for Standards and Removal of References to PSAOs from Standards" pending the issuance of ASOP No. 41 as a final revision. Due to the passage of time since that adoption, the ASB will update this document to reflect changes in ASOP No. 41, as well as to update references for other new and revised ASOPs. It is expected that the ASB will adopt this document as a final revision at its March meeting, with an effective date of May 1, 2011, consistent with the effective date of this revised standard.

Second Exposure Draft

In December 2009, the ASB approved a second exposure draft of a revised ASOP No. 41, reflecting significant modifications of the first draft, with a comment deadline of March 31, 2010. Thirty-seven comment letters were received in response. For a summary of the substantive issues contained in the second exposure draft comment letters and the responses, please see appendix 2.

ASOP No. 41—December 2010

Changes from Second Exposure Draft

The review and revision of the second exposure draft focused on the dominant issue raised in 19 of 37 comment letters; namely, the apparent requirement for an actuary to complete an actuarial report with full disclosures in nearly all circumstances. This was not the intent of the second exposure draft, but the reviewers were sensitive to this possible interpretation. Accordingly, this final version reflects clarification to the guidance within this standard, in particular to recognize that in some internal and informal settings, complete disclosure of all applicable supporting information is neither practical nor necessary. Section 3.3 (formerly section 3.5) has been moved and expanded to provide guidance in these situations. Additional discussion has also been added to appendix 1.

In response to other comments some definitions have been added and other clarifying modifications have been made.

Summary of Key Changes from Current ASOP

1. The concept of a single formal actuarial report, which is required to contain all necessary disclosures, has been removed. Instead, the concept that communication is an ongoing and interactive process and that an actuarial report with all necessary disclosure elements may comprise several different pieces of communication, perhaps delivered in different forms, has been adopted. The standard directs the actuary to identify all applicable documents whenever multiple documents are used to satisfy all of the disclosure requirements of an actuarial report.
2. Section 3.4.4 makes it clear that the actuary is responsible for all actuarial assumptions and methods utilized in producing the actuarial communication, unless the actuary discloses otherwise.
3. Section 3 has been reorganized. All disclosure requirements have been moved to section 4, while additional guidance relating to disclosures remains in section 3.4.
4. The treatment of deviations from the guidance of any ASOP (including situations where assumptions are not set by the actuary) is also codified in section 4.
5. Reference to Prescribed Statements of Actuarial Opinion (PSAOs) has been removed.
6. The ASB has decided that specifying what material should be retained and for how long is not appropriate for this standard (except as may be provided in section 3.8).

The General Committee thanks everyone who took the time to contribute comments and suggestions on both exposure drafts.

The ASB voted in December 2010 to adopt this standard.

ASOP No. 41—December 2010

General Committee of the ASB

Thomas K. Custis, Chairperson

Michael S. Abroe	William J. Schreiner
Peter Hendee	Martin M. Simons
Godfrey Perrott	Chester J. Szczepanski

Actuarial Standards Board

Albert J. Beer, Chairperson

Alan D. Ford	Patricia E. Matson
Patrick J. Grannan	Robert G. Meilander
Stephen G. Kellison	James J. Murphy
Thomas D. Levy	James F. Verlautz

The ASB establishes and improves standards of actuarial practice. These ASOPs identify what the actuary should consider, document, and disclose when performing an actuarial assignment. The ASB's goal is to set standards for appropriate practice for the U.S.

ACTUARIAL STANDARD OF PRACTICE NO. 41

ACTUARIAL COMMUNICATIONS

STANDARD OF PRACTICE

Section 1. Purpose, Scope, Cross References, and Effective Date

- 1.1 Purpose—This actuarial standard of practice (ASOP) provides guidance to actuaries with respect to actuarial communications.
- 1.2 Scope—This standard applies to actuaries issuing actuarial communications within any practice area. This standard does not apply to communications that do not include an actuarial opinion or other actuarial findings (for example, this standard does not apply to brochures, fee quotes, or invoices).

This standard provides guidance for preparing actuarial communications, including those that may be required by the *Qualification Standards* or by other ASOPs. If such other guidance contains communication requirements that are additional to or inconsistent with this standard, the requirements of such other guidance supersede the guidance of this ASOP. However, the guidance in this ASOP applies to the extent it is not inconsistent with such other guidance.

Law, regulation, or another profession's standards may prescribe the form and content of a particular actuarial communication (such as a government form). In such situations, the actuary should comply with the guidance in this standard to the extent not prohibited by applicable law, regulation, or standard.

If the actuary departs from the guidance set forth in this standard in order to comply with applicable law (statutes, regulations, and other legally binding authority), or for any other reason, the actuary should refer to section 4 regarding deviation.

- 1.3 Cross References—When this standard refers to the provisions of other documents, the reference includes the referenced documents as they may be amended or restated in the future, and any successor to them, by whatever name called. If any amended or restated document differs materially from the originally referenced document, the actuary should consider the guidance in this standard to the extent it is applicable and appropriate.
- 1.4 Effective Date—This standard is effective for actuarial communications issued on or after May 1, 2011.

ASOP No. 41—December 2010

Section 2. Definitions

The terms below are defined for use in this actuarial standard of practice.

- 2.1 **Actuarial Communication**—A written, electronic, or oral communication issued by an actuary with respect to actuarial services.
- 2.2 **Actuarial Document**—An actuarial communication in any recorded form (such as paper, e-mail, spreadsheets, presentations, audio or video recordings, web sites, and court or hearing transcripts). Notes taken by someone other than the actuary are not considered actuarial documents.
- 2.3 **Actuarial Finding**—The result (including advice, recommendations, opinions, or commentary on another actuary's work) of actuarial services.
- 2.4 **Actuarial Report**—The set of actuarial documents that the actuary determines to be relevant to specific actuarial findings that is available to an intended user.
- 2.5 **Actuarial Services**—Professional services provided to a principal by an individual acting in the capacity of an actuary. Such services include the rendering of advice, recommendations, findings, or opinions based upon actuarial considerations.
- 2.6 **Deviation**—The act of departing from the guidance of an ASOP.
- 2.7 **Intended User**—Any person who the actuary identifies as able to rely on the actuarial findings.
- 2.8 **Oral Communication**—An actuarial communication made orally that has not, to the knowledge of the actuary, been recorded or transcribed verbatim. Such an oral communication is an actuarial communication, but is not an actuarial document.
- 2.9 **Other User**—Any recipient of an actuarial communication who is not an intended user.
- 2.10 **Principal**—A client or employer of the actuary.

ASOP No. 41—December 2010

Section 3. Analysis of Issues and Recommended Practices

- 3.1 Requirements for Actuarial Communications—The performance of a specific actuarial engagement or assignment typically requires significant and ongoing communications between the actuary and the intended users regarding the following: the scope of the requested work; the methods, procedures, assumptions, data, and other information required to complete the work; and the development of the communication of the actuarial findings.
- 3.1.1 Form and Content—The actuary should take appropriate steps to ensure that the form and content of each actuarial communication are appropriate to the particular circumstances, taking into account the intended users.
- 3.1.2 Clarity—The actuary should take appropriate steps to ensure that each actuarial communication is clear and uses language appropriate to the particular circumstances, taking into account the intended users.
- 3.1.3 Timing of Communication—The actuary should issue each actuarial communication within a reasonable time period, unless other arrangements as to timing have been made. In setting the timing of the communication, the needs of the intended users should be considered.
- 3.1.4 Identification of Responsible Actuary—An actuarial communication should clearly identify the actuary responsible for it. When two or more individuals jointly issue a communication (at least some of which is actuarial in nature), the communication should identify all responsible actuaries, unless the actuaries judge it inappropriate to do so. The name of an organization with which each actuary is affiliated also may be included in the communication, but the actuary's responsibilities are not affected by such identification. Unless the actuary judges it inappropriate, the actuary issuing an actuarial communication should also indicate the extent to which the actuary is available to provide supplementary information and explanation.
- 3.2 Actuarial Report—The actuary should complete an actuarial report if the actuary intends the actuarial findings to be relied upon by any intended user. The actuary should consider the needs of the intended user in communicating the actuarial findings in the actuarial report.

An actuarial report may comprise one or several documents. The report may be in several different formats (such as formal documents produced on word processing, presentation or publishing software, e-mail, paper, or web sites). Where an actuarial report for a specific intended user comprises multiple documents, the actuary should communicate which documents comprise the report.

In the actuarial report, the actuary should state the actuarial findings, and identify the methods, procedures, assumptions, and data used by the actuary with sufficient clarity

ASOP No. 41—December 2010

that another actuary qualified in the same practice area could make an objective appraisal of the reasonableness of the actuary's work as presented in the actuarial report.

- 3.3 Specific Circumstances—The content of an actuarial report may be constrained by circumstances. The actuary should follow the guidance of this standard to the extent reasonably possible within such constraints. When those constraints exist, it may be appropriate not to include some of the otherwise required content in the actuarial report. However, limiting the content of an actuarial report may not be appropriate if that report or the findings in that report may receive broad distribution.

If the actuary believes circumstances are such that including certain content is not necessary or appropriate, the actuary must be prepared to identify such circumstances and justify limiting the content of the actuarial report.

- 3.4 Disclosures Within an Actuarial Report—Consideration of the items to be disclosed is an important part of the preparation of any actuarial communication. The actuary should review the list of required disclosure items included in section 4 of this ASOP, and in any other relevant ASOP. Further discussion regarding some of these disclosure items follows:

- 3.4.1 Uncertainty or Risk—The actuary should consider what cautions regarding possible uncertainty or risk in any results should be included in the actuarial report.

- 3.4.2 Conflict of Interest—An actuary who is not financially, organizationally, or otherwise independent concerning any matter related to the subject of an actuarial communication should disclose any pertinent information that is not apparent. This includes any situation where the actuary acts, or may appear to be acting, as an advocate. However, applicable financial disclosure is limited in accordance with Precept 6 of the *Code of Professional Conduct* to sources of material compensation that are known to, or are reasonably ascertainable by, the actuary.

- 3.4.3 Reliance on Other Sources for Data and Other Information—An actuary who makes an actuarial communication assumes responsibility for it, except to the extent the actuary disclaims responsibility by stating reliance on other sources. Reliance on other sources for data and other information means making use of those sources without assuming responsibility for them. An actuarial communication making use of any such reliance should define the extent of reliance, for example by stating whether or not checks as to reasonableness have been applied. An actuary may rely upon other sources for information, except where limited or prohibited by applicable standards of practice or law or regulation. Further guidance on when such reliance is appropriate, and what the actuary's responsibilities are when such reliance is stated, is found in ASOP No.23, *Data Quality*.

- 3.4.4 Responsibility for Assumptions and Methods—An actuarial communication

ASOP No. 41—December 2010

should identify the party responsible for each material assumption and method. Where the communication is silent about such responsibility, the actuary who issued the communication will be assumed to have taken responsibility for that assumption or method. The actuary's obligation when identifying the other party who selected the assumption or method depends upon how the assumption or method was selected.

- a. If the assumption or method is specified by applicable law (statutes, regulations, and other legally binding authority), the actuary should include the disclosures identified in section 4.2. These disclosures should be made whether or not the actuary believes the assumption or method is reasonable for the purpose of the communication. The actuary should also follow the guidance in paragraph (b) below whenever required by another ASOP.
 - b. If a material assumption or method is selected by another party, the actuary has three choices:
 1. If the assumption or method does not conflict significantly with what, in the actuary's professional judgment, would be reasonable for the purpose of the assignment, the actuary has no disclosure obligation;
 2. If the assumption or method significantly conflicts with what, in the actuary's professional judgment, would be reasonable for the purpose of the assignment, the actuary must disclose that fact and the additional information specified in section 4.3; and
 3. If the actuary has been unable to judge the reasonableness of the assumption or method without performing a substantial amount of additional work beyond the scope of the assignment, or if the actuary was not qualified to judge the reasonableness of the assumption, the actuary should disclose that fact as specified in section 4.3.
 - c. In all other situations, the actuary is responsible for all assumptions and methods utilized in the preparation of a communication unless the actuary discloses otherwise within the communication by including the disclosures identified in section 4.4.
- 3.4.5 Information Date of Report—The actuary should communicate to the intended user the date(s) through which data or other information has been considered in developing the findings included in the report.
- 3.4.6 Subsequent Events—The actuary should disclose any relevant event that meets the following conditions:

ASOP No. 41—December 2010

- a. it becomes known to the actuary after the latest information date described in section 3.4.5;
- b. it becomes known to the actuary before the report is issued;
- c. it may have a material effect on the actuarial findings if it were reflected in the actuarial findings; and
- d. it is impractical to revise the report before it is issued.

If the actuary learns of changes to data or other information (on or before the information date) after some findings have been communicated, but before the report is completed, the actuary should communicate those changes, and their implications, to any intended user to whom the actuary has communicated findings.

- 3.5 Explanation of Material Differences—If a later actuarial communication produced by the same actuary, which opines on the same issue, includes materially different results or expresses a different opinion from the former communication, then the later communication should make it clear that the earlier results or opinion are no longer valid and explain why they have changed. If the later communication is oral, the actuary should follow-up with a document that clarifies the reason(s) for the changes.
- 3.6 Oral Communications—When the actuary is providing an oral communication, the actuary should consider the extent to which (if any) the disclosures listed under section 3.4 should be included in the oral communication and include each such disclosure if appropriate in the particular circumstances. Where the actuary has a concern that the oral communication may be passed on to other parties, the actuary should consider following up with an actuarial document.
- 3.7 Responsibility to Other Users—An actuarial document may be used in a way that may influence persons who are not intended users. The actuary should recognize the risks of misquotation, misinterpretation, or other misuse of such a document and should take reasonable steps to ensure that the actuarial document is clear and presented fairly. To help prevent misuse, the actuary may include language in the actuarial document that limits its distribution to other users (for example, by stating that it may only be provided to such parties in its entirety or only with the actuary’s consent).

Nothing in this standard creates an obligation for the actuary to communicate with any person other than the intended users.

- 3.8 Retention of Other Materials—An actuary may choose to keep file material other than that which is to be disclosed under this ASOP. Nothing in this ASOP requires the actuary to disclose such additional materials to any party.

ASOP No. 41—December 2010

If, as may be appropriate in accordance with section 3.3., a report does not include all of the supporting information identified in this ASOP, the actuary should consider retaining the supporting information that was not included in the report. The actuary is not required to create additional documentation for this purpose.

An actuary should consider retaining sufficient information for any recurring project so that another actuary could assume the assignment.

Section 4. Communications and Disclosures

- 4.1 Disclosures in any Actuarial Communication—Disclosures in any actuarial communication should include the following:
- 4.1.1 Identification of Responsible Actuary—Any actuarial communication should identify the actuary who is responsible for the actuarial communication (see section 3.1.4).
 - 4.1.2 Identification of Actuarial Documents—Any actuarial document should include the date and subject of the document with any additional modifier (such as “version 2” or time of day) to make this entire description unique.
 - 4.1.3 Disclosures in Actuarial Reports—In addition to the information necessary to satisfy section 3.2, any actuarial report should disclose the following information, unless the actuary determines that it is inappropriate to do so (see section 3.3):
 - a. the intended users of the actuarial report;
 - b. the scope and intended purpose of the engagement or assignment;
 - c. the acknowledgement of qualification as specified in the *Qualification Standards*;
 - d. any cautions about risk and uncertainty (see section 3.4.1);
 - e. any limitations or constraints on the use or applicability of the actuarial findings contained within the actuarial communication including, if appropriate, a statement that the communication should not be relied upon for any other purpose;
 - f. any conflict of interest as described in section 3.4.2;
 - g. any information on which the actuary relied that has a material impact on the actuarial findings and for which the actuary does not assume responsibility (see section 3.4.3);

ASOP No. 41—December 2010

- h. the information date as described in section 3.4.5;
- i. subsequent event(s) (if any) as described in section 3.4.6.; and
- j. if appropriate, the documents comprising the actuarial report.

Note that other ASOPs that apply to a particular assignment may have additional disclosure requirements that should also be followed.

- 4.2 Certain Assumptions or Methods Prescribed by Law—Where any material assumption or method was prescribed by applicable law (statutes, regulations, and other legally binding authority), the actuary should disclose the following in the actuarial report:

- a. the applicable law under which the report was prepared;
- b. the assumptions or methods that are prescribed by the applicable law; and
- c. that the report was prepared in accordance with the applicable law.

If the actuarial report is in a prescribed form that does not accommodate these disclosures, the actuary should make these disclosures in a separate communication (such as a cover letter to the principal), requesting that both communications be disseminated together where practicable.

- 4.3 Responsibility for Assumptions and Methods—In any situation not covered under section 4.2, where the actuary states reliance on other sources (as described in section 3.4.4(b) 2 and 3) and thereby disclaims responsibility for any material assumption or method, the actuary should disclose the following in the actuarial report, unless it is inappropriate to do so (see section 3.3):

- a. the assumption or method that was set by another party;
- b. the party who set the assumption or method;
- c. the reason that this party, rather than the actuary, has set the assumption or method; and
- d. either
 - 1. that the assumption or method significantly conflicts with what, in the actuary's professional judgment, would be reasonable for the purpose of the assignment; or
 - 2. that the actuary was unable to judge the reasonableness of the assumption or method without performing a substantial amount of additional work beyond the scope of the assignment, and did not do so, or that the actuary

ASOP No. 41—December 2010

was not qualified to judge the reasonableness of the assumption.

If the actuarial report is in a prescribed form that does not accommodate these disclosures, the actuary should make these disclosures in a separate communication (such as a cover letter to the principal), requesting that both communications be disseminated together where practicable.

- 4.4 Deviation from the Guidance of an ASOP—If, in the actuary's professional judgment, the actuary has deviated materially from the guidance set forth in an applicable ASOP, other than as covered under sections 4.2 or 4.3 of this standard, the actuary can still comply with that ASOP by providing an appropriate statement in the actuarial communication with respect to the nature, rationale, and effect of such deviation.

ASOP No. 41—December 2010

Appendix I

Background and Current Practices

Note: This appendix is provided for informational purposes, but is not part of the standard of practice.

Background

The current version of ASOP No. 41, adopted in March 2002, was adapted from and superseded Interpretative Opinion No. 3, *Professional Communications of Actuaries*. Interpretative Opinion No. 3 was itself adopted by the American Academy of Actuaries in 1981. The 2002 version of ASOP No. 41 conformed to the format adopted by the Actuarial Standards Board in May 1996 for all actuarial standards of practice, and while this standard generally followed Interpretative Opinion No. 3, it also expanded upon, clarified, and eliminated portions of that opinion.

This standard offers guidance to complement the requirements imposed by the *Code of Professional Conduct*. It was drafted and is still intended to help actuaries apply the *Code of Professional Conduct* when making professional communications (by written, electronic, or oral means) to clients, employers, regulators, policyholders, plan participants, investors, and other users of actuarial services. Actuaries commonly deal with confidential or proprietary information. The *Code of Professional Conduct* clearly precludes the actuary from disclosing this type of information to inappropriate parties.

This revision has used definitions that are consistent with those found in the *Code of Professional Conduct* and in the recently revised *Qualification Standards for Actuaries Issuing Statements of Actuarial Opinions*. This revision also incorporates language in section 4 that is the foundation of the ASB's new approach to creating consistency in the treatment of deviation language within all ASOPs.

It should be noted that all recorded forms of communication (including—but not limited to—paper, e-mail, spreadsheets, presentations, audio or video recordings, web sites, and court or hearing transcripts) could be considered records of such communications and may be, therefore, discoverable in legal proceedings.

Current Practices

Actuaries are currently guided by the *Code of Professional Conduct*, by ASOP No. 41, and by other actuarial standards of practice, depending on the nature of the work at hand.

In general, actuarial communications are provided in order to answer questions or address specific needs of one or more intended users. Actuarial communications may be made available to a variety of users of actuarial work products including clients, employers, regulators, policyholders, plan participants, and investors, as well as external audiences such as the general public. Actuarial communications may be delivered in many forms, including written, electronic,

ASOP No. 41—December 2010

or oral; and may stand alone or be part of a broader pattern of communication. While preparing an actuarial communication, an actuary should be mindful of the needs and concerns of each of the intended users. In certain situations, some intended users may receive different actuarial documents. Thus, an actuarial report for one intended user may differ from the report for a different intended user. Even the least comprehensive version of an actuarial report is subject to the guidance of this standard.

An actuary, while functioning in a professional capacity, may be involved in informal communication with others. Actuarial findings may be communicated under circumstances that make inclusion of all supporting information impractical or unnecessary. This may be particularly common in a company environment. Other circumstances such as severe time constraints (for example, union negotiations, mergers and acquisitions) may make inclusion of all recommended disclosure items impractical, if not impossible. In these instances, the content of the actuarial report is often limited. These situations are addressed in section 3.3.

ASOP No. 41—December 2010

Appendix 2

Comments on the Second Exposure Draft and Responses

The second exposure draft of this ASOP, *Actuarial Communications*, was issued in December 2009 with a comment deadline of March 31, 2010. Thirty-seven comment letters were received, some of which were submitted on behalf of multiple commentators, such as by firms or committees. For purposes of this appendix, the term “commentator” may refer to more than one person associated with a particular comment letter. The General Committee carefully considered all comments received, reviewed the exposure draft and proposed changes. The ASB reviewed the proposed changes and made modifications where appropriate.

Summarized below are the significant issues and questions contained in the comment letters and the responses.

The term “reviewers” in appendix 2 includes the General Committee and the ASB. Also, unless otherwise noted, the section numbers and titles used in appendix 2 refer to those in the second exposure draft.

