Touchstone Financial Module: Core Algorithms

Publication Date: February 2024

Table of Contents

List of Figures

List of Tables

1 Touchstone and the financial module

Touchstone's financial module works alongside Verisk's catastrophe modeling framework to processes uncertainty and event-losses to generate loss results.

The Touchstone financial module applies financial and insurance/reinsurance policy terms to the client's exposure. Touchstone takes the output from the financial module and, in conjunction with Verisk's catastrophe modeling framework, applies model peril and hazard information and vulnerability components to estimate property damage (for each simulated event at each modeled location) into contractually insured losses, and then, in turn, into event *loss distributions* for each location, layer, contract, portfolio, and event included in a Touchstone loss analysis.

The following discussion covers:

Modeling uncertainty

Emphasizes the inherent role uncertainty plays in the modeling process, provides a description of these uncertainties, and explains Touchstone's expression of uncertainty in terms of probability loss distribution.

Statistical methodologies

Overview of the statistical methodologies applied in Touchstone's financial module to generate losses.

Actuarial methodologies

Overview of actuarial methodologies and workflows applied in Touchstone's financial module.

Determining event level loss

Overview of how Touchstone incorporates location, layer, and policy terms alongside model perils and uncertainties to generate loss estimates.

Financial terms and exposure data

A dive into key inputs of any analysis: financial and policy terms and exposures.

How the financial module works with catastrophe models

The Touchstone financial module amalgamates model data to create a probability distribution of loss.

The financial engine works with these kinds of data

- Scientific information on the frequency and severity of hazards
- Data regarding properties exposed to those hazards
- Data regarding the contracts that share the losses associated with those hazards

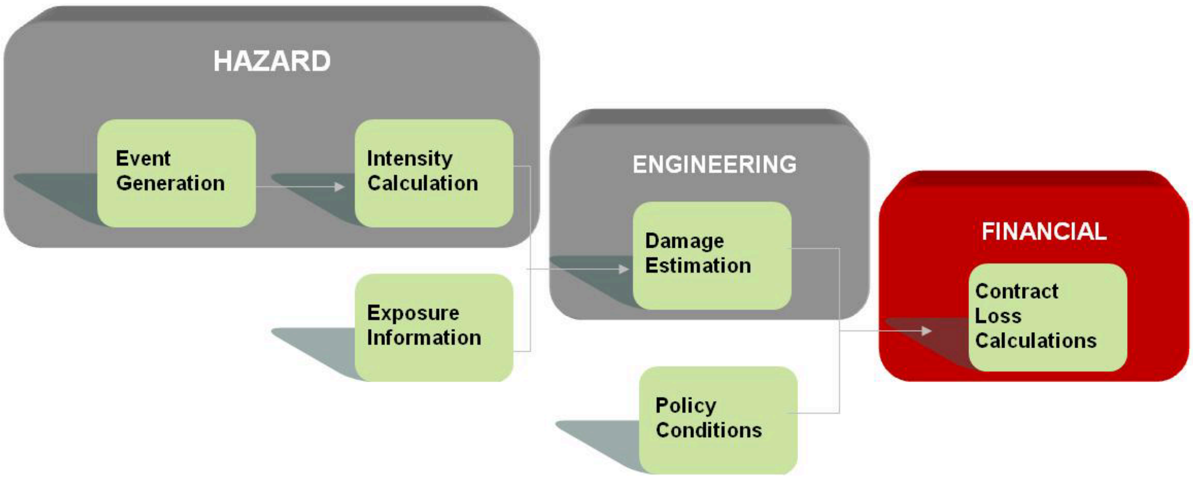


Figure 1. Basic catastrophe model architecture

The modeling approach uses a *catalog of simulated events*. The process to generate the event catalog is model- or peril-specific but generally driven by either sampling the probability distributions of various physical parameters or explicitly simulating them. The employed methods are the result of continuous scientific research and are updated with each new model versions. The catalog is specified in terms of simulated years. Each event is assigned a year and date of occurrence within a fixed simulation period, such as 10,000 or 100,000 years. Different methods, depending on the nature of the hazard, are used to calculate a *measure of local intensity* for each event (e.g. wind speed or ground motion intensity). For instance, the intensity of a tropical cyclone is profiled over geographic location and time for the duration of the event, making it a critical step in accurately modeling the hazard. Note that assumptions must be made for event parameters and formulation, because the local intensity of simulated events reflects incomplete knowledge of the hazard.

Intensity data and exposure data are linked by geographic location. Using structural engineering expertise, Verisk applies a vulnerability analysis to each location. Based on the intensity of each simulated event, a probability distribution of damage is developed for the property at the policy coverage level (buildings, other structures, contents, and time element).

This distribution has two important practical characteristics.

- Damage is expressed as a ratio to the replacement value, which is provided by the user in the exposure data
- Damage is not known with certainty

The core “damage functions” relate a mean damage ratio to event intensity. Each damage ratio distribution is parameterized using the mean damage ratio. The distribution contains a wide range of possible damage ratios. For most events and locations, that range includes the possibility (however small) of both zero damage and total loss. The figure below illustrates this concept.

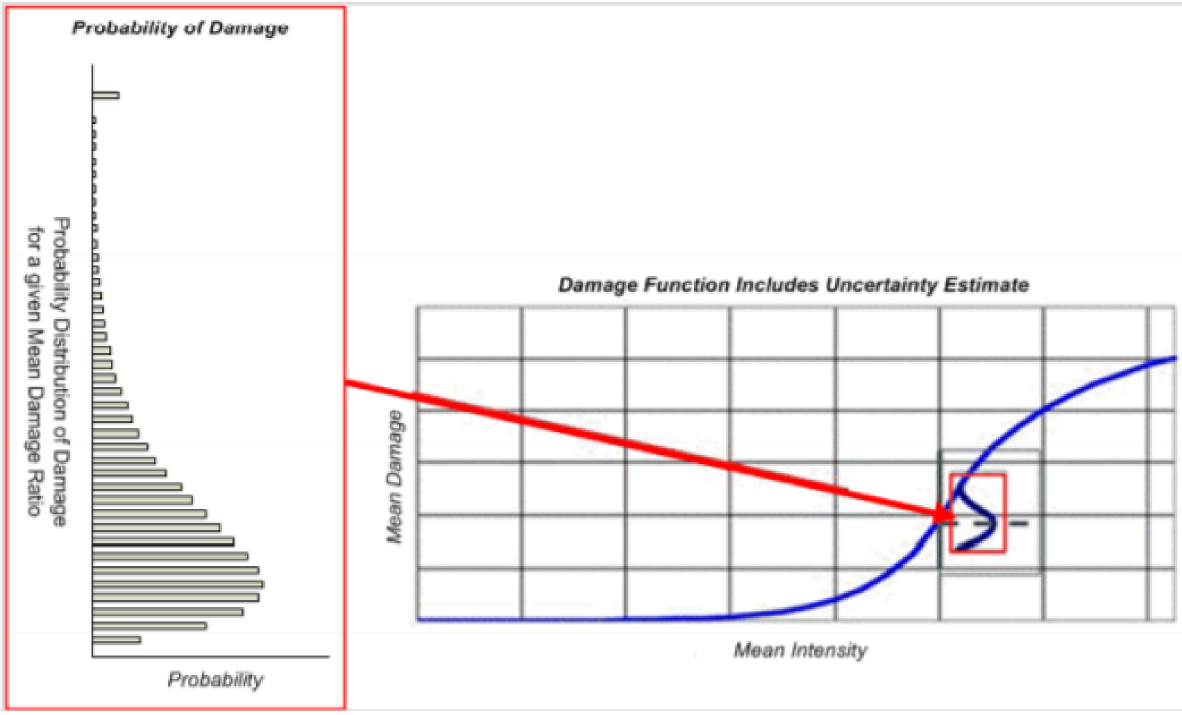


Figure 2. Depiction of a stochastic vulnerability function

In the next figure, each damage ratio also has a separate probability distribution. The actual parameters of the probability distribution differ depending on the mean damage ratio modeled for the natural peril, event, location, and coverage.

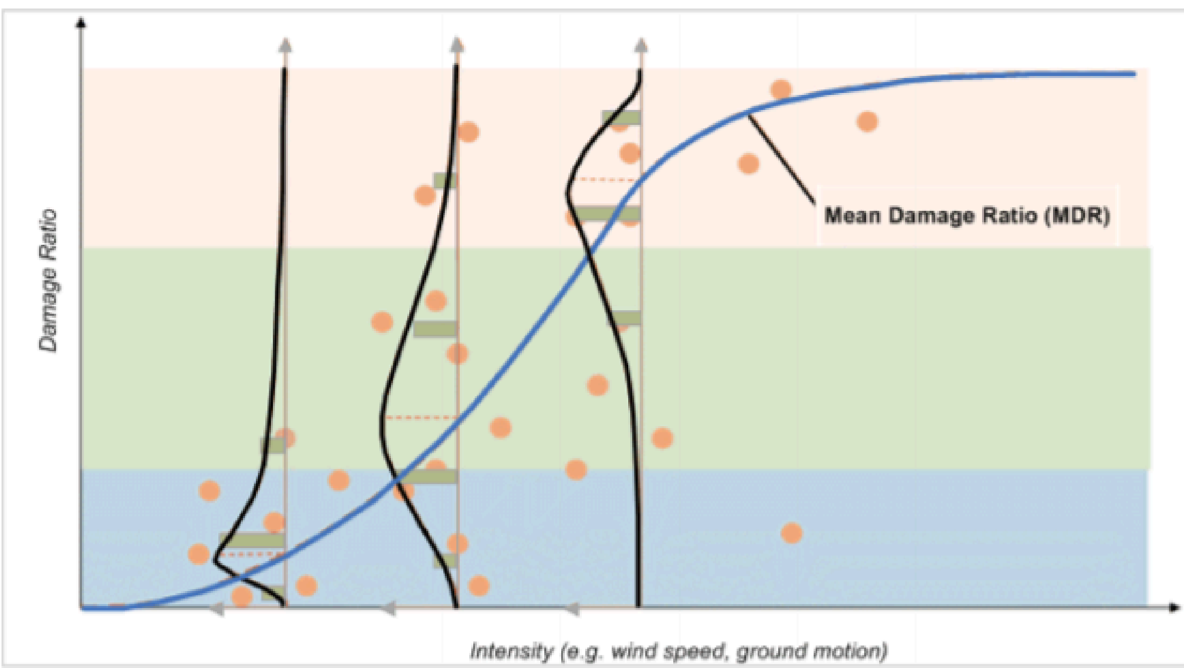


Figure 3. Variation of damage ratio distributions according to mean damage

2 Modeling uncertainty

Modeling uncertainty

Uncertainty is an inherent part of catastrophe modeling, therefore must be explicitly reflected in the modeling process in Touchstone.

Uncertainty is inherit in both a general modeling framework (aleatory, epistemic, and ontological) and within a catastrophe model (primary and secondary). In Touchstone, uncertainty is expressed in loss as a probability distribution.

Classes of uncertainty within catastrophe models

There are three broad classes of uncertainty in catastrophe modeling.

Aleatory	The uncertainty that is inherent in any model.
Epistemic	The known uncertainty in the model.
Ontological	The unknown uncertainty in the model.

Since the sources of ontological uncertainty are unknown, the following discussion focuses on the sources of aleatory and epistemic uncertainty present in the models.

The word "aleatory" is derived from the Latin *alea* (a game of dice), which implies that this inherent uncertainty is due to the random nature of a physical or financial process. It should be expected that, even as our knowledge of the process increases over time, aleatory uncertainty will never decrease; however, we may acquire better tools for its measurement. For example, consider a fault that generates earthquakes on average once every ten years. Assume that the physical nature of the fault becomes perfectly understood. Then, even if we know the average time between earthquakes, we will not know when the next earthquake will occur.

The word "epistemic" is derived from the Greek term for knowledge, *episteme*. Epistemic uncertainty stems from incomplete or inaccurate knowledge of an underlying process. Using the previous example, about a fault that generates earthquakes on average once every 10 years, the uncertainty would be called "epistemic" if the same number of observations was used but new information on GPS measurements was obtained such that the average recurrence rate was determined to be closer to 12 years rather than 10 years.

The following figure illustrates that, as more knowledge or data becomes available, aleatory uncertainty cannot be reduced while epistemic uncertainty should decrease.

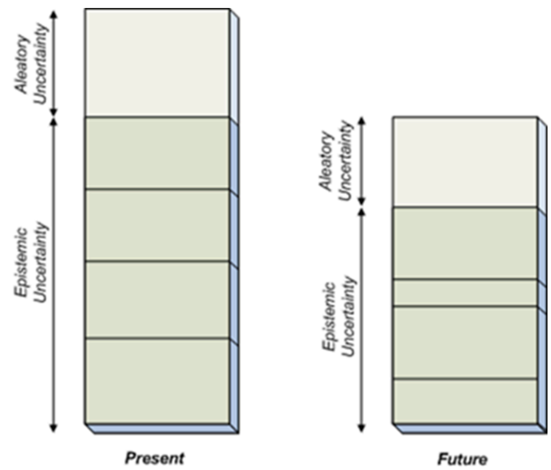


Figure 4. Depiction of uncertainties in models at present and in the future

Uncertainty within a catastrophe model

Verisk uses advanced methods to derive uncertainty and apply it to model loss estimates.

At Verisk, the uncertainties estimated by different model components are referred to as *Primary Uncertainty* and *Secondary Uncertainty*. **Primary uncertainty** is the uncertainty in the modeling and estimation of the natural peril physical parameters that are included in an event catalog. **Secondary uncertainty** is the uncertainty in the estimation of the intensity footprint for an event, the damage functions, which are used to calculate expected damage, and the user input exposure data. It can also be thought of the uncertainty in losses given that an event has occurred.

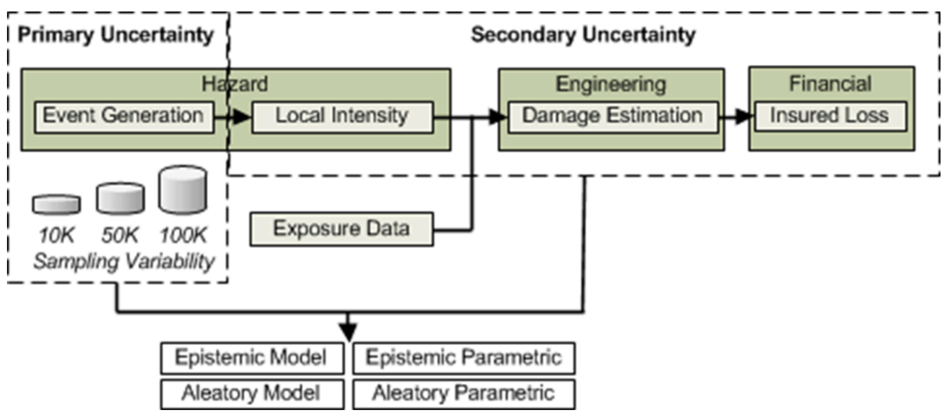


Figure 5. Primary and secondary uncertainty in the model architecture

Primary uncertainty is associated with the stochastic catalog of events for a given model. It includes uncertainty in the parameterization of the probability distributions of outcomes used to create the catalog (parameter uncertainty), the choice of the model used to represent the process under consideration (model uncertainty), and whether the size of the stochastic event set wholly accounts for the uncertainties present in the expected realization of the modeled hazard (sampling variability or process risk uncertainty).

Taking each of these in turn, there is uncertainty in past data due to the implicit deficiencies in the historical record. Since there is underreporting both of small events and of significant events in recorded history, both tails of the probability distribution, and thus the parameters that govern the distribution, are affected by this deficiency in the historical record. This uncertainty is called parameter uncertainty. To address this uncertainty, Touchstone uses multiple sources or information, then supplements it with geophysical information, such as GPS observations, where available. For example, when fitting a Gutenberg-Richter distribution to model the frequency of earthquake occurrences in a given fault segment, physical characteristics of the fault can be used to estimate the largest magnitude earthquake possible since it is likely that this data is not present in the historical record.

Verisk offers multiple stochastic event catalogs for certain models. For example, for the U.S. hurricane model, it offers both the standard and climate-conditioned catalogs (the latter catalog shows the effect of a warmer ocean on hurricane frequency). There are also time-dependent and time-independent earthquake catalogs for the U.S. and Japan. (The time-dependent earthquake catalog accounts for a decreased probability of an earthquake at a seismic fault after the occurrence of an earthquake at that fault). In the absence of a clear consensus in the scientific community, a multiple-catalog approach better captures the current state of knowledge and should be used by clients as a means of sensitivity testing the impact on their portfolio loss estimates.

The sampling variability or process risk uncertainty is associated with catalog size. A catalog with more scenario years (e.g., 100,000 years vs. 10,000 years) has inherently less sampling variability than a smaller catalog because it better reflects the full range of possible outcomes for the upcoming year. Although this source of variability can be reduced by using ever-larger samples of events, for the purposes of computational efficiency and workflow requirements (a larger catalog results in longer analysis times), it is desirable to constrain the size of the catalog. Verisk uses constrained sampling to reduce its 100,000-year or larger catalogs to a 10,000-year catalog that most closely resembles the losses of the 100,000-year or larger catalogs at certain geographic resolutions.

Secondary uncertainty is the uncertainty in the intensity footprints, damage functions, and user input exposure data within a catastrophe modeling framework. This type of uncertainty is reflected in the Touchstone financial module documentation and propagated throughout the loss calculation.

First, consider the intensity footprint of a hurricane. Within that footprint, there may be areas which see higher (or lower) winds than a model would estimate. For example, if a hurricane spawns a tornado within its footprint, that could cause higher than otherwise expected damage within the area the tornado impacts. These impacts would not, however, be explicitly captured by the model, and are therefore a source of uncertainty in the expected damage and loss.

A second example relates to vulnerability or damage functions. A model's damage functions are meant to estimate the expected level of damage or mean damage ratio (MDR) for a given location and event, taking into account the characteristics of said location. However, there is variation in how structures may perform given a level of intensity of hazard that the damage function cannot capture in estimating damage on a deterministic basis. Imagine two buildings with the same basic risk characteristics adjacent to one another. The model would predict a similar, if not the same level of damage to each of these two buildings. However, perhaps one of these buildings was built somewhat shoddily, with the contractors taking shortcuts and using cheaper materials, while the other was constructed to strict building codes using high quality materials. The damage function would not reflect these details, nor the resulting variation in damage that could then ultimately occur between the two risks in a real-world scenario.

Finally, an example regarding how exposure data can also feed into secondary uncertainty. Consider the use of construction class to categorize risks and better understand their vulnerability. These classifications (e.g., wood frame, masonry, reinforced concrete) provide useful information to the model to classify risks and thereby estimate their relative vulnerabilities and expected damage for simulated events. However, these are just qualitative classifications within each construction class. There is a range of structures that could be classified within a given group, and across this range there are variations in vulnerability, which in turn drives uncertainty in the eventual damage and loss within the model.