GENERAL COMMENTS	
Comment	Several commentators raised the issue of a potential deficiency in guidance should the proposed ASOP No. 41 be adopted as final at the same time current ASOP No. 9, <i>Documentation and Disclosure in Property and Casualty Insurance Ratemaking, Loss Reserving, and Valuations</i> , is withdrawn.
Response	The reviewers do not believe that this issue can or should be resolved within ASOP No. 41.
Comment	One commentator believed that the distinction between the guidance for “oral only communication” (for example, a phone call) and guidance for e-mail may not be practical.
Response	The reviewers disagree. E-mail creates a permanent record that can be discovered and referred to in subsequent proceedings (legal or otherwise). Accordingly, the reviewers believe that it is appropriate to consider e-mail as a “document” and subject to the applicable guidance.
Comment	Several commentators expressed concern that the guidance in the second exposure draft was slanted to the consulting environment and not practical within many company situations.

ASOP No. 41—December 2010

Response	The reviewers did not intend this interpretation. In rewriting the final version of ASOP No. 41 the reviewers have attempted to be more sensitive to this issue. It is not the intention of this ASOP to impose unnecessary burdens on the internal communications of an organization.
TRANSMITTAL MEMORANDUM	
Question 1: Is the revised concept of an actuarial report reflected in this draft both clear and appropriate?	
Comment	Nineteen commentators responded to this question; only one responded in the affirmative. Most interpreted the second exposure draft to significantly "raise the bar," requiring a full-fledged report in many situations where it would be neither necessary nor practical.
Response	This interpretation was not the intent of the second exposure draft. The reviewers have been sensitive to these concerns in this revision. Section 3.3 of this standard has been expanded to clarify the guidance in those circumstances where it is not necessary or practical to include all supporting information. Additional discussion was added to appendix 1.
Question 2: Is the revised ASB position on documentation appropriate?	
Comment	A few commentators felt it was appropriate. The ones that disagreed were those that raised concerns about the withdrawal of ASOP No. 9 (see the first "General" comment above).
Response	After considering the comments, the reviewers still believe that the general approach is appropriate. Some modifications have been made to section 3.8 to incorporate guidance in those situations where full supporting information is not supplied within the document(s) of an actuarial report.
Question 3: Does this revised draft incorporate an appropriate emphasis on the need for the actuary to consider the needs of the intended users?	
Comment	The few commentators that did respond to this question answered in the affirmative. One suggested that the second exposure draft may have gone too far in this regard.
Response	The reviewers believe that the purpose of an actuarial communication is to satisfy the needs of the intended user. Accordingly, this final version has retained this perspective.

ASOP No. 41—December 2010

SECTION 1. PURPOSE, SCOPE, CROSS REFERENCES, AND EFFECTIVE DATE	
Comment	Two commentators made suggestions with respect to the description of the standard's guidance.
Response	The description has been revised.
Comment	One commentator expressed concern that the term "actuarial opinion" is not defined.
Response	The reviewers believe that "actuarial opinion" is well understood and did not add a definition.
Comment	One commentator suggested an expansion of the commentary on which communications did not fall within the purview of the standard.
Response	The reviewers believe that the wording is satisfactory.
SECTION 2. DEFINITIONS	
Comment	Several commentators suggested that the definitions in the ASOP adopt the definitions in the Qualification Standards.
Response	The reviewers agreed and adopted the Qualification Standards' definitions for "actuarial communication" and "actuarial services."
Comment	One commentator suggested that "actuarial services" be clearly defined.
Response	A definition consistent with the Qualification Standards has been added. Furthermore, the definition of "actuarial finding" was modified to tie more consistently to this definition.
Comment	One commentator suggested that definitions be added for "data," "methods," and "procedures."
Response	The reviewers concluded that the meanings of these terms were well understood and specific definitions were not needed.
Comment	Several commentators were concerned that the proposed standard can be read to imply that any notes taken by an actuary may be considered an actuarial document.

ASOP No. 41—December 2010

Response	The reviewers do not believe that an actuary's notes constitute an actuarial communication unless they are provided to an intended user. If an actuary does not distribute his/her notes to an intended user, there is no actuarial communication and the personal notes taken by the actuary are not subject to the requirements of ASOP No. 41. If either the notes or the material contained in the notes is distributed to an intended user or becomes part of the actuarial report, this creates an actuarial communication and the resulting documents would be subject to the requirements of the standard.
Section 2.1, Actuarial Communication	
Comment	A few commentators suggested that the word "electronic" be deleted from definition 2.1, stating that actuarial communications may be written or oral. Either type (written or oral) can be in electronic or hard copy form. One commentator noted the definition of "actuarial communication" deleted the current reference to a principal.
Response	The reviewers retained the definition to remain consistent with the <i>Code of Professional Conduct</i> and the Qualification Standards.
Section 2.6, Intended Audience	
Comment	Several commentators suggested deletion of the definition "intended audience" and that definitions be provided for "principal" and "actuarial services."
Response	The reviewers agree with these suggestions and have removed the definition of "intended audience" and provided definitions for "principal" and "actuarial services."
SECTION 3. ANALYSIS OF ISSUES AND RECOMMENDED PRACTICES	
Section 3.1, Requirements for Actuarial Communications	
Comment	One commentator requested the definition of "principal" be retained; another questioned the usage in sections 3.1.3 and 3.2.
Response	The reviewers agreed. The definition of "principal" from the <i>Code of Professional Conduct</i> was added, and it was used only when appropriate in the context of the guidance throughout the standard.
Comment	One commentator requested wording in section 3.1 and the addition of a section 3.1.5 to make it clear that, when an actuary communicates to the designated representative of a group of intended users, the actuary is deemed to have communicated to the group.

ASOP No. 41—December 2010

Response	The reviewers considered this a non-actuarial issue and made no change.
Section 3.1.2, Clarity	
Comment	One commentator felt the phrase “language appropriate to the particular circumstances, taking into account the intended audience” needed further guidance.
Response	The reviewers believe this language is sufficient; not all circumstances can be anticipated.
Section 3.1.3, Timing of Communication	
Comment	Several commentators questioned the wording of section 3.1.3, while one commentator preferred the “guidance” in appendix 1 of the Qualification Standards.
Response	The reviewers agreed and revised section 3.1.3. The reviewers note that appendix 1 of the Qualification Standards is not guidance, and made no change on this account.
Section 3.1.4, Identification of Responsible Actuary	
Comment	Several commentators suggested revised wording for section 3.1.4.
Response	The reviewers were generally satisfied with the wording in the exposure draft but did incorporate minor changes.
Section 3.2, Actuarial Report	
Comment	Several commentators felt that the ASB had “raised the bar” too much in section 3.2 or that the wording seemed only to address consulting situations.
Response	The reviewers modified and expanded former section 3.5 and moved it to section 3.3 to clarify that an actuarial report may be abbreviated in certain situations.
Comment	One commentator felt that the requirement to provide adequate information so that another actuary could assess the reasonableness of the findings was more than was needed if the report was directed to non-actuaries.
Response	Absent circumstances allowing for an abbreviated report under section 3.3, the reviewers believe that information sufficient to make an objective appraisal of the work is a valuable standard. This information does not have to detract from the understandability of a report; it can be presented separately, such as in an appendix.

ASOP No. 41—December 2010

Comment	One commentator indicated that the principal, as well as the actuary, should be able to determine what was relevant to an actuarial report.
Response	The reviewers disagreed and did not include such authority for the principal.
Section 3.3 (formerly 3.5), Specific Circumstances	
Comment	Two commentators suggested that further examples or clarification of time pressure was needed.
Response	The reviewers believe this is accomplished as part of the modification of this section for clarity, and the additional discussion added to appendix 1.
Section 3.4.2 (formerly 3.3.2), Conflict of Interest	
Comment	One commentator requested a definition of “information.”
Response	The reviewers did not feel such a definition was needed and made no change.
Section 3.4.4 (formerly 3.3.4), Responsibility for Assumptions and Methods	
Comment	One commentator felt that the actuary is always responsible for the assumptions and methods; that the lead paragraph of 3.4.4 should so state and that 3.4.4.c. should be deleted. A second commentator suggested that the ASOP should allow the actuary to simply disclose that the assumption or method was not set by the actuary and does not represent the actuary’s professional judgment.
Response	The reviewers disagree with both commentators. The first position is not practical in all situations. The second position would be an overly broad exception enabling an actuary to inappropriately avoid professional responsibility. The reviewers believe that the revisions to section 3.4.4 in this version of the standard strike the proper balance between professional responsibility and real-life practicality.
Comment	Two commentators wondered whether “specified by law” (section 3.4.4(a)) could be interpreted to include situations (FAS 87) where assumptions are specified by a third party under some binding authority.
Response	The reviewers believe the language and intent are clear. FAS 87 situations (and all circumstances where the assumption or method is not specified within law) fall under section 3.4.4(b).
Section 3.4.4(b) (formerly 3.3.4(b)), Responsibility for Assumptions and Methods	

ASOP No. 41—December 2010

Comment	One commentator suggested rewording to accommodate assumptions the actuary is not qualified to make.
Response	The reviewers agreed and changed the wording of 3.4.4(b)(3) and 4.3(d)(2) to reflect this.
Comment	One commentator thought that the actuary should be required to provide an affirmative statement of agreement with assumptions that "do not conflict significantly with what the actuary considers to be reasonable."
Response	The reviewers believe this would be an impractical and unnecessary requirement.
Section 3.4.4(c) (formerly 3.3.4(c), Responsibility for Assumptions and Methods	
Comment	One commentator suggested removing the word "prominently."
Response	The reviewers agreed and removed it.
Section 3.4.5 (formerly 3.3.5), Information Date of Report	
Comment	One commentator suggested making dates plural as different information may have different dates.
Response	The reviewers agreed and changed the word to "date(s)."
Section 3.4.6 (formerly 3.3.6), Subsequent Events	
Comment	Two commentators suggested wording changes.
Response	The reviewers agreed and changed some words.
Comment	One commentator suggested that if an actuary is aware of an event that has a material effect on the findings, then it is possible that the actuary would need to submit a revised report.
Response	The reviewers agree, but recognize that this is not always possible. Section 3.4.6(d) has been added to clarify this situation.
Section 3.5 (formerly 3.4), Reconciliation of Material Differences	
Comment	Several commentators suggested "reconcile" was too strong a requirement, and "same assignment" was imprecise.
Response	The reviewers agreed and revised this section.
Section 3.6, Oral Communications	

ASOP No. 41—December 2010

Comment	One commentator expressed concern that “passed on to other parties” was too broad, and should be restricted to intended users.
Response	The reviewers disagreed and made no change.
Section 3.8, Documentation	
Comment	One commentator felt the actuary should take reasonable steps to ensure that another qualified actuary could take over the work if necessary.
Response	The reviewers agreed and revised this section.
SECTION 4. COMMUNICATIONS AND DISCLOSURES	
Section 4.1.2, Identification of Actuarial Documents	
Comment	One commentator suggested that this provision seems overly broad and cumbersome, and should be removed.
Response	The reviewers disagreed, feeling identification of documents is important, and made no change.
Section 4.1.3, Disclosures in Actuarial Reports	
Comment	One commentator felt that a report provided by the actuary will be so laden down by disclosures that clear and concise communications will be difficult.
Response	The reviewers disagreed and made no change. They noted that disclosures could be in a separate section of the report from the findings, and so do not prevent clarity of communication.
Comment	One commentator felt section 4.1.3 should be expanded to include disclosures required by section 3.4.4.
Response	The reviewers disagreed and made no change. The disclosures required by section 3.4.4 are addressed in sections 4.2 and 4.3.
Comment	One commentator felt section 4.1.3 should reference the exceptions addressed in section 3.3.
Response	The reviewers agreed and referenced section 3.3 in section 4.1.3.
Comment	One commentator felt where the actuarial report consists of more than one document, the actuary should disclose the documents that comprise the full report.

ASOP No. 41—December 2010

Response	The reviewers agreed and added paragraph j. to section 4.1.3.
Comment	One commentator felt that “on which the actuary relied” should be moved to immediately after “any information.”
Response	The reviewers agreed and made this change.
Comment	One commentator felt it would be helpful to include examples to clarify the phrase “unless it is inappropriate to do so.”
Response	The reviewers felt that incorporating a list of examples may limit the actuary’s judgment, and made no change.
Section 4.2, Certain Assumptions or Methods Prescribed by Law	
Comment	One commentator requested that section 4.2 should be expanded to clarify that assumptions and methods prescribed by or under the authority of FASB, should be treated as “prescribed by law.”
Response	The reviewers disagreed in part and made no change. An assumption or method prescribed by FASB would come under section 4.2 (assuming FASB is “other binding authority”). An assumption or method prescribed by a third party under the authority of FASB would not be covered by section 4.2.
Section 4.3, Responsibility for Assumptions and Methods	
Comment	One commentator questioned whether every assumption or method used for a monthly valuation had to be addressed in each actuarial report, or could reference be made to a master document?
Response	The reviewers made no change as this is the intent of section 3.2, which recognizes that an actuarial report often consists of multiple documents. The master document referred to in the comment fits this concept well.
Comment	One commentator questioned the need to disclose in an internal document “the reason why the other party set the assumption or method”
Response	The reviewers agreed and qualified section 4.3 by reference to section 3.3.
Comment	One commentator suggested adding a section 4.3(d)(3) with language such as “that the actuary agreed with the assumption or method.”
Response	The reviewers made no change, since section 4.3 is only triggered if the actuary disowns the assumption or method.

ASOP No. 41—December 2010

Comment	One commentator pointed out that the guidance in this section is different than the guidance for similar situations under section 5.4.5 of ASOP No. 20.
Response	The reviewers believe the guidance in this section is appropriate to the general situation and have made no change. Section 1.2 of this standard states that where guidance of other standards conflicts with the guidance in this standard, the other standard applies.
Section 4.4, Deviation From the Guidance of an ASOP	
Comment	One commentator objected to the revision of section 4.4 (from the existing ASOP) and requested the original language be retained.
Response	The reviewers disagreed and made no change. The reviewers believe that the disclosures required under section 4.4 are adequately strong to address the concerns of the commentator. The revised section 4.4 is part of the ASB initiative to move all substantive guidance on deviation into ASOP No. 41 (and thus achieve consistency across ASOPs.) Part of this initiative is to clarify that "deviation" means deviating from the guidance of an ASOP. Compliance with the ASOP is still possible through adequate disclosure.

21. Assignment 6, Module 2: Industry Good Practice for Cat Modeling:

<https://www.catriskcredentials.org/wp-content/uploads/2025/03/Industry-Good-Practice-for-CAT-modelling-under-SII1-1.pdf>

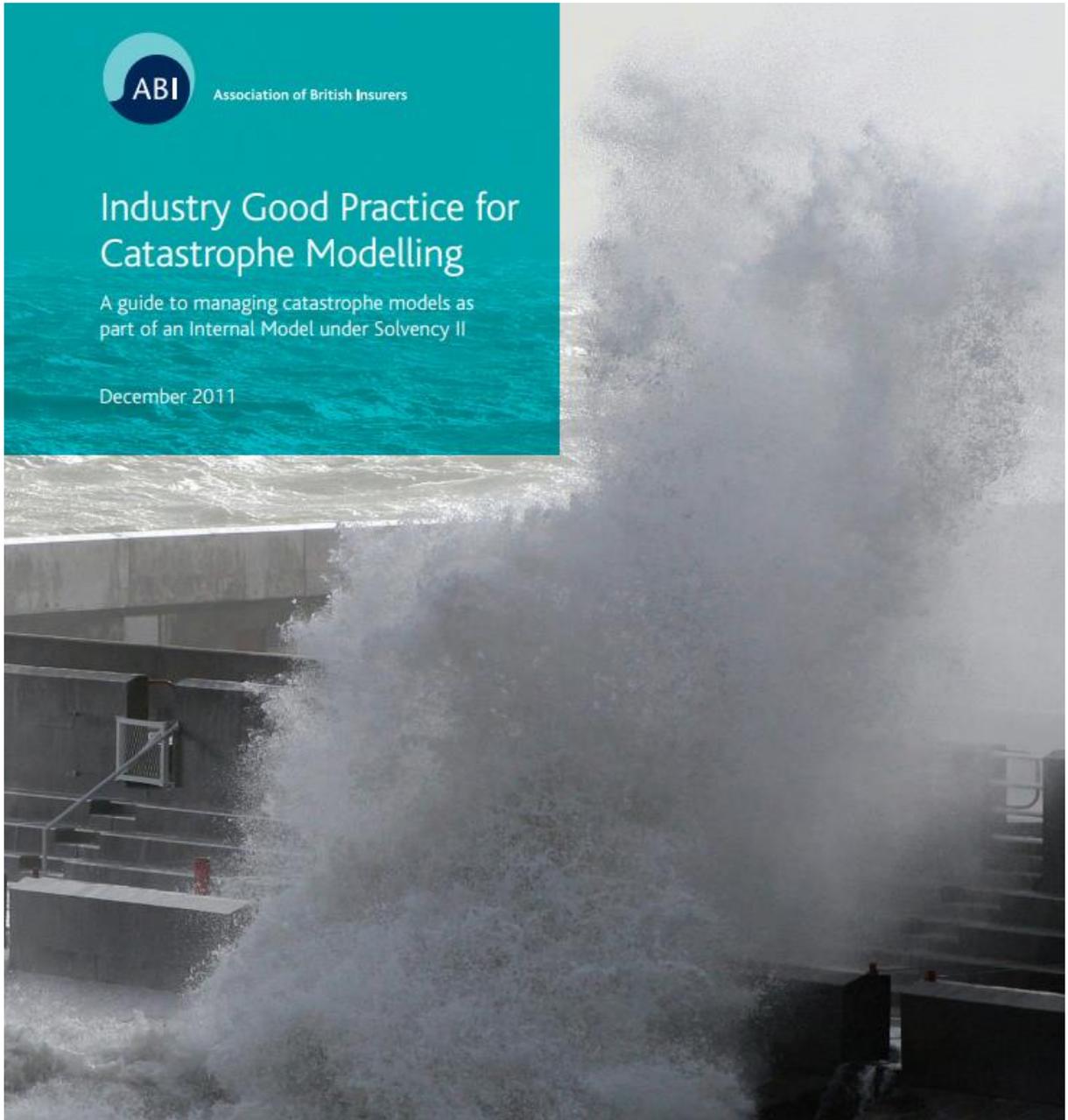


Table of Contents

Background	5
Good practice, not current practice	5
Who are the authors?	5
Publication date of this document	6
The limitations of this document as regulatory guidance	6
One size does not fit all	6
Which Solvency II material is referenced?	6
Notes on the text	7
Introduction	8
How to read this document.....	9
Section 1 – General principles	9
Section 2 – Operational principles.....	9
Section 3 – Technical principles	10
Nil desperandum	11
SECTION 1 – GENERAL PRINCIPLES	12
Chapter 1 Governance around catastrophe risk modelling	12
1.1 Introduction.....	12
1.2 Solvency II text.....	12
1.3 Senior management.....	13
1.4 Risk management team	15
1.5 Processes and controls	16
Chapter 2 The use of third-party service providers	17
2.1 Introduction.....	17
2.2 Solvency II text.....	17
2.3 Outsourcing policy.....	18
2.4 The outsourcing agreement	18
2.5 Catastrophe modelling functions that may be outsourced	20
2.6 Specific examples and considerations	21
Chapter 3 Catastrophe modelling documentation	22
3.1 Introduction.....	22
3.2 Solvency II text.....	22
3.3 The company's own documentation.....	22
3.4 Vendor documentation	25

SECTION 2 – OPERATIONAL PRINCIPLES	30
Chapter 4 Use and management of catastrophe models data	30
4.1 Introduction.....	30
4.2 Solvency II text.....	30
4.3 Key considerations	30
4.4 Business data.....	31
4.5 Model development data.....	36
4.6 Catastrophe modelling and Internal Models	37
4.7 Solvency II and data quality	38
4.8 Management of catastrophe data	38
Chapter 5 Model selection and model change policy.....	39
5.1 Introduction.....	39
5.2 Solvency II text.....	39
5.3 Model selection criteria.....	40
5.4 Changes in catastrophe model output	40
5.5 Timelines for adopting a new model version.....	41
5.6 Switching to a different catastrophe model	42
Chapter 6 Options and settings of catastrophe models	43
6.1 Introduction.....	43
6.2 Solvency II text.....	43
6.3 Definition of 'options' and 'settings'	43
6.4 Key considerations	44
6.5 Options	45
6.6 Settings	47
6.7 Using options and settings for sensitivity testing of exposure data	48
Chapter 7 Catastrophe model validation.....	49
7.1 Introduction.....	49
7.2 Solvency II text.....	49
7.3 Vendor validation and its limitations for Solvency II	50
7.4 Validation by the company	50
7.5 Documentation and process	52
7.6 The limitations on validations for individual companies	53

SECTION 3 - TECHNICAL CONSIDERATIONS	54
Chapter 8 Multi-modelling approaches	54
8.1 Introduction.....	54
8.2 Solvency II text	54
8.3 Current practice.....	54
8.4 Practical considerations	55
8.5 Multi-modelling techniques.....	55
8.6 Guidelines	56
8.7 Examples of typical approaches	57
Chapter 9 Treatment of uncertainty in catastrophe modelling output	59
9.1 Introduction.....	59
9.2 Uncertainty as a fundamental notion in catastrophe modelling	59
9.3 Companies' understanding of uncertainty in key loss estimates	60
9.4 Different sources of uncertainty in catastrophe modelling	61
9.5 The role of more accurate data and company processes in reducing overall uncertainty.....	63
9.6 Communicating modelling uncertainty to non-experts	64
9.7 Approaches for embedding catastrophe modelling uncertainty in a company's risk management function.....	64

Background

In July 2011, the UK Financial Services Authority (FSA) convened a meeting, in London, of representatives from insurers and reinsurers, reinsurance brokers and commercial catastrophe model vendors operating in the UK and other European Member States.

The purpose of the meeting was to consider ways of encouraging good practice amongst companies using catastrophe models as part of their supervisory authority-approved Internal Models under the impending Solvency II regime.

From that meeting emerged the idea of a document setting out 'industry good practice' for catastrophe modelling under Solvency II. The document would be written by professionals, for professionals. It would offer technical guidance and suggestions for companies seeking to 'implement Solvency II' for the catastrophe model component of their Internal Models, by describing industry good practice.

The result is this document.

The group members agreed to collaborate on drafting the technical content under the auspices and editorship of the Association of British Insurers (ABI); it is under this badge that this text is published. The views and opinions expressed here are those of the individual authors; not necessarily those of the authors' respective organisations.

The FSA was kept informed throughout the composition stage, but was not responsible for defining or drafting the document. Accordingly, this document does not amount to FSA guidance and does not necessarily represent the FSA's views on this topic.

Good practice, not current practice

The intention of the authors has been to consider what constitutes 'industry good practice' for catastrophe modelling within the framework of the Solvency II requirements, pertaining to the approval and use of an Internal Model.

Therefore, the authors have attempted to describe 'good' practice, rather than necessarily the 'current' practices in their own organisations or the wider market. One of the pleasures of this collaborative process for the authors has been realising how much they have to learn from each other. It is in the spirit of sharing their own challenges and aspirations that these thoughts about industry good practice are presented here.

Who are the authors?

The authors all work in areas more or less directly concerned with catastrophe modelling within their respective organisations. A full list of the authors, and their companies, can be found at the front of this document.

Publication date of this document

The world of Solvency II is still very much evolving, with the Directive's requirements not due to be finalised until late 2012. Readers should note, therefore, that the composition and editing of the technical content of this document concluded on **11th October 2011**.

Changes to Solvency II regulations or guidance since then are not taken into account.

The limitations of this document as regulatory guidance

Clearly, everything in this document represents only the collective opinion of the authors. As a group of industry practitioners, they do not have any formal or regulatory status.

Therefore, readers should always bear in mind that the content reflects a best attempt at guidance, based on the authors' own expertise and experience. It does not - in any way - represent the views of any regulatory authority, including the FSA, or any European statutory or regulatory body.

Adopting the suggestions here will not mean, or in any way imply, that an insurance or reinsurance undertaking is necessarily meeting regulatory requirements. Wherever there is any apparent inconsistency between the text of this document and the relevant Solvency II material, the latter must always be regarded as definitive.

In short, *companies need to comply with all legal requirements placed upon them by regulators*. Nothing in this document officially qualifies, limits or extends those requirements.

One size does not fit all

While the authors have done their best in this document to suggest what constitutes 'industry good practice', they are aware that every regulated entity is different, and will have different needs.

Therefore, readers should always test the relevance of these guidelines against the needs of their particular companies. In particular, what is 'proportionate and material' under Solvency II will greatly vary from company to company, and even within different parts of each company's insurance or reinsurance portfolio. A reasonable requirement for one company may not be appropriate for another, and vice versa.

Which Solvency II material is referenced?

The evolving nature of Solvency II is reflected in the available documentation. There is currently a welter of drafts, guidance notes and consultation papers, all in different stages of composition, publication and official adoption.

The authors were keen for this document to reflect, as closely as possible, the latest iteration of Solvency II guidance. The materials used as references during composition and editing were:

Level 1 – formally known as ‘The Solvency II Directive 2009/138/EC (Level 1)’, which was adopted by the European Parliament and the Council of Ministers and published in the Official Journal of the European Union in 2009.

As at November 2011, this is still the only official Solvency II text. However, the Directive has not yet been implemented. Therefore, the Level 1 document is still subject to revision, and can be considered ‘official, but not final’.

Level 2 – the consolidated draft Level 2 measures informally issued in February 2011, which are not official but represented the latest guidance available from the European Commission at the time of this document’s creation.

Level 3 – the pre-consultation paper for External Models and Data dated 10th August 2011; drafted by the European Insurance and Occupational Pensions Authority (EIOPA).

We strongly recommend that readers of this document refer to the latest Solvency II documentation when considering what the authors have written here. The reference documents cited above are available from the ABI.

Notes on the text

‘Company’

European insurance and reinsurance ventures come in many corporate forms, including mutuals, limited-liability companies and Lloyd’s Managing Agents. Solvency II texts refer to these entities captured by the new regime as ‘insurance and reinsurance undertakings’. This document uses the term ‘company’ throughout.

‘Catastrophe model vendor’

The term ‘catastrophe model vendor’ is used throughout this document to represent the *developer and supplier* of a catastrophe model.

Many companies use catastrophe models provided by vendors, or by reinsurance brokers. However, the principles here apply equally to companies that develop their own catastrophe models, in-house. In this case, the term ‘vendor’ would apply to the internal developer of the model.

Introduction

This document has been written to help insurance and reinsurance professionals understand the implications of Solvency II for the catastrophe modelling component of their company's (or client's) Internal Model. It also suggests business practices that the authors hope will make 'implementing Solvency II' in this area as smooth and efficient as possible.

Few people are likely to be reading a technical document like this one for pleasure. The authors assume, therefore, that most readers will fit the following description:

- you either work for, or are in some capacity assisting (for example as a broker, catastrophe model vendor or third-party service provider), an insurance or reinsurance company that needs to demonstrate compliance with the Solvency II requirements for an Internal Model
- for assessing the catastrophe element of their underwriting risk, the company has decided to use one or more catastrophe models, rather than utilising the Solvency II Standard Formula for catastrophe risk based on premium income
- you want to ensure the most efficient possible use of the company's resources in meeting the challenges of Solvency II for catastrophe modelling in this context

The last point is important. Given unlimited time, energy and funding, ensuring compliance with Solvency II would present few challenges. However, most industry professionals do not work in such a beneficent environment. The task is more likely to involve finding a way to meet the requirements – both now and in future – by leveraging the Solvency II principles in a way that benefits the 'business as usual' processes.

The hope of the authors is that - by adopting appropriate levels of what they consider to be industry good practice - insurance and reinsurance companies will find that they are meeting their Solvency II obligations for catastrophe modelling.

Finally, it is worth remembering that Solvency II does not seek to dictate exactly what companies should do. That is up to individual insurers and reinsurers. From the perspective of this document, the purpose of Solvency II is to ensure that:

- insurance and reinsurance companies have assessed, in a structured fashion and using a risk-based approach, the catastrophe risks they face
- there are appropriate processes in place to manage these risks, taking into account proportionality and materiality
- the processes are being followed and there is adequate evidence that they are

How to read this document

The document is divided into three sections, beginning with the general principles of Solvency II before moving on to operational and, finally, more technical subjects. Each chapter contains the relevant Solvency II text (*see Background*), except Chapter 9.

Section 1 – General principles

[Chapter 1 - Governance](#) describes the responsibilities of senior managers to understand a company's risk exposures, and the high-level controls and processes that should be in place to manage them.

The authors encourage everyone to read this Chapter, since it provides the framework for understanding everything that follows. The general principles established here apply to all other chapters.

[Chapter 2 - Third-party service providers](#) describes the principles governing the use of external service providers for catastrophe modelling under Solvency II. These include the requirements to have a formal outsourcing policy, a specific agreement for catastrophe modelling services to be separate from any other service provision (such as reinsurance broking), and the limitations on what can be outsourced.

This Chapter will be of interest primarily to companies who rely on a service provider for all or part of the catastrophe modelling in their Internal Model (e.g. a broker, catastrophe model vendor, or other service provider). It emphasises that companies cannot outsource their understanding of - or responsibility for - any part of the catastrophe modelling process: 'responsibility for all components of an Internal Model lie with the company itself.'

[Chapter 3 - Documentation](#) covers the requirement for companies to document every part of the catastrophe modelling process, including model selection, model validation and change management. It also describes some of the documentation that catastrophe model vendors provide.

As with Chapter 1 on governance, the authors recommend that everyone reads this Chapter. Documentation is the main way in which companies can (and must) provide evidence that they are following the governance principles in Chapter 1.

Section 2 – Operational principles

[Chapter 4 – Catastrophe model data](#) describes the data commonly used in catastrophe modelling, and how it differs from companies' other data requirements.

Managing data for the catastrophe model component of an Internal Model presents unique challenges. This Chapter assesses what comprises 'accurate, complete and appropriate' data – taking into account proportionality and materiality – and how to manage it.

[Chapter 5 – Model selection and model change](#) covers the process whereby companies consider, select and (when appropriate) change their catastrophe model(s). There needs to be a clear policy, and processes that are both robust and evidenced.

This is a significant new challenge presented by Solvency II. Many companies currently delegate the business of model selection and model change to technical specialists, either internally or to their service providers.

Under Solvency II, companies must be able to demonstrate that they have appropriate in-house understanding of model selection and model change, and that the processes for managing them are well defined, properly documented, and evidenced. This responsibility cannot be outsourced, or delegated away.

[Chapter 6 – Options and settings of catastrophe models](#) describes the process by which companies decide how catastrophe models are run to provide an appropriate view of risk. This includes understanding what choices are available, and deciding which ones matter when modelling particular sets of exposures.

For the purpose of this document, ‘options’ and ‘settings’ are defined as meaning different things, explained here. This may be helpful in distinguishing the different levels of decision-making a company faces, and how assessing proportionality and materiality help in this process.

[Chapter 7 – Catastrophe model validation](#) describes companies’ obligation to provide evidence that their catastrophe models are ‘validated and appropriate to their own portfolio, and if they are not comfortable with the level of validation, they must identify this as a weakness and remedy this according to company strategy.’

This represents another significant new challenge, and is another area where assessing proportionality and materiality is of primary importance.

Section 3 – Technical principles

[Chapter 8 – Multi-modelling approaches](#) describes why a company may choose to use more than one catastrophe model in relation to a particular peril and/or region, and some of the consequences of doing so under Solvency II.

There is no requirement under Solvency II to use multiple catastrophe models. This Chapter explores the benefits and challenges of multi-modelling. As always, a company must have a robust, documented, evidenced policy for making the decision to multi-model (or not), and for managing the process.

[Chapter 9 – Uncertainty in catastrophe modelling output](#) explains 'how companies may seek to understand, describe, and ultimately mitigate against the uncertainty that is invariably present in catastrophe models.'

Dealing with uncertainty in a defined and evidenced way is perhaps the most technically challenging of requirements for catastrophe modelling. This Chapter describes different types of uncertainty, how they may be considered in a structured way, and possible approaches to their mitigation.

Nil desperandum

The Solvency II requirements for catastrophe modelling as part of an Internal Model can seem dauntingly complex and demanding. Certainly, during the composition and editing of this document, the authors spent hours and days wrestling with the exact meaning of certain clauses, or trying to grasp the underlying intention of this or that general principle.

In the end, however, Solvency II is about routine good governance. There is nothing in the requirements that, ideally, companies should not all be doing anyway.

The process of understanding, selecting and using catastrophe models is sufficiently complex that the industry should welcome the clarity offered by Solvency II. The more certainty companies have about the processes they use, and why they use them, the more confident they can be that the inevitable – and irreducible – uncertainties of catastrophe models themselves are being managed as well as possible.

SECTION 1 – GENERAL PRINCIPLES

Chapter 1 Governance around catastrophe risk modelling

1.1 Introduction

To make informed and prompt risk management decisions, senior management must have a sound understanding of a company's risk exposure and its key drivers.

This Chapter examines good practice to ensure senior managers understand their obligations, how information can best be obtained and communicated among the senior management team, and some controls that can assist in this process.

These good practice recommendations apply if catastrophe risk represents a material portion of the company's insurance risk profile.

1.2 Solvency II text

The following articles from the Solvency II Level 1 text are particularly relevant to governance in this context:

Article 44 (paragraph 5) – Risk management

For insurance and reinsurance undertakings using a partial or full internal model approved in accordance with Articles 112 and 113, the risk-management function shall cover the following additional tasks:

- a) to design and implement the internal model*
- b) to test and validate the internal model*
- c) to document the internal model and any subsequent changes made to it*
- d) to analyse the performance of the internal model and to produce summary reports thereof*
- e) to inform the administrative, management or supervisory body about the performance of the internal model, suggesting areas needing improvement, and up-dating that body on the status of efforts to improve previously identified weaknesses.*

Article 116 (paragraph 2) – Responsibilities of the administrative, management or supervisory bodies

The administrative, management or supervisory body shall have responsibility for putting in place systems which ensure the internal model operates properly on a continuous basis.

Article 120 – Use test

Insurance and reinsurance undertakings shall demonstrate that the internal model is widely used in and plays an important role in their system of governance, referred to in Articles 41 to 50, in particular:

- a) *their risk-management system as laid down in Article 44 and their decision-making processes*
- b) *their economic and solvency capital assessment and allocation processes, including the assessment referred to in Article 45.*

In addition, insurance and reinsurance undertakings shall demonstrate that the frequency of calculation of the Solvency Capital Requirement using the internal model is consistent with the frequency with which they use their internal model for the other purposes covered by the first paragraph.

The administrative, management or supervisory body shall be responsible for ensuring the ongoing appropriateness of the design and operation of the internal model, and that the internal model continues to appropriately reflect the risk profile of the insurance and reinsurance undertakings concerned.

1.3 Senior management

To make proper and timely decisions on risk management issues, senior management must have an overall understanding of where the company is exposed to catastrophe risk, and what its key drivers are. This can be obtained through regular, transparent reports and presentations that highlight changes in exposure and modelling approach.

Examples include:

- exposure reports
- risk trigger reports
- peril-specific exceedance probability curves

An importance ranking of catastrophe scenarios should help senior management to focus on the most important perils and regions.

Senior management should:

- understand the strengths and weaknesses of catastrophe risk models
- be aware of potential gaps and quality differences in the company's catastrophe risk modelling landscape
- actively seek the levels of information and detail it needs to feel comfortable with taking decisions
- ensure that the proper policies and procedures for doing so are in place

At least one senior manager - for example, the Chief Risk Officer - should be responsible for keeping the rest of the senior management team informed and up to date.

Key 'catastrophe risk specialists' should have an overall understanding of the building blocks of stochastic catastrophe risk models, such as:

- event set
- hazard
- vulnerability
- financial module

These risk specialists should also understand the main challenges faced in developing each of these components for the perils that are most relevant to the company. This will inform their understanding of the purpose of the model, and help ensure that the modelling approach reflects the nature, scale and complexity of the risks inherent in the company's business.

Senior managers do not need to have the same level of knowledge about catastrophe risk models as the members of the catastrophe risk management team, but there should be regular, transparent and evidenced exchanges of information between the two groups.

Exactly how this knowledge is transferred between the catastrophe risk management team and senior management is up to the company, but could include, for example:

- management-level technical documentation
- seminars
- workshops

Senior management's overall understanding should include, for the areas relevant and material to the company, knowledge about:

- general principles of catastrophe modelling and building blocks of stochastic models
- key measures to define the company's risk appetite: the concept of return period (and, if relevant, Value at Risk – VaR – versus Tail Value at Risk –TVaR), occurrence exceedance probability and annual exceedance probability
- publicly available data about the company's exposures
- the catastrophe exposures modelled, areas and perils modelled, peak zones of exposures, lines of business (LOB) or products modelled and a view on variability of the models' results
- the catastrophe exposures *not* modelled:
 - identification of 'cold spots', and the reasons for them in terms of areas, perils, model limitations and data limitations
 - how the exposures are assessed
- expected near-term catastrophe model updates and a view on the most significant impacts expected
- sensitivity of the model results with regard to assumptions, parameter calibration, and the quality of underlying input data (portfolio information)

- a view of the models' limitations, including:
 - strengths and weaknesses of the models
 - possible divergence between the catastrophe model outputs and actual loss experience, due, for instance, to model limitations, data limitations and specificities of the risk profile
- how the risk management team gets comfort that the catastrophe model results appropriately reflect the risk profile of the company, such as testing results against experience or real-time event data
- data quality by region and perils, appropriateness, completeness and accuracy

This good practice document contains chapters on data handling and the treatment of uncertainty, as well as policies on model: selection; change; validation; and documentation - all of which should prove helpful in addressing the topics listed above.

1.4 Risk management team

The catastrophe risk management team – those responsible for maintaining, running, and evaluating the catastrophe risk models either in-house or through a third-party service provider such as a reinsurance broker – should be the provider of the information mentioned above.

The catastrophe risk management team, in co-ordination with the risk management function, should regularly review the company's approach to catastrophe risk modelling. They should do this especially for the most relevant perils to ensure that:

- the modelling approach continues to reflect the risks within the company
- adequate changes in the modelling approach are implemented as a result of changes in the scope or nature of the company's business, or any relevant change in the perception of the risk

(See also chapters on model selection (Chapter 5), model change (Chapter 5), and model validation policies (Chapter 7) in this good practice document)

In their training and education, the catastrophe risk management team should be made aware of the importance of data quality, how the results of their modelling may impact the company's Internal Model, and the relationships with other internal steering and risk management processes.

Responsibility for risk and processes should be clearly documented to ensure businesses are confident that the model continues to operate properly. The delegation of responsibilities should take into consideration the skills, experience and qualifications of individuals and teams and should provide for appropriate training and relevant knowledge sharing to maintain suitable skills.

1.5 Processes and controls

The controls in place should include a process for the escalation of issues arising.

There should be clear processes in place so that results from catastrophe risk models are used to inform decision-making and risk management. These might include, for example:

- pricing
- capital allocation
- accumulation control
- setting of risk appetite
- risk transfer mechanisms

Exactly how the results of catastrophe models are incorporated into a company's Internal Model for the determination of their Solvency Capital Requirement (SCR) – the regulatory capital that a company must hold under Solvency II – should be appropriately documented, including outlining the relevant internal auditing and control checks. The process and controls in place should ensure that the model outputs and the reports produced are consistent.

There should be processes in place in relation to model changes, be it an update of an existing model, or a change to a new model.

(See chapters on model change (Chapter 5), validation (Chapter 7), and documentation (Chapter 3) later in this good practice document)

Chapter 2 The use of third-party service providers

2.1 Introduction

Under Solvency II, responsibility for all components of an Internal Model lies with the company to whom its use is granted. This includes the catastrophe model component, and applies even when a company outsources catastrophe modelling to third-parties such as reinsurance brokers or catastrophe model vendors.

This Chapter explains the Solvency II obligations for companies that choose to outsource any functions linked to the catastrophe modelling component of their internal model.

These obligations – including responsibility for model selection, model validation, and model change management – *cannot* be outsourced or delegated, even if some of the actual functions are performed by third-party service providers. It is important to note that, in the context of Solvency II, outsourcing considerations also apply to functions performed outside of the individual company but that remain within the same group of companies.

2.2 Solvency II text

The following text is from the Solvency II Level 1 text and deals with the issues surrounding outsourcing:

Article 49 – Outsourcing

1. *Member States shall ensure that insurance and reinsurance undertakings remain fully responsible for discharging all of their obligations under this Directive when they outsource functions or any insurance or reinsurance activities.*
2. *Outsourcing of critical or important operational functions or activities shall not be undertaken in such a way as to lead to any of the following:*
 - a) *materially impairing the quality of the system of governance of the undertaking concerned*
 - b) *unduly increasing the operational risk*
 - c) *impairing the ability of the supervisory authorities to monitor the compliance of the undertaking with its obligations*
 - d) *undermining continuous and satisfactory service to policy holders.*
3. *Insurance and reinsurance undertakings shall, in a timely manner, notify the supervisory authorities prior to the outsourcing of critical or important functions or activities as well as of any subsequent material developments with respect to those functions or activities.*

2.3 Outsourcing policy

Under Solvency II, companies are obliged to demonstrate robust governance. The outsourcing of any function connected to a company's Internal Model under Solvency II is subject to such governance arrangements. Specifically, a company that outsources any function is expected to have a dedicated outsourcing policy. Any part of the catastrophe modelling process that may be outsourced to an external service provider must therefore be governed by the company's outsourcing policy.

In the context of catastrophe modelling provided by an external party, the outsourcing policy needs, specifically, to cover the following:

- the selection of a suitable service provider, ensuring that:
 - the service provider has the capacity and resources to perform the outsourced functions in a reliable, correct and punctual manner
 - no conflicts of interest exist that may affect the provision of the outsourced service
- the existence of a formal outsourcing agreement between the company and the service provider, specifically covering the rights and obligations of both the company and the service provider (*see The outsourcing agreement, below*)
- timely notification - to company management, legal and regulatory bodies - that a particular function is to be outsourced, including authorisation to use the nominated service provider and the terms of their specific outsourcing agreement
- provision that local data protection law is complied with under the terms of the outsourcing agreement. Specifically, this should govern information exchange between the company and service provider

In addition, the outsourcing policy should apply to both new and existing outsourcing agreements, meaning any pre-existing arrangement will be expected to be made Solvency II-compliant.

2.4 The outsourcing agreement

The outsourcing agreement is a legal contract between the company and service provider, and should describe the roles and responsibilities of both the service provider and the company.

An outsourcing agreement covering any aspect of catastrophe modelling work should cover the following points:

- a clear description of the receivables, timelines, deliverables, and legal responsibilities of the service provider under the agreement, detailing the responsibilities accepted by the service provider and those retained by the company

- the requirement of the service provider to comply with all applicable laws and any other guidelines designated by the company
- the company's ultimate ownership of the service provider's deliverable, including the company's ability to:
 - provide guidance to the service provider when performing the outsourced function
 - formally approve any assumptions made by the service provider in performing the outsourced function
- lines of communication between the company, service provider(s) and regulatory authorities, including:
 - confidentiality agreements between the service provider and company
 - the contractual obligation of the service provider to assist the company in all regulatory issues relating to the outsourced function, including, but not limited to:
 - direct access to the service provider by the regulatory authority
 - supervised on-site inspections of the service provider by the regulatory authority
- the performance measures agreed between the company and the service provider to ensure the provision of services as detailed above, such as the company conducting regular performance reviews with the service provider
- the obligation of the service provider to inform the company of any change in circumstances that could materially affect the provision of the service as agreed under the outsourcing agreement
- the contingency measures to be taken in the event of the service provider not meeting its performance criteria
- the procedures in place to ensure continuity of outsourcing to the company if termination of the outsourcing agreement is enacted by either the company or service provider, such that either changing service provider or discontinuing the outsourcing of this function (bringing the function in-house) should not materially affect the stability or integrity of the company's Internal Model
- the terms and conditions under which the service provider may itself outsource any aspect of the outsourced functions, including provision that the outsourcing of work by the service provider in no way affects the service provider's responsibilities as described in the outsourcing

2.4.1 Formulating an outsourcing agreement

The following may prove useful in formulating an outsourcing agreement to cover catastrophe modelling.