Primary uncertainty

Primary uncertainty in catastrophe modeling represents both the epistemic and aleatory uncertainty included in the generation of the *stochastic event catalog*.

The stochastic event catalog is developed by dividing the peril under consideration, such as a hurricane, into the components that define the peril, such as landfall angle or radius of maximum winds. Touchstone's financial module then stochastically samples from the probability distributions developed to model those components.

The figure below is a schematic representation of the components of the hurricane model's stochastic event catalog.

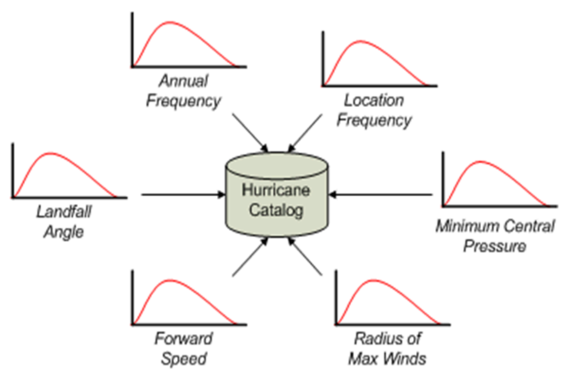


Figure 6. Hurricane model components in the stochastic catalog

There is uncertainty in the following areas:

- The parameterization of these probability distributions (parameter uncertainty)
- The choice of the model used to represent the process under consideration (model uncertainty)
- Whether the size of the stochastic event set wholly accounts for the uncertainties present in the expected realization of the modeled hazard (sampling variability or process risk uncertainty)

Taking each of these in turn, there is uncertainty in past data due to the *implicit deficiencies in the historical record*. Since there is under reporting both of small events and of significant events in recorded history, both tails of the probability distribution, and thus the parameters that govern the distribution, are affected by this deficiency in the historical record. This uncertainty is called *parameter uncertainty*. To address this uncertainty, the financial engine uses multiple sources of data and supplements the data with geophysical data, such as GPS observations, where available. For example, when fitting a Gutenberg-Richter distribution to model the frequency of earthquake occurrences in a given fault segment, physical characteristics of the fault can be used to estimate the largest magnitude earthquake possible since it is likely that this data is not present in the historical record.

There is uncertainty in the choice of model used to represent the process, which is called *model uncertainty*. Verisk offers multiple stochastic event catalogs for certain models; for example, for the U.S. hurricane model, it offers both the standard and climate-conditioned catalogs (the latter catalog shows the effect of a warmer ocean on hurricane frequency). There are also time-dependent and time-independent earthquake catalogs for the U.S. and Japan. (The time-dependent earthquake catalog accounts for a decreased probability of an earthquake at a seismic fault after the occurrence of an earthquake at that fault). In the absence of a clear consensus in the scientific community, a multiple-catalog approach better captures the current state of knowledge and should be used by clients as a means of sensitivity testing the impact on their portfolio loss estimates.

The *sampling variability or process risk uncertainty* is associated with catalog size. A catalog with more scenario years (e.g. 100,000 years vs. 10,000 years) has inherently less sampling variability than a smaller catalog because it better reflects the full range of possible outcomes for the upcoming year. Although this source of variability can be reduced by using ever-larger samples of events, for the purposes of computational efficiency and workflow requirements (a larger catalog results in longer analysis times), it is desirable to constrain the size of the catalog. Verisk uses *constrained sampling* to reduce its 100,000-year or larger catalogs to a 10,000-year catalog that most closely resembles the losses of the 100,000-year or larger catalogs at certain geographic resolutions.

Secondary uncertainty

Secondary uncertainty in catastrophe modeling is the uncertainty associated with the structural damage to physical risks, locations, and facilities should a given event occur..

- **Model uncertainty**, as described in the *primary uncertainty* section, is also a source of secondary uncertainty. There is uncertainty in the local intensity (e.g. ground motion or wind speed) of an event at a given location. Depending on the underlying assumptions, parameters, and data used, different equations, that is, alternative models, for calculating local intensity are possible.
- Translating **local intensity** to building performance is another source of secondary uncertainty. Since actual damage data is scarce, especially for the most severe events, statistical techniques alone are inadequate for estimating building performance. As a result, Verisk constructs damage functions based on a combination of historical data, engineering analyses, claims data, post-disaster surveys, and information on the evolution of building codes. At Verisk, the variability of damage for a building of a particular typology is represented by a probability distribution, which represents the intrinsic uncertainty in the estimation of both local intensity and damage.
- Another source of secondary uncertainty is **parameter risk**, which is related to the inclusion of further characteristics such as the selection of the percentage of storm surge impact that affects wind losses. The catastrophe modeler needs to consider the implications of whether demand surge should be included in the analysis.

Secondary uncertainty may also occur because of **inaccuracies in the exposure data**. For example, the building characteristics or replacement values may be input incorrectly. To reduce these sources of uncertainty it is important that the exposure data is accurate.

MDR and modeling secondary uncertainty

The entry point to the Touchstone financial module is probabilistic secondary uncertainty description for coverage loss, given in the form of loss distribution.

One characteristic of cost, estimated by catastrophe models, is the mean damage ratio (MDR), or when multiplied by replacement value, mean ground-up loss. This loss is a function of peril intensity (e.g., wind speed) and exposure characteristics. However, given that the exposure characteristics can never be fully captured and there is uncertainty in the local hazard intensity representation, there is no 1:1 relation between hazard intensity and loss. The following image shows an ensemble of damage ratios around the model-predicted MDR. This ensemble characterizes variability of insurance claims data (in red) around damage function (in blue) which translates peril intensity into the mean damage ratio. For a particular value of the intensity a probability distribution of damage (in gray) is developed for the different insurance policy coverages, that is, for buildings, other structures, contents, and time element.

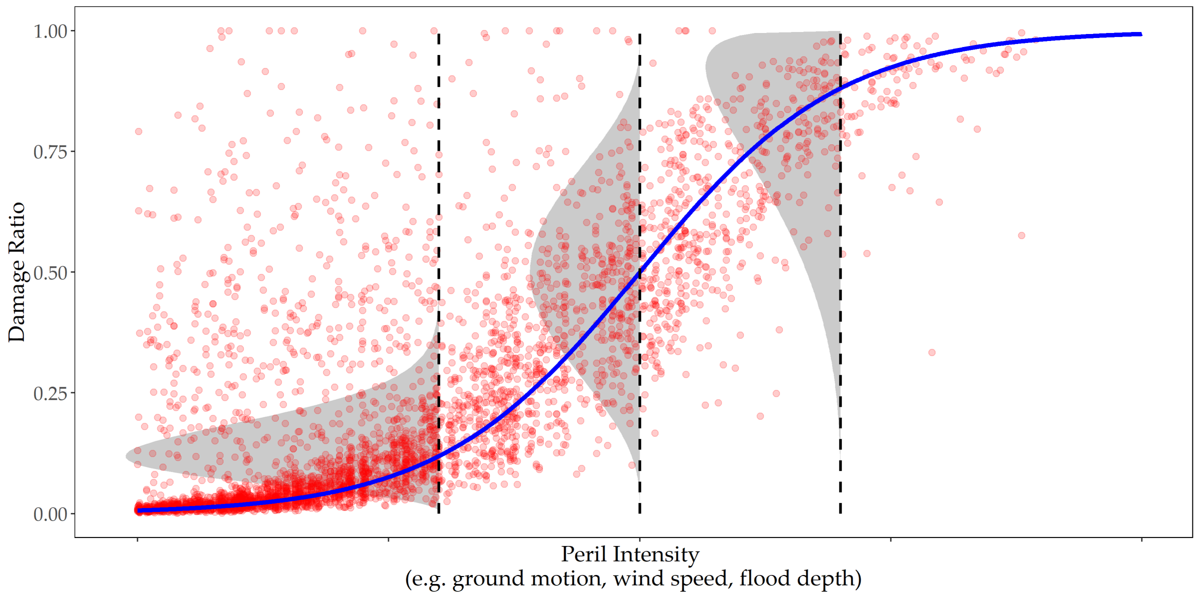


Figure 7. Secondary uncertainty distributions around a given mean damage ratio

An example of a discrete probability density function (PDF) of coverage loss distribution is shown below. This PDF has two important practical features. The first is the presence of discrete spikes called atoms at zero loss and total loss, representing the probability of no damage (shown in orange) or full damage (shown in green), respectively. Zero damage might occur because a particular exposure was not affected by a particular peril during a catastrophic event or the model-predicted footprint of the event did not match the actual footprint causing mean damage to be slightly above zero for areas unaffected by the event. The spike at total damage might be for example attributed to a house shifting off its foundation, overall structure racking, unrepairable structural damage (structure still partly intact) or total structural failure.

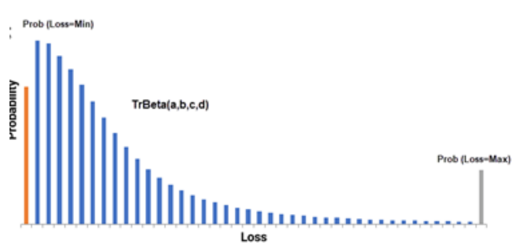


Figure 8. Discrete probability density function of loss

The second feature of a typical coverage loss distribution is the main part (shown in blue bars) which models the bulk of the distribution for the losses in between the two atoms. NGFM uses the discretized 4-parameter Transformed Beta family [1] to describe the main part. This selection was based on analysis of insurance claims data. In essence, damage ratios for different perils and different coverage types can be created for each claim as a function of the loss divided by replacement value. By normalizing the frequency of claim damage ratios, the uncertainty distribution for a given modeled mean damage ratio can be inferred. Accordingly, an empirical damage distribution is derived for each intensity and modeled mean damage ratio. These empirical relationships are then mirrored into a functional form of 4-parameter transformed beta rather than, for example, 2-parameter distributions like beta, gamma or log-logistic.

This allows for more accuracy in modeling the tail of the empirical loss distribution inferred from insurance claims data. The distributions have smoothly transitioning shapes between the two atoms and the main part, as MDR increases and there are no large gaps with zero probability in the main part of the distribution. For example, the following image shows a set of loss distributions for the hail peril and for the building coverage. The distributions are aligned in a spiral as shown in the left panel going from low to high mean damage ratios. Each distribution is colored by the value of its MDR using the heatmap in the right panel.

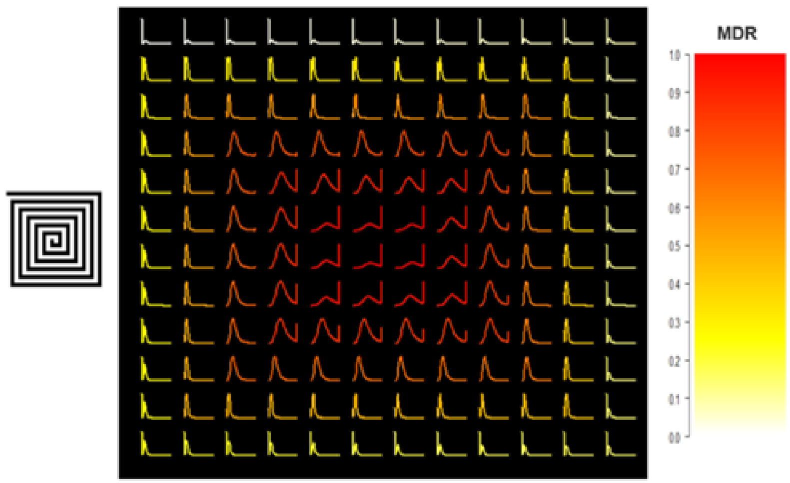


Figure 9. New transformed beta family of damage distributions for hail

Distributions shown in white represent mean damage ratios approaching 0 (no loss), while distributions in red represent mean damage ratios approaching 1 (maximum loss). Moving along the spiral, the distributions transition from the spike at zero damage, monotonically inflating a bell-shaped main part, which then smoothly shifts towards the spike at total damage in the middle of the figure.

The procedure described above for fitting the distributions is performed for Residential Coverages A and C. Additionally, intuitive relationships between different Coverages' distributions are enforced. Because the large majority of the claims have low or moderate MDR, the fitting of distribution parameters to data (i.e., determining the functional form mentioned above) was performed in this MDR range. In other MDR ranges, extrapolation of the parameters was used to determine the shape of loss distributions. An example of the fitted distributions for inland flood are shown in the figure below, for selected MDRs with

[1] Venter, G. (1983), Transformed beta and gamma distributions and aggregate losses. *Proceedings of the Casualty Actuarial Society*, Vol. LXX. http://www.casact.org/pubs/proceed/proceed83/83156.pdf

sufficient amounts of data. The interior part of the fitted distributions matches well with the distributions of the claims.

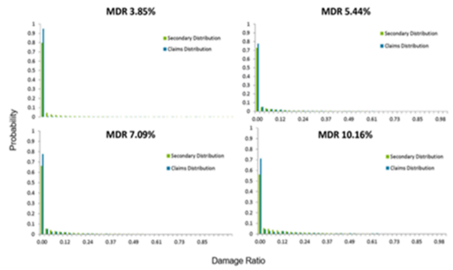


Figure 10. Smoothed parametric fit of Coverage A inland flood distributions to claims data

Some assumptions can be made about the differences between the behavior for certain coverages and construction types, and these assumptions can be used to derive distributions from the Residential Coverage A uncertainty distribution, as illustrated below. For Coverage B, the following conditions regarding the distribution of uncertainty are used for the inland flood peril:

- Because appurtenant structures are likely built to a lower construction standard than the primary building, the probability of total loss (P1) for Coverage B is higher than for Coverage A.
- In claims data a higher frequency of zero loss for coverage B as compared to coverage A is observed, which can be due to insurance practices in terms of replacement value assignment to Coverage B and/or coverage assignment to damaged property. Thus, the probability of zero loss (P0) for Coverage B is higher than for Coverage A.
- The variety in appurtenant structures and the less stringent enforcement of construction standards for Coverage B, relative to Coverage, A imply that the standard deviation (SD) will be higher for Coverage B than for Coverage A.

Using a similar method implemented for the derivation of the uncertainty distribution for Coverage B from Coverage A, assumptions are used to derive the distribution of uncertainty for commercial structures relative to uncertainty for residential buildings. Again, the example below is for the inland flood peril:

- The probability of zero loss (P0) and total loss (P1) for commercial and residential buildings are the same because commercial buildings are not expected to provide significantly different resistance to flood damage than residential structures.
- Since there are more variable construction types for commercial structures than standard residential homes, standard deviation (SD) is higher for commercial buildings than residences.

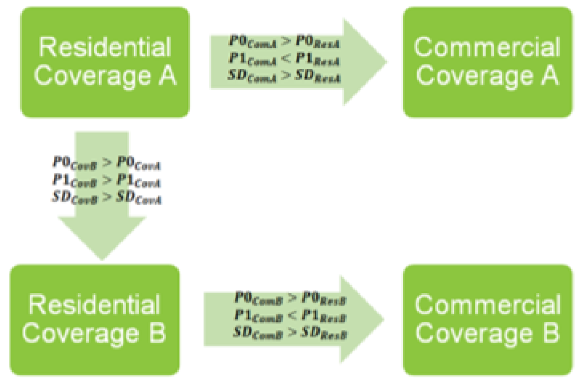


Figure 11. Residential and commercial inland flood distributions for Coverages A and B

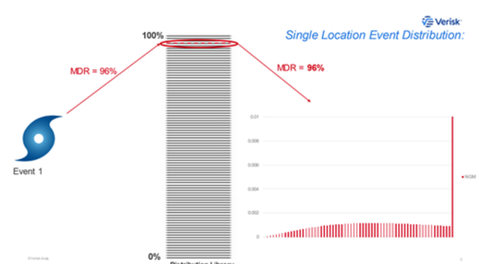
As part of the fitting procedure explained above, the distributions were validated against the claims data for agreement on some basic statistics, such as the standard deviation. Another important statistic to validate is the behavior of gross losses (GR) relative to ground up losses (GU). At a given location,

$$Gross - to - Ground\ Up\ Loss\ Ratio = \frac{Mean\ GR\ Loss}{Mean\ GU\ Loss}$$

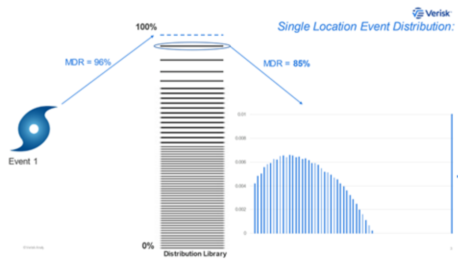
where the gross loss is calculated based on a deductible that is given as a proportion of the replacement value. For residential claims, the limit is typically equal to the replacement value.

In this case, the ground up loss change driver in NGM the enhanced distribution library which allows for more accurate mapping of mean damage ratios to secondary uncertainty distributions, which can more accurately reflect the simulated MDR for a specific location. In Touchstone for a specific location and a specific event, the model will calculate a mean damage ratio for that location based off the hazard/vulnerability at that location and then select a corresponding secondary uncertainty distribution to reflect all of the variables that could impact losses.

In NGM, as the first chart below shows, Touchstone will get an MDR for a location from an event, such as the hypothetical Event 1 below, and then pick the corresponding uncertainty distribution that reflects that MDR.



Previously, the methodology was the same as we can see below in the current financial module for the same location/hypothetical event, however the distribution library was more sparse. As such, there may not always be a distribution available that exactly reflects the incoming MDR, and when the distribution is used to calculate the final MDR at the location, the value can differ as result.



The impact of this change to more closely reflect a wide range of MDRs by increasing the number of distributions available can be positive or negative depending on each location/ event but will be noticeable for the larger events where higher MDRs are experienced. This change does apply for hurricane wind and surge, and the impact will vary depending on which sub-perils are run, and the level of hazard the locations in the portfolio are experiencing.

Empirical evidence of uncertainty in claims data

Catastrophe models are not exempt from uncertainty.

For example, look at the set of buildings in the following image. The buildings are of equal height and similar construction but, from a structural point of view, the buildings experience different levels of damage.

Catastrophe models must account for such variability, which is represented by a probability distribution of damage for a building given that an event has occurred. The type of probability distribution used varies according to the type of modeled peril and the level of intensity experienced by the structure. As illustrated below, different perils can have a wide variation of damage when affected by the same intensity. For example, for the U.S. Wildfire peril there is a strong incidence of 100% damage when the intensity is both low and high. This is modeled using an empirical distribution that allows for low levels of damage at 0% up to 30% and then no damage until 100%.