In general, under Solvency II, a company must be able to demonstrate that outsourcing any function in no way adds undue operational risk. In the case of catastrophe modelling, the company should demonstrate that outsourcing this work does not impede their ability to:

- maintain understanding and control of all aspects of their Internal Model
- allow the regulator to monitor their compliance with Solvency II obligations
- maintain the stability and integrity of their Internal Model
- demonstrate the ability to measure a service provider's performance
- demonstrate that their service provider has sufficient disaster recovery functions, such that the company's audit obligations, Internal Model, stability, and integrity, cannot be affected by failures of the service provider

Whatever controls are in place to ensure the service provider's performance, outsourcing the catastrophe modelling function does not allow a company to delegate the *responsibility* for any element of its Internal Model to the service provider.

2.5 Catastrophe modelling functions that may be outsourced

Whilst, technically, any aspect of catastrophe modelling may be outsourced, it is important to recognise that the ownership of the modelling process cannot be outsourced. When employing a service provider to perform any catastrophe modelling, responsibility for understanding the model - and key decisions on use and governance - remains with the company.

For example, *ownership* of the model selection (*covered in Chapter 5*) and model validation (*covered in Chapter 7*) processes must remain in-house, with input from third-party service providers where required. A clause in the outsourcing agreement could cover, for example, the circumstance under which a reinsurance broker acting as a service provider could employ a catastrophe modelling vendor to perform any aspect of the outsourcing work.

The following examples show stages of the catastrophe modelling processes that may be outsourced, either individually or in any combination:

- exposure data cleansing
- address geo-coding
- exposure data formatting
- exposure data entry into the catastrophe modelling software
- portfolio analysis within the catastrophe model
- use of catastrophe model output in other simulation tools

It is anticipated that, in most cases, these functions will have been outsourced to either reinsurance brokers or catastrophe model vendor consultancy groups. Reinsurance brokers may be using either licensed vendor models or their own in-house catastrophe models.

2.6 Specific examples and considerations

Under Solvency II, ultimate responsibility for any aspect of an Internal Model always remains with the company, even when components of the Model have been outsourced to third-party service providers. Therefore, recommendations in other chapters apply equally to the company and the service provider performing any function covered.

If an external model is used, the vendor should help the insurance company licensing their model to understand the data underlying the model, and the assumptions used. The greater the risk to the business, the more granular the understanding should be, subject to reasonable expectations of non-expert, third-party understanding.

It is crucial, therefore, for a company to understand the processes and workflow covering outsourced work. A thorough audit trail is essential.

Examples of key checks that could be in place might include:

- when outsourcing data cleansing, ensuring that exposure data from all business entities and underwriting units is included, where available (including agency business)
- when outsourcing stand-alone geo-coding functions, the company should understand address correction algorithms employed by the external service provider. For example, where a street address apparently mismatches a postal code or city, is the same street address in a 'corrected' city or postal code used, or is the risk located in a known city or postal code?
- the company should understand how and why its risk classification schemes are mapped to model-specific construction and occupancy codes, particularly where this may deviate from a purely semantic one-to-one mapping

It is recommended that the company's and service provider's audit trail includes the implementation of checks and balances at all stages of the catastrophe modelling process:

- before delivery of data to a third-party
- during the outsourced work at the service provider
- as part of the company's validation of the service provider's deliverable

Chapter 3 Catastrophe modelling documentation

3.1 Introduction

A company's obligation to document 'the design and operational details of the Internal Model' applies to the use of an external catastrophe model as part of its Internal Model.

This Chapter looks at two different types of documentation:

- the sections of a company's Internal Model documentation that covers the catastrophe model, in accordance with Article 125, pertaining to the Internal Model
- documentation that catastrophe model vendors may provide to help the company understand and use the catastrophe model

3.2 Solvency II text

The following is from the Solvency II Level 1 text and specifically references documentation standards:

Article 125 – Documentation standards

Insurance and reinsurance undertakings shall document the design and operational details of their internal model.

The documentation shall demonstrate compliance with Articles 120 to 124.

The documentation shall provide a detailed outline of the theory, assumptions, and mathematical and empirical bases underlying the internal model.

The documentation shall indicate any circumstances under which the internal model does not work effectively.

Insurance and reinsurance undertakings shall document all major changes to their internal model, as set out in Article 115.

3.3 The company's own documentation

For Solvency II, the company must 'own' their internal documentation in relation to the catastrophe model. Merely referencing the vendor's documentation or passing on information are unlikely to be considered adequate.

The company should document the design and operational details of the catastrophe model, and demonstrate compliance with Solvency II requirements for the Internal Model.

The documentation could be a suite of documents, provided that there is an index or clear reference system. Appropriate controls should be in place, for example, version control. Documentation must be kept up to date.

More than one level of documentation is likely to be needed to address the different audiences within the company, from the catastrophe risk specialists to senior management.

It is important that the documentation should be consistent with the intended use of the model, and its materiality and proportionality to the overall Internal Model.

3.3.1 Demonstrating understanding

The company's documentation should provide evidence of the processes followed to develop an appropriate understanding of the catastrophe model or models prior to selection, validation and use. This may include material such as:

- a list of documents provided by the vendor modelling company
- description of training and conferences attended by individuals within the company and relevant qualifications obtained
- records of meetings held between the company and the vendor modelling company, as well as descriptions of any additional support provided by the vendor modelling company

Actual documentation, e-mails, and any other form of written communication, as well as any training material provided by the vendor modelling company, may be subject to the specific licensing arrangements between the vendor modelling company and the company and/or their outsourced service providers.

3.3.2 Demonstrating operation

Important factors a company should take into account for Solvency II documentation may include the following topics:

- **Access to – and use of – catastrophe models**
The documentation should include a description of how the catastrophe model is being used, for example, through direct licensing, or through a service provider such as a broker or catastrophe model vendor. It should also include the process for ensuring and validating that the model has been used appropriately.
- **Use of a third-party service provider**
Where the company uses a third-party provider to operate the catastrophe model, or for related activities such as data cleansing, the Solvency II obligations for the purpose of an Internal Model remain with the company (*see Chapter 2*). The documentation should include the company outsourcing policy and the current service level agreement.

- **Use and management of catastrophe model data**

Documentation could include:

- a directory of the data used in the catastrophe model, specifying source, characteristics and usage
- a description of the processes for collecting and preparing the data, including a description and justification of any adjustment or correction made
- a description of the process for updating the data, and the frequency of updates
- an assessment of data quality
- an assessment of compliance with the company's data policy

- **Model selection**

The documentation should include the reason(s) for selecting a particular catastrophe model, and a list of the alternatives considered.

- **Model change**

The documentation should cover an assessment of changes to the catastrophe model, the effects of a change in an external catastrophe model to the Internal Model and evidence of the company's internal approval process.

- **Model validation**

The documentation should show why the selected model is valid for the business, and may include:

- a description of the process to validate the catastrophe model in accordance with the validation policy of the Internal Model
- a validation report
- a description of how the findings have been escalated and communicated in the company, and any decision or action taken

The validation may use documentation provided by the vendor or the service provider, but it should also reflect the company's own validation.

- **Model methodology**

The company may use documentation provided by the vendor or service provider, and it should include:

- an explanation of the basic components of the catastrophe model and how such components interrelate, focusing on the aspects and features of the model that are relevant to the particular risk profile of the company
- which fields of expertise were used in developing the model, and whether the model is based on generally accepted practices within the applicable fields of expertise
- a description and justification of the assumptions relevant to the particular risk profile of the company

- **Circumstances under which the catastrophe model may not work effectively**

The documentation may include:

- risks relevant to the company that are not covered by the catastrophe models
- an assessment of the nature, degree and sources of uncertainty
- the sensitivity of the results for the key assumptions
- any deficiency of data, or lack of data
- the limitations and risks of the underlying IT system used to support the functioning of the model

- **Governance around catastrophe modelling**

The documentation may include:

- policies, controls and procedures for managing the catastrophe model
- a description of how the catastrophe model is embedded in the business process
- a description of the role played by the catastrophe model in the decision-making process and risk management system as part of the use test
- a description of the relationship with vendors and other third-party providers

- **Use and management of outputs**

The documentation may include:

- an assessment of any potential inconsistency between the catastrophe model and the Internal Model, such as inconsistent assumptions or granularity of outputs, that can compromise the use of the catastrophe model as a source of data or parameters for the company's Internal Model
- a description of the process to integrate the catastrophe model output into the Internal Model
- an explanation and justification of any adjustments made to the outputs of the catastrophe model, such as loading factors
- blending procedures applied to catastrophe models within a multi-model framework and associated justification of weights

3.4 Vendor documentation

The purpose of vendor documentation is to give companies a sufficient level of understanding of the catastrophe model to help with model selection, usage and validation.

By their very nature, catastrophe models incorporate specialised knowledge outside the expertise of many of the people within a company who will use them. Vendor documentation helps a company to develop an appropriate level of understanding (*see 3.3.1*). The exact level of knowledge required will vary according to different functions within the company, and the proportionality and materiality of the catastrophe model component of the company's Internal Model.

Documentation, in this context, means any information the vendor provides to help companies understand its products, such as documents, websites, and seminars – not just words on a page.

3.4.1 Restrictions on vendor documentation

The Solvency II obligations to understand a catastrophe model, for the purpose of an Internal Model submission, rest squarely on the company itself.

It should be noted that Solvency II places no obligation on catastrophe model vendors to provide documentation, although many do provide a significant amount of information to their licensees.

Vendors are not obliged to provide documentation to non-licensees. However, where a company does not directly license a catastrophe model, and so has no direct access to vendor documentation or support, the company's obligation to document their use of the catastrophe model remains.

Finally, it should be noted that much detailed vendor documentation is subject to restricted distribution, including regulatory submissions. Unless special provisions apply, a company, whether or not a direct licensee, is not necessarily entitled to pass vendor catastrophe model documentation (including excerpts) to regulators.

3.4.2 Suggested content

In addition to helping the company understand, select and use a catastrophe model, vendor documentation can play a useful role in helping a company discharge the obligations created by the use of an external model in its Internal Model.

Therefore, although (*as noted in 3.4.1*) Solvency II places no obligation on vendors to provide documentation, it would be extremely helpful if vendors addressed some or all of the following:

- **Version control information**

Companies should know they are looking at current information. Therefore, where relevant, it is important to know the document's provenance and history, including version control, change history and author.

- **Model history**

Knowledge about the model and/or peril history provides perspective on how long it has been in existence, how many revisions it has undergone, and why.

- **Methodological approach**

Although a common 'language' is emerging for catastrophe modelling, each vendor employs its own modelling and statistical approach. A summary of the approach taken, including idiosyncrasies the vendor believes are particularly significant, is helpful. For example: 'Numerical weather prediction underpins our approach to European windstorm modelling.'

- **Validation**

This should explain the validation the vendor has performed on the model. Information could include: the validation approach, different tests and tools used (such as formal peer review and expert judgement) and an explanation of how the validation of the model is independent from its development (*See Chapter 7.3 for examples*).

- **Limitations and weaknesses**

Knowledge of the catastrophe model's limitations and weaknesses is important for its appropriate and effective use. For example, vulnerability curves tend to relate the percentage of a structure's replacement value that has been damaged to the severity of the hazard at that structure's location. These are calibrated to represent the average behaviour of a collection of structures and may not accurately represent the behaviour of a single structure.

Vendor documentation should also discuss the specific limitations of the particular catastrophe model (*see Chapter 7.3 for more examples*). These may include:

- limitations and weaknesses in modelling particular exposures
- weaknesses and assumptions in the financial calculations. For example, reinstatements or policy structures that cannot be modelled, and the means of accounting for this (if any)
- non-modelled perils or sub-perils such as tsunamis, landslides, or volcanic eruptions

- **Uncertainty**

Information about the nature, degree and sources of uncertainty should help identify circumstances under which the model may not perform effectively.

- **Geographical information, including geo-coding**
 This should be a list of areas and regions covered by the model, as well as particular regions not covered, such as off-flood plain areas (if relevant for a flood model). Other documentation may include levels of geographical resolution accepted by the model to geo-code the exposures data, as well as the related resolution of analysis of the geo-coded data.
- **Hazard information**
 This should explain how the particular physical peril is represented within the model. An example in a windstorm model could be three-second peak gusts versus 10-minute sustained winds. It may include a description of often-spatial information incorporated within the calculation of hazards, such as geological, hydrological, geomorphologic, soil, climate, land use, and anthropogenic parameters, and the data sources used.
- **Vulnerability information**
 This should explain how a particular hazard translates to the actual damage caused at specific geographical locations in the model, and describe how vulnerability curves are developed, together with the data sources and expertise utilised in this process.
- **Construction, occupancy, and LOB**
 These are lists of construction, occupancy and other risk-specific information - for example, roof type and age - accepted by the model, and containing sufficient detail in order for companies to relate their own exposure sets to the available options. This also applies to LOB and other exposure variables. Additional documentation on what impact the different available options may have on the risk assessment or model outputs is of interest.
- **Financial information**
 This should explain what policy and financial structures, including reinsurance, can be modelled and how such modelling may be carried out.
- **Options and settings**
 This documentation should list possible options and settings, and their meanings. The reason for any default or recommended settings should be made clear (*see Chapter 6*).

- **Access to and – and use of – system/software**
 The documentation should set any technical requirements and recommendations regarding the installation and use of the supporting system and software. There should be full database schemas, with each field explicitly identified.
- **Model change**
 This should identify and describe any changes made to the catastrophe model, identifying the main drivers of change and the impact on the output at industry level or benchmark portfolios, together with validation of the new model results.

SECTION 2 – OPERATIONAL PRINCIPLES

Chapter 4 Use and management of catastrophe models data

4.1 Introduction

Under Solvency II, catastrophe modelling and modelling data should reflect a company's risk profile and characteristics, so that those with greater catastrophe exposure have a more detailed understanding of the models being used.

This Chapter examines the specifics of catastrophe modelling data, common industry practices, and recommendations in relation to Solvency II and looks at the use of:

- catastrophe models (business data)
- developer building models (model development data)
- catastrophe modelling and a company's Internal Model

Data commonly used in catastrophe modelling can differ significantly from other areas of the insurance industry. A key challenge for companies using a catastrophe model is gathering accurate and detailed data about the risks insured, especially if it is supplied through third-parties, and is based on various databases and models.

4.2 Solvency II text

The following excerpt from the Solvency II Level 1 text is of particular relevance to catastrophe modelling data:

Article 121 (paragraph 3) - Statistical quality standards

Data used for the internal model shall be accurate, complete and appropriate. Insurance and reinsurance undertakings shall update the data sets used in the calculation of the probability distribution forecast at least annually.

4.3 Key considerations

Key points of consideration for companies using a catastrophe model include:

- understanding that the impact of data quality in the development and use of catastrophe models should be directly related to the materiality of the catastrophe-exposed business in comparison to the rest of the insurance portfolio
- the accuracy and appropriateness of catastrophe models is highly dependent on the data used to build the model
- any company using the models should try to get as accurate, complete and appropriate data to feed into the model as possible

- this activity should focus on the perils and geographic regions that present the greatest risks to the business
- monitoring in-house data quality regularly and having defined, accepted and manageable data standards is recommended good practice

4.4 Business data

Gathering detailed and accurate data on risks can be challenging for companies using a catastrophe model, especially if it is supplied by a third-party.

For building-related risks, characteristics including age and construction type, as well as the sums insured and any policy structures in place, are commonly captured.

For other risks, including life and workers' compensation, motor, aviation and marine risks, there are additional challenges related to the issues of time-variable value, location, as well as specific risk themes relevant to those types of risks and their vulnerability.

For catastrophe modelling focussing on property data, the issue of risk materiality is a primary consideration in terms of relative importance of particular exposure data attributes. Here, the relative materiality is influenced by the model design and calculation approach as well as the availability and ease of initial data collection.

Of particular relevance to many perils will be the geo-location of risks relative to the hazards being modelled. Other factors may include the limits and deductibles of the policy attaching to the location, as well as the specific characteristics of the catastrophe model. The company should be able to demonstrate awareness of the locations and characteristics that are likely to impact their loss results most significantly for their book of business.

Exposure data represents the risks taken by the company. For example, in relation to property risks:

- detailed location data:
 - sum insured
 - location address information
 - primary and secondary modifiers
- aggregate exposure data

Policy conditions typically contain the financial structure of the insurance contract. For example:

- deductibles
- limits
- shares/participation
- rate on line/premium
- reinstatements
- inception/expiry date

The third class of data used in insurance companies is operational data. Each contract could include information such as:

- broker
- underwriter name
- historical claims data
- premium in previous years

4.4.1 Using a third-party service provider

Companies using reinsurance brokers for their catastrophe modelling, or other outsourced service, should demonstrate knowledge of any data quality testing conducted by the broker, and any manipulations made to the data to improve either the accuracy, completeness or appropriateness, compared to the data provided by the original supplier.

4.4.2 Data accuracy

The company is responsible for deciding how to monitor and potentially improve data accuracy. There are several options for achieving this, including commercial tools. Companies should be aware: data that is complete but inaccurate can generate more risk than incomplete data.

Analytical tools and techniques adopted by the company can also highlight the characteristics and locations that have the biggest impact on the model output, through data quality scoring. However, it is important to note that this is only one way of checking data quality, and a more comprehensive approach would be to apply a range of data quality assessments that, taken together, provide a coherent assessment of spatial, temporal and thematic data quality relative to the company's portfolio and business processes.

4.4.3 Aggregate data

In some cases, aggregate data, where thematic attributes including value are combined and/or spatial resolution reduced, might be the most readily available, or appropriate data for use in modelling.

Reasons to use aggregate data could include situations where:

- no detailed model exists from the model vendor
- no detailed data is available from the client
- aggregate data provides a cross-territorial or cross-peril consistency of data quality
- the aggregate model is simply judged to be the best fit for the business being modelled

This reflects the general requirement for the data used to be of appropriate accuracy and precision for the model and its calibration. In many cases, the aggregate level of data supplied will dictate the most appropriate thematic (attribute) characteristics applied in the model. For example, if data is supplied at CRESTA level, certain policy or other conditions affecting absolute values may be inapplicable at aggregate level.

Aggregated data should be treated with a similar level of care as detailed data. Because of the data processing chain, which will have led to the final form of aggregate data being made available to the modeller, there are a number of common issues relating to aggregate data. An example of a common error could be where erroneous currencies and values are represented in multiples such as thousands but are interpreted as absolute values. Care should be taken to capture and refer to information reflecting a database's source, quality and construction when applying it for modelling or aggregate management.

4.4.4 More accurate data versus lower loss estimates

More complete or accurate data does not necessarily mean lower loss estimates.

The models often translate missing information into an average value for the relevant area, in order to produce a reasonable approximation of loss for the company. For example, an unknown construction type input by the company might be interpreted by the model as the average construction type in the city where the building is located. The impact of missing information on the loss estimates is model-dependent and needs to be understood by the people using the catastrophe model. Sensitivity testing of incomplete data is advised, with most appropriate tests likely to be specific to the model being used.

Those using the catastrophe model should also be aware of the connection between the modelled results and common underwriting practice. More uncertainty in the results in general implies a higher price, but may require a commensurately conservative view on capital allocation.

4.4.5 Check for accuracy

Often, it is difficult to check how accurate the information actually is. Examples of techniques to check and improve accuracy might include the use of:

- comparisons of a company's own data to industry databases, although it is important to understand the quality and provenance of the comparison dataset in order to ensure that appropriate benchmarking is carried out
- geo-browsers to check high value locations individually, although caution should be exercised when using secondary sources of information such as aerial or ground imagery, as interpretive mistakes can create additional error
- sense checks based on logical interdependency checks. For example, a 50-storey wood frame building is highly unlikely to be a correct representation of the actual construction
- more detailed validation rules based on additional knowledge of local conditions. For example, a location that conflicts with local building regulations or common construction practices is unlikely to be correct

- a strong audit trail and assigned 'data champions' to ensure that the data process pathways that manipulate and modify data are fully recorded and understood
- training for third-party providers of data, and close communication in-house between data stakeholders. Also, the use of third-party data augmentation tools to enhance company-provided data
- comparisons of recorded building valuation-to-valuation model results
- completeness and accuracy scoring metrics that are linked to catastrophe models and their outputs

4.4.6 Data appropriateness

Data quantity does not necessarily mean data quality. Quality refers to all aspects of accuracy, consistency and completeness.

Data relevance (a key attribute of appropriateness) is thus key to quality, and is dependent on the requirements of the model, which is, in turn, a function of the type of hazard being modelled and the method of calibration.

For example, address-level geo-coding accuracy might be of lower importance to modelled European wind exposure - depending on the model used - than to flood or earthquake risks. It is also important to know the resolution of the underlying model (for example, wind speed computed to a one-kilometre grid) compared with the resolution of the underlying exposure, in order to understand the impact of improvements in data quality on the accuracy of loss results.

Some primary modifiers might be critical for one peril, but be less relevant for another. There is a symbiotic relationship between the model itself and the data used. Demonstrating an understanding of such relationships helps build a robust case for any assumptions made in relation to the data.

The company using the catastrophe model should also be aware of how appropriate the data is for the task. For example, data could be accurate for a contract but out of date and may therefore not reflect the risk correctly anymore. Using data in inappropriate ways can lead to false confidence and be a risk to the business.

4.4.7 Data completeness

Nowadays, there is generally a drive to build more and more detailed location information into catastrophe models, and it can be quite difficult to check how complete the current data is.

Examples of queries in this regard (in relation to building risk) could be:

- what percentage of locations contains the full street address?
- how many buildings have number of storeys given?
- how many locations have unknown square footage?
- how old is the data collected?

The users of the catastrophe model should also consider if all sources of risk have been included, and work closely with external departments and underwriting units to ensure all appropriate data is captured.

A check for completeness of data could cover, for example:

- data from known exposures, such as instance data capture for LOB identified as exposed to catastrophe risk
- potential additional data that could be impacted by a catastrophe event, such as LOB that may be impacted

4.4.8 How to treat missing or incorrect data

If exposure data is missing or incorrect, which could mean, for example, an unknown occupancy type for a house or a location with high value missing from a schedule, then the company's reaction should be proportional to the potential risk posed. It is important, therefore, that the company understands the main risk areas to the business and the impact – on the modelled results – of missing information.

The company should have guidelines on how to handle data that the catastrophe model users deem to be potentially incorrect, and there should be clear responsibilities regarding the data control. The company should decide who is responsible for the data.

If it is not possible to receive updated, corrected data then several approaches can be taken. For example:

Missing data:

- reflect in the capture rate and potentially apply loading factors to the modelled results
- use industry information to estimate values

Incorrect data:

- try to find the correct values through external tools or databases, for example, geo-browsers such as Google Earth (subject to appropriate licence agreements)
- use conservative or mean values. For example, average number of storeys in the area and model using appropriate methods for that data quality
- sensitivity checks of the portfolio using the most or least conservative estimators

The proportionality principle should be applied when selecting the approach and may take into account how the specific data records and their representation of those risks could impact the overall result for the portfolio.

4.4.9 Reinsurance

Reinsurance poses specific challenges to data quality. Reinsurers often receive large amounts of data, including data that represents the property business of the insured cedant. Whilst a direct insurer has one portfolio of locations and contracts to maintain, a reinsurer potentially has hundreds of portfolios of varying levels of quality and provenance.

A reinsurer arguably has less ability to improve the accuracy of a cedant's portfolio, at least directly, but there are several ways of mitigating risk through potentially inaccurate data received. For example:

- conducting their own tests on data completeness and accuracy of the cedant's exposure data, including valuation
- using other sources to enhance data, where appropriate
- carrying out sensitivity testing on selected portfolios, in order to understand the impact of data quality issues
- reflecting data quality in the pricing decision and capital allocation
- working closely with brokers and clients to improve data quality

4.5 Model development data

Any company using a catastrophe model - whether developed in-house or externally - should be aware of the data sets employed in the construction, calibration and validation of that model and the process employed by the model developer, in order to make a quality assessment of the data.

The company should also be aware of any major adjustments made by the model developer in order to take into account changes in event probabilities or severities compared to the historical record. The level of knowledge required should be proportionate to the type of model, its application and the level of knowledge deemed appropriate to provide a reasonable level of confidence in the model and its construction.

As catastrophe models produce loss estimates based on the underlying data used during development, a model could potentially be inappropriate for a specific portfolio. For example, there may be no vulnerability curves provided for the modelled LOB.

Examples of data used for the development data might include:

- a catalogue of historical events
- historical event data and loss experience
- geographical data sets
- scientific research data

4.5.1 Materiality and proportionality

For both model developers and companies using the model, the materiality of the data is essential and the principal focus should always be on the most critical areas. For example, a company with a large exposure on the Florida coast with high hurricane risk, and another set of exposures in an area of significantly lower catastrophe risk, should focus first on improving the accuracy and completeness of the Florida-related data.

4.6 Catastrophe modelling and Internal Models

One major use of catastrophe models is in a company's Internal Model and, therefore, in the calculation of capital requirements.

For larger companies exposed to catastrophe risk, the catastrophe modelling function will often be separated from the capital modelling team, and data must be passed between the two. In other cases, the teams may be combined, or the catastrophe losses directly embedded inside the Internal Model.

Where data is passed from catastrophe modelling to the Internal Model, it is essential that there is good communication and agreed data standards between the relevant groups. The following questions should be answered and documented:

- how will catastrophe loss data be passed to the Internal Model (a common solution could be to pass event loss or year loss tables directly to the Internal Model)?
- which perils and territories are included in the catastrophe data?
- what is the level of detail included? For instance, by major business units or by LOB?
- what is the frequency of updates?
- what is the financial perspective from specific assumptions? For instance, on gross loss, or net loss?
- assumptions for a particular update:
 - what are the capture rates?
 - what currencies and rates have been used?
 - what is the source of the modelling (vendor model and version) and what are the options and settings applied?
 - have adjustment factors - loading or other - been applied?
 - what exposure point in time is captured?
- how is uncertainty around event losses captured, if at all?

The data format passed on between reporting periods should be consistent, if possible. Meta-data should also be produced, for example, in the form of a 'data dictionary' providing onwards use of that data with confidence; particularly where that data is combined with others from varying sources.

A feedback loop between the team operating and developing the Internal Model and the catastrophe modelling team is very important to ensure that the calculation applied to the catastrophe-modelled data (for instance, aggregation or attribution to major business) is consistent with the data provided.

4.7 Solvency II and data quality

Poor data quality will ultimately affect the results of the Internal Model, so companies should decide how to take incomplete data into account and justify the methods applied and assumptions made. One example could be scaling exposure to compensate for non-geo-coded data. There are several viable options to achieve appropriate modelling of gross exposures.

For example, the company could:

- decide to use 'percentage captured' based on premium income, and load catastrophe data accordingly, per peril
- use more sophisticated techniques, depending on the level of confidence in the existing data and its level of overall completeness

It is not likely to be possible to develop a single methodology and each company is responsible for understanding the method used and justifying the assumptions made.

It is good practice to monitor in-house data quality - most likely by client or account - on a regular basis, ensuring the process reflects key data manipulation stages and through defined roles within the organisation, with appropriate lines of communication and problem escalation.

For example, scoring an account's data quality on an annual basis would help to recognise improvements and allow a quick reaction if data standards should deteriorate for parts of the book.

A company with significant catastrophe exposure should have in-house data standard policies and standards of data exchange to ensure everyone in the modelling team treats data in a similar fashion.

4.8 Management of catastrophe data

A company should have documentation to describe how data is used in-house, so that a trained catastrophe modeller should, in principle, be able to reproduce the work done.

The following documentation is recommended:

- workflows describing how data is handled inside the company
- documents describing where data is stored and recovery procedures
- data quality analysis. For instance, data quality scores describing the judged quality of data received. For example, a high score for detailed US hurricane data on the reinsurance side and a lower score for aggregate data use in a minor peril
- documents providing guidelines on how to interpret data and how to handle missing or incorrect data
- a data policy that should also include the frequency of data updates for all relevant areas

Chapter 5 Model selection and model change policy

5.1 Introduction

Under Solvency II, companies must fully understand the catastrophe models they use. This applies to the initial selection of a catastrophe model, and the process of managing how changes in a catastrophe model are assessed and implemented within the company.

This Chapter describes how companies should manage model selection and model change under Solvency II.

As discussed in Chapter 2, companies' responsibilities apply regardless of whether they license catastrophe models directly from a vendor, or use the services of reinsurance brokers or other third-party service providers.

5.2 Solvency II text

The following articles and excerpts from articles in the Solvency II Level 1 text are relevant to this Chapter:

Article 126 – External models and data

The use of a model or data obtained from a third party shall not be considered to be a justification for exemption from any of the requirements for the internal model set out in articles 120 to 125.

Article 115 – Policy for changing the full and partial internal models

As part of the initial approval process of an internal model, the supervisory authorities shall approve the policy for changing the model of the insurance or reinsurance undertaking [...]

Article 121 (paragraph 2) – Statistical quality standards

The methods used to calculate the probability distribution forecast shall be based on adequate, applicable and relevant actuarial and statistical techniques [...]

The methods used to calculate the probability distribution forecast shall be based upon current and credible information and realistic assumptions.

Insurance and reinsurance undertakings shall be able to justify the assumptions underlying their internal model to the supervisory authorities.

Article 120 – Use test

[...] The administrative, management or supervisory body shall be responsible for ensuring the ongoing appropriateness of the design and operations of the internal model, and that the internal model continues to

appropriately reflect the risk profile of the insurance and reinsurance undertakings concerned.

5.3 Model selection criteria

The first criterion for selecting a catastrophe model or models is the materiality of risk exposure involved. Where there are high concentrations of exposure and risk, it is advisable to use a catastrophe model. However, some catastrophe models do not cover every peril in every part of the world, which may limit their use, depending on the business written by a particular company.

Secondly, catastrophe models may be available in both aggregate and detailed versions. The choice of one or the other should be proportionate, reflect the company's risk profile, and take into account the availability of exposure data on the risk a company insures.

Once a company has decided to use a catastrophe model, the following points may be relevant when choosing the most appropriate one:

- the adequacy of the model for the company's risk profile, including the company's ability to collect the appropriate data required in order to run the model effectively
- whether the model has passed an objective and unbiased validation process in line with the company's own validation process, which may include certain adjustments to the model to comply with the company's book of business
- the expertise and experience of the model developer
- the level of support and transparency the company receives as it develops an understanding of the theory and assumptions applied to the model
- the experience of the company's staff with both the model and its provider, either directly or through an outsourced service provider such as a reinsurance broker
- if licensed directly, the usability and fit within the company's workflow and business processes, and integration into their Internal Model
- an analysis of the strengths, weaknesses and limitations arising from the use of a particular model, as well as any potential restrictions to the on-going fulfilment of the Solvency II requirements

It is advisable to review the model selection criteria regularly, in order to ensure that it remains appropriate for the business. New information, such as a major event or new alternatives coming to the market, may also trigger a review of the model.

5.4 Changes in catastrophe model output

Catastrophe model developers frequently validate and update their models, and publish documentation on the scientific drivers of any change in output, and the impact at an industry level.

Catastrophe modellers need to bring the most up to date view of risk possible to their intended audience. New research or events such as the 2011 Japanese earthquake and tsunami, can reveal the potential for unexpected events, and lead to a shift in the perception of risk. Other changes are more incremental, such as annual updates to event rates.

The magnitude of change will vary by LOB and location, and it is difficult to predict the precise impact of a catastrophe model change on any individual portfolio without actually running the new model.

Companies, or their third-party service providers, may be able to conduct stress tests on catastrophe model output to determine what magnitude of change to the model output - and to which perils or regions - may have a significant impact on their risk profile.

Companies should be aware of model update plans in advance, so that they can start to react and adjust their view of risk before the model release. Model development companies are encouraged to give insight into upcoming model changes, and their potential impacts.

After release, companies should ensure that they understand the drivers of the model changes, either directly or through their service provider.

It is good practice for companies to develop an understanding of the model or models by:

- engaging with the developers
- asking questions
- studying the documentation and attending relevant conferences
- conducting their own validation processes either in-house or in partnership with an outsourced service provider, such as a reinsurance broker

5.5 Timelines for adopting a new model version

Developers will, from time to time, release updates to their catastrophe models as a result of:

- new scientific research
- learning from past events
- the release of new data

When this happens, companies using a catastrophe model should be familiar with the reasons for the update, the new information and data used, and how the vendor has validated the updated version of the model.

Companies should also allow for adjustments to vendor output. This means the impact of a single external catastrophe model change that can change an individual company's internal view of risk. Companies are expected to have suitable programmes in place to alter their Internal Models in light of changes to any of the component risks, including catastrophe.

Each company will have its own timelines for testing and developing the new model. Companies should consider the time of year when the new model is released relative to their own business processes, when deciding when to adopt the new version.

Upon receiving the updated model, companies will again go through their own validation process, taking into account proportionality and materiality. This may result in an updated set of adjustment factors. Unless the new version fails the company's own validation process, it may not be necessary to re-assess all the possible alternatives.

If the overall modelling process is systematised or semi-automated, there should be demonstration of a revision of the process when model version changes introduce new modifier codes for inputs, such as change to the applicability of insurance terms and conditions.

After completing the validation process, a company may find the previous model continues to be the most appropriate version for their business.

5.6 Switching to a different catastrophe model

When reviewing their catastrophe model or models, companies may decide to switch to a different model, possibly from a different provider. The decision can follow a validation or assessment process of the existing model, or other reasons that could include:

- adopting a consistent approach within a company or a group, especially following a merger or acquisition
- a more appropriate solution becomes available

Regardless of the model chosen, the company must always be able to explain the rationale behind their selection decision.

Chapter 6 Options and settings of catastrophe models

6.1 Introduction

Almost all catastrophe models have options and settings that allow their users to calibrate the outputs. Companies using a catastrophe model should have an appropriate level of familiarity with the available options and settings, and any vendor recommendations concerning their use.

This Chapter examines the various choices in the context of Solvency II including:

- the difference between 'options' and 'settings' in the context of this document
- how to ensure that options and settings are used appropriately
- examples of common choices, including:
 - replacement value versus sum insured
 - adjustment of results
 - geo-coding

6.2 Solvency II text

The following articles and excerpts from articles in the Solvency II Level 1 text are relevant to this Chapter.

Article 121 (paragraph 2) – Statistical quality standards

See Chapter 5 of this good practice document.

Article 121 (paragraph 4) – Statistical quality standards

[...] The internal model shall cover all of the material risks to which insurance and reinsurance undertakings are exposed. Internal models shall cover at least the risks set out in Article 101(4)

Article 121 (paragraph 5) – Statistical quality standards

As regards diversification effects, insurance and reinsurance undertakings may take account in their internal model of dependencies within and across risk categories, provided that supervisory authorities are satisfied that the system used for measuring those diversification effects is adequate.

6.3 Definition of 'options' and 'settings'

For the purpose of this document, 'options' and 'settings' are defined as follows:

- an '**option**' is defined as the choice a company makes when deciding how best to approach the overall modelling of its exposure. For example, whether to use detailed or aggregate modelling
- a '**setting**' is defined as a choice provided by the vendor modelling company that allows users to decide how a model is run. For example, ticking certain boxes in the analysis options at the time when the model is run

6.4 Key considerations

The use of individual options and settings may be highly interdependent, and all choices made in the modelling process should be regarded as part of a holistic modelling approach rather than the choice of individual and independent options or settings. This should be documented as part of the model validation and model selection policies and, when appropriate, for model change policies as well.

Those individuals within a company that have defined technical responsibilities for model use and interpretation under the risk management function should be aware of, and understand:

- the options and settings available for the territory and peril under consideration
- what causes of loss and risk processes these represent
- any recommendations made by the vendor modelling company regarding their use, the context of these recommendations in relation to the company's own risk profile, and any implications for loss results

The company can achieve this from documentation or through communication with their vendor or third-party responsible for outsourced catastrophe modelling, as well as by testing to understand the impact of the different choices.

6.4.1 Vendor recommendations

Where a vendor makes a clear recommendation for an option or setting, the company needs to understand this view and its applicability to their business.

A company may disagree with a vendor's recommendation, when applied to their own portfolio, and take a different view. In all cases, a company should be able to demonstrate the rationale for arriving at their decision on the settings used, and the validation process employed to validate the choice made. For example, a company might have their own view on the existence of demand surge for parts of their portfolio in a particular region, typically derived from their own claims experience, which may be different to the model's default options and/or settings.

Where the vendor company does not make any formal recommendations, an understanding of the use of a particular setting is fundamental to the company making an informed decision of whether it should be used, and when.

If a company does not license a model directly but obtains model output from a third-party such as a reinsurance broker, the above considerations still apply. Companies must decide which options and settings should be used by their third-party provider.

6.4.2 Ensuring choices are appropriate

Model developers produce their view of the risk posed by natural catastrophes based on combining knowledge of independent published research, their own research, and analysis of claims data (from both public and company-specific sources) to which they have access. Calibrating the catastrophe model, and validating from such data, results in an 'industry' view of the risk that might be different to the company's internal view of the risk; tailored to their business. It is important to understand the information used by the vendor in calibrating the model itself and the settings that the vendors have provided. This knowledge should enable companies to inform their own internal view of the risk and, hence, the agreed settings for reporting analysis results.

6.5 Options

Options are choices about the overall approach that a company may take to modelling all or part of its portfolio. These are likely to be concerned with the high-level characteristics of both the model and the portfolio.

6.5.1 Detailed versus aggregate modelling

Some data available to modellers may not be of sufficient resolution to be modelled in a detailed manner, and an aggregate model may be more appropriate. The principle of proportionality is often taken into account when deciding whether detailed modelling is essential for the final results of the modelling exercise. In some cases, where the company chooses to use a vendor model exposure database, adjustments to the results from aggregate models may need to be performed. An example could be where the assumptions used by the vendor model to compute aggregate losses are not completely correlated to the company's book of business.

6.5.2 Replacement value versus sum insured

Catastrophe models are often designed - and calibrated - under the assumption that replacement values will be used as an input into the model. For example, the sums insured that are available may effectively be limits, in which case they should be entered as such, and true replacement values sought or calculated independently.

6.5.3 Geo-coding options

Many geo-coding options are available, based on varying methods and source datasets. Vendor models allow for different levels of geo-coding and, in some instances, will have their own proprietary geo-coding databases, providing varying levels of geo-spatial resolution.

Companies using a catastrophe model may also want to consider alternative, third-party sources of geo-coding, where these can provide - in some cases - a higher geo-spatial resolution and additional information related to ambiguous geo-locations: for example, additional means to assess ambiguous address possibilities. The type, level and accuracy of geo-coding can have a large impact on the results, and due to the ambiguous nature of some geo-coding solutions, the choices made should be fully assessed and recorded.

6.5.4 Coding options

The term 'coding', in this context, is best described as choices that companies make when assigning appropriate construction and occupancy type attributes (among others) to the modelled risks. It is important to decide on the appropriate codes to best represent risks, particularly if this information is not clear and has to be deduced. The impact of coding options on loss results can be quite significant and it is, therefore, highly important that companies' coding choices are fully justified in relation to the available data and portfolio character.

6.5.5 Policy conditions

Policy conditions represent the provision of insurance terms that mitigate a company's loss exposure, such as deductibles and limits. Where possible, the most detailed policy conditions should be inputted to obtain the most accurate estimates of loss to the company. If the model being used does not represent certain policy or location-specific conditions in their entirety, or if the information provided to the company is not complete, assumptions can be applied based on knowledge of the portfolio. As with coding options, the company should justify this alternative approach.

6.5.6 Adjustment of results

The options for non-modelled perils and exposures are important towards obtaining a more comprehensive view of risk. For example, possible ways of accounting for non-modelled exposures may be by inflating country-wide exposures or by inflating modelled losses. Again, any decisions on model adjustment should be made with knowledge of model coverage, and limitations, to reduce the potential for double-counting or other errors of commission.

6.5.7 Types and use of loss results

Vendor catastrophe model results are frequently used as an input into capital modelling tools, and several options may be available in this regard. One way could be to include losses net of location terms, but gross of pre-layer terms and, therefore, model policy conditions in the Internal Model. Another option may be to use losses net of all policy conditions in the vendor model as input into the Internal Model.

Irrespective of the loss perspective output from the vendor model, assumptions on the loss output can then be made depending on the vendor model used. For example, the distribution of the number of events in a year, clustering of events (as typical in European winter storms), and distribution of events by month, can be investigated and altered if necessary. Decisions to expand the number of simulated years in the stochastic catalogue can also be made through re-simulation from the output of the catastrophe model. The reasoning behind any such actions should be explained and documented by the company.

6.6 Settings

Settings are choices - using box-ticking, switching or adjusting dials - provided by the vendor modelling companies and sometimes referred to as 'switches', which can affect modelled results.

Settings typically vary by peril or region, and also between different catastrophe model vendors. This can be confusing. Even for the same peril, settings can be referred to by different names. Furthermore, some settings may be present in some models but not in others, for example 'secondary uncertainty' and 'average properties'. Even if the settings are the same between different catastrophe model vendors, the recommendations for their use may vary. Companies need to understand how the settings in the analysis options have been developed, what they represent, and what information and data have been used in their derivation.

6.6.1 Analysis settings, which represent different sources of loss within a peril

Turning these on or off may add or remove the impact of these loss drivers to the overall portfolio loss. Some are common across multiple vendors. An example of a common category of settings is 'secondary perils.'

A 'secondary peril' may be fire-following-earthquake, sprinkler leakage, storm surge, precipitation-driven flood; or some form of loss inflation, such as demand surge, or post-event loss amplification.

The existence of these settings helps companies understand how much each of these factors contributes to their overall risk profile. Typically, companies should assess the potential of loss from all sources that the model vendor has provided, unless they can demonstrate their particular business is not at all exposed, such as through exclusions.

6.6.2 Alternative settings, aimed at providing alternative choices to the core model

A good example of this is the provision of alternative event-catalogues, reflecting the fact that risk can change with time. For hurricane risk, the main modelling companies provide a 'near/medium-term' or climate-conditioned view, to account for cycles and changes in hurricane frequency levels over time. This attempts to reflect the phenomenon known as non-stationarity in activity levels. Some vendors explicitly recommend this near-term view of North Atlantic Hurricane risk, whilst others do not offer an explicit recommendation.

Similarly, some vendors provide alternative earthquake catalogues reflecting 'time dependent' or 'time independent' views.

6.6.3 Settings to allow model sensitivity testing

An example of this would be settings used to vary the multiple ground-motion attenuation relationships released by the U.S. Geological Survey in 2008. Other sensitivity testing can cover varying correlation percentage in vendor models, where possible.

6.7 Using options and settings for sensitivity testing of exposure data

Apart from settings provided by vendor models, modifications to the company's exposure data can be made relatively easily for sensitivity testing. For example, loss results for a portfolio with unknown occupancies can be compared with loss results for the same portfolio where those unknown occupancies were set to a defined occupancy, such as commercial occupancy. Another example could be the setting of all secondary modifiers to 'unknown.'

Chapter 7 Catastrophe model validation

7.1 Introduction

Under Solvency II, a company must 'own' the validation of their external catastrophe models, regardless of whether they license them directly, or use brokers or third-party service providers to run them.

This Chapter examines good practice in model validation. Companies need to decide the most appropriate validation methods for themselves, considering their underlying business and the proportionality and materiality of the relevant risks.