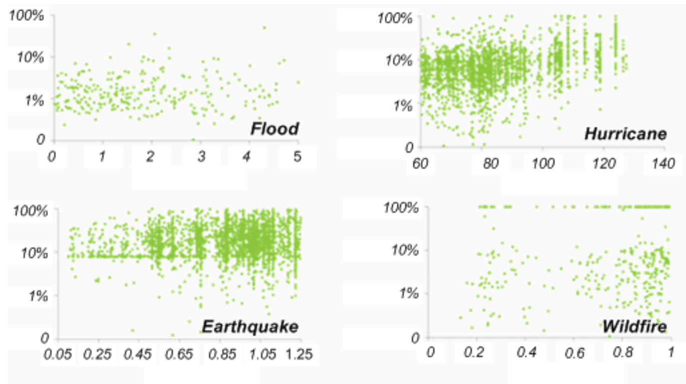


Figure 12. Claims data plot for four different perils

In addition, to model the damage to a structure for a given intensity in North America, synthetic bi-modal beta distributions are used for the earthquake peril and a truncated Gamma distribution for the wind peril. For some earthquake models, Beta distributions are used to model the damage given an intensity and a Beta-Bernoulli distribution used in flood modeling. The following table identifies the type of secondary uncertainty distributions used by each peril type.

Table 1. Type of secondary uncertainty distribution used by each peril type

Peril	Type of uncertainty distribution
Flood	Zero-inflated, limited transformed beta
Earthquake	Zero-inflated, limited transformed beta
Wind	Zero-inflated, limited transformed beta
Wildfire	Empirical distribution with spike at 100% damage and triangular shape from 0% to x% damage where x<100%

This section has described several sources of uncertainty in catastrophe models. As science becomes more advanced and more data is collected, epistemic uncertainty present in modeling will decrease. However, there will always be some variability that is intrinsic and cannot be removed from any stochastic model.

Distributions for severe thunderstorms

Table 2. Distributions for severe thunderstorms

Coverage	Residential (Res)/ Non-Engineered (NE)			Commercial (Com)/Engineered (Eng)		
	Hail	Wind	Tornado	Hail	Wind	Tornado
A	Loglogistics, based on hail claims	Tr[2] Beta, based on HU[3] claims	Tr Beta, adjusted version of Res/ NE	Loglogistics, adjusted version of Res/ NE	Tr Beta, adjusted version of Res/ NE	Tr Beta, adjusted version of Res/ NE
B	Loglogistics adjusted coverage A	Tr Beta, based on HU claims	Tr Beta, adjusted version of Res/ NE	Loglogistics, adjusted version of Res/ NE	Tr Beta, adjusted version of Res/ NE	Tr Beta, adjusted version of Res/ NE
C	Tr Beta, based on HU claims	Tr Beta, based on HU claims	Tr Beta, based on HU claims	Tr Beta, based on HU claims	Tr Beta, based on HU claims	Tr Beta, based on HU claims
D	Tr Beta, based on HU claims	Tr Beta, based on HU claims	Tr Beta, Adjusted Res/NE, Higher limit	Tr Beta, Adjusted Res/NE, Higher limit	Tr Beta, Adjusted Res/NE, Higher limit	Tr Beta, Adjusted Res/NE, Higher limit

Concept of a distribution

Insurance loss accumulation under multiple degrees and types of modeled uncertainty is a complex statistical task.

Doing so with transparency, while enabling the flexibility of additional user-defined assumptions and accomplishing it with minimum runtime, is a further challenge.

Note

- Loss uncertainty is captured using a probability distribution that represents the range of losses to a location as a result of being affected by a hazard of a specific intensity.
- The fundamental axiom that governs a probabilistic distribution is that the total probability summed across all bins is 1.

Example of loss uncertainty

Loss uncertainty is illustrated in the figure below, where the X-axis represents the range of losses for a given location for a single event and the Y-axis represents the probability of loss. Touchstone peril models produce probabilistic distributions for each coverage and each

[2] Tr = Transformed
[3] HU = Hurricane

location for every event. The probability distribution is divided into discrete intervals. Each interval of loss is called a "bin" and the amount on the Y-axis represents the corresponding probability that the incurred loss lies within the range of the bin. For example, the last bin in the plot below ranges from $48,750 to $50,000, and the probability that the loss for this location and coverage occurs within this range is 0.005 for the event under consideration.

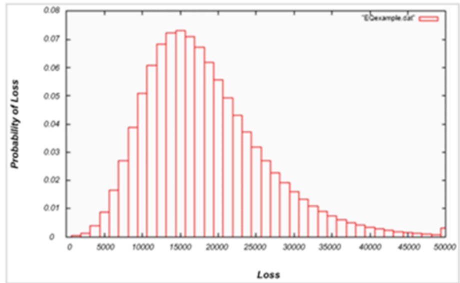


Figure 13. Sample distribution of loss uncertainty

For each location and coverage, losses can range from zero loss to total loss and each value of loss has an associated probability of occurrence. *It should be intuitively reasonable that the total probability across all possible losses should be 100% or 1.* Touchstone uses this discretized probability distribution to apply policy terms.

3 Statistical methodologies

Statistical methodologies and loss accumulation

Statistical methods and algorithms in catastrophe modeling are employed to generate loss accumulation.

Touchstone now employs a more sophisticated loss distribution accumulation than the legacy financial module. Coverage loss distributions are now aggregated to a location loss distribution in the sequential actuarial order.

Changes to loss distribution accumulation

The method of determining loss distribution accumulation in Touchstone.

Four coverage loss distributions are aggregated to a location loss distribution in the sequential actuarial order: A (building), C (contents), B (appurtenant structures) and D (time element). This is done using the Mixture Method for computing the distribution of the arbitrary sum f_S of dependent random variables [4] . The sums of interest are referred to as the A+C, A+C+B and A+C+B+D. Each time the financial engine adds one coverage to the sum of coverages, the mixture weight, is used to obtain a new distribution characterizing this sum. The weight quantifies the strength of comonotonic dependency between two random variables. The financial engine imports three weights w_1, w_2, w_3 for A+C, A+C+B and A+C+B +D, respectively from hard-coded tables. Then, the Mixture Method is applied sequentially using the following convolution-based scheme:

$$
\begin{aligned}
f_{X_A+X_C} &= (1-w_1)\cdot f_{X_A^{\perp}+X_C^{\perp}} + w_1 \cdot f_{X_A^{+}+X_C^{+}} \\
f_{X_A+X_C+X_B} &= (1-w_2)\cdot f_{(X_A+X_C)^{\perp}+X_B^{\perp}} + w_2 \cdot f_{(X_A+X_C)^{+}+X_B^{+}} \\
f_{X_A+X_C+X_B+X_D} &= (1-w_3)\cdot f_{(X_A+X_C+X_B)^{\perp}+X_D^{\perp}} + w_3 \cdot f_{(X_A+X_C+X_B)^{+}+X_D^{+}} \\
f_S &\approx f_{X_A+X_C+X_B+X_D}
\end{aligned}
$$

where , $f_{X_A+X_C}$ $f_{X_A+X_C+X_B}$ and $f_{X_A+X_C+X_B+X_D}$ are the discrete PDFs describing (partial) sums of coverages and the superscripts “⊥” and “+” represent independent and comonotonic (or maximally correlated) counterparts of coverage losses and their sums. [5]

Loss accumulation algorithms

Loss algorithms generate loss distributions by location, layer, contract, portfolio, and event.

Algorithms apply convolution and comonotonic distribution, and a process to combine them called the Mixture Method.

Loss distribution algorithms

To produce loss distributions, the Touchstone uses several core algorithms.

[4] https://www.air-worldwide.com/publications/air-currents/2020/next-generation-modeling-loss-accumulation/

[5] https://www.air-worldwide.com/publications/air-currents/2021/next-generation-financial-modeling-for-residential-and-small-business-lines/

- **Convolution**: Loss distributions are aggregated assuming that losses are completely independent from each other.

  For example, convolution cannot account for the fact that if a building is severely damaged, the contents of the building are also likely severely damaged.
- **Comonotonic distribution**: Loss distributions are aggregated assuming that losses are maximally correlated.
- **Mixture method**: Combines convolution and comonotonic distribution.

Since Verisk's models must sometimes account for dependencies among loss distributions, Touchstone employs the *mixture method*. Verisk's scientists calibrate the algorithm such that it closely reflects historical claims data or a detailed model of dependency.

Touchstone determines which algorithm to apply at each point in the analysis based on user-specified analysis options and the point of aggregation.

About convolution

The process by which probability distributions in Touchstone are combined or added together is known as convolution.

There are various implementations of convolution, one of the core algorithms employed by the financial module. The original Touchstone financial module used a numerical convolution; the new financial module uses split-atom convolution which is more accurate, computationally faster, and limits the strain on storage resources.

Convolution is the process of combining two independent probability density functions (PDFs). For example, one can calculate the density function $p_s(s)$ of the sum S=X+Y of two independent discrete random variables X and Y characterizing catastrophe losses with the densities p_x and p_y, respectively, as follows:

$$p_S(s) = p_X \oplus p_Y = \sum_x p_X(x) p_Y(s - x)$$

Where $\oplus$ is the mathematical symbol for convolution.

Brute force convolution

The most precise method to compute the sum of two random variables $p_X \oplus p_Y$ is *brute force convolution*. This is illustrated in the figure below. The algorithm computes all cross-products of probabilities, all cross-sums of losses, and requires redundancy removal. Taken together, these steps amount to a computationally costly and impractical method for modeling event loss distributions for large portfolios of insured locations.

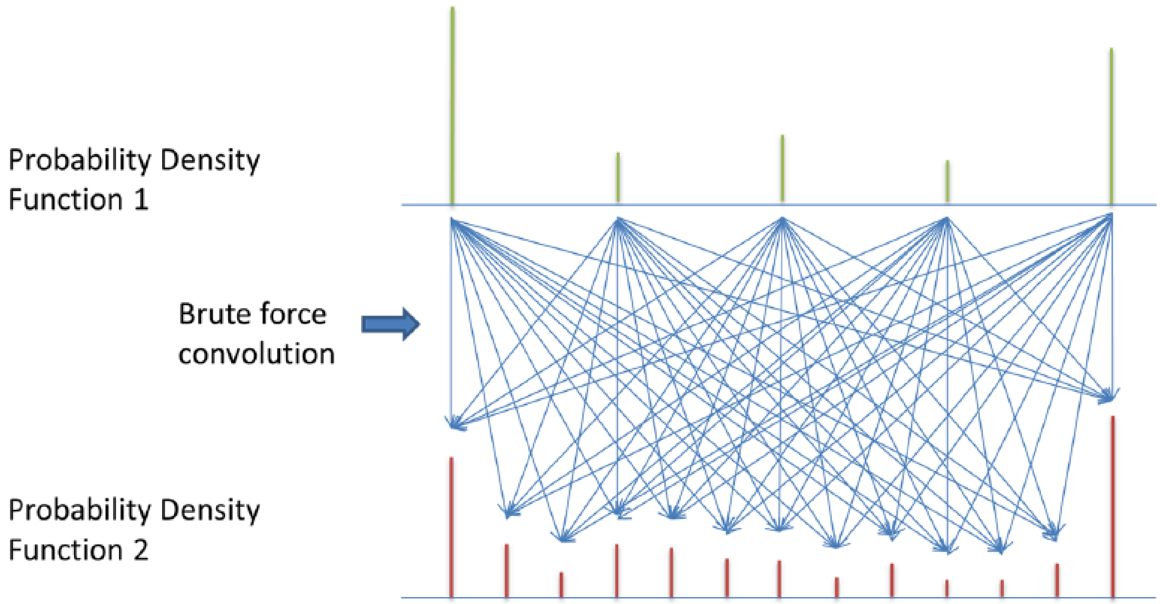


Figure 14. Brute force convolution

Split-atom convolution

Touchstone employs split-atom convolution with 2-point (or linear) regridding. Split-atom convolution is a computationally efficient approximation to brute force convolution[6]. As its name suggests, the algorithm involves separating two atoms at the minimum and maximum points of a distribution and resampling the remainder of the distribution such that the new distribution maintains the mean and general shape of the original distribution. The principle of split-atom convolution is illustrated below. Notice that the cobweb of connections are more spare than those in the figure above, resulting in a more computationally efficient process at the acceptable expense of some precision.

[6] Wójcik, R.; Liu, C.W.; Guin, J. Direct and Hierarchical Models for Aggregating Spatially Dependent Catastrophe Risks. Risks 2019, 7, 54. Available online: https://www.mdpi.com/2227-9091/7/2/54/pdf (accessed on 17 March 2020).

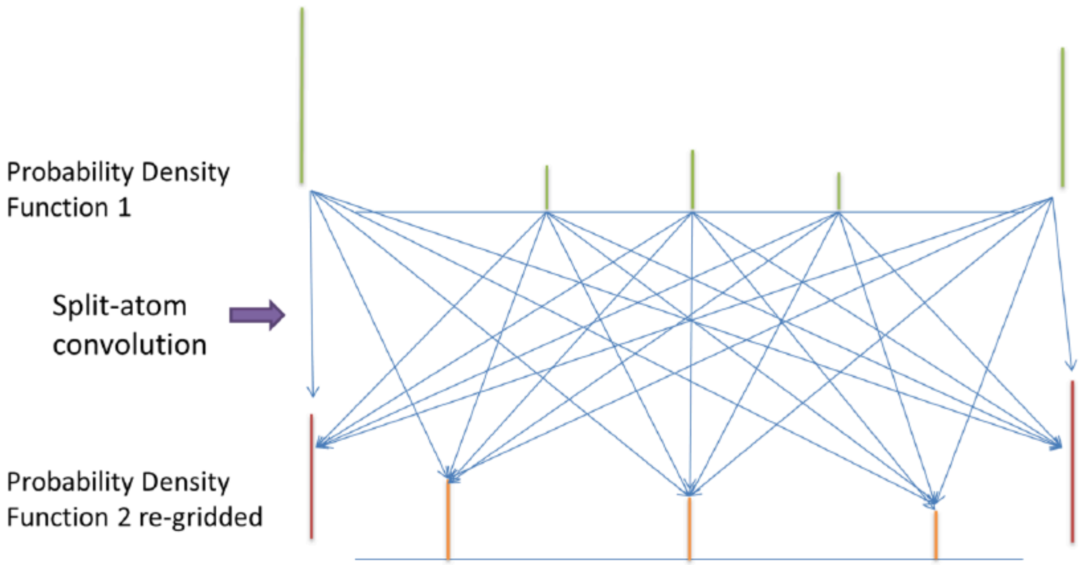


Figure 15. Split-atom convolution

The atoms are inferred from claims data and are the result of applying financial terms such as deductibles and limits in the context of complex reinsurance structures. Consequently, split-atom convolution preserves the minimum and maximum losses at various loss perspectives.

Comonotonicity

Comonotonicity describes a very highly correlated dependence structure among random variables.

The process by which probability distributions are combined or added together for a group of such comonotonic variables is known as the *Distribution of Comonotonic Sum*.

About comonitonic distribution

The second core algorithm employed by the Touchstone financial module is comonotonic distribution.

Where convolution assumes independence, comonotonic distribution imposes the strongest possible correlation.

For example, one can calculate the cumulative distribution function F_S^+ of the sum of two maximally dependent discrete random variables X_1 and X_2 characterizing catastrophe losses with the cumulative density functions (CDFs) F_{X_1} and F_{X_2}, respectively, as follows:

$$F_{S^c}(x) = \sup\left\{p \in [0, 1] \sum_{i=1}^{n} F_{X_i}^{-1}(p) \le x\right\}$$

Comonotonic random variables are quantile additive, so the following statement holds:

$$F_{S^c}^{-1}(p) = \sum_{i=1}^{n} F_{X_i}^{-1}(p),\ p \in [0, 1]$$

Example of comonitonic distribution

The following example shows how comonotonic distribution is used in Touchstone to combine two sets of losses and their associated probabilities.

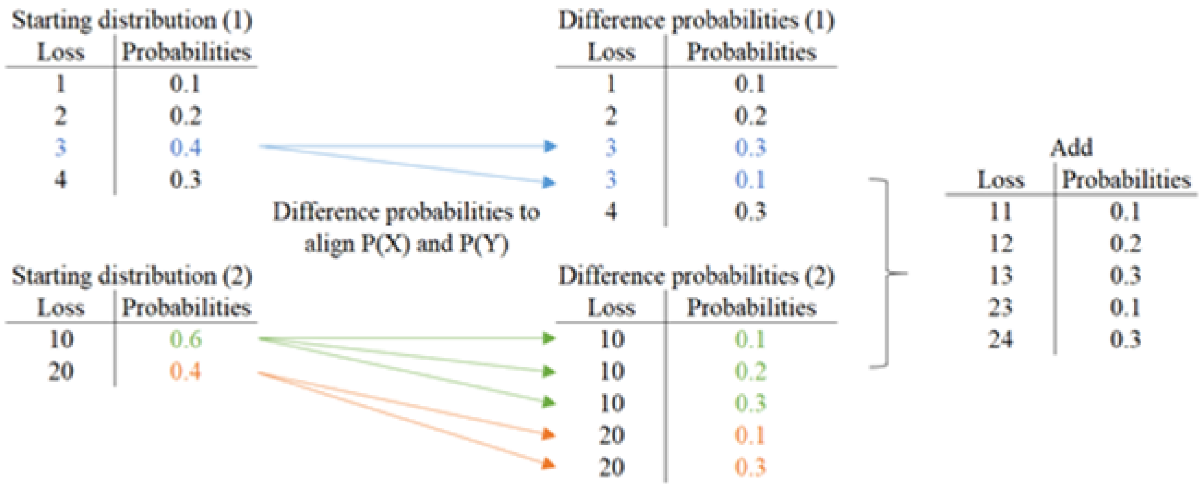


Figure 16. Example of comonotonic distribution

About the Mixture Method

The Mixture Method is a way to generate a probability distribution for the sum of two random variables in a manner that incorporates correlation.

The Mixture Method is a third core algorithm employed by Touchstone. This method weighs the convolution distribution with distribution of the comonotonic sum.

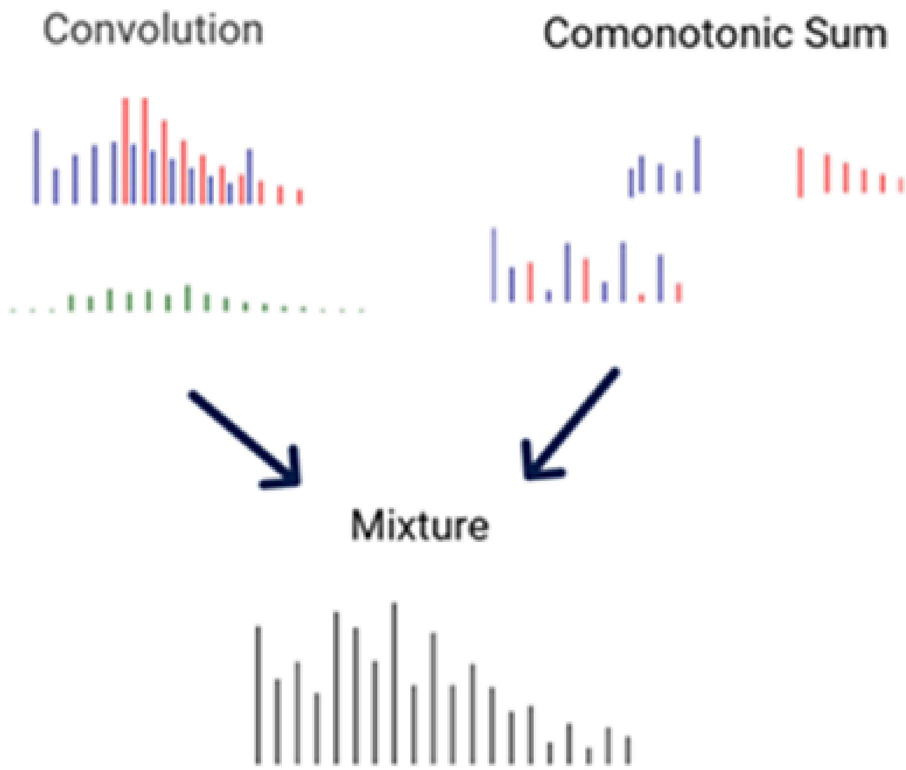


Figure 17. Example of Mixture Method

Since the convolution algorithm for aggregating distributions assumes the complete independence of the distributions, and the comonotonic distribution algorithm assumes maximum correlation, neither can model the intermediate level of dependence between probability distributions of loss due to catastrophic events.