There are two main types of catastrophe model validation:

- model vendor validation to ensure that results are appropriate for the specific peril at a country-wide level
- individual company validation that the model is suitable for its actual portfolio

Companies must provide evidence that their catastrophe models are validated and appropriate to their own portfolio, and if they are not comfortable with the level of validation, they should identify this as a weakness and remedy this according to company strategy.

7.2 Solvency II text

The following article from the Solvency II Level 1 text is relevant to this Chapter.

Article 124 – Validation standards

Insurance and reinsurance undertakings shall have a regular cycle of model validation which includes monitoring the performance of the internal model, reviewing the ongoing appropriateness of its specification, and testing its results against experience.

The model validation process shall include an effective statistical process for validating the internal model which enables the insurance and reinsurance undertakings to demonstrate to their supervisory authorities that the resulting capital requirements are appropriate.

The statistical methods applied shall test the appropriateness of the probability distribution forecast compared not only to loss experience but also to all material new data and information relating thereto.

The model validation process shall include an analysis of the stability of the internal model and in particular the testing of the sensitivity of the results of the internal model to changes in key underlying assumptions. It shall also include an assessment of the accuracy, completeness and appropriateness of the data used by the internal model.

Companies must apply the above requirements to any third party models, as required by Article 126 in the Solvency II Level 1 text.

7.3 Vendor validation and its limitations for Solvency II

Companies must ensure they have confidence in the model validation undertaken by model vendors, and demonstrate an awareness of the methods used in this process.

The willingness of the vendors to share knowledge on how they have validated the models is extremely important. Companies can face potentially significant challenges when trying to validate catastrophe models due to the proprietary nature of some catastrophe modelling components. Ideally, vendors should provide enough information about their models to ensure all licensees can gain the required level of confidence in the strengths and limitations of the models. However (see 3.4.1), they are typically not *obliged* to do so.

Vendors traditionally use a variety of sources of information to validate and calibrate their model. Their documentation may include information on model components as well as the total output from the model, such as:

- validation of model event frequency rates: for example, relative to the known historical catalogue, and any adjusted event catalogues to account for time-dependency or non-stationarity in the historical record
- validation of the hazard model: for example, through reconstruction of historical event footprints where possible
- evidence of scientific basis used to determine physical conditions of events such as wind speed, wind tracks, and climate science
- use of claims data to validate vulnerability
- use of historical market-wide data to validate the overall model against wider industry losses
- expert judgement and independent peer review of whether individual components and whole model outputs - particularly at longer return periods and in the absence of historical information - are robust and sensible
- application of policy conditions
- documentation validating changes to the model calibration and output, together with an explanation of why these are necessary
- known model limitations, covered perils, and known sources of non-modelled losses
- data sources used in the model development

7.4 Validation by the company

A company must validate the appropriateness of the catastrophe model to their portfolio. The validation process requires a detailed understanding of the company's own data and how the catastrophe model or models have

been built. It should also consider what the model does not allow for, and use sensitivity testing to support the validation process.

Companies may have past claims data that can be used to help validate high-frequency catastrophe losses, but for low-frequency events, they should ensure they are comfortable with the vendor's model validation, potentially using a variety of models and expert judgement.

The following paragraphs list types of validation that can be carried out. These lists are not exhaustive, and the most appropriate choice of tests will vary for each company based on the underlying portfolio and proportionality and materiality of the risks to which the company is exposed.

7.4.1 Data validation

The company should be able to validate that the exposure data used in the models is representative of their actual exposures. This can be done through the use of reports (supported by appropriate governance) that describe the exposures used in the models.

Where a company relies on exposure data provided by third-parties - for example, industry exposure and loss-curves provided by model vendors - they should ensure that this data is validated against any appropriate historic losses. Where historic loss information is unavailable, the company should have a process for agreeing the use of these curves, for perils based on the materiality of the risk.

7.4.2 Model validation

A company must gain an appropriate understanding of how the model applies to their own portfolio, which may require investigating one or more of the model's modules, such as hazard, data handling, vulnerability and the financial module. These tests should be pre-defined and also include basic hazard testing such as Annual Average Loss (loss cost) maps, and performance regarding historical key events.

Companies should compare the quality of their own data to the key data items required by the model. For example:

- validation of selected distribution of exposure data where no location is given: for example, country-wide values
- unknown or limited exposure data versus vendor model industry data or market data
- unknown secondary modifier data – so, using vendor view on LOB, structure type, and occupancy

Companies should understand how the model has been built to ensure it is appropriate for their portfolio. For example:

- the materiality of the peril to the company's business
- LOB that are allowed for in the catastrophe model

Where available, companies should use their own claims data to validate the catastrophe model output for high-frequency catastrophe events. For example, what perils does the model cover? Is it tsunami following earthquake?

Other questions that may be addressed include:

- data handling with respect to aggregation or disaggregation
- ex-ante and ex-post testing, where major change drivers should be identified

7.4.3 Sensitivity tests

A number of sensitivity tests can be carried out, although companies should be careful not to under-estimate the resource-heavy and data-intensive nature of much sensitivity testing. Tests might include:

- varying the granularity of data used: for example aggregate versus detailed (yet only to the degree of available portfolio data)
- testing if the available geographical data resolution is adequately reflected in the model
- reviewing the impact of the various options and settings such as loss amplification in the model, and the validity for the portfolio being modelled versus vendor guidance
- results from different vendor models, if available: either in-house or through a third-party such as reinsurance broker. Companies should bear in mind the use of catastrophe results from multiple models as different models may better represent events in different parts of the curve
- reconciling changes in year-on-year model results by identifying changes due to their own portfolio, and those due to the model

7.4.4 Non-modelled perils and biases

Model validation will highlight to companies any areas where the model may not be adequate for their risk, for example: non-modelled perils, coverage, exposure data, model biases, and planned portfolio changes. The company should decide the most appropriate way to deal with any validation issues taking into account the uncertainty, materiality and proportionality of the relevant risks.

7.5 Documentation and process

Companies should fully document the validation process, and clearly demonstrate the reasoning behind why they feel that the model they have chosen is appropriate for their business portfolio. Companies should be able to demonstrate the independence and impartiality of the validation process, and prove that robust challenge exists in relation to the validation of the model. The uncertainty in the model, limitations and required future developments should also be documented.

Companies would also be expected to clearly set out the frequency of model validation, and allow for modifications when a vendor releases a new version. There should also be a clear internal governance procedure to ensure model validation is appropriate.

7.6 The limitations on validations for individual companies

Catastrophe models are predominantly required by insurance and reinsurance companies to estimate extreme natural catastrophe losses, because they do not have past data to model the risk adequately.

To simulate extreme losses, catastrophe modelling vendors employ significant scientific expertise and build models to recreate the underlying physical processes. However, there is a limit to how far an individual company can validate low-frequency, high-severity events without replicating the scientific knowledge required to build the original model. For extreme events, companies should focus on satisfying themselves that the validation undertaken by vendors is robust, and consistent with currently accepted scientific knowledge. However, key assumptions and methods should be understood and documented.

SECTION 3 - TECHNICAL CONSIDERATIONS

Chapter 8 Multi-modelling approaches

8.1 Introduction

Under Solvency II, companies may use one or more catastrophe model(s) to produce parameters for input into their Internal Models. Companies are required to explain why they might consider the use of external models or information preferable to internal ones, to list the alternatives considered, and to explain why they have chosen a particular external model or data.

This Chapter addresses the needs and obligations of companies that are using – or thinking about using – multiple catastrophe models.

Provided that companies meet their obligations, there is no requirement under Solvency II to use more than one catastrophe model in order to derive the relevant parameters. The overriding consideration is for the company to form their own view of their catastrophe risk, using whatever methods are appropriate for the portfolio and business. This may be a single model or a multi-model approach. *There is no single correct approach.*

8.2 Solvency II text

The following article from the Solvency II Level 1 text is relevant to this Chapter.

Article 121 (paragraph 2) – Statistical quality standards (see Chapter 5)

Also relevant, is the following text from the Committee of European Insurance and Occupational Supervisors' (CEIOPS) Advice for Level 2 Implementing Measures on Solvency II: Articles 120 to 126, Tests and Standards for Internal Model Approval (former consultation paper CP56):

10.20. Undertakings shall be also able to explain the reasons for preferring external models or data to internal ones. They shall also be able to list the alternatives considered and explain the decision for a particular external model or data.

8.3 Current practice

In the insurance industry, it is common – but by no means universal – practice for companies to run several catastrophe models for a given portfolio. This has arisen partly through reinsurance brokers providing results from all available models, including their own proprietary models; partly through companies who licence one model wanting a second opinion on their risks.

There are two main reasons for this practice: (1) model benchmarking; and (2) blending results from different models.

For model benchmarking, output from the second, third or even fourth model can be used to calibrate the output from the first model. In this case, the additional results are not used further in the business process. Demonstrating that some kind of model comparison has been carried out may allay regulatory concerns about over-reliance on a single external model, although this is not a requirement.

In terms of blending results, companies may seek to combine two or more model outputs into a single output: that is, actual multi-modelling.

However multi-models are being used, the process should continue to follow good practice on model selection (*covered in Chapter 5*) and model validation (*covered in Chapter 7*).

8.4 Practical considerations

There are a number of practical considerations for companies selecting and using multiple models, including:

- ensuring that output selected from the range of multiple models should not be used to cherry-pick a commercially desirable outcome
- the cost of ownership and resource requirements for multiple model runs

Although a number of reinsurance brokers do provide modelling output, it should be recognised that some companies will have difficulty accessing multiple models and, therefore, may not be able to make informed choices between models as required.

Additionally, there are consequences for applying the use and validation tests, and some potential incompatibility with rating agency approaches.

The use of multiple models is sometimes seen as one way to reduce uncertainty by providing several informed estimates of loss, though it can be better seen as a way to reduce the risk of model incompleteness or bias. However, if the models represent risk poorly, then the use of multiple models can compound this risk or lead to a lesser understanding of uncertainty. In CEIOPS' documentation, there is concern that external models or data can cause deficiencies in the Internal Model, or actually increase the risk that a company assumes.

8.5 Multi-modelling techniques

For a company that has decided to use multiple model output, there are a variety of approaches available. For example:

- a simple comparison of the alternative outputs
- blended use of output to form a bespoke loss probability distribution

These approaches may vary across the company. For example, in some cases, a single model might be used for underwriting and portfolio management, but several models could be used for capital management.

The term 'multi-modelling' necessarily implies use of more than one catastrophe model. It also covers processes using both a standard output from a single model and a *variation* of that output. For example, recalibrating the output of a catastrophe model to specific entity loss experience, or loadings for model incompleteness, could both be termed 'multi-modelling'.

8.6 Guidelines

The following guidelines may assist companies using, or thinking of using, multiple models:

- the objective should be to produce an independent view of risk, specific to the company's own portfolio
- materiality and proportionality are important, and it is appropriate for the key catastrophe risk in a portfolio to be modelled, even if the remainder of the portfolio is not. However, this multiple model output could be used as a benchmark - not necessarily as a combined output - if the comparison process is clearly documented
- the choice of single or multiple models used as inputs to the independent view of catastrophe risk should be closely related to good practice on model validation and model selection
- it may be useful for the company to describe the circumstances in which they feel it may be necessary to look at more than one model to help calculate their SCR
- the company should show that they are aware of the available alternative models
- if multiple model outputs are to be used in combination, the company should document both their own understanding of the individual models used and the process used to blend or combine their outputs
- if a second (or third or fourth) model is used as a benchmark, the company should ensure that the model selection good practice guidelines (*see Chapter 5*) are followed and documented clearly
- documentation should set out the criteria used to select the models (*see Chapter 3.3*); these criteria should, in turn, be used to set out the methods used to combine the model outputs, in terms of choice of weights, blending method, selection of data such as loss experience or other scientific data. This should also demonstrate the fundamental compatibility of the models used
- exposure data consistency is important across the models used, and the method used to capture and report exposure data should be demonstrated to be appropriate to all models used

- model set-up should be consistent, where possible. For example, treatment of unrecognised data, any methods used for disaggregation of exposure data, or where there are differences, such as different approaches to economic demand surge. These should be documented in the model blending methodology with reasons given for the differences
- process management should be consistent across the models used; the same level of checks and review applied to the data, model imports and model output
- when selecting weights, companies should use technical considerations based on an understanding of the underlying models, breaking them down by module and component and supplemented by wider considerations, such as:
 - age
 - type and frequency of model revision
 - vendor documentation
 - external scrutiny – for example, peer review
 - ranking of output
 - risk appetite

8.7 Examples of typical approaches

The following is a range of approaches that could be taken by companies using multi-modelling:

- **single model with assumptions and/or data** – assumptions and data should be shown to be appropriate for the portfolio and the model
- **simple weights, common approach** - this can use a weighted average of model outputs, although it assumes that the underlying models are calibrated to the same extent at the stage of model output. The choice of weights is based on high level assumptions, rather than model detail, and weights can be applied to the output severity distributions or the frequency distributions
- **simple weights, alternative approach** - this is based on event loss table data and applies weights to the event rates. Simulation methods can be used to take account of models with year loss tables. This approach preserves event sets with physical events and footprints, and is a probability-weighted model that can enable correlation between portfolios
- **model decomposition** - this approach weights different components of models differently, which can help with sensitivity testing of specific components and take advantage of the perceived specific strengths of different models. A blended model run might include per portfolio or country marginals, such as a blend of models with other adjustments and loss calibration, correlations between countries, and clustering

- **variable weight blending** - this isolates a component of a model and applies a distribution of weights. For example, a revised event rate distribution that gives model A the same event relationship as model B, and can be based on vintage of data, and new research
- **'shoehorning'** refers to the need to incorporate output from two or more models in an accumulation or dynamic financial analysis platform, based on the format of output from one model. It takes account of grouping across different models appropriate for different portfolios, where the portfolios cannot all be run in the same model

This uses transformation functions that return losses with the same return period from the multiple models and applies a distribution to enable the event loss table from one model to give the results in the same format as another. For example, this can be used where the model selected for scientific credibility does not enable policy terms and conditions to be applied correctly, and the output from the first model can be run with those applied in the second. The transformation function can be statistical or physical, or based on a proxy portfolio.

Chapter 9 Treatment of uncertainty in catastrophe modelling output

9.1 Introduction

Under Solvency II, companies should be able to demonstrate a reasonable understanding of uncertainty and the sources of uncertainty associated with catastrophe models. In particular, companies must understand the effect that modelled uncertainty may have on their Internal Model and how capital is assessed.

This Chapter describes how companies may seek to understand, describe, and ultimately mitigate against uncertainty that is present in catastrophe models.

The following topics are considered:

- uncertainty as a fundamental notion in catastrophe modelling
- companies' understanding of implications of uncertainty in key loss estimates
- different sources of uncertainty in catastrophe modelling
- the role of more accurate data and company processes in reducing overall uncertainty
- communicating modelling uncertainty to non-experts
- approaches for embedding catastrophe modelling uncertainty in the risk management function of companies

9.2 Uncertainty as a fundamental notion in catastrophe modelling

Uncertainty can be described as the imperfect knowledge of a process or system and is a natural consequence of any complex process such as natural or anthropogenic hazards.

This means that 'prediction' of events is impossible.

Uncertainty underpins the concepts of probabilistic and stochastic modelling and, if properly understood, is a positive factor in improving risk assessment above and beyond deterministic approaches. All risk assessment is inherently uncertain, and catastrophe models provide methods to treat risk uncertainty through stochastic means. As such, models are a useful way of characterising the type of high-severity, low-frequency events that may not exist in a company's own claim history.

While catastrophe model vendors try to reduce uncertainty in their models, these models themselves are simplifications of complex physical phenomena. This simplification, the sparsity of data, and incomplete understanding, may introduce material sources of uncertainty into the models. It is important to understand that although some of the uncertainty in the modelled results are characterised in current catastrophe models, many sources of uncertainty are not fully represented or understood. As

such, relying on the results without reference to the uncertainties, can lead to a material misrepresentation of risk.

This is particularly relevant in Solvency II, where catastrophe risk is a material risk that may be measured by a company's Internal Model.

These uncertainties about how well the model reflects reality can introduce bias, where the systematic skewing of results is not representative of the portfolio being considered. Companies should seek to identify material biases that may exist in how the model adequately represents their portfolio. Subject to appropriate governance, modelled results should be adjusted to minimise any identified biases.

9.3 Companies' understanding of uncertainty in key loss estimates

Typically, uncertainty is handled in the stochastic event set and resultant exceedance probability (EP) curve, where the EP curve represents the range of losses that could be experienced for the modelled peril. It is important to note that when looking at a single point in an EP curve, uncertainty becomes significant; probably more so than might be imagined.

It is critical that companies resist pressure to focus on individual points on the EP curve as this encourages optimisation of portfolios around weaknesses in the model.

Biases relate to systematic mis-statements of the risk by a model, and are of particular concern where only one model is used in all risk management decisions. For example, a company may use one model, without reference to additional risk measures, for all risk decisions from pricing to capital management. That model may understate vulnerability of an occupancy type as no claims data is available, and frequency of events in a location as there are limited observational records in the area.

As the model may favour these occupancy types or regions, there is a reasonable likelihood the resultant portfolio is skewed towards accounts with these characteristics. If the same model is then used to assess the amount of reinsurance to purchase, these deficiencies will not be identified, and the suggested level of reinsurance protection may be inadequate.

Typical sources of bias include:

- non-modelled perils, coverages and LOB
- by geography
- by peril
- as a consequence of building characteristics
- financial policy structure

9.4 Different sources of uncertainty in catastrophe modelling

There are three broad classes of uncertainty:

- uncertainty that is inherent in any model
- known uncertainty in the model
- unknown uncertainty in the model

9.4.1 Types of uncertainty

'**Aleatory uncertainty**' refers to inherent uncertainty due to the random nature of a physical or financial process such as a fault that generates earthquakes on average once every 10 years. This means that even if the physical nature of the fault is perfectly understood, it will still not be possible to predict when the next earthquake will occur. This uncertainty is also found in the apparent randomness in damage suffered by similar properties exposed to the same level of hazard.

'**Epistemic uncertainty**' arises as a result of an incomplete or inaccurate knowledge of the underlying system or process. A range of equations and parameters may be thought to describe a physical process; however science has not evolved sufficiently to know for sure. As the understanding of physical processes increases and more empirical data becomes available, epistemic uncertainty might be expected to reduce.

Catastrophe models often also describe uncertainty in terms of primary and secondary uncertainty, although this is not the case for all models:

'**Primary uncertainty**' relates to uncertainties in defining event and hazard characteristics. These are typically epistemic and arise from a lack of understanding, so are difficult to measure. As this uncertainty affects the event or hazard, it is often heavily correlated across an entire portfolio. For example, if event frequency is incorrect by a factor of two, losses may double.

'**Secondary uncertainty**' relates to the uncertainty in loss given that an event has occurred. Typically, this relates to the precise local intensity of the hazard, and the vulnerability of a property to this hazard. As much of this uncertainty is random (aleatory) in nature, it is not heavily correlated within a portfolio, and as such, does not introduce a significant amount of variation in loss results. Most of the uncertainty represented in the modelled results is secondary uncertainty.

9.4.2 Uncertainty within the catastrophe model

Uncertainties within catastrophe models can be divided into a number of categories, including:

- event generation
- local intensity
- vulnerability
- exposure
- financial modules

9.4.3 Parameter uncertainty

There is uncertainty in the parameterisation of probability distributions used to build the stochastic catalogue and in the choice of the model used to represent the process. There is also uncertainty in whether the size of the stochastic event set wholly accounts for the uncertainties present in the expected realisation of the modelled hazard. In addition, uncertainty in past data due to implied deficiencies in the historic record, and under-reporting of both small events as well as significant events manifests itself in recorded history. Therefore, both tails of the probability distribution, and thus the parameters that govern the distribution, are affected by this deficiency.

To address parameter uncertainty, multiple sources of data may be used, supplemented with geo-physical data such as GPS observations, where available. In addition, historical data may be non-stationary; that is, the record of a time-varying process such as water height or wind speed is affected over time by shifts in the measurement baseline.

9.4.4 Model uncertainty

Model uncertainty refers to, for example, the use of multiple catalogues for certain models, such as the standard and climate-conditioned catalogues for the US hurricane model.

Uncertainty is also associated with the structural damage to physical risks, locations and facilities. Secondary uncertainty incorporates sources such as variations in model choice, intrinsic variability in damage given that an event has occurred, and uncertainty in the exposure data provided by the company.

Uncertainty may exist in the local intensity - for example ground motion or wind speed - of an event at a given location. Depending on underlying assumptions, parameters, and data used, different equations - alternative models - for calculating local intensity are possible, and the choice of which model or models to use is a source of secondary uncertainty; that is, uncertainty in the size of the loss. This is related to variabilities in potential loss to specific risks from a given event magnitude, from both aleatory and epistemic sources.

9.4.5 Vulnerability module

This secondary uncertainty is captured within the vulnerability module, which translates local intensity to building performance or other response to the damage-causing event. Because actual damage data is scarce, especially for the most severe events, statistical techniques alone are inadequate for estimating building performance.

As a result, catastrophe modelling companies construct damage functions based on a combination of:

- historical data
- engineering analyses
- claims data
- post-disaster surveys
- information on the evolution of building codes

Model outputs will reflect uncertainty due to the model's secondary uncertainty, through statistical measures of standard deviation and coefficient of variation. The exact influence will vary with peril, exposure data quality and resolution as well as the distribution of exposures and their likely correlation.

9.4.6 Financial module

In the financial module, there is parameter risk with regard to the inclusion of further characteristics via options and settings (see *Chapter 6*).

Another source of epistemic uncertainty is non-modelled risk and is related to the materiality and proportionality considerations of the Solvency II process. For example, models may not include certain loss-causing factors or parameters in their construction, such as storm surge around all coastlines, or specific loss functions such as vulnerability functions for automobiles. The impact of such loss additions should, within reason, be assessed during the analytical process, and taken into account if they have a material contribution to the total risk.