The Mixture Method algorithm

This method accounts for coverage and spatial correlation. Specifically, the distribution F_S of the arbitrary sum S is approximated by the weighted mixture of independent and comonotonic sums:

$$F_S(s) = (1-w)\ F_S^{\perp}(s) + w\ F_S^{+}(s) \quad where \quad 0 \le w \le 1, \quad for \quad all \quad s$$

The weight w in the equation measures how correlated the pairs of risks are and $F_S^{\perp}$ represents convolution and F_S^{+} represents the comonotonic sum.

Convolution	
Probabilities	Loss Values
0.1	0
0.2	50
0.3	100
0.2	150
0.1	200
0.1	250

Comonotonic	
Probabilities	Loss Values
0.3	0
0.2	50
0.1	100
0.1	150
0.1	200
0.2	250

Mixture, weight = 0.2	
Probabilities	Loss Values
0.1 x (1 - 0.2) + 0.3 x 0.2 = 0.14	0
0.2 x (1 - 0.2) + 0.2 x 0.2 = 0.20	50
0.3 x (1 - 0.2) + 0.1 x 0.2 = 0.26	100
0.2 x (1 - 0.2) + 0.1 x 0.2 = 0.18	150
0.1 x (1 - 0.2) + 0.1 x 0.2 = 0.10	200
0.1 x (1 - 0.2) + 0.2 x 0.2 = 0.12	250

Mixture, weight = 0.5	
Probabilities	Loss Values
0.1 x (1 - 0.5) + 0.3 x 0.5 = 0.20	0
0.2 x (1 - 0.5) + 0.2 x 0.5 = 0.20	50
0.3 x (1 - 0.5) + 0.1 x 0.5 = 0.20	100
0.2 x (1 - 0.5) + 0.1 x 0.5 = 0.15	150
0.1 x (1 - 0.5) + 0.1 x 0.5 = 0.10	200
0.1 x (1 - 0.5) + 0.2 x 0.5 = 0.15	250

Figure 18. Example of mixture method use

What is loss accumulation

Loss accumulation is the backbone of any enterprise risk modeling platform, as it is in Touchstone, and includes support for detailed location-level modeling.

Loss accumulation is not a straightforward exercise; the process is both complex—requiring modern and sophisticated statistical methodologies—and computationally demanding.

Accurately modeling the dependencies in loss accumulation is a component of Verisk's overall strategy of propagating and reporting all modeled uncertainty, due to the central role that loss accumulation plays in a catastrophe modeling platform. A robust catastrophe model must be able to do two things:

- Roll up loss results from low-level granular analyses—losses by insurance coverage, by location and by event—to top-level insurance portfolios, including pre- and post-catastrophe insurance and reinsurance net loss.
- Propagate all modeled uncertainty to all financial and actuarial operations for insurance and reinsurance and for all reporting perspectives.

In a catastrophe modeling platform, there are a few general tiers of loss accumulation. The tiers themselves are defined by the generalized structure of the insurance portfolio and reflect market conditions, portfolio structuring, and risk management practices. These accumulation tiers also have an explicit and inherent element of geographical distance, and therefore include some dependencies based on their spatial proximity.

Uncertainty and ground-up loss accumulation

Propagating the uncertainty inherent in loss calculations in Touchstone involves accumulating the loss distributions of multiple risks.

When accumulating losses for ground-up calculations, the accumulation tiers can be generalized and thought of in the following order:

- Insurance coverages to an insured location
- Locations to contracts and contracts to portfolios or books of business

Uncertainty and gross loss accumulation

Propagating the uncertainty inherent in Touchstone loss calculations involves accumulating the loss distributions of multiple risks.

There are a number of accumulations involved in this procedure and in the process of uncertainty propagation in general. These accumulation tiers can be generalized and thought of in the following order:

- Insurance coverages to an insured location
- Locations to sublimits and other groups and campus structures
- Sublimits to excess layers
- Layers to contracts and contracts to portfolios

Portfolios and aggregation trees

The structure of a portfolio in Touchstone determines the order of accumulation steps and this order of operations can be visualized as an *aggregation tree*.

Both the order of loss accumulation and the grouping of risks need to be accounted for to effectively assess and manage risk and abide by accepted statistical principles. Touchstone uses a combination of direct and hierarchical trees (as depicted in the figure below) for both ground-up and gross loss accumulation. Direct trees are computationally the most efficient because the weight in the mixture method only needs to be calculated once—at the root node. Whenever partial correlation between groups of risks and/or their partial sums is of interest (e.g., because of a particular portfolio structure), Touchstone uses hierarchical sequential or hierarchical general trees.

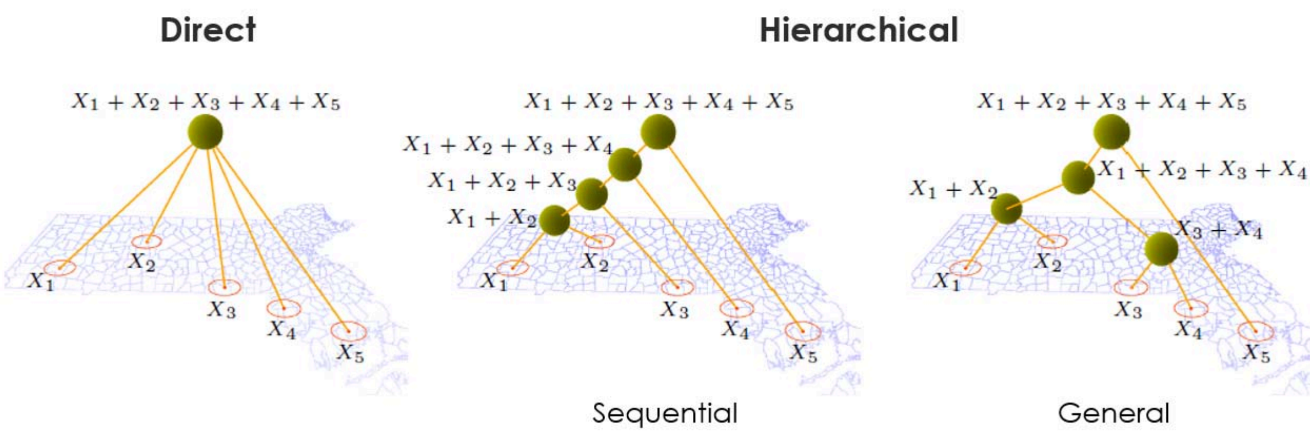


Figure 19. Types of loss aggregation trees used

The topology of a particular tree depends on (i) the type of results requested to be saved and (ii) the different tiers and types of financial terms. (Source: Verisk)

Direct trees are for ground-up — only if there are no financial terms in between. Direct trees can be used up to first tier of financial terms (e.g. locations to sublimits). *Hierarchical trees* are typically applied in all other situations.

Aggregation trees and ground-up losses

In general, the following statements apply to how Touchstone implements aggregation trees for ground-up losses:

- Topology of the event total tree depends on the type of results requested to be saved.
- If losses to be saved are event total, then locations are accumulated using a direct tree.
- If the save request is by line of business, a hierarchical tree is used by first accumulating locations into different lines of business and then lines of business into event totals.

Aggregation trees and gross losses

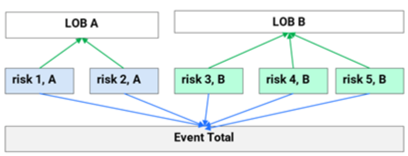
For the aggregation of gross losses, the following statements generally apply:

- Loss is accumulated directly up to the level of the first tier of financial terms (policy).
- Losses are then accumulated hierarchically from policy to event total.
- Levels of hierarchy and groupings of risks depend on different tiers and types of financial terms.

Estimating standard deviations of event loss

Estimating standard deviations of event loss for portfolio, LOB and geography perspectives.

Standard deviations of event loss (GUP, Gross, Net) for portfolio, line-of-business (LOB), geography areas (GEO), and user-defined-zones are estimated by accumulation of location standard deviations with an analytical approach that takes into account spatial correlations. Location, geography and LOB tags are used to determine the grouping of locations and respectively of their standard deviations of loss for the application of accumulation methodology and the selection of the spatial correlation coefficients $[\rho_{i,j}]$ between any two locations (risks). In the diagram below, the example of LOB and portfolio event total accumulation of standard deviations $[\sigma_j^2]$ is used to illustrate the principles of this approach.

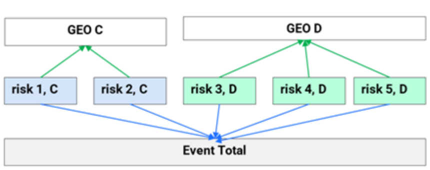


The portfolio standard deviation for event total loss is estimated by the standard analytical formula for sum of correlated variances which includes the spatial correlations among all locations (loc) within the physical event footprint.

$$Portfolio\ Event\ Total\ \sigma = \sqrt{\sum_{i=1}^{n} loc\ \sigma_i^2 + 2 * \sum_{i,\,j=1}^{n} loc\ \sigma_i * loc\ \sigma_j * \rho_{i,j}}$$

This same analytical approach is applied for the estimation of the standard deviation for LOB A in the diagram above, where ρ1A,2A $\rho_{1A,2A}$ is the spatial correlation between locations 1A and 2A. The grouping of location losses and their respective standard deviations is done on account of the location line-of-business tags – in this example tags LOB A and LOB B.

$$LOB\ A\ Event\ Total\ \sigma = \sqrt{loc\ \sigma_{1A}^2 + loc\ \sigma_{2A}^2 + 2 * loc\ \sigma_{1A} * loc\ \sigma_{2A} * \rho_{1A,2A}}$$



By the same methodology the standard deviation for geography C in the diagram above is estimated from the location standard deviations with the geography tag C and their spatial correlation coefficient.

$$GEO\ C\ Event\ Total\ \sigma = \sqrt{loc\,\sigma_{1C}^2 + loc\,\sigma_{2C}^2 + 2 * loc\,\sigma_{1C} * loc\,\sigma_{2C} * \rho_{1C,2C}}$$

Estimated spatial correlation coefficients for selected perils

Estimated values for various intraclass correlation coefficients in financial engine along with their respective scales.

Table 3. Estimated spatial correlation coefficients for selected perils

Peril	Grid 1 Bin Size (km)	Correlation Coefficient	Grid 2 Bin Size (km)	Correlation Coefficient	Auxiliary Correlation
Wind	1	0.07	20	0.02	0.0032
Earthquake	1	0.26	25	0.09	0.0024
Flood	14	0.15			0.051
Severe Thunderstorm	1	0.23			0.00008
Europe Severe Thunderstorm	1	0.11			0.001
Wildfire	1	0.28			0.00

Mapping of spatial correlation coefficients by peril type to individual peril models

Table 4. Mapping of spatial correlation coefficients by peril type to individual peril models

Correlation Coefficients by Peril	Peril models
Wind	Hurricane Model for US, Verisk Tropical Cyclone Model for Hawaii, Verisk U.S. Hurricane Model for Offshore Assets, Verisk Tropical Cyclone Model for the Caribbean, Verisk Winter Storm Model for the United States, Verisk Tropical Cyclone Model for Mexico, Verisk Tropical Cyclone Model for Canada, Verisk Extratropical Cyclone Model for Europe, Verisk Winter Storm Model for Canada Verisk Tropical Cyclone Model for Australia, Verisk Typhoon Model for Japan, Verisk Typhoon Model for Mainland China, Verisk Typhoon Model for Southeast Asia, Verisk Typhoon Model for South Korea, Verisk Tropical Cyclone Model for Central America, Verisk Tropical Cyclone Model for India

Correlation Coefficients by Peril	Peril models
Earthquake	Verisk Earthquake Model for the United States, Verisk Earthquake Model for Canada, Verisk Earthquake Model for Hawaii, Verisk Earthquake Model for Alaska, Verisk Earthquake Model for Caribbean, Verisk Earthquake Model for the Pan-European Region,Verisk Earthquake Model for Southeast Europe, Verisk Earthquake Model for Australia, Verisk Earthquake Model for Japan, Verisk Earthquake Model for New Zealand, Verisk Earthquake Model for Southeast Asia, Verisk Earthquake Model for Mainland China, Verisk Earthquake Model for India, Verisk Earthquake Model for South America, Verisk Earthquake Model for Mexico, Verisk Earthquake Model for Central America.
Flood	Verisk Inland Flood Model for the United States, Verisk Inland Flood Model for Japan, Verisk Inland Flood Model for Central Europe, Verisk Inland Flood Model for Great Britain, Verisk Inland Flood Model for Southeast Europe
Severe Thunderstorm	Verisk Severe Thunderstorm Model for the United States, Verisk Severe Thunderstorm Model for Canada, Verisk Severe Thunderstorm Model for Australia
Europe Severe Thunderstorm	Verisk Severe Thunderstorm Model for Europe
Wildfire	Verisk Wildfire Model for the United States, Verisk Bushfire Model for Australia

Spatial correlation coefficients for accumulating losses from non-conventional weapons in the Verisk Terrorism Model

Table 5. Spatial correlation coefficients for accumulating losses from non-conventional weapons in the Verisk Terrorism Model

	Bomb size	UrbanCla	UrbanCla	UrbanCla	UrbanCla	UrbanClass5
Portable	0.25	0.585	0.498	0.434	0.357	0.170
Car	0.75	0.649	0.585	0.542	0.478	0.309
Van	2.50	0.716	0.680	0.659	0.629	0.514
Small truck	6.00	0.735	0.724	0.720	0.709	0.655
Medium truck	10.00	0.748	0.748	0.748	0.745	0.718
Large truck	25.00	0.778	0.792	0.799	0.805	0.807

The Verisk model validation methodology

Verisk has conducted thorough and comprehensive model validation studies that demonstrate that the methodology implemented in Touchstone best reflects the physical reality of a natural catastrophe and closely approximates the claims risk management workflows of insurers.

These studies ensure that the approach is modern, realistic, and addresses the needs of the industry today.

Predictability analysis

One way to validate the accuracy of our modeled loss estimates for the aggregate risk of a portfolio including spatial correlation is to run a portfolio rollup for historical catastrophe events and compare the predicted distribution of the total loss with the sum of insurance claims for that event. An example for Hurricane Frances is shown in the upper left panel of the figure below. The red curve is the distribution of the total loss predicted by our loss aggregation procedure and the green dashed line represents the sum of the claims.

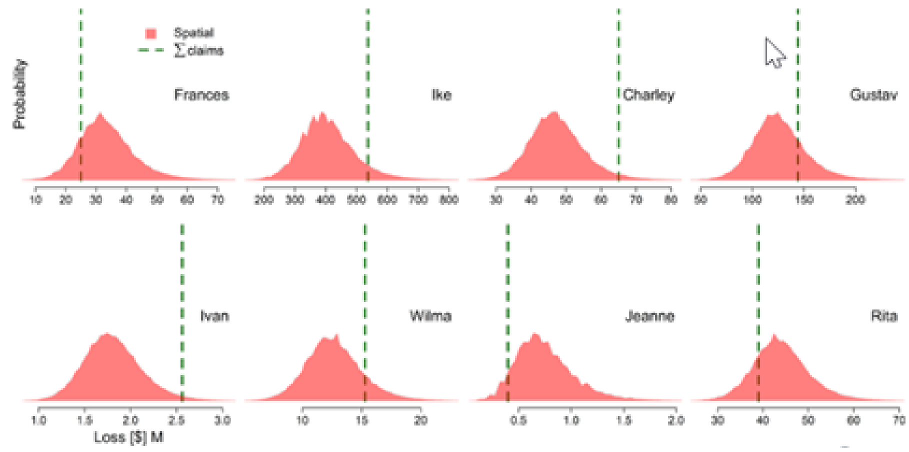


Figure 20. Validation of spatial correlation model in Touchstone using historical claims data for U.S. hurricanes. (Source: Verisk)

Good agreement can be seen, as the sum of claims falls within the potential support of loss distribution, and this sum has a relatively high probability within that distribution. We repeated this procedure for other historical hurricane events. Results show that generally the sum of the claims falls within the predicted loss distribution for a particular event.

This kind of comparison is limited, however, by the fact that we are comparing a full probability distribution with only one number, i.e., one historical realization of the sum of claims. Ideally, we would like to have many such realizations for one historical event and would expect that the distribution of the sum of claims will closely reflect the total loss distribution estimated using our new aggregation scheme. One way to artificially make such a comparison feasible is to randomly draw subsets of available claims data for a particular historical event and repeat the validation procedure for many random subsets. Preliminary results of this type of analysis indicate that the total loss distributions estimated using our mixture method compare favorably with empirical distributions of the sum of claims.

Non-stationary covariance model

One of the core assumptions underlying this model is stationarity. This assumption makes the estimates of spatial correlation coefficients insensitive to shifts in the nested grid system and allows us to use a simplified, yet computationally efficient, block diagonal correlation approach. To validate this methodology and see if this assumption is realistic, we compared loss estimates based on our stationary model to those obtained from a more complex and very computationally expensive non-stationary alternative (see *Higdon,* 2002 for details). Statistical properties of non-stationary phenomena vary in space. A good example is a vortex as shown in the left panel of the next figure. This type of non-stationarity is common in hurricane modeling. The velocity field for a hurricane exhibits strong directional preference that varies in space as the air rotates around the eye of the storm. For comparison, in the right panel, we plotted the model errors for Hurricane Ike (2008). These errors exhibit locally stationary pattern in the areas of Texas and Louisiana, where the hurricane made landfall and caused the most damage. Globally, the model error field for Ike is non-stationary due to the distinct blue pattern caused by its move on an east-northeastward track.

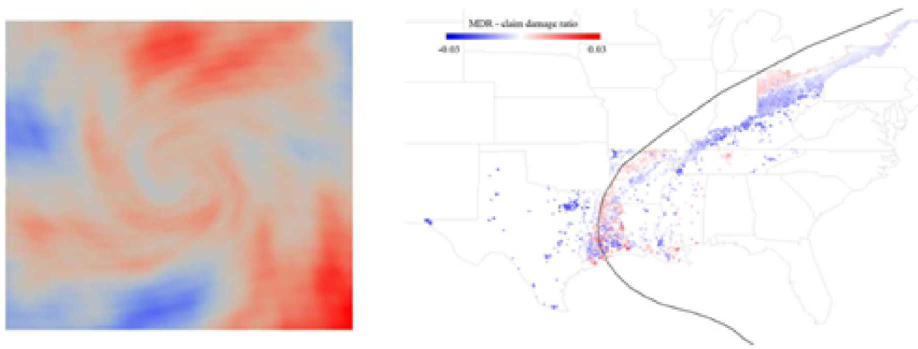


Figure 21. Non-stationary vortex simulation (source: Kleiber, William. (2016)

High resolution simulation of non-stationary Gaussian random fields, Computational Statistics & Data Analysis. 101. 10.1016/j.csda.2016.03.005 (left); model errors for Hurricane Ike event in September 11, 2008. AIR posted estimated losses of between USD 8.2 billion and USD 12.2 billion on September 13, 2008 (right).

The figure below shows the validation results of our stationary spatial correlation model; we compared the total loss distributions (in red) with those obtained from a very computationally expensive non-stationary alternative (shown in blue) for a number of historical hurricane events. The results show that while there are some differences in shape, those differences represent the trade-off between the computational speed and the accuracy of the results; but in general these distributions are similar.

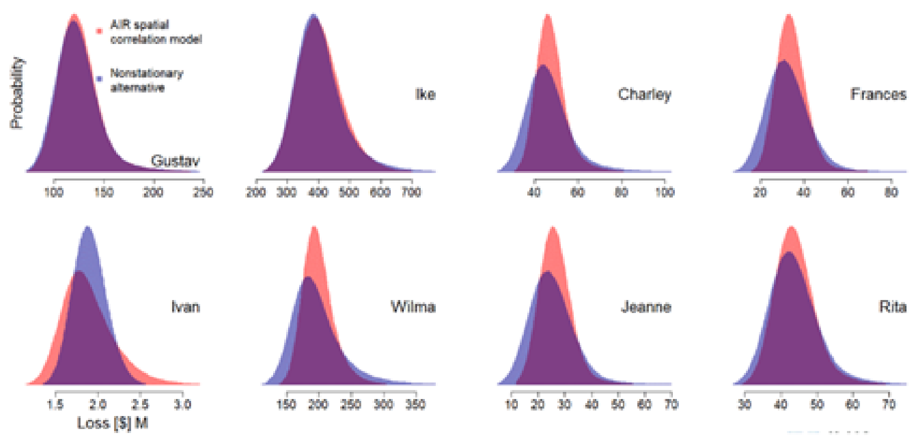


Figure 22. Validation of Touchstone event loss distributions using non-stationary correlation model

4 Actuarial methodologies

About back-allocation

Back-allocation is the process by which the Touchstone apportions an overall loss to locations, coverages, layers, or contracts.

Touchstone continues to support back-allocation of the following losses:

- Contract loss to locations
- Location loss to coverages
- Treaty losses to contracts

Touchstone's new financial engine introduces the following methods to back-allocation:

- Considers the application of sublimits between location and layer.
- Introduces multiple tiers of sublimits beneath a layer.
- Accurately applies coverage terms (e.g. limits) after the application of site terms (e.g. deductibles) on the same risk (location, layer, sublimit, etc) through back-allocation of site losses to coverage losses.
- Applies ratio of pre- and post-term mean losses for certain situations:
  - Portfolio level terms to the individual contributing risks in treaty reinsurance processing
  - Contract to locations after applying contract reinsurance

Back-allocation of contract loss to locations

Touchstone back allocates contract gross loss to locations to obtain location gross loss.

In most cases, Touchstone scales a location's gross loss after application of all location terms (GRLi) by a ratio k, where:

$$k = \frac{GR_{Con}}{GR_{POST\_LOCTERM}}$$

However, in some cases, most notably when there is a Maximum Deductible on a layer, Touchstone uses a different methodology for back allocation. If the contract gross loss is larger than the sum of the location gross loss after the application of location terms (that is, k >1), the Touchstone uses a different methodology, which is based on scaling contract retained loss to the location level by a coefficient h and then subtracting it from ground up loss.

Default contract back-allocation method

Describes Touchstone's method for generating loss and using contract back-allocation.

Touchstone:

- Retrieves the loss (GR_{L_i}) for each location i after application of the location terms but before application of the layers.

- Retrieves the total loss from all locations after application of the location terms: $\sum_{i=1}^{n} GR_{L_i}$. It then applies all layer terms from all layers to this total loss to give the Contract loss after application of the layers, referred to as GR_{Con}
- Calculates the coefficient $k = \frac{GR_{Con}}{\sum_{i=1}^{n} GR_{L_i}}$.
- Uses the following equation to determine the location's Gross loss, which is the portion of the layer loss that is back allocated to the specific location. The table below provides an example of the multi-layer contracts method.

$$Back\ Allocated\ Amount\ for\ location\ i = k \times GR_{L_i}$$

Table 6. Back allocation example: multi-layer contracts method (terms)

Ground-up Loss	Location Site Deductible	Ground-Up Loss – Location Site Deductible GR_{L_i}	Layer Attachment Point	Layer limit
$ 1,500	$ 100	$ 1,400	$ 2,000	$10,000
$ 2,000	$ 100	$ 1,900	$10,000	$15,000
$ 2,500	$ 200	$ 2,300		
$ 3,000	$ 200	$ 2,800		
$ 4,500	$ 150	$ 4,350		
$ 6,500	$ 250	$ 6,250		
TOTAL $20,000	**$ 1,000**	**$19,000**		

$$Total\ Loss\ from\ all\ locations\ (after\ location\ terms\ are\ applied): \sum_{i=1}^{n} GR_{Li} = \$19{,}000$$

$$Total\ Contract\ Loss: GR_{Con} = 15{,}000$$

$$For\ all\ locations:\ k = \frac{GR_{Con}}{\sum_{i=1}^{n} L_i} = \frac{\$15{,}000}{\$19{,}000} = 0.7895$$

$$For\ location\ 1, back\ allocated\ amount = \$1{,}400 \times 0.7895 = \$1{,}105$$

Table 7. Back allocation example: multi-layer contracts method (results)

Location	Ground-Up Loss – LocationSite Deductible GR_{L_i}	Coefficient k	Back allocated LocationGross Loss k_i x Contract
1	$ 1,400	0.7895	$ 1,400 x 0.7895 = $ 1,105
2	$ 1,900	0.7895	$ 1,900 x 0.7895 = $ 1,500
3	$ 2,300	0.7895	$ 2,300 x 0.7895 = $ 1,816
4	$ 2,800	0.7895	$ 2,800 x 0.7895 = $ 2,211
5	$ 4,350	0.7895	$ 4,350 x 0.7895 = $ 3,434
6	$ 6,250	0.7895	$ 6,250 x 0.7895 = $ 4,934
Totals	**$19,000**		**$15,000**

Max deductible priority layers method

Touchstone primarily uses the max deductible priority layers method with maximum deductible.

Touchstone:

1. Calculates the delta (or difference) between the layer Ground-Up loss and the layer Gross loss by subtracting the layer Gross loss from the layer ground-up loss (you can think of this as the layer Retained loss).

   $D_{LR} = GU - GR_{LR}$

2. Calculates the delta (or difference) between the location's Ground-Up loss (GU_{Li}) and the location's Gross loss.

   $D'_{Li} = GU_{Li} - GR_{Li}$

3. Sums the delta for each location in the previous step.

   $D' = \sum D'_{Li}$

4. Determines the back-allocation coefficient by finding the ratio of the layer Retained loss to the total location Retained loss.

   $h = \frac{D_{LR}}{D'}$

5. Multiples this coefficient by the delta between the location's ground up loss and the location's gross loss, and then subtracts this value from the location's ground up loss.
6. The result is back allocated to the locations.

This process is then repeated for all locations.

$GR_{Li} = GU_{Li} - h \times D'_{Li}$

With this method, the back allocated losses to locations are related to the ground up location loss and to the post-Location Terms Retained Loss scaled by a factor h. Thus, the scenario where gross losses are larger than ground up losses is not observed.

$h = \frac{D_{LR}}{D'} = \frac{50}{25} = 2$

For location 3: Back Allocated Gross Loss = 25 – (2 x 10) = 5(2 x 10) = 5

	Locations			
	1	2	3	TOTAL
Ground-Up loss	$70	$25	$25	**$120**
Location Deductible	$60	$20	$15	**$95**
Ground Up—Location Deductible	$10	$5	$10	**$25**
Layer Maximum Deductible	$50			
Post Layer loss	$70			
Layer Retained Loss (maximum = 50); D_{LR}	$50			
Coefficient h	2			
Back Allocated location Gross loss	$50	$15	$5	**$70**

Figure 23. Example of the back allocation method with maximum deductible

Back-allocation of location loss to coverages

Touchstone back allocates location loss to individual coverages.

After Touchstone has back-allocated the layer loss to each location, Touchstone can then back allocate each location's loss to the individual coverages, provided that the loss by coverage option was selected for the analysis. The location losses are apportioned to each coverage based on the contribution to the total location loss by that coverage, after coverage terms have been applied. Therefore, the back allocated amount for Coverage A, for example, should be higher than that for Coverage D if Coverage A constituted a higher proportion of the total location loss (after the application of coverage terms) compared with Coverage D.

Touchstone calculates the back-allocated coverage loss from the location using the following equation.

$$\text{Back Allocation Coverage Loss} = \frac{\text{Coverage loss after coverage terms applied}}{\text{Location loss after coverage terms applied}} \times \text{Back allocated location gross loss}$$

Table 8. Back allocation: location loss to coverages example

	Loss after Coverage Terms are Applied				
Location	**Coverage A**	**Coverage C**	**Coverage D**	**Total Location Loss**	**Back allocated Location Gross Loss**
1	$ 900	$ 400	$ 200	$ 1,500	$ 1,505
2	$ 1,200	$ 400	$ 400	$ 2,000	$ 1,500
3	$ 1,300	$ 700	$ 500	$ 2,500	$ 1,816
4	$ 2,000	$ 500	$ 500	$ 3,000	$ 2,211
5	$ 2,100	$ 1,400	$ 1,000	$ 4,500	$ 3,434
6	$ 2,700	$ 1,800	$ 2,000	$ 6,500	$ 4,934
Totals	**$ 10,200**	**$ 5,200**	**$ 4,600**	**$ 20,000**	**$ 15,000**

Location 1: $\text{Back allocated coverage A loss for location } 1 = \frac{900}{1{,}500} \times\ 1{,}105 = 663$

Table 9. Back allocated coverage loss

	Back allocated Coverage Loss			
Location	**Coverage A**	**Coverage C**	**Coverage D**	**Total**
1	$ 663	$ 295	$ 147	$ 1,105
2	$ 900	$ 300	$ 300	$ 1,500
3	$ 944	$ 508	$ 363	$ 1,816
4	$ 1,474	$ 369	$ 369	$ 2,211
5	$ 1,603	$ 1,068	$ 763	$ 3,434
6	$ 2,050	$ 1,366	$ 1,518	$ 4,934
TOTAL	**$ 7,633**	**$ 3,906**	**$ 3,460**	**$ 15,000**

Back-allocation of treaty losses to contracts

For the calculation of net losses in Touchstone, treaty losses need to be back-allocated to the policy if there are terms that apply to a set of locations/policies.

For example, a set of policies contains two treaties. The first is a per-risk excess of loss contract for each location and the second is an occurrence limit treaty. Touchstone calculates the net loss for each location after applying the per-risk excess of loss treaty. If there are multiple policies affected by an event that breaches the treaty's occurrence limit, the calculated net loss is no longer valid and must be inflated to account for the excess loss that is not ceded to the treaty.

The following example is for a set of contracts, each with a layer of $8 million XS $1 million. In addition, there is a treaty with an occurrence limit of $5 million; the treaty covers a set of policies where each policy has a per-risk (layer) excess of loss of $2.5 million XS $2.5 million. In Touchstone, the first tier of treaty terms is applied probabilistically, and each tier thereafter is applied deterministically (i.e., retention and limits are applied to mean losses with operations of minimum, subtraction, and maximum). Hence, the net loss in the table below is obtained from a probabilistic estimation and the net loss thereafter is computed using a deterministic calculation. This is due to computational efficiency, where run times are not significantly increased for multiple-tiered treaties.

Table 10. Net loss for each policy is computed after the per-risk is applied

	Loss after Coverage Terms are Applied			
Policy	**Gross Loss**	**Net Loss**	**Gross - Net =Treaty Loss**	**Contribution to TreatyBefore Limit**
1	$ 3,180,756	$ 2,385,394	$ 795,362	15%
2	$ 12,620,322	$ 10,242,761	$ 2,377,561	43%
3	$ 15,515,047	$ 13,199,919	$ 2,315,128	42%
Total			$ 5,488,051	100%

Touchstone first calculates the Gross loss for each contract after the application of the layer terms; see table just above. The per risk excess of loss contract is then applied, and the occurrence limit is applied to all contracts combined. Since the treaty loss is greater than the occurrence limit of $5 million, the excess over this amount, $488,051, is back allocated to the net loss above in proportion with the contribution of each policy to the treaty before the occurrence limit has been applied.

$$\textit{Back allocated Net Loss for Policy} = \frac{\textit{Treaty Loss for Policy before limit}}{\textit{Total Treaty Loss before limit}} \times (\textit{Total Treaty loss} - \textit{Occurrence limit}) + \textit{Net Loss before treaty limit is applied}$$

For example, using the data from the table Table 7 above, the back allocated net loss for policy 1 is calculated in the following table.

$$\$2{,}385{,}394 + \frac{\$795{,}362}{\$5{,}488{,}051} \times (\$5{,}488{,}051 - \$5{,}000{,}000) = \$2{,}456{,}125$$

Table 11. "New" net loss after back allocation for each policy

Policy	**Allocation**	**"Old" Net Loss**	**"New" Net Loss ="Old" Net Loss + Allocation**
1	0.15 * $488,051	$ 2,385,394	$ 2,456,125
2	0.43 * $488,051	$ 10,242,761	$ 10,454,197
3	0.42 * $488,051	$ 13,199,919	$ 13,405,803

Policy	Allocation	"Old" Net Loss	"New" Net Loss ="Old" Net Loss + Allocation
Total		$ 25,828,074	$ 26,316,125

Back-allocation of layers to locations

Touchstone back-allocates contract gross loss to locations to obtain location gross loss.

In the simplest of cases, Touchstone scales a location's gross loss after application of all location terms by a ratio k, where: $k = \frac{GR_{Con}}{GR_{POST\_LOCTERM}}$.

This would describe, for example, back allocation when the contract has a single layer with no sublimits.

However, many cases are more complex than the above. Touchstone's approach to layer/ sublimit back-allocation considers which locations participate in which sublimits and layers and the individual effect of terms at each sublimit and layer. For example, if Location A participates in Sublimit A and that sublimit limits the loss to zero, this will be seen in the location gross results and if Locations B, C, and D only participate in the layer, that will also be reflected in the location gross results with losses determined strictly from the application of layer terms. Further, if a contract has multiple layers associated with it, the application of terms on each of these layers is tracked and associated with the correct locations.

This is accomplished with a back-allocation coefficient for each sublimit/location or layer/ location pair. After terms are applied to a sublimit or a layer, the coefficients for participating locations are updated by the ratio of post term/pre term mean loss. If the contract has multiple layers, then not only is the post location term location distribution scaled by this coefficient during back-allocation, but multiple copies of that distribution are created (one for each layer), they are each scaled by their individual coefficient (hence the key of location and layer for the back allocation coefficients), and they are comonotonically accumulated to form the back allocated location gross loss distribution.

Multi-tiered sublimits

Touchstone's new financial module introduces multiple tiers of sublimits beneath a layer.

The same methodology from above is used to determine the location back-allocation coefficients. That is, for each tier of sublimits, participating locations are determined, the parent layer is determined, and the correct coefficient is updated by the ratio of post term/ pre term mean loss. The coefficient will be equal to 1 before any terms are applied and then at each tier of sublimits, the current coefficient is multiplied by the ratio for the sublimit currently being processed.

For example, consider a layer with a sublimit, which also has a child sublimit and a location that participates at all levels. If the post term/pre term mean ratios for the first sublimit, second sublimit, and layer are 0.8, 0.5, and 0.9 respectively, the final back-allocation coefficient will be 1 * 0.8 * 0.5 * 0.9 = 0.36.

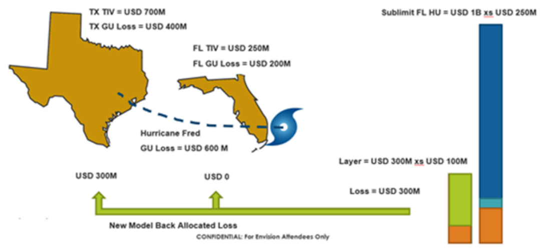


Figure 24. Support for multi-tiered back allocation to enhance accuracy of reported single risk losses

Layer	USD 300M xs USD 100M
Sublimit: Florida Windstorm	USD 1B xs USD 250M
TIV in FL	USD 250M
GU Loss for One Event Impacting TX and FL	USD 600M of which FL = USD 200M and TX = USD 400M
Existing Model Layer Loss	USD 300M (USD 200M loss in FL becomes USD 0, remaining USD 400M loss goes to layer and maxes layer)
Existing Model Back Allocated Loss	$Florida = \frac{200}{600} \times 300 = 100M$ and $Texas = \frac{400}{600} \times 300 = 200M$
New Model Back Allocated Loss	$Florida = 0 \times 300 = 0$ and $Texas = 300M$

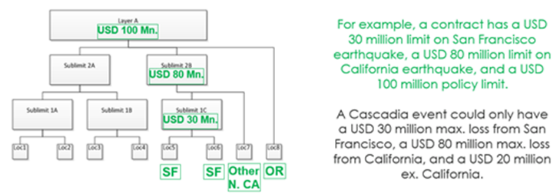


Figure 25. Inuring sublimits enable users to model more than one tier of inuring relationships

Back-allocation of total to coverages

Total to coverage back-allocation is more commonly applied with a site term (one that is applied on the distribution representing the total losses for the risk).

After applying a site term, the total loss and the individual coverage losses become out of sync. In total to coverage back-allocation, the total losses are apportioned to each coverage based on the contribution to the total loss by that coverage. Therefore, the back-allocated amount for Coverage A, for example, may be higher than that for Coverage D if Coverage A constituted a higher proportion of the total location loss (immediately prior to the application of the site term) compared with Coverage D.