Uncertainty also exists in relation to cross-peril and multi-location correlations that may not be captured in the models, and whose causal processes are not understood to the level that they may be incorporated with confidence into the models. Again, the materiality of the uncertainty on the overall risk assessment should be considered.

Risk management functions should take account of model uncertainty within the decision-making process in as effective a way as possible; recognising that all models will include uncertainty within their structure.

9.5 The role of more accurate data and company processes in reducing overall uncertainty

Catastrophe models cannot faithfully represent risk if inaccurate exposure data is used. Companies should strive to obtain the best data available to describe their risks. This includes, for example, trying to understand the potential effects of mis-stated property values, and demonstrating how building values are assessed before their use in catastrophe models.

Detailed data can also introduce uncertainties into the model when the data used is more refined than the resolution of claims information used to develop the model. In this case, modelled results may have increased precision, but less accuracy, as the model responds to data based on aggregated data and not detailed data.

There are numerous options when performing catastrophe risk modelling and the choice of approach or settings will have a material impact on results, even if carried out within the same catastrophe model. It should also be borne in mind that companies themselves can introduce uncertainty into the process.

Companies should demonstrate that standards for data usage and modelling process are in place, supported by documentation.

9.6 Communicating modelling uncertainty to non-experts

It is crucial that companies are able to demonstrate the key elements of uncertainty and how this has been communicated within the organisation. Companies should be able to demonstrate that an appropriate individual is able to describe the key uncertainties, and how they affect the metrics that are used to run their business.

It is important that these uncertainties are presented in a way that does not devalue the modelled results. Rather, decisions should be taken with reference to the fact that the tools used have material uncertainties, and should always be considered with this in mind.

9.7 Approaches for embedding catastrophe modelling uncertainty in a company's risk management function

Modelled results should be adjusted to account for identified biases. Companies need not necessarily load the models because of uncertainty, as this can manifest itself in both directions. Companies should, however, have a clearly defined view on uncertainty in models and how its effects are mitigated in the risk management function. Less complex models than catastrophe models may calculate risk statistically and describe it by error bars around the distribution of results. Some - but not all - vendor catastrophe models do this.

Companies can, however, investigate relative uncertainties by:

- peril
- region
- LOB

Companies should, for material perils, be able to demonstrate how their understanding of these uncertainties is incorporated into their risk management approach. Generally, perils and regions that have experienced frequent or recent events are expected to have less uncertainty than those that have not.

To mitigate against the effects of uncertainty in models, companies can employ a suite of risk measures beyond the results from one model. For example:

- use of multiple models
- control of total limits exposed or deterministic measures, such as Lloyd's Realistic Disaster Scenarios

Companies may also adopt tolerances to a range of metrics beyond those required by regulators and ratings agencies, including measures such as TVaR, and points higher in the EP curve than the one-in-200 years' stress.

22. Assignment 6, Module 2: NAIC ORSA: <https://www.catriskcredentials.org/wp-content/uploads/2025/03/NAIC-ORSA.pdf>



NAIC OWN RISK AND SOLVENCY ASSESSMENT (ORSA) GUIDANCE MANUAL

**Maintained by the
Group Solvency Issues (E) Working Group
of the Financial Condition (E) Committee**

As of December 2022

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Date: August 11, 2022

To: Users of the *NAIC Own Risk and Solvency Assessment (ORSA) Guidance Manual*

From: Group Solvency Issues (E) Working Group

This edition of the ORSA Guidance Manual has been revised from the previous edition. The following summarizes the most significant changes since the December 2017 edition:

- I. Added various updates throughout the ORSA Guidance Manual to incorporate additional elements deemed appropriate by state insurance regulators, including additions from International Association of Insurance Supervisors (IAIS) guidance to incorporate:
 - A. Enhancements related to the treatment and disclosure of liquidity and business strategies within the Own Risk and Solvency Assessment (ORSA).
 - B. Enhancements related to additional considerations relevant to internationally active insurance groups (IAIGs), as outlined in the Common Framework for the Supervision of Internationally Active Insurance Groups (ComFrame).

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
A. EXEMPTION	2
B. APPLICATION FOR WAIVER	3
C. GENERAL GUIDANCE	3
D. MAINTENANCE PROCESS	5
SECTION 1 – DESCRIPTION OF THE INSURER’S ENTERPRISE RISK MANAGEMENT FRAMEWORK	7
SECTION 2 – INSURER’S ASSESSMENT OF RISK EXPOSURES	7
SECTION 3 – GROUP ASSESSMENT OF RISK CAPITAL AND PROSPECTIVE SOLVENCY ASSESSMENT	9
A. GROUP ASSESSMENT OF RISK CAPITAL	9
B. PROSPECTIVE SOLVENCY ASSESSMENT	11
ADDITIONAL EXPECTATIONS FOR INTERNIONALLY ACTIVE INSURANCE GROUPS	12
APPENDIX – GLOSSARY	14

The requirements outlined in this manual are based on the requirements of the *Risk Management and Own Risk and Solvency Assessment Model Act* (#505). An insurer using this manual should refer to the laws adopted by the insurer's state of domicile when determining its requirements for risk management, determining its Own Risk and Solvency Assessment (ORSA), and preparing its ORSA Summary Report.

INTRODUCTION

The purpose of this manual is to provide guidance to an insurer and/or an insurance group of which the insurer is a member, hereinafter referred to as "insurer" or "insurers," with regard to reporting on its Own Risk and Solvency Assessment (ORSA), as required by the domestic state's version of the *Risk Management and Own Risk and Solvency Assessment Model Act* (#505).

The ORSA, which is a component of an insurer's enterprise risk management (ERM) framework, is a confidential internal assessment appropriate to the nature, scale, and complexity of an insurer conducted by that insurer of the material and relevant risks identified by the insurer associated with an insurer's current business plan and the sufficiency of capital resources to support those risks. As described below, an insurer that is subject to the ORSA requirements will be expected to:

1. Regularly—i.e., no less than annually—conduct an ORSA to assess the adequacy of its risk management framework, as well as its current and estimated projected future solvency position.
2. Internally document the process and results of the assessment.
3. Provide a confidential high-level ORSA Summary Report annually to the lead state commissioner if the insurer is a member of an insurance group and, upon request, to the domiciliary state insurance regulator.

The ORSA has two primary goals:

1. To foster an effective level of ERM at all insurers, through which each insurer identifies, assesses, monitors, prioritizes, and reports on its material and relevant risks identified by the insurer using techniques that are appropriate to the nature, scale, and complexity of the insurer's risks in a manner that is adequate to support risk and capital decisions.
2. To provide a group-level perspective on risk and capital as a supplement to the existing legal entity view.

An insurer that is subject to the ORSA requirement should consider the guidance provided in this manual when conducting its ORSA and compiling its ORSA Summary Report. As the process and results are likely to include proprietary and forward-looking information, any ORSA Summary Report submitted to the commissioner shall be confidential by state law.

A. EXEMPTION

An insurer shall be exempt from maintaining a risk management framework, conducting an Own Risk and Solvency Assessment (ORSA) and filing an ORSA Summary Report, if:

1. The individual insurer's annual direct written and unaffiliated assumed premium, including international direct and assumed premium but excluding premiums reinsured with the Federal Crop Insurance Corporation (FCIC) and the National Flood Insurance Program (NFIP), is less than \$500 million.
2. If the insurer is a member of an insurance group and the insurance group's—i.e., all insurance legal entities within the group—annual direct written and unaffiliated assumed premium, including international direct and assumed premium but excluding premiums reinsured with the FCIC and the NFIP, is less than \$1 billion.

If the insurer does not qualify for an exemption, upon the commissioner's request, and no more than once each year, an insurer shall submit to the commissioner an ORSA Summary Report that contains the information described in this manual. If the group is an internationally active insurance group (IAIG) with a U.S. global group-wide supervisor, a group ORSA Summary Report should be filed; otherwise, a single or combination of reports may be used by the insurer to represent the group perspective. For example, the property/casualty (P/C) insurers within a group could be included in one ORSA Summary Report or a combination of reports, and the life insurers within the same group could be included in another ORSA Summary Report or a combination of reports if those groups operate under different enterprise risk management (ERM) frameworks. Notwithstanding any request from the commissioner, if the insurer is a member of an insurance group, the insurer shall submit the ORSA Summary Report(s) required by this manual to the lead state commissioner of the insurance group. The lead state is determined by the procedures within the *Financial Analysis Handbook*.

If an insurer qualifies for an exemption pursuant to paragraph 1 but the insurance group of which the insurer is a member does not qualify for an exemption pursuant to paragraph 2, then the insurer may supply an ORSA Summary Report in any combination, as long as every insurer within the group is covered by the ORSA Summary Report(s).

If an insurer does not qualify for an exemption pursuant to paragraph 1 but the insurance group of which it is a member qualifies for an exemption under paragraph 2, then the only ORSA Summary Report that may be required is the report of that insurer. However, such an exemption does not eliminate the requirement for any insurer that is subject to the *Risk Management and Own Risk and Solvency Assessment Model Act (#505)* to complete Section III – Group Assessment of Risk Capital and Prospective Solvency Assessment.

Notwithstanding the above exemptions, the commissioner may require the insurer to maintain a risk management framework; conduct an ORSA; and file an ORSA Summary Report based on unique circumstances, including, but not limited to, the type of business written, ownership and organizational structure, federal agency requests, international supervisor requests, and regulatory concerns about the rapidly growing concentration of risk or risk exposure.

A commissioner may also require the insurer to maintain a risk management framework; conduct an ORSA; and file an ORSA Summary Report if the insurer has triggered a risk-based capital (RBC) company-action-level event, meets one or more of the standards of an insurer deemed to

be in hazardous financial condition, or otherwise exhibits qualities of a troubled insurer, as determined by the commissioner.

If an insurer that qualifies for an exemption subsequently no longer qualifies for that exemption due to changes in premium, as reflected in the insurer's most recent annual financial statement or in the most recent annual financial statements of the insurers within the insurance group of which the insurer is a member, the insurer shall have one year following the year the threshold is exceeded to comply with the ORSA requirements.

B. APPLICATION FOR WAIVER

An insurer that does not qualify for an exemption may apply to the commissioner for a waiver from the requirements of the Own Risk and Solvency Assessment (ORSA) based upon unique circumstances. The commissioner may consider various factors, including, but not limited to, the type of business entity, volume of business written, and material reduction in risk or risk exposures. If the insurer is part of a nonexempted insurance group, the commissioner shall coordinate with the lead state commissioner and the other domiciliary commissioners in considering the request for a waiver.

C. GENERAL GUIDANCE

The Own Risk and Solvency Assessment (ORSA) should be one element of an insurer's enterprise risk management (ERM) framework. The ORSA and the ORSA Summary Report link the insurer's risk identification, assessment, monitoring, prioritization, and reporting processes with capital management and strategic planning. Each insurer's ORSA and ORSA Summary Report will be unique, reflecting the insurer's business, strategic planning, and approach to ERM. The commissioner will utilize the ORSA Summary Report to gain a high-level understanding of the insurer's ORSA. The ORSA Summary Report will be supported by the insurer's internal risk management materials.

To allow the commissioner to achieve a high-level understanding of the insurer's ORSA, the ORSA Summary Report should discuss three major areas, which will be referred to as the following sections:

- **Section 1** – Description of the Insurer's Risk Management Framework
- **Section 2** – Insurer's Assessment of Risk Exposures
- **Section 3** – Group Assessment of Risk Capital and Prospective Solvency Assessment

When developing an ORSA Summary Report, the content should be consistent with the ERM information that is reported to senior management and/or the Board of Directors or the appropriate committee. While some of the format, structure, and content of the ORSA Summary Report may be tailored for the state insurance regulator, the content should be based on the insurer's internal reporting of its ERM information. The ORSA Summary Report itself does not need to be the medium of reporting its ERM to the Board of Directors or the appropriate committee, and the report to the Board of Directors or the appropriate committee may not be at the same level of detail as the ORSA Summary Report.

In order to aid the commissioner's understanding of the information provided in the ORSA Summary Report, it should include certain key information. The ORSA Summary Report should

identify the basis(es) of accounting for the report (e.g., generally accepted accounting principles [GAAP], statutory accounting principles [SAPs], or international financial reporting standards) and the date or time period that the numerical information represents. The ORSA Summary Report should also explain the scope of the ORSA conducted such that the report identifies which insurer(s) are included in the report. This may be accomplished by including an organizational chart. In subsequent years, the ORSA Summary Report should also include a short summary of material changes to the ORSA from the prior year, including supporting rationale, as well as updates to the sections listed above, if applicable.

The commissioner may develop a deeper understanding of the insurer's ERM framework upon examination or an annual risk-focused update. Additionally, as part of the risk-focused analysis and/or examination process, the commissioner may also request and review confidential supporting materials to supplement his/her understanding of the information contained in the ORSA Summary Report. These materials may include risk management policies or programs, such as the insurer's underwriting, investment, claims, asset and liability management (ALM), reinsurance counterparty, and operational risk policies.

This manual is intended to provide guidance for completing each section of the ORSA Summary Report. The depth and detail of information are likely to be influenced by the nature and complexity of the insurer and should be updated at least annually for the insurer. The insurer is permitted discretion to determine how best to communicate its ERM processes. An insurer may avoid duplicative information and supporting documents by referencing other documents, provided that those documents are available to the state insurance regulator upon examination or request. In order to ensure that the commissioner is receiving the most current information from an insurer, the timing for filing the ORSA Summary Report during the calendar year may vary from insurer to insurer, depending on when an insurer conducts its internal strategic planning process. In any event, the ORSA Summary Report shall be filed once each year, with the insurer apprising the commissioner as to the anticipated time of filing.

The ORSA Summary Report shall include a signature of the insurer's chief risk officer or other executive having responsibility for the oversight of the insurer's ERM process attesting to the best of his/her belief and knowledge that the insurer applies the ERM process described in the ORSA Summary Report and that a copy of the ORSA Summary Report has been provided to the insurer's board of directors or the appropriate committee.

An insurer may comply with the ORSA requirement by providing the most recent report(s)¹ filed by the insurer or another member of an insurance group of which the insurer is a member to the commissioner of another state or a supervisor or regulator of a foreign jurisdiction if that report provides information that is comparable to the information described in this manual. If a U.S. state insurance commissioner is the global group-wide supervisor of an internationally active insurance group (IAIG), the U.S. state insurance commissioner should receive the ORSA Summary Report covering all material group-wide insurance operations. In addition, the insurer should work with a U.S. global group-wide supervisor to identify the scope of the group, whether the group is an IAIG or not; identify the head of the IAIG using the guidance contained in the *Financial Analysis Handbook*; and determine which noninsurance operations, if any, within the group should be included within the scope of the group and therefore the ORSA Summary Report. However, for all ORSA filers, the noninsurance operations that present material and relevant risks to the insurer should be included in the scope of the ORSA Summary Report.

¹ Reports filed to foreign jurisdictions that are a report on an insurer's ORSA shall henceforth for the purposes of this manual be referred to as an ORSA Summary Report.

If the U.S. is not the global group-wide supervisor, the insurer may file ORSA Summary Reports encompassing, at a minimum, the U.S. insurance operations as long as the lead state receives ORSA Summary Reports encompassing the non-U.S. insurance operations from the global group-wide supervisor. If an ORSA Summary Report encompassing the non-U.S. insurance operations is not provided by the global group-wide supervisor, it should be provided by the insurer. If the insurer files an ORSA Summary Report encompassing only the U.S. insurance operations, and in it, the insurer states that the U.S. ERM framework is based on the insurers' global ERM framework, then the global ERM framework should be explained either within the U.S. ORSA Summary Report or in an ORSA Summary Report encompassing the non-U.S. insurance operations and be provided to the lead state at a time agreed upon by the insurer and the lead state. If the report is in a language other than English, it must be accompanied by a translation into the English language. The commissioner should discuss with the global group-wide supervisor from the relevant foreign jurisdiction(s) the report received to inquire about any concerns and either confirm that the report was compliant with the foreign jurisdiction's requirements or consistent with the applicable principles outlined in the International Association of Insurance Supervisors (IAIS) Insurance Core Principle (ICP) 16: Enterprise Risk Management to the extent included in this manual, as well as this manual to determine if additional information is needed. The commissioner will, where possible, avoid creating duplicative regulatory requirements for internationally active insurers.

In analyzing an ORSA Summary Report, the commissioner will expect that the report represents a work product of the ERM framework that includes all of the material risks identified by the insurer to which an insurer(s), if applicable, is exposed.

The ORSA Summary Report may assist the commissioner in determining the scope, depth, and minimum timing of risk-focused analysis and examination procedures. For example, insurers may have varying ERM frameworks, ranging from a business plan to a combination of investment plans and underwriting policies to more complex risk management processes and sophisticated modeling. Insurers with ERM frameworks appropriate to their risk profile may not require the same scope or depth of review upon examination and analysis as those with less relatively comprehensive ERM frameworks. Therefore, the insurer should consider whether the ORSA Summary Report demonstrates the strengths of its framework, including how it meets the guidelines within this manual for the relative risk of the insurer.

In addition to the ORSA Summary Report, the insurer should internally document the ORSA results to facilitate a more in-depth review by the commissioner through analysis and examination processes. Such a review may depend on several factors, such as the nature, complexity, financial position, and/or prioritization of the insurer, as well as external considerations such as the economic environment. These factors may result in the commissioner requesting additional information about the insurer's ERM framework through the financial analysis or examination processes. The information requested may include, but is not limited to, risk management policies and programs, such as the insurer's underwriting, investment, claims, duration, or ALM, as well as reinsurance counterparty or operational risk policies.

D. MAINTENANCE PROCESS

The following establishes procedures of the Group Solvency Issues (E) Working Group or its designated subgroup for proposed changes, amendments, and/or modifications to the manual:

1. The Working Group may consider relevant proposals to change the manual at any conference call, interim, or national meeting throughout the year as scheduled by the Working Group.
2. If a proposal for suggested changes, amendments, and/or modifications is submitted to or filed with NAIC staff support, it may be considered at the next regularly scheduled meeting of the Working Group.
3. The Working Group publishes a formal submission form and instructions that can be used to submit proposals, which are available on the Working Group's web page. However, proposals may also be submitted in an alternate format provided that they are stated in a concise and complete format. In addition, if another NAIC committee, task force, or working group is known to have considered this proposal, that committee, task force, or working group should provide any relevant information.
4. Any proposal that would change the manual will be effective Jan. 1 following the NAIC Summer National Meeting—i.e., of the preceding year—in which it was adopted by the Working Group (e.g., a change proposed to be effective Jan. 1, 2018, must be adopted by the Working Group no later than the 2017 Summer National Meeting) and the Fall National Meeting in which it was adopted by the NAIC.
5. Upon receipt of a proposal, the Working Group will review the proposal at the next scheduled meeting and determine whether to consider the proposal for adoption. If the proposal is to be considered by the Working Group, it will be exposed for public comment. The public comment period shall be no less than 30 days and may be extended by the Working Group. The Working Group will consider comments received on each proposal at its next meeting and take action to revise, adopt, reject, refer, or continue the consideration of the proposal and comments thereto. Proposals under consideration may be deferred by the Working Group until the following scheduled meeting. The Working Group may form an ad hoc group to study the proposal, if needed. The Working Group may also refer proposals to other NAIC committees for technical expertise or review. If a proposal has been referred to another NAIC committee, the proposal will temporarily be removed from the Working Group's agenda until a response has been received. At that time, it will be added back to the Working Group's agenda.
6. NAIC staff support will prepare an agenda inclusive of all proposed changes. The agenda and relevant materials shall be sent via e-mail to each member of the Working Group, interested state insurance regulators, and interested parties and posted to the Working Group's web page approximately 5 to 10 business days prior to the next regularly scheduled meeting during which the proposal would be considered.
7. In rare instances, or where emergency action may be required, suggested changes and amendments can be considered as an exception to the above-stated process and timeline based on a two-thirds majority consent of the Working Group members present. Notwithstanding the foregoing, in no event may a proposal be adopted without an exposure for public comment.
8. NAIC staff support will publish the manual on or about Dec. 15 of each year. NAIC staff will post to the Working Group and NAIC Publications web pages the current versions and any material subsequent corrections to these publications.

SECTION 1 – DESCRIPTION OF THE INSURER’S ENTERPRISE RISK MANAGEMENT FRAMEWORK

An effective enterprise risk management (ERM) framework should, at a minimum, incorporate the following key principles:

- **Risk Culture and Governance** – A governance structure that clearly defines and articulates roles, responsibilities, and accountabilities; and a risk culture that supports accountability in risk-based decision making.
- **Risk Identification and Prioritization** – A risk identification and prioritization process that is key to the organization; responsibility for this activity is clear; the risk management function is responsible for ensuring that the process is appropriate and functioning properly at all organizational levels; key risks of the insurer are identified, prioritized, and clearly presented.
- **Risk Appetite, Tolerances, and Limits** – A formal risk appetite statement and associated risk tolerances and limits are foundational elements of risk management for an insurer; an understanding of the risk appetite statement ensures alignment with risk strategy by the Board of Directors.
- **Risk Management and Controls** – Managing risk is an ongoing ERM activity, operating at many levels within the organization.
- **Risk Reporting and Communication** – Provides key constituents with transparency into the risk management processes and facilitates active, informal decisions on risk-taking and management.

Section 1 of the Own Risk and Solvency Assessment (ORSA) Summary Report should provide a high-level summary of the aforementioned ERM framework principles, if present. The ORSA Summary Report should describe the main goals and objectives of the insurers’ business strategy—i.e., for all insurance and noninsurance operations in scope—and how the insurer identifies and categorizes relevant and material risks and manages those risks as it executes its business strategy. The ORSA Summary Report should also describe risk monitoring processes and methods, provide risk appetite statements, and explain the relationship between risk tolerances and the amount and quality of risk capital. The ORSA Summary Report should identify assessment tools (e.g., feedback loops) used to monitor and respond to any changes in the insurer’s risk profile due to economic changes, operational changes, or changes in business strategy. Finally, the ORSA Summary Report should describe how the insurer incorporates new risk information in order to monitor and respond to changes in its risk profile due to economic and/or operational changes and changes in strategy.