Given μ_{GU_A}, μ_{GU_B}, μ_{GU_C}, and μ_{GU_D}, as the four Coverage Ground Up Means, $\mu_{GU_{LOC}}$, as the Location Ground Up Mean, and $\mu_{GR_{LOC}}$ as the Location Gross Mean:

$$\mu_{GR_A} = \mu_{GR_{LOC}} \cdot \frac{\mu_{GU_A}}{\mu_{GU_{LOC}}}$$

$$\mu_{GR_B} = \mu_{GR_{LOC}} \cdot \frac{\mu_{GU_B}}{\mu_{GU_{LOC}}}$$

$$\mu_{GR_C} = \mu_{GR_{LOC}} \cdot \frac{\mu_{GU_C}}{\mu_{GU_{LOC}}}$$

$$\mu_{GR_D} = \mu_{GR_{LOC}} \cdot \frac{\mu_{GU_D}}{\mu_{GU_{LOC}}}$$

Totals and coverages are synchronized after each term is applied (i.e. after limits and after deductibles individually), therefore the proportional contribution of coverages to totals can be accurately calculated at each step.

Back-allocation using pre- and post-term losses

In some cases, back-allocation is completed using the ratio of pre- and post-term mean losses.

An example of this is a per-risk excess of loss treaty that covers three risks. In this example, the per-risk treaty covers 3M in excess of 2M in gross contract losses, subject to an occurrence limit across all contracts of 5M. In the table below, we see three policies subject to this treaty, and for the simulated event the total loss ceded to the per-risk layer is 6M. Therefore, there is 1M above the treaty occurrence limit which should actually be paid by the insurer as part of the pre-CAT net loss perspective. In order to calculate the proportion of the 1M in loss above the treaty occurrence limit to the individual contracts, we use the proportion of loss initially ceded to the treaty for each policy out of the total. The respective proportions of the 1M per policy are then included within the final reported pre-CAT net loss.

	Gross Loss	**Ceded to Treaty Prior to Occ Limit**	**Contribution %**	**Loss Over Treaty Limit**	**Final Pre-CAT Net Loss**	**Final Treaty Loss**
Policy 1	4M	2M	33.3%	0.333M	2.333M	1.67M
Policy 2	5M	3M	50.0%	0.5M	2.5M	2.5M
Policy 3	3M	1M	16.7%	0.167M	2.167M	0.83M
Total	12M	6M	100.00%	1M	7M	5M

Location loss

Location loss in Touchstone evaluates event losses by location and refines these losses by applying location and coverage-level terms, as well as limits and deductibles.

Coverage terms after site terms

All combinations of coverage and site terms are supported in Touchstone through the combination of accumulation of coverages to total and the proration of totals to coverage.

When site terms are applied, coverages are adjusted to match the total loss through proration, which is the mean based scaling of the coverage distributions by the post-term to pre-term ratio of the total losses. This method is described by:

$$\textit{Distribution Loss Values}\ [0:n]^{*} = \frac{\mu_{\textit{total post-term}}}{\mu_{\textit{total pre-term}}}$$

Where μ is the mean of the distribution.

Calculating coverage terms after site terms

When coverage terms are applied in Touchstone, the total, or site, distribution is recreated by accumulating the coverages together.

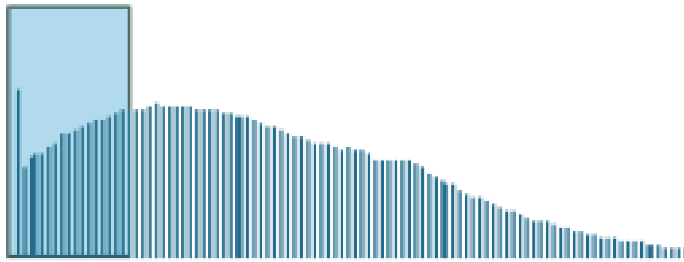


Figure 26. Apply site deductible

$$\frac{GR\ after\ Deductible}{GUP\ Location} *$$

$$\frac{GR\ after\ Deductible}{GUP\ Location} *$$

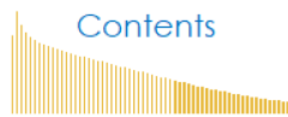


Figure 27. Prorate coverage loss

How step functions are used in Touchstone

Step functions in Touchstone define policy payouts for particular damage ratios (expressed as a percentage) or loss amounts (monetary value).

While step functions are designed to enable the implementation of single-location residential endowment policies in Japan, they can be used for any region, peril, or line of business. They are placed at the policy level and the terms are applied to each location in the policy.

A cap in Touchstone keeps gross losses from exceeding ground-up losses. This cap was removed for Japan policies because the gross losses may exceed ground-up losses when loss analyses are run with step functions. If you use step functions with non-Japan policies, you may want to create a second policy record where you make your replacement value a very large number so that the gross losses do not exceed the ground-up losses.

Note

See the *Touchstone Help* for detailed information about using step functions in Touchstone. Topics include: importing step function files, validation rules for step functions, and construction of CSV step function files.

Step functions are applied as follows:

1. Converts the Probability Density Functions (PDFs) for the appropriate coverages to Survival Density Functions (SDFs) using the following function, where *i* is the PDF index. The figure below provides a graphical view of the function.

$$\begin{cases} i = 0 \quad : \quad Prob_{SDF}[0] = 1 - Prob_{PDF}[0] \\ i > 0 : Prob_{SDF}[i] = Prob_{SDF}[i-1] - Prob_{PDF}[i] \end{cases}$$

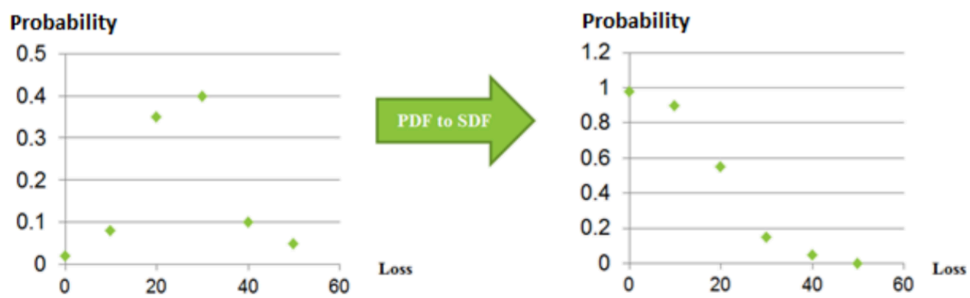


Figure 28. Converting PDFs to SDFs

2. After the conversion is complete, Touchstone applies the steps. Where a discrete probability point is not present at the start or end of a step, Touchstone applies interpolation to create a probability point at that loss.
3. For every point in the step, Touchstone calculates the gross based on the ground-up loss (GU), the deductible (Ded), the payout (PO), and whether the limit at damage is turned on.

   If there is a deductible present:

   $GR_{After\ ded} = min(0,\ \ PO - Ded)$

   If limit at damage is turned on:

   $GR_{After\ lim} = min(GR_{After\ ded},\ \ GU)$
4. Outputs a gross SDF distribution and converts it back to a PDF, where the gross can be calculated using a sum product.

Policy loss

Policy loss in Touchstone applies conditions to event losses to accumulate loss across multiple locations.

Policy loss involves applying:

- Spatial correlation coefficients
- Layer and sublimit terms by location and by coverage
- Layer and sublimit terms by limit and deductible

The NGM financial engine introduces a variety of enhancements to loss policy modeling including:

- The loss aggregation algorithm accounts for dependencies between different insurance coverage types and for spatial correlation between risks.
- Risk aggregation is performed by combining probability distributions with differing loss sizes. Therefore, deductibles and limits are applied directly on these distributions.
- Dependent sub-perils are modeled independently.
- All combinations of coverage and site terms are supported through the combination of accumulation of coverages to total and the proration of totals to coverage
- Coverage and combined deductibles (as well as site) on any layer or sublimit.
- Ability to create two additional tiers to sublimit losses which allows users to to model a policy.
- Introduction of sublimit deductible scenario.
- Aggregate policies are available for both single peril model analysis as well as for multi-model analysis.

Gross loss accumulation with spatial correlation

The financial engine loss aggregation algorithm accounts for dependencies between different insurance coverage types and for spatial correlation between risks.

This involves computation of gross loss after each set of financial conditions is applied at each hierarchical level of portfolio rollup.

Mathematically, gross loss estimation is equivalent to solving the problem of a transformation of an arbitrary sum of risks $S = X_1 + X_2 \ldots + X_D$. Here the word "arbitrary" stands for "positively dependent". Risks attributed to different types of locations are represented by random variables $X_1, X_2, \ldots, X_D$. We assume that our arbitrary sum S is enclosed within two bounds: independent S^1 where risks are assumed to be independent and comonotonic S^+ where risks are assumed to be maximally correlated. The distribution of the arbitrary S is computed using the mixture method (Mixture Method) which reads:

$$f_S(s) = w\ f_{S^\perp}(s) + (1-w)\ f_{S^+}(s) \quad (1)$$

The value of the weight depends on positive correlation between pairs of risks and/or their partial totals. During portfolio roll-up, the sum of risks S is subject to the transformation Φ (S) which represents application of financial terms. Using the standard method of inverse mappings for discrete random variables, the distribution of the transformed sum reads:

$$f_{\phi(S)}(s') = w\ f_{\phi(S^\perp)}(s') + (1-w)\ f_{\phi(S^+)}(s') \quad (2)$$

where S^1=Φ (S). It is easy to see that the application of the financial terms to the sum S isequivalent to the application of financial terms separately to the independent sum and the maximally correlated sum S^+, without affecting the value of the weight w. This implies that correlation between pairs of risks and/or their partial sums is invariant under application of financial terms Φ. In other words, correlation remains unchanged during both ground-up and gross loss estimation.

The financial engine and risk aggregation

Insurance financial terms in Touchstone are features designed to modify the loss payments.

For an overview of standard financial operations refer to Basic Financial Operations. In the new financial engine risk aggregation is performed by combining probability distributions with differing loss sizes. Therefore, deductibles and limits are applied directly on these distributions.

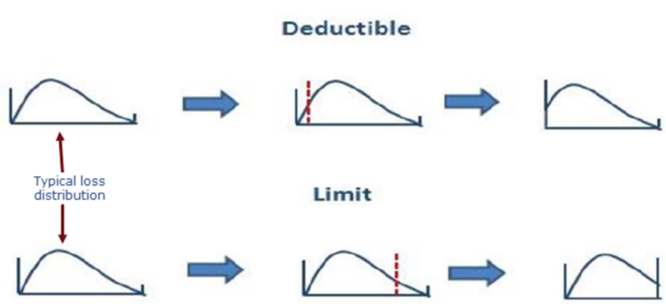
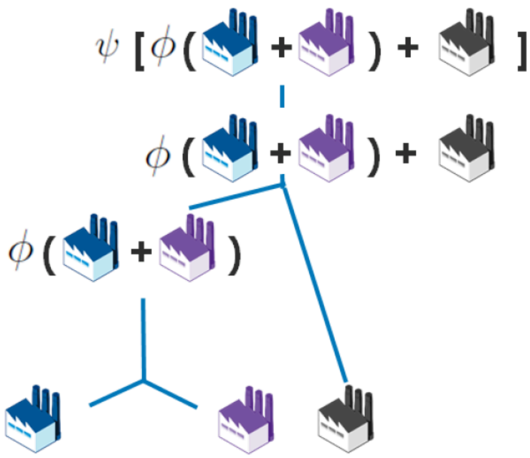


Figure 29. Example of deductible application and limit to a loss distribution

A typical loss distribution is shown in the figure above. To apply the deductible, place it on the loss axis (dashed red line, upper pane), then accumulate the probability mass below the deductible onto the deductible, and finally set the deductible as zero of the new loss axis. Similarly, application of the limit (dashed red line, lower pane) takes all the probability mass above the limit and accumulates it onto the limit. In NGM, gross loss estimation for a portfolio can be thought of as the mathematical function composition, that is, application of one function to the result of another. In this case, functions represent application of deductibles and limits at different tiers of financial terms like sublimits, layers, policies, and so on.

Loss accumulation with spatial correlation workflow

Example of multi-risk contracts in Touchstone are often located in close geospatial proximity.



This physical attribute of multi-location policy structuring in the financial engine makes modeling of dependencies in loss accumulation of critical importance in modern catastrophe analysis. Such commercial contracts could also be sub-limited and layered with detailed structures for individual or for dependent sub-peril losses.

Dependent sub-perils

In the NGM financial engine, dependent sub-perils are modeled independently.

Combinations of layer term peril codes and model sub-perils exist that have only a partial intersection and in this case those perils that are not covered by the layer term peril are accumulated directly to the contract. They do not participate in the application of layer terms at all and will therefore not be seen in layer results but will be present in all other results views.

Coverage and site terms

In the financial engine, all combinations of coverage and site terms are supported through the combination of accumulation of coverages to total and the proration of totals to coverage.

When site terms are applied, coverages are adjusted to match the total loss through proration, which is the mean based scaling of the coverage distributions by the post-term to pre-term ratio of the total losses. This method is described by:

$$\textit{Distribution Loss Values}\,[0:n]^{*} = \frac{\mu_{\textit{total post–term}}}{\mu_{\textit{total pre–term}}}$$

Where μ is the mean of the distribution.

Calculating layers and sublimits by coverage after site location or layer terms

When coverage terms are applied, the total, or site, distribution is recreated by accumulating the coverages together.

Layer and sublimits by coverage after site location or layer terms

Examples of layer and sublimits in Touchstone by coverage after site location or layer terms.

One example would be a location with site deductible and limits and a layer with coverage deductibles. In this case, the location coverage distributions are updated after site terms as described in the previous section. For all of the locations participating in the layer, the location total and coverage distributions are accumulated to the corresponding layer loss distribution (total or individual coverage) and coverage or combined terms can be applied accurately.

A second example would be a layer site deductible with a coverage or combined limit. In this case the coverage distributions are updated after the deductible as described in the previous section and the limit is applied on those coverage distributions (in the combined limit case, after an accumulation of coverages A, B, and C).

Combined coverage deductibles on layer and sublimit

The financial engine keeps accurate coverage and total distributions for layers after every term application.

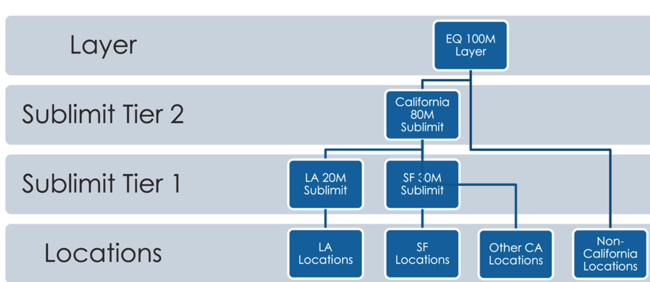
This is true whether it be site, coverage, or combined deductible or limit, so it is now possible to have coverage and combined deductibles (as well as site) on any layer or sublimit.

Example of second- and third-tier (nested) sublimits

Touchstone can support 2nd and 3rd tier sub-limits.

Here is an example of that policy language:

- $100,000,000 Limit for Earth Movement in the Aggregate during any policy year but not to exceed the following limits in the Aggregate during any policy year for property located in:
  - $80,000,000: California
  - $20,000,000: Los Angeles County
- With nested sub-limits users can set up a $100M layer limit for earthquake, with a first-tier sublimit of $80M for all locations in California, as well as a second-tier sub-limit of $20M for all locations in Los Angeles county.



Min/max deductible on layer or sublimit workflow

Example of min/max deductible in the financial engine on layer or sublimit workflow.

Min Deductible Only - Choose the Smallest Gross					
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (1000)	100,000	99,000			
Loc Deductible 2 (2000)	150,000	148,000			
Total	250,000	247,000		Loc GR > Min GR	Layer Min Ded Scenario
	Layer GU Loss	Layer Min Ded Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000	245,000		
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (3000)	100,000	97,000			
Loc Deductible 2 (4000)	150,000	146,000			
Total	250,000	243,000	243,000	Loc GR > Min GR	Location Ded Scenario
	Layer GU Loss	Layer Min Deductible Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000			

Figure 30. Sublimit workflow layer min

Figure 31. Sublimit workflow max

Max Deductible Only - Choose the Largest Gross					
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (1000)	100,000	99,000			
Loc Deductible 2 (2000)	150,000	148,000			
Total	250,000	247,000	247,000	Loc GR > Max GR	Location Deductible
	Layer GU Loss	Layer Max Ded Scenario GR			
Layer Max Deductible (5,000)	250,000	245,000			
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (3000)	100,000	97,000			
Loc Deductible 2 (4000)	150,000	146,000			
Total	250,000	243,000		Loc GR < Max GR	Layer Max Deductible
	Layer GU Loss	Layer Max Ded Scenario GR			
Layer Max Deductible (5,000)	250,000	245,000	245,000		

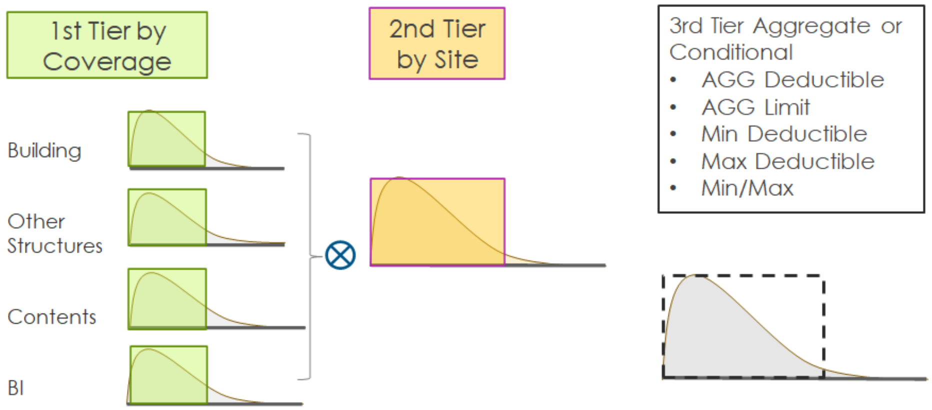
Figure 32. Sublimit workflow layer min and max

Max and Max Deductible - Choose the Median Gross					
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (1000)	100,000	99,000			
Loc Deductible 2 (2000)	150,000	148,000			
Total	250,000	247,000		Loc GR > Min GR > Max GR	Layer Min Ded Scenario
	Layer GU Loss	Layer Min Max Ded Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000	245,000		
Layer Max Deductible (10,000)	250,000	240,000			
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (3000)	100,000	97,000			
Loc Deductible 2 (4000)	150,000	146,000			
Total	250,000	243,000	243,000	Min GR > Loc GR > Max GR	Location Deductible Scenario
	Layer GU Loss	Layer Min Max Ded Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000			
Layer Max Deductible (10,000)	250,000	240,000			

Combine a layer-level min/max deductible with a sublimit deductible

This example desribes how a policy-level min/max deductible works in combination with a sublimit-level deductible.

The engine chooses the applicable scenario from the layer minimum, layer maximum, location deductibles, and sublimit deductible scenario. In the sublimit deductible scenario, locations that take part in a sublimit do not have the location level deductibles applied. Instead, losses are accumulated to the sublimit and the sublimit deductible is the applied while locations not subject to a sublimit have their location deductibles in this scenario. To select the scenario, for a minimum deductible, the scenario with the smallest gross loss (GR) is chosen, for a maximum deductible the scenario with the largest gross loss is chosen, and for a minimum maximum deductible the second smallest gross loss is chosen.



Min Deductible Only - Choose the Smallest Gross					
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (1000)	100,000	99,000			
Loc Deductible 2 (2000)	150,000	148,000			
Total	250,000	247,000		Loc GR > Min GR	Layer Min Ded Scenario
	Layer GU Loss	Layer Min Ded Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000	245,000		
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (3000)	100,000	97,000			
Loc Deductible 2 (4000)	150,000	146,000			
Total	250,000	243,000	243,000	Loc GR > Min GR	Location Ded Scenario
	Layer GU Loss	Layer Min Deductible Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000			

Figure 33. Sublimit deductible layer min

Max Deductible Only - Choose the Largest Gross					
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (1000)	100,000	99,000			
Loc Deductible 2 (2000)	150,000	148,000			
Total	250,000	247,000	247,000	Loc GR > Max GR	Location Deductible
	Layer GU Loss	Layer Max Ded Scenario GR			
Layer Max Deductible (5,000)	250,000	245,000			
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (3000)	100,000	97,000			
Loc Deductible 2 (4000)	150,000	146,000			
Total	250,000	243,000		Loc GR < Max GR	Layer Max Deductible
	Layer GU Loss	Layer Max Ded Scenario GR			
Layer Max Deductible (5,000)	250,000	245,000	245,000		

Figure 34. Sublimit deductible layer max

Max and Max Deductible - Choose the Median Gross					
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (1000)	100,000	99,000			
Loc Deductible 2 (2000)	150,000	148,000			
Total	250,000	247,000		Loc GR > Min GR > Max GR	Layer Min Ded Scenario
	Layer GU Loss	Layer Min Max Ded Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000	245,000		
Layer Max Deductible (10,000)	250,000	240,000			
	Site Ground Up Loss	Site Ded Scenario GR	Actual Layer GR	Notes	Choice
Loc Deductible 1 (3000)	100,000	97,000			
Loc Deductible 2 (4000)	150,000	146,000			
Total	250,000	243,000	243,000	Min GR > Loc GR > Max GR	Location Deductible Scenario
	Layer GU Loss	Layer Min Max Ded Scenario GR			
Layer Min Deductible (5,000)	250,000	245,000			
Layer Max Deductible (10,000)	250,000	240,000			

Figure 35. Sublimit deductible layer min and max

Annual aggregate policy structures

The methodology for annual aggregate deductible and limit in Touchstone allows the modeler to build various complex and aggregate policy structures.

The aggregate deductible and limit can be placed both on the sub-limit level and or on the policy layer level. This design provides flexibility for creating multi-tiered and nested policies, which addresses market demand for increased accurate rendering of insurance and reinsurance terms, conditions and clauses.

Aggregate policies in the financial engine are structured and placed for single peril model analysis as well as for multi-model analysis. This is accomplished by using and setting the peril codes on contract and layer level accordingly to a single peril or to multiple covered perils. The aggregate policy structure is applied on the first stochastic event of the year. Then the aggregate policy is exhausted and transitioned to the second stochastic event of the year and so forth until all events in the stochastic year are covered. The same principle is utilized in the case single model coverage, as well as in the case of multi-model and multi-peril coverage by the aggregate structure.

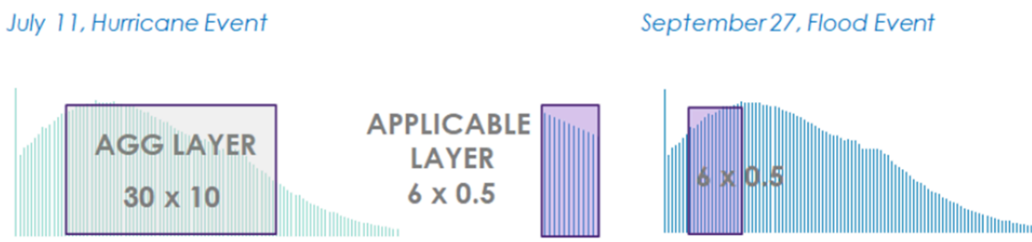


Figure 36. Annual aggregate policy structures

Modeling of % participation

Modeling of % participation on layers and sub-limits with annual aggregate limits and limits by coverage.

In Touchstone 2023 (11.5) we support the modeling of [% participation] on layers and sub-limits with all combinations of annual aggregate policy limits and limits by insurance coverage. This functionality was not available in Touchstone 2022 (11.0) or the Technical Preview. In 2023 (11.5) we enable the actuarial modeling for four complex commercial and industrial facilities policy structures and excess layers, which cover all combinations of occurrence, aggregate and coverage limits with % participation. These use cases and policy structures are:

- Occurrence limits and annual aggregate limits with [% participation]
- Annual aggregate limits with [% participation]
- Occurrence limits by coverage with [% participation]
- Occurrence limits by coverage and annual aggregate limits with [% participation]

The actuarial methodology in deterministic form follows below for the four use cases of occurrence, coverage and annual aggregate limits placed on policy layers with user defined [% participation]. The cases assume two peril events with GUP-to-layer loss in the stochastic year. The methodology is extendable for three and more stochastic events.

1. Policy layers with occurrence limits and annual aggregate limits with [% participation]. Modeling of this policy structure is also supported on sub-limits.

   For first event of the year layer gross is computed:

   ```
   Layer Gross= min[min[Occurrence Limit 1, Layer GUP event 1],Annual Aggregate Limit]*
   %Participation
   ```

   Applicable annual aggregate limit is estimated for second even of the year:

   ```
   Applicable Annual Aggregate Limit=max[Gross Loss First Event-Annual Aggregate
    Limit,0]
   ```

For Second event of the year layer gross is computed:

```
Layer Gross= min[min[Occurrence Limit 1,Layer GUP event 2],Applicable Annual
 Aggregate Limit]*%Participation
```

2. Policy layers annual aggregate limits with [% participation]. Modeling of this policy structure is also supported on sub-limits.

   For first event of the year layer gross is computed:

   ```
   Layer Gross= min[Annual Aggregate Limit,Layer GUP event 1]*%Participation
   ```

   For Second event of the year layer gross is computed, after estimating the applicable annual limit as in case (1)

   ```
   Layer Gross= min[Annual Aggregate Limit,Layer GUP event 2]*%Participation
   ```

3. Policy layers with occurrence limits by coverage with [% participation]

   ```
   Layer Gross Coverage A=min[Limit A,Layer GUP A]*%Participation
   ```

   ```
   Layer Gross Coverage B=min[Limit B,Layer GUP B]*%Participation
   ```

   ```
   Layer Gross Coverage C=min[Limit C,Layer GUP C]*%Participation
   ```

   ```
   Layer Gross Coverage D=min[Limit D,Layer GUP D]*%Participation
   ```

   ```
   Final Layer Gross Loss= Gross Loss by Coverage(A+B+C+D)
   ```

4. Policy layers with occurrence limits by coverage and annual aggregate limits with [% participation]

   ```
   Layer Gross Coverage A=min[Limit A,Layer GUP A]*%Participation
   ```

   ```
   Layer Gross Coverage B=min[Limit B,Layer GUP B]*%Participation
   ```

   ```
   Layer Gross Coverage C=min[Limit C,Layer GUP C]*%Participation
   ```

   ```
   Layer Gross Coverage D=min[Limit D,Layer GUP D]*%Participation
   ```

   ```
   Layer Gross Loss pre Annual Aggregate Limit= Gross Loss by Coverage(A+B+C+D)
   ```

   ```
   Final Layer Gross Loss= min[Layer Gross Loss pre Annual Aggregate Limit][,Annual
    Aggregate Limit]*%Participation
   ```

For use case (1) % participation is estimated from the occurrence excess limits - %Participation=[(Limit 2 Value)/(Limit 1 Value)] or it is taken from user defined field – ‘Participation Limit % (0-1)’. For use cases (2, 3, 4) % participation is supported only from the user defined exposure field ‘Participation Limit % (0-1)’.

Apply a policy-level min/max deductible

Steps to apply a policy-level minimum/maximum deductible in Touchstone.

This method is used when the minimum (MI), maximum (MA), or minimum & maximum (MM) layer- or sublimit-level deductible is present. Touchstone:

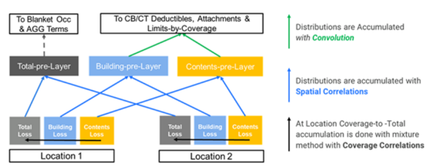
1. Convolves the ground-up loss distributions for each location in the layer without applying the location terms. It then applies the min/max deductibles point by point on the distribution as if they were blanket deductibles. The resulting distributions are the GR_{Min} and GR_{Max} distributions respectively.
2. Calculates the GR' distribution. For sublimit min/max, GR' is the incoming gross loss (GR) after location terms that accumulates to the sublimit. For layer min/max, GR' is the pre-layer gross distribution.
3. Chooses a distribution.
    a. If there is a min deductible, it chooses between distribution with lower mean from GR_{Min} and the GR' distributions.
    b. If there is a max deductible, it chooses between distribution with higher mean from GR_{Max} and the GR' distributions.
    c. If there is a min/max deductible, it chooses the distribution whose mean is the median of the following distributions' means: GR_{Min}, GR_{Max}, and GR'.
4. Chooses the final min/max policy distribution then applies limits.

Accumulations to layers and sub-limits for application of combined deductibles and terms-by-coverage

In Touchstone. when terms-by-coverage are placed on sub-limits and layers, then coverage loss distributions need to flow to these higher tiers of the insurance portfolio.

Terms-by-coverage can be attachment points and limits-by-coverage, or combined deductibles with and without time element.

These pre-layer distributions by coverage loss are constructed from location distributions by coverage with mixture method accumulation with spatial correlations.



In the case of combined deductibles with and without time element, the combined distributions for the application of the deductibles are constructed with the methodology of split atom convolution. Accumulation with coverage correlations at this higher portfolio tier is not possible as these coverage correlation factors are available only for accumulation of coverages at the single location level.

When attachment points and limits by coverage are placed on sub-limits and layers they are applied on the multi-location by-coverage loss distributions accumulated with mixture method with spatial correlations. After application of layer terms by coverage gross loss distributions are accumulated again with split atom convolution for processing of next tier of insurance terms or reinsurance treaties.

Computation of the CSLAI or 100% participation CSL100 layer limit types

The Combined Single Limit types (CSL) is primarily used by the offshore industry.

This limit is unique in that it is an excess limit with an inuring order for the application of coverage losses to the layer. That is, after the coverage losses have been computed (after the application of location terms), the coverage with priority 1 is applied to the layer first, then the coverage with priority 2, and so on. The CSLAI (Combined Single Limit with Assured Interest) and 100% Participation CSL100 layer limit types are CSL limits that use a percentage of ownership at the location level to scale the coverage losses after the CSL is applied.

To compute the losses to a CSL, after coverage terms are applied at the location level, the individual coverage distributions for all locations are convolved, resulting in loss distributions for Coverages A, B, C, and D. Next, when the limit type is CSL100 or CSLAI, Touchstone applies the attachment point and limit to each coverage gross loss distribution using the provided coverage priority order.

If you have a CSLAI layer and C100 sublimit, the coverage gross losses that are specified in the sublimit are then scaled by the Weighted Average Assured Interest (WAAI). Weighted Average Assured Interest is needed because the layer type is CSLAI and the sublimit type is C100—this means that the two losses are of different types, where the layer is in AI terms and the sublimit is in 100% terms. WAAI is used to put the 100% sublimit losses into AI terms so that they are compatible with the layer.

After the coverages specified in the sublimit are in the same terms as the layer, they are added to the other non-sublimit coverages, after scaling by WAAI or dividing by WAAI (in the case of CSL100 layer and CAI sublimit). The attachment point and limit to each coverage loss distribution are then applied in the user-provided coverage priority order. Additional information is available in the document *Using the Verisk U.S. Hurricane Model for Offshore Assets* which is available on the Client Portal.

The following is a deterministic example for the CSLAI limit type:

- There are 3 locations in a policy.
- All locations combined have $75 million C100 sublimit on OEE.
- All locations combined have a CSLAI of $350 million XS $50 million with the following coverage priority order.
  1. Physical Damage (PD)
  2. Operator's Extra Expense (OEE)
  3. Removal of Debris (RoD)

Note

Business Interruption (BI) has an Exhaustion Order of 0 in this example. Thus, BI will not be included in the calculation of loss to the CSL—all loss for this coverage will be retained by the insured.

- Assured Interest (AI): Location 1 = 50%, Location 2 = 100%, Location 3 = 25%

Table 12. Deterministic example for CSLAI limit type

Loss	Location 1 100% Ground-Up Loss	Location 2 100% Ground-Up Loss	Location 3 100% Ground-Up Loss	Total 100% Ground-Up Loss
PD	200	150	50	400
RoD	150	100	50	300

Loss	Location 1 100% Ground-Up Loss	Location 2 100% Ground-Up Loss	Location 3 100% Ground-Up Loss	Total 100% Ground-Up Loss
OEE	100	75	25	200
BI	50	40	10	100
	AI for each location			
	0.5	1	0.25	

Calculations are applied in the following order:

1. Individual coverage losses are computed using the formula below for each location in AI terms:

$$Location\ \ loss\ \ in\ \ AI\ \ terms_{Cov\ i} = Location\ \ loss\ \ in\ \ 100\%\ \ terms_{Cov\ i} \times Location\ \ AI$$

Table 13. Computing individual coverage losses in AI terms

Loss	Location 1 Loss After Application of AI	Location 2 Loss After Application of AI	Location 3 Loss After Application of AI	Total Loss After Application of AI
PD	100	150	12.5	262.5
RoD	75	100	12.5	187.5
OEE	50	75	6.25	131.25
BI	25	40	2.5	67.5

The Weighted Average Assured's Interest (WAAI) is calculated and applied to the OEE coverage using the following equation:

$$Weighted\ \ Average\ \ AI\ \ by\ \ Coverage = \frac{Total\ \ Loss\ \ for\ \ all\ \ locations\ \ after\ \ scaling\ \ by\ \ AI}{Total\ \ Loss\ \ for\ \ all\ \ locations\ \ before\ \ scaling\ \ AI}$$

For example: $OEE\ \ WAAI = \frac{131.25}{200} = 0.65625$

Table 14. Computing the WAAI

Loss	Location 1 Loss After Application of AI	Location 2 Loss After Application of AI	Location 3 Loss After Application of AI	Total Loss After Application of AI	Weighted Average AI (WAAI)
OEE	50	75	6.25	131.25	0.65625

2. The $75 million C100 sublimit is applied to the 100% OEE losses across all locations.

Loss	Total (millions)
OEE	$\cancel{200} \rightarrow 75$

3. OEE loss is multiplied after the sublimit has been applied by the OEE WAAI.

Loss	Total	
	Losses in 100% Terms After OEE Sublimit	Losses in AI Terms After OEE Sublimit

PD	400	262.5
RoD	300	187.5
OEE	75	49.2
BI	100	67.5

4. The $50 million CSL attachment point is applied to the first coverage in the priority order, in this case PD in Assured's Interest terms.

Loss	Total (millions)
PD	~~262.5~~ → 212.5

5. Since the limit amount is $350 million, the full PD amount goes through to the layer. The second loss in the priority order is OEE and the full amount also goes through as the sum of these two losses is below $350 million. However, the full RoD loss is $187.5 million, and this loss combined with the PD and OEE losses would bring the total layer loss larger than the limit. As a result, the RoD loss becomes $88.3 million ($350 million - $212.5 million - $49.2 million).

Loss	Total (millions)		Loss	Total (millions)
OEE	49.2		RoD	~~187.5~~ → 88.3

The calculations have now been completed because the layer limit has been entirely exhausted. Furthermore, since Business Interruption is not in the priority order, its loss is not included in the calculation of loss to the CSL.

Enhancements to risk reinsurance loss

Risk reinsurance loss in Touchstone refers to probabilistic losses computed for a reinsurance portfolio.

Enhancements offered with the newest financial engine include:

- Support for new "Location" and "Layer" risk target types.
- Support for location-level treaty reinsurance, which is applied immediately after location facultative reinsurance and before any layer terms.
- Support has been expanded to reflect the growing complexity in treaty and reinsurance underwriting. The application of all terms and conditions are fully probabilistic.
- Expanded support for reinsurance terms and conditions.
- All existing reinsurance results views have been extended to include '.

Risk target types

Summary of risk target types in Touchstone.

In addition to *Contract* and *Location or Layer* target types, the financial engine supports the new "Location" and "Layer" target types. The actual target type of the *Location or Layer* type is dependent on the presence of layers in the portfolio (if with layers, the layers are the target and if not, the locations are the target). With the introduction of location reinsurance for locations under a layer, the explicit target types have been added and will target their named risk types regardless of the presence of layers in the portfolio (note that for portfolios without layers, the layer target type should not be used).

The table below illustrates the different levels at which each target type can be applied.

Table 15. Reinsurance target types

	FAC	Quota Share	SS	XoL PR
Location	Y	Y	Y	Y
Layer	Y	Y	Y	Y
Contract	N	Y	N	Y

Location reinsurance with policy layers

The financial engine includes updates to how location-level treaty insurance is applied.

Location-level facultative reinsurance on a policy with layers is referred to as spot facultative. Such policy terms are typically used to reduce the loss to the layer by using facultative insurance for individual locations (typically those of high value/risk). This policy condition applies location-level deductibles and limits first, then applies the location facultative terms, and finally applies the layer terms. Similarly, the NGM framework allows location-level treaty reinsurance, which is applied immediately after location facultative reinsurance and before any layer terms. That is, all location-level reinsurance is applied before layer level insurance or reinsurance. Losses are produced and reported within the gross perspective instead of within the Net perspective that is common for reinsurance policy conditions.