The manner and depth in which the insurer addresses these principles are dependent upon its own risk management processes. Any strengths or weaknesses noted by the commissioner in evaluating this section of the ORSA Summary Report will have relevance to the commissioner’s ongoing supervision of the insurer, and the commissioner will consider the entirety of the risk management program and its appropriateness for the risks of the insurer.

SECTION 2 – INSURER’S ASSESSMENT OF RISK EXPOSURES

Section 2 of the Own Risk and Solvency Assessment (ORSA) Summary Report should provide a high-level summary of the quantitative and/or qualitative assessments of risk exposure in both

normal and stressed environments for each material risk category in Section 1. This assessment process should consider a range of outcomes using risk assessment techniques that are appropriate to the nature, scale, and complexity of the risks. Examples of relevant material risk categories may include, but are not limited to, credit, market, liquidity, underwriting, and operational risks.

Section 2 may include detailed descriptions and explanations of the material and relevant risks identified by the insurer, the assessment methods used, key assumptions made, risk-mitigation activities, and outcomes of any plausible adverse scenarios assessed. The assessment of each risk will depend on its specific characteristics. For some risks, quantitative methods may not be well established, and in these cases, a qualitative assessment may be appropriate. Examples of these risks may include certain operational and reputational risks. In addition, each insurer's quantitative methods for assessing risk may vary; however, insurers generally consider the likelihood and impact that each material and relevant risk identified by the insurer will have on the firm's balance sheet, income statement, and future cash flows. Methods for determining the impact on a future financial position may include simple stress tests or more complex stochastic analyses. When evaluating a risk, the insurer should analyze the results under both normal and stressed environments. Lastly, the insurer's risk assessment should consider the impact of stresses on capital, which may include the consideration of risk capital requirements; available capital; and regulatory, economic, rating agency, and/or other views of capital requirements.

The analysis should be conducted in a manner that is consistent with the way in which the business is managed, whether on a group, legal entity, or another basis. Stress tests for certain risks may be performed at the group level. Where relevant to the management of the business, some group-level stresses may be mapped into legal entities. The commissioner may request additional information to map the results to an individual insurance legal entity.

Any risk tolerance statements should include material quantitative and qualitative risk tolerance limits and how the tolerance statements and limits are determined, taking into account relevant and material categories of risk and the risk relationships that are identified.

Because the risk profile of each insurer is unique, each insurer should utilize assessment techniques (e.g., stress tests, etc.) applicable to its risk profile. U.S. state insurance regulators do not believe there is a standard set of stress conditions that each insurer should test. The commissioner may provide input regarding the level of stress that the insurer's management should consider for each risk category. The ORSA Summary Report should provide a general description of the insurer's process for model validation, including factors considered and model calibration. Unless a particular assumption is stochastically modeled, the group's management should set assumptions regarding the expected values based on its current anticipated experience, what it expects to occur during the next year or multiple future years, and consideration of expert judgment. The commissioner may provide input to an insurer's management on the assumptions and scenarios to be used in its assessment techniques. For assumptions that are stochastically modeled, the commissioner may provide input on the level of the measurement metric to use in the stressed condition or specify particular parameters used in the economic scenario generator (ESG). Commissioner input will likely occur during the financial analysis process and/or the financial examination process.

By identifying each material risk category independently and reporting results in both normal and stressed conditions, insurer management and the commissioner are better placed to evaluate certain risk combinations that could cause an insurer to fail. One of the most difficult exercises in modeling insurer results is determining the relationships, if any, between risk categories. History

may provide some empirical evidence of relationships, but the future is not always best estimated by historical data.

SECTION 3 – GROUP ASSESSMENT OF RISK CAPITAL AND PROSPECTIVE SOLVENCY ASSESSMENT

Section 3 of the Own Risk and Solvency Assessment (ORSA) Summary Report should describe how the insurer combines the qualitative elements of its risk management policy with the quantitative measures of risk exposure in determining the level of financial resources needed to manage its current business and over a longer-term business cycle (e.g., the next one to three years). The group risk capital assessment should be performed as part of the ORSA, regardless of the basis (e.g., group, legal entity, or another subset basis) and in a manner that encompasses the entire insurance group. The information provided in Section 3 is intended to assist the commissioner in assessing the quality of the insurer's risk and capital management.

A. GROUP ASSESSMENT OF RISK CAPITAL

Within the group assessment of risk capital, aggregate available capital is compared against the various risks that may adversely affect the enterprise. The insurer should consider how the group capital assessment is integrated into the insurer's management and decision-making culture, how the insurer evaluates its available capital, and how risk capital is integrated into its capital-management activities.

The insurer should have sound processes for assessing capital adequacy in relation to its risk profile, and those processes should be integrated into the insurer's management and decision-making culture. These processes may assess risk capital through myriad metrics and future forecasting periods, reflecting varying time horizons, valuation approaches, and capital-management strategies (e.g., the mix of capital). While a single internal risk capital measure may play a primary role in internal capital adequacy assessment, insurers may evaluate how risk and capital interrelate over various time horizons or through the lens of alternative risk capital or accounting frameworks; i.e., economic, rating agency, and/or regulatory frameworks. This section is intended to assist the commissioner in understanding the insurer's capital adequacy in relation to its aggregate risk profiles.

The group capital assessment should include a comparative view of risk capital from the prior year, including an explanation of the changes, if not already explained in another section of the Own Risk and Solvency Assessment (ORSA) Summary Report. This information may also be requested by the commissioner throughout the year, if needed (e.g., if material changes in the macroeconomic environment and/or microeconomic facts and circumstances suggest that the information is needed for the ongoing supervisory plan).

The analysis of an insurer's group assessment of risk capital requirements and associated capital adequacy description should be accompanied by a description of the approach used in conducting the analysis. This should include key methodologies, assumptions, and considerations used in quantifying available capital and risk capital. Examples might include:

Considerations	Description of Methodologies and Assumptions	Examples (not exhaustive)
Definition of Solvency	Describe how the insurer defines solvency for the purpose of determining risk capital and liquidity requirements.	Cash flow basis; balance sheet basis
Accounting or Valuation Regime	Describe the accounting or valuation basis for the measurement of risk capital requirements and/or available capital.	Generally accepted accounting principles (GAAP); statutory; economic or market consistent; International Financial Reporting Standards (IFRS); rating agency model
Business Included	Describe the subset of business included in the analysis of capital.	Positions as of a given valuation date; new business assumptions
Time Horizon	Describe the time horizon over which risks were modeled and measured.	One-year, multi-year; lifetime; run-off
Risks Modeled	Describe the risks included in the measurement of risk capital, including whether all relevant and material risks identified by the insurer have been considered.	Credit; market; liquidity; insurance; operational
Quantification Method	Describe the method used to quantify the risk exposure.	Deterministic stress tests; stochastic modeling; factor-based analysis
Risk Capital Metric	Describe the measurement metric utilized in the determination of aggregate risk capital.	Value at risk (VaR), which quantifies the capital needed to withstand a loss at a certain probability; tail value at risk (TVaR), which quantifies the capital needed to withstand average losses above a certain probability; probability of ruin, which quantifies the probability of ruin given the capital held
Defined Security Standard	Describe the defined security standard utilized in the determination of risk capital requirements, including linkage to business strategy and objectives.	AA solvency; 99.X% one-year VaR; Y% TVaR or conditional tail expectation (CTE); X% of risk-based capital (RBC)

Considerations	Description of Methodologies and Assumptions	Examples (not exhaustive)
Aggregation and Diversification	Describe the method of aggregation of risks and any diversification benefits considered or calculated in the group risk capital determination.	Correlation matrix; dependency structure; sum; full/partial/no diversification

The approach and assessment of group-wide capital adequacy should also consider the following:

- Elimination of intra-group transactions and double gearing, where the same capital is used simultaneously as a buffer against risk in two or more entities.
- The level of leverage, if any, resulting from holding company debt.
- Diversification credits and restrictions on the fungibility of capital within the holding company system, including the availability and transferability of surplus resources created by holding company system-level diversification benefits.
- The effects of contagion risk, concentration risk, and complexity risk in the group assessment of risk capital.

The goal of the group capital assessment is to provide an overall determination of risk capital needs for the insurer based on the nature, scale, and complexity of risk within the group and its risk appetite; and compare that risk capital to available capital to assess capital adequacy. Group assessment of risk capital should not be perceived as the minimum amount of capital before regulatory action will result (e.g., the triggers in the *Risk-Based Capital (RBC) for Insurers Model Act* [#312]); rather, it should be recognized that this is the capital needed within a holding company system to achieve its business objectives.

The insurer should also monitor the effect of liquidity risk, including calls on the insurer's cash position due to microeconomic factors—i.e., internal operational—and/or macro-economic factors; i.e., economic shifts. The insurer should assess its resilience against severe but plausible liquidity stresses and whether the current liquidity position is within any liquidity risk appetite and/or limits. The insurer should describe in the ORSA the policies and processes in place to manage liquidity risk, as well as contingency funding or other plans to mitigate potential liquidity stresses.

B. PROSPECTIVE SOLVENCY ASSESSMENT

The insurer's capital assessment process should be closely tied to business planning. To this end, the insurer should have a robust capital forecasting capability that supports its management of risk over the planning time horizon in line with its stated risk appetite. The forecasting process should consider material and relevant changes identified by the insurer to the insurer's internal operations and the external business environment. It should also consider the prospect of operating in both normal and stressed environments.

The insurer's prospective solvency assessment should demonstrate that it has the financial resources necessary to execute its multi-year business plan in accordance with its stated risk appetite. If the insurer does not have the necessary available capital in terms of quantity and/or quality to meet its current and projected risk capital requirements, then it should describe the management actions it has taken or will take to remedy any capital adequacy concerns. These management actions may include or describe any modifications to the business plan or identification of additional capital resources.

The prospective solvency assessment is, in effect, a feedback loop. The insurer should project its future financial position, including its projected economic and regulatory capital to assess its ability to meet the regulatory capital requirements. Factors to be considered are the insurer's current risk profile, its risk management policy, and its quality and level of capital, including any changes to its current risk profile caused by executing the multi-year business plan. The prospective solvency assessment should also consider both normal and stressed environments.

While the prospective solvency assessment includes capital projections, the prospective solvency assessment should also include a discussion of prospective risks impacting the capital projections. This discussion should address whether risk exposures are expected to increase or decrease in the future and what steps the insurer plans to take that may change its risk exposures. The term "prospective" should pertain to both existing risks likely to intensify and emerging risks with the potential to impact the insurer in the future.

If the prospective solvency assessment is performed for each individual insurer, the assessment should take into account any risks associated with group membership. Such an assessment may involve a review of any group solvency assessment and the methodology used to allocate group capital across insurance legal entities, as well as consideration of capital fungibility; i.e., any constraints on risk capital or the movement of risk capital to legal entities.

ADDITIONAL EXPECTATIONS FOR INTERNATIONALLY ACTIVE INSURANCE GROUPS

This section identifies additional enterprise risk management (ERM) expectations that are applicable to internationally active insurance groups (IAIGs) and should be discussed in the Own Risk and Solvency Assessment (ORSA) Summary Report. These expectations are generally consistent with elements outlined in the International Association of Insurance Supervisors (IAIS) Common Framework for the Supervision of Internationally Active Insurance Groups (ComFrame), and they have been incorporated into this manual to the extent deemed appropriate by state insurance regulators.

As stated earlier in this document, an aggregated ORSA Summary Report should be filed at the head of the IAIG level. The head of the IAIG should ensure that the risk management strategy and framework described in the ORSA, whether located at the head of the IAIG or within another legal entity of the IAIG, encompass both the head of the IAIG and the legal entities within the IAIG to promote a sound risk culture across the group.

The risk management strategy should be approved by the IAIG Board, with regular risk management reporting provided to the IAIG Board or one of its committees.

The risk management framework should be integrated with the organizational structure of the IAIG and within its legal entities, as appropriate, to ensure that the decision-making processes, business operations, and risk culture of the IAIG are implemented. In addition, the framework should allow for the measurement of risk exposures of the IAIG against established risk limits on an ongoing basis in order to identify potential concerns as early as possible. This framework should cover, at a minimum:

- The diversity and the geographical reach of IAIG activities.

- The nature and degree of risks in individual legal entities and business lines.
- The aggregation of risks across entities within the IAIG.
- The interconnectedness of legal entities within the IAIG.
- The level of sophistication and functionality of information and reporting systems in addressing key risks.
- The applicable laws and regulations of the jurisdictions where the IAIG operates.

The risk management framework should promote a sound risk culture across all legal entities of the IAIG by having policies and processes that include risk management training, address independence, create appropriate incentives for staff involved in risk management, and encourage timely evaluation and open communication of emerging risks that may be significant to the IAIG and its legal entities.

The risk management framework of the IAIG should be reviewed at least annually to ensure that existing and emerging risks, as well as changes in structure and business strategy, are taken into account. Necessary modifications and improvements to the risk management framework should be made in a timely manner.

The IAIG's ORSA should explain how the risk management function, actuarial function, and internal audit function are involved in the risk management of the IAIG. The ORSA should explain the main activities of each of these functions. Furthermore, the ORSA should describe how the risk management function remains independent from risk-taking activities. The ORSA should describe how the actuarial function is involved in the risk assessment and management of the risks emanating from the legal entities in determining the IAIG's solvency position, in any actuarial-related modeling in the ORSA, and in the annual reporting to the IAIG Board of Directors on the risks posed to the IAIG. Finally, the ORSA should describe how the audit function provides an independent assessment and assurance to the IAIG Board of Directors of the operational effectiveness of the internal controls incorporated into the risk management framework.

The risk management strategy and framework of an IAIG should generally be consistent, and any material differences should be described in the ORSA strategic risk. The investment policies should ensure that assets are properly diversified and asset concentration risk is mitigated across the IAIG:

- Mechanisms to keep track of intra-group transactions that have a significant impact on the IAIG, the risks arising from these transactions, and the qualitative and quantitative restrictions on these risks. These intra-group transactions may include loans, guarantees, dividend payments, reinsurance, transactions across different financial services entities within the IAIG, and any activity undertaken by individual legal entities that may change the risk profile of the IAIG.
- An economic capital model to measure all relevant and material risks that the IAIG faces in different sectors, jurisdictions, and economic environments. The model should estimate the amount of capital needed in reasonably foreseeable adverse situations. The results of the model, how the risks were aggregated in the model, how the diversification benefit was estimated, and the underlying assumptions used in the model should be presented in the ORSA. The ORSA should show both the economic and the regulatory capital at the head of the IAIG level. A discussion of the fungibility of capital and the transferability of assets within the group should also be included.
- Risk measurements that include stress and reverse stress testing and scenario analysis deemed relevant to the risk profile of the IAIG.

- Risk measurements of the resilience of its total balance sheet against plausible macroeconomic stresses.
- Risk measurements that assess the aggregate investment counterparty exposures and the effect of severe but plausible stress events on those exposures. In addition, the IAIG should have an investment counterparty risk appetite statement to determine if the current exposures are within the risk appetite, and this should be presented in the ORSA.

The risk management framework should include a series of mechanisms to manage the IAIG's liquidity risk and demonstrate the IAIG's resilience against severe but plausible liquidity stresses. These mechanisms include:

- A liquidity risk appetite statement and liquidity risk limits to determine if the current liquidity position of the IAIG is within the risk appetite and the limits.
- Strategies, policies, and processes to manage liquidity risk.
- Liquidity stress testing.
- An adequate level of unencumbered highly liquid assets.
- Contingency funding to mitigate potential liquidity stresses.

The IAIG may be asked by the group-wide supervisor to develop a recovery plan, if warranted. A recovery plan identifies in advance options to restore the financial position and viability of the group if it comes under severe stress. The full recovery plan is not expected to be included in the ORSA Summary Report; however, the ORSA Summary Report should discuss at a high level the severe stresses that could trigger a recovery plan, and it should summarize the recovery options available.

The risk management framework should be reviewed by the insurer at least once every three years in order to ascertain that it remains fit for purpose based on the risk profile, structure, and business strategy of the IAIG. The review may be carried out by an internal or external body as long as it is neither responsible nor involved in the risk management framework that it reviews.

APPENDIX – GLOSSARY

Term	Definition
Available Capital	The amount of resources that an enterprise has at a given point in time under a defined valuation or accounting basis (e.g., economic, statutory, generally accepted accounting principles [GAAP], or a combination) to support its business and under the defined valuation represents the insurer's assessment of the types of capital required to support its business.
Conditional Tail Expectation (CTE) (also known as Tail Value at Risk [TVaR])	A measure of the amount of risk that exists in the tail of a distribution of outcomes, expressed as the probability-weighted average of the outcomes beyond a chosen point in the distribution. Typically expressed as CTE (1-x), which would be calculated as the probability-weighted average of the worst x% of outcomes. For example, CTE 95 is calculated as the probability-weighted average of the worst 5% of outcomes, CTE 97 is the probability-weighted average of the worst 3% of outcomes, etc. CTE can be used as a way of defining a particular <i>security standard</i> .

Term	Definition
Correlation Matrix	A symmetric matrix specifying pairwise interactions between a set of variables or data. A correlation matrix is commonly applied to risks or capital amounts and is an important determinant of calculated <i>risk capital</i> , including levels of <i>diversification</i> .
Deficit Capital	If the amount of <i>available capital</i> is less than the determined <i>risk capital</i> of an enterprise, then the enterprise is said to have <i>deficit capital</i> .
Defined Security Standard	The minimum threshold of <i>available capital</i> that a company wishes to achieve or maintain, consistent with the company's business strategy, <i>risk appetite</i> , and <i>risk tolerance</i> .
Dependency Structure	Specification of the relationship between different variables. Commonly specified in a <i>correlation matrix</i> .
Diversification	The extent to which the combined impact of risks inherent to assets and liabilities is less than the sum of the impacts of each risk considered in isolation.
Double Gearing	Used to describe situations where multiple companies, typically parent and subsidiary, are using shared capital to buffer against risk occurring in separate entities.
Economic Capital	The amount of capital that an insurer is required to absorb in unexpected losses based on its risk profile and risk appetite.
Excess Capital	If the amount of <i>available capital</i> is greater than the determined <i>risk capital</i> of an enterprise, the enterprise is said to have <i>excess capital</i> .
Fungibility	Within a group context, the ability to redeploy <i>available capital</i> from one entity to another. Fungibility is reduced where the movement of <i>available capital</i> within the group is constrained or regulation prohibits it.
Group Capital	Group capital represents the aggregate <i>available capital</i> or <i>risk capital</i> for the entire group. It will be impacted by the interaction of the risks and capital of the individual entities within the group, with properties such as <i>diversification</i> , <i>fungibility</i> , and the quality and form of capital being important drivers.
Internationally Active Insurance Group (IAIG)	An insurance holding company system meeting the following criteria: <ol style="list-style-type: none"> 1. Premiums written in at least three countries. 2. The percentage of gross premiums written outside the home country is at least 10% of the insurance holding company system's total gross written premiums. 3. Based on a three-year rolling average, the total assets of the insurance holding company system are at least \$50 billion, or the total gross written premiums of the insurance holding company system are at least \$10 billion.
Probability of Ruin	The likelihood of liabilities exceeding assets for a given time horizon.
Reverse Stress Test	An analysis of those scenarios that would render the insurer insolvent.
Risk Appetite	Documents the overall principles that a company follows with respect to risk-taking, given its business strategy, financial

Term	Definition
	soundness objectives, and capital resources. Often stated in qualitative terms, a risk appetite defines how an organization weighs strategic decisions and communicates its strategy to key stakeholders with respect to risk-taking. It is designed to enhance management's ability to make informed and effective business decisions while keeping risk exposures within acceptable boundaries.
Risk Capital	An amount of capital calculated to be sufficient to withstand adverse outcomes associated with various risks of an enterprise, up to a pre-defined <i>security standard</i> .
Risk Capital Metric	A quantitative variable used to gauge risk.
Risk Exposure	For each risk listed in the company's <i>risk profile</i> , the amount the company stands to lose due to that particular risk at a particular time, as indicated by a chosen metric.
Risk Limit	Typically quantitative boundaries that control the amount of risk that a company takes. Risk limits are typically more granular than <i>risk tolerances</i> and may be expressed at various levels of aggregation; i.e., by type of risk, category within a type of risk, product or line of business, or some other level of aggregation. Risk limits should be consistent with the company's overall <i>risk tolerance</i> .
Risk Profile	A delineation and description of the material risks to which an organization is exposed.
Risk Tolerance	The company's qualitative and quantitative boundaries around risk-taking, consistent with its <i>risk appetite</i> . Qualitative risk tolerances are useful to describe the company's preference for, or aversion to, particular types of risk, particularly for those risks that are difficult to measure. Quantitative risk tolerances are useful to set numerical limits for the amount of risk that a company is willing to take.
Security Standard	The level of a <i>measurement metric</i> used to determine <i>risk capital</i> . It signifies the strength of capital and, in practice, should be chosen to be consistent with the <i>risk appetite</i> and <i>risk tolerance</i> .
Solvency	For a given accounting basis, the state where, and extent to which, assets exceed liabilities.
Stochastic Analysis	A methodology designed to attribute a probability distribution to a range of possible outcomes. May use closed form solutions, or large numbers of scenarios in order to reflect the shape of the distribution.
Scenario Analysis	An analysis of the impact of possible future outcomes based on alternative projected assumptions. This can include changes to a single assumption or a combination of assumptions.
Stress Test	A type of scenario analysis in which the change in parameters is considered significantly adverse or even extreme.
Time Horizon	In the context of risk capital calculations, the period over which the impact of changes to risks is tested.
Value at Risk (VaR)	An estimate of the maximum loss over a certain period of time at a given confidence level.