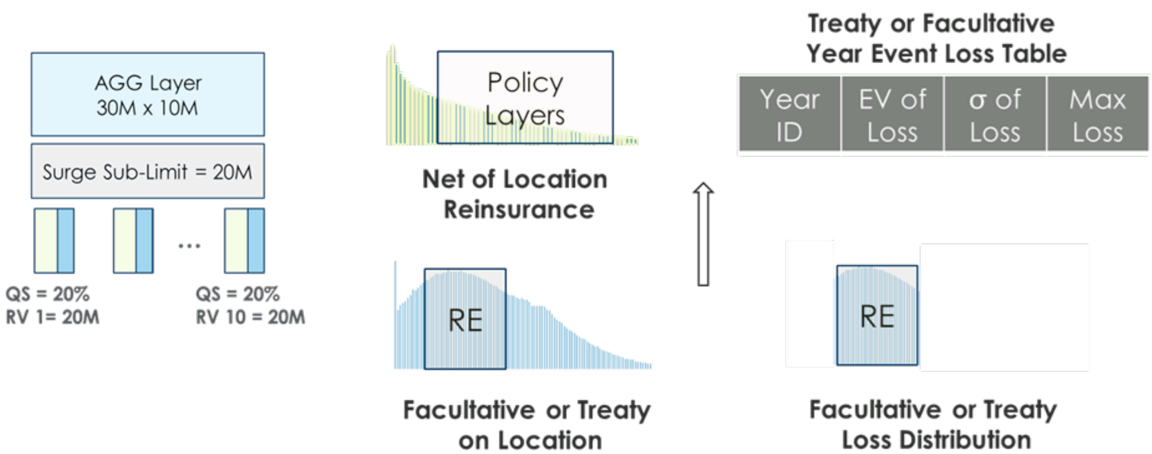


Figure 37. Location reinsurance with policy layers

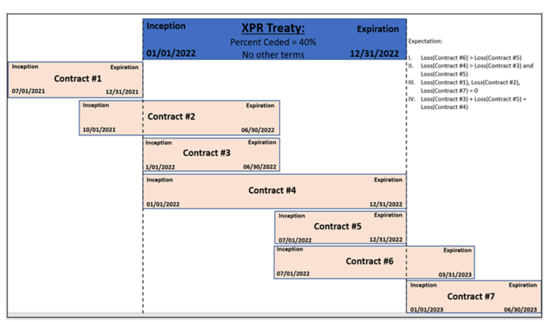


Figure 38. Example of attaching risks to trigger types

Location treaty with policy layers workflow

Example of location treaty with policy layers in Touchstone.

With Next Generation Models (NGM), Verisk provides the ability to place a location treaty such as quota share, surplus share or excess per risk on the location level and include policy layer and sub-limit structures in the same contract. The enhancement and innovation in this case comes with our new methodology to derive the actuarial net-of-location treaty distribution in a fully probabilistic form. This methodology is based on the principles of comonotonic subtraction, described in an earlier section. Then the net-of-location treaty distributions are accumulated, and the aggregate distribution propagated to policy structures such as sub-limits and excess layers.

At the same time, and in parallel secondary uncertainty parameters are computed for reinsurance treaty loss – standard deviation of treaty loss and maximum of treaty loss. These are reported in the treaty-event-loss tables.

The figure below shows how and when event losses are transferred between locations, layers, and policies. First, the location ground up loss is calculated. In this diagram location terms are omitted, so the next stage of processing is the location reinsurance. The result of that is shown in light blue and light green for each location and as the ground up loss to the layer. Next, layer primary terms are applied and at that point gross loss processing is complete. The losses shown in yellow and orange at the layer are the direct result of the layer limits and deductibles while the yellow and orange losses for each location are the result of back allocation from the layers. Next, layer reinsurance is applied and the net of that reinsurance is propagated to contracts. Finally, contract level reinsurance is applied and net loss processing is complete. The final net losses are shown in dark green and blue at the contract level where they are directly calculated and again at the location level where they are the result of back allocation from the contract."

Treaty Program		
Treaty ID	Target Type	Inuring Order
1	Location	1
2	Layer	2
3	Contract	3

Exposure ID Mapping		
Contract ID	Layer ID	Location ID
1	1	1
1	1	2
2	2	3

Intermediate By Location Results		
Location ID	Ground Up Loss	Net of Location Reinsurance
1	$ 10,000	$ 5,000
2	$ 25,000	$ 10,000
3	$ 50,000	$ 20,000

Intermediate By Layer Results			
Layer ID	Ground Up Loss (to the layer)	Gross Loss (Layer Primary Insurance)	Net Of Layer Reinsurance
1	$ 15,000	$ 10,000	$ 8,000
2	$ 20,000	$ 15,000	$ 12,000

Intermediate By Policy Results		
Contract ID	Net of Layer Reinsurance	Net Loss
1	$ 8,000	$ 5,000
2	$ 12,000	$ 10,000

Final By Location Results			
Location ID	Ground Up Loss	Gross Loss	Net Loss
1	$ 10,000	$ 3,333	$ 1,667
2	$ 25,000	$ 6,667	$ 3,333
3	$ 50,000	$ 15,000	$ 10,000

Figure 39. Workflow example for location treaty with policy layers

Probabilistic loss computation

Distributions and probabilistic loss in Touchstone.

The financial engine uses distributions through every stage of application and therefore, loss computations are fully probabilistic. Loss computation is accomplished almost entirely through methods shared with the fully probabilistic insurance module with the notable addition of the probabilistic computation of net loss through comonotonic subtraction. Probabilistic computation of net loss generates distributions for the insurers view of the resulting loss from a tier of reinsurance application, which can then be used to report distribution statistics (mean loss, max loss, and standard deviation of loss) and which can be propagated to a subsequent tier or reinsurance terms.

Terms and conditions for reinsurance

Support for new terms and conditions in Touchstone reflects the growing complexity in treaty and reinsurance underwriting.

The financial engine has expanded support; all applications of terms and conditions are now fully probabilistic:

- All loss accumulations are performed with probabilistic distributions with correlation factors
- All reinsurance terms and conditions applied on probabilistic distributions
- All net of reinsurance losses are modeled through probabilistic distributions
- All modeled uncertainty is propagated to the parameters of standard deviation, max of loss in year event loss tables

The following table presents the supported reinsurance terms and conditions in order of application from top to bottom.

Table 16. Supported reinsurance terms and conditions

Order of application	Facultative	Quota Share	Surplus Share	XoL PR
Pecent Placed		Y	Y	Y
Percent Ceded (SS/ QS)		Y	Y	
Risk Occurrence Retention	Y		Y	Y
Risk Aggregate Retention	Y		Y	Y
Risk Occurrence Limit	Y		Y	Y
Risk Aggregate Limit	Y		Y	Y

Order of application	Facultative	Quota Share	Surplus Share	XoL PR
Percent Ceded (Fac/ XOL)	Y			Y
Treaty Occurrence Limit		Y	Y	Y
Treaty Aggregate Limit		Y	Y	Y

How step functions are used in Touchstone

Step functions in Touchstone define policy payouts for particular damage ratios (expressed as a percentage) or loss amounts (monetary value).

While step functions are designed to enable the implementation of single-location residential endowment policies in Japan, they can be used for any region, peril, or line of business. They are placed at the policy level and the terms are applied to each location in the policy.

A cap in Touchstone keeps gross losses from exceeding ground-up losses. This cap was removed for Japan policies because the gross losses may exceed ground-up losses when loss analyses are run with step functions. If you use step functions with non-Japan policies, you may want to create a second policy record where you make your replacement value a very large number so that the gross losses do not exceed the ground-up losses.

Note

See the *Touchstone Help* for detailed information about using step functions in Touchstone. Topics include: importing step function files, validation rules for step functions, and construction of CSV step function files.

Step functions are applied as follows:

1. Converts the Probability Density Functions (PDFs) for the appropriate coverages to Survival Density Functions (SDFs) using the following function, where *i* is the PDF index. The figure below provides a graphical view of the function.

$$\begin{cases} i = 0 \quad : \quad Prob_{SDF}[0] = 1 - Prob_{PDF}[0] \\ i > 0 : Prob_{SDF}[i] = Prob_{SDF}[i-1] - Prob_{PDF}[i] \end{cases}$$

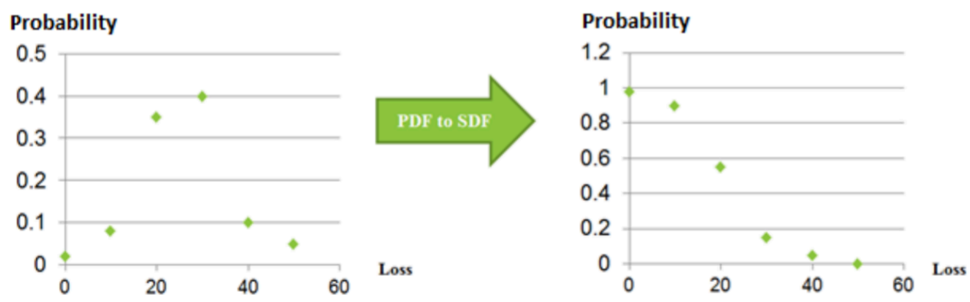


Figure 40. Converting PDFs to SDFs

2. After the conversion is complete, Touchstone applies the steps. Where a discrete probability point is not present at the start or end of a step, Touchstone applies interpolation to create a probability point at that loss.
3. For every point in the step, Touchstone calculates the gross based on the ground-up loss (GU), the deductible (Ded), the payout (PO), and whether the limit at damage is turned on.

   If there is a deductible present:

   $GR_{After\ ded} = min(0, \quad PO - Ded)$

   If limit at damage is turned on:

   $GR_{After\ lim} = min(GR_{After\ ded}, \quad GU)$
4. Outputs a gross SDF distribution and converts it back to a PDF, where the gross can be calculated using a sum product.

Risk reinsurance loss modeling

Risk reinsurance

There are four risk reinsurance contract types that can be applied in Touchstone.

- Facultative
- Treaty
  - Excess of Loss (XOL) treaties
  - Quota Share (QS) treaties
  - Surplus Share (SS) treaties

These are referred to here as “risk reinsurance” as they all have a component of their terms which apply to individual risks and/or insurance contracts. Catastrophe excess of loss (XOL) treaty reinsurance can also be applied in Touchstone can also be applied in Touchstone, but these treaties apply to an aggregation of losses across a number of risks, typically at the region or book level. There are a number of user input options for financial terms for risk reinsurance, depending on the type of contract.

All terms for these types of reinsurance - whether the individual risk terms or, as applicable, treaty occurrence and/or aggregate limits, are applied probabilistically; that is, to a distribution of possible loss outcomes for that risk. This is true for all steps in the calculation, including inuring treaties.

Facultative reinsurance

Facultative certificates (FAC) are applied at the location and/or at the layer level. Spot FAC can be applied on a location when a layer is present.

Ceding companies negotiate facultative certificates separately with facultative reinsurers for each insurance contract that they want to reinsure and the facultative reinsurer may accept or decline a risk from the ceding company. Ceding companies frequently purchase Facultative certificates to provide coverage for distinct and unusual risks that their reinsurance treaties do not cover, such as large commercial properties. Such risks are usually of high value, where a single risk may represent a large percentage of the portfolio.

There are three types of facultative certificates that you can apply in Touchstone, including:

- Proportional Facultative certificate expressed as a ceded percent (PFCP)
- Proportional Facultative certificate expressed as a ceded amount (PFCA)
- Non-proportional Facultative certificate (NFG) expressed as a ceded percent

The following table illustrates the expected loss when applying a PFCP certificate to a layer. In this example, the losses were shared from the first dollar amount. Since you cannot apply limits to Proportional Facultative certificates, the loss in the Ceded Amount per Layer row illustrates the loss to the Facultative certificate for each policy/layer. When you sum the losses, the total loss ceded to the PFCP certificate is $476,000. The ceding company is responsible for the remaining loss.

Table 17. Example of expected loss when using proportional facultative certificates attached to single layers

	Policy A	Policy B	Policy C	Policy D
Percent Ceded per Layer	0%	50%	67%	100%
Loss to Layer	$100,000	$150,000	$300,000	$200,000
Ceded Amount per Layer	0%	$75,000	$201,000	$200,000
Total Loss Ceded to Facultative Certificate	$476,000 (sum of amounts ceded per layer for policies B, C, and D)			

The next table illustrates expected losses when applying an NFG certificate that is attached to a policy/layer. The losses are not shared proportionally between the reinsurance company and the ceding company. Once the attachment point for each policy/layer is exceeded, the loss is ceded to the Facultative certificate according to the ceded percent, up to a defined limit. For example, with Policy B the loss to the layer ($150,000) exceeds the attachment point ($50,000) by $100,000. Since the percent ceded is 50%, the ceded amount is $50,000. The ceded amount per Policy/Layer row illustrates the loss to the Facultative certificate for each policy/layer.

Table 18. Example of expected loss when using an NFG certificate attached to a policy/layer

	Policy A	Policy B	Policy C	Policy D
Percent Ceded per Layer	0%	50%	67%	100%
Attachment Point for Certificate	$10,000	$50,000	$100,000	$100,000
Limit for Certificate	$50,000	$300,000	$400,000	$200,000
Loss to Layer	$100,000	$150,000	$700,000	$200,000
Ceded Amount per Layer	$0	$50,000	$268,000	$100,000
Total Loss Ceded to Facultative Certificate	$418,000			

When you sum the losses, the total loss ceded to the Facultative certificate is $418,000. The ceding company is responsible for the remaining loss.

Total loss to layer	$1,150,000
Minus total loss ceded to facultative certificate	$418,000
Equals	$732,000

Treaty reinsurance

With reinsurance treaties, the ceding company is contractually bound to cede loss and the reinsurer is bound to insure all risks defined in the contract.

Ceding companies frequently purchase reinsurance treaties to provide coverage for risks of the same kind, such as homes or automobiles. Such risks are usually of low value, where a single risk is a small percentage of the entire portfolio. Treaty reinsurers do not separately evaluate each individual risk assumed under their contract. Instead, they use:

- Retention/attachment points to define the amount of loss that must be met before reinsurance is triggered. The ceding company retains any portion of the loss below the retention/attachment point. The reinsurer covers losses above the retention/attachment point.
- Limits to define the maximum amount of loss that the reinsurer is responsible for covering for a single event. Any amount above the limit is ceded to another reinsurance contract or retained by the ceding company.

Excess of loss treaties

Excess of Loss (XOL) treaties are the most common form of reinsurance.

Touchstone supports the following types of XOL treaties:

- Per-Risk Excess of Loss (XOL): Reinsurance terms, such as the risk limit and risk retention, apply per risk rather than per occurrence or aggregate limit. XOL terms are applied at the location, layer level, or contract level.
- Catastrophe Excess of Loss (CATXOL): Provides coverage, at the portfolio level (the entire exposure view), for the accumulation of losses resulting from a catastrophic event

The second table illustrates the expected loss when using a per-risk XOL treaty with the following total loss and terms.

Total Loss for Locations (Risks) 1-4	$1,225,000
Risk Retention	$10,000
Risk Limit	$250,000
Occurrence Limit	$500,000

In the example, the loss for Location 3 is $300,000 and the loss for Location 4 is $600,000. The risk limit (shown in the preceding table) restricts the amount of loss ceded to the XOL treaty to $250,000 per location (or risk).

Table 19. Example of expected loss when using per-risk XoL treaty

Location	Loss	Loss After Risk Retention	Loss After Risk Limit
Location 1	$125,000	$115,000	$115,000
Location 2	$200,000	$190,000	$190,000
Location 3	$300,000	$290,000	$250,000
Location 4	$600,000	$590,000	$250,000
Total	$1,225,000		

With the occurrence limit applied, the reinsurer is responsible for covering a maximum of $500,000. The ceding company is responsible for covering the balance of $725,000:

Total loss	$1,225,000
Minus occurrence limit	$500,000
Ceding company responsibility	$725,000

Quota share treaties

Quota share treaties are applied per risk at the location, layer, or contract level.

Quota share treaties are the simplest form of reinsurance, where the premium and losses are shared proportionally (pro-rata) between the ceding company and the reinsurer. The premium and losses are shared on a fixed percentage basis from the first dollar of loss.

The second table below illustrates the expected loss responsibilities when using a quota share treaty with the following total loss and terms.

Total Insurable Value	$50,000
Percent Ceded	80%
Premium Amount	$2,500
Loss Amount	$1,500

Table 20. Example of expected loss when using a quota share treaty

	Ceding Company Responsibility	Reinsurer Responsibility	Calculations
Total Insurable Value	$10,000	$40,000	• Ceding Company: $50,000 x 20% • Reinsurer: $50,000 x 80%
Premium Amount	$500	$2,000	• Ceding Company: $2,500 x 20% • Reinsurer: $2,500 x 80%
Loss Amount	$300	$1,200	• Ceding Company: $1,500 x 20% • Reinsurer: $1,500 x 80%
Maximum Responsibility	$10,800	$43,200	

The next table illustrates how the retention and percent ceded can vary according to the total insurable value of the exposures. For example, when the loss is $25,300, the reinsurer covers $15,180 of the loss ($25,300 * 60%) and the ceding company covers $10,120 of the loss ($25,300 minus $15,180).

Table 21. Example of maximum amount ceded to a quota share treaty

Total Insurable Value of Exposures	Quota Share Percent Ceded	Maximum Ceded Amount (Reinsurer Responsibility)
$0 - $25,000	20%	$5,000
$25,000 - $50,000	60%	$30,000
$50,000 - $75,000	75%	$56,250
$75,000 - $100,000	80%	$80,000

Surplus share treaties

Surplus share treaties are applied per risk at the location or layer level, depending on the structure of the treaty.

Similar to quota share treaties, surplus share treaties assume a proportional share of the loss. However, unlike quota share treaties where the percent ceded is fixed, the percent ceded to surplus share treaties varies by the risk. You achieve this by attaching surplus share treaties to specific risks (locations or layers).

To qualify for reinsurance coverage, the loss incurred for a risk (location or layer) must be greater than the risk retention—the ceding company retains all risks below the risk retention.

After calculating all the losses ceded to the surplus share treaty for each risk, Touchstone sums the losses. The treaty's occurrence and aggregate limits then determine the total amount of loss that the surplus share treaty can sustain.

The following table illustrates the expected loss when using a surplus share treaty attached to a single layer with the designated percentages ceded per policy and the following terms.

- Risk Retention: $100,000
- Treaty Limit on Ceded Losses: $10,000

Table 22. Example of expected loss when using a surplus share treaty

	Policy A	Policy B	Policy C	Policy D
Total Insured Value	$75,000	$120,000	$150,000	$200,000
Value Above the Risk Retention	0	$20,000	$50,000	$100,000
% of First Dollar Loss Ceded to Treaty	0%	16.7%	33.3%	50.0%
Sample Policy Loss	$10,000	$15,000	$16,500	$20,000
Retained by Ceding Company	$10,000	$12,500	$11,000	$10,000
Ceded to Treaty (based on ceded %)	$0	$2,500	$5,500	$10,000
Total Losses Ceded to Treaty	$18,000			
Treaty Limit	$10,000			
Total Loss Sustained by Treaty	$10,000			

	Policy A	Policy B	Policy C	Policy D
Retained by Cedant	$8,000			

General reinsurance workflow

Overview of the propagation of loss between treaties and facultative certificates as well as across risk types (location, layer, and contract).

For the purposes of this section, the important attributes of a treaty reinsurance program to consider are the target risk type and the inuring order of each treaty. We can then group the treaties in a reinsurance program first by their target types and then their inuring orders to help illustrate this process.

Within a group of treaties of the same target type, the application of each treaty proceeds from the lowest to the highest inuring order. The net result of each group of treaties of the same inuring order (or each "tier" of reinsurance) is used as the input to the next tier of treaties.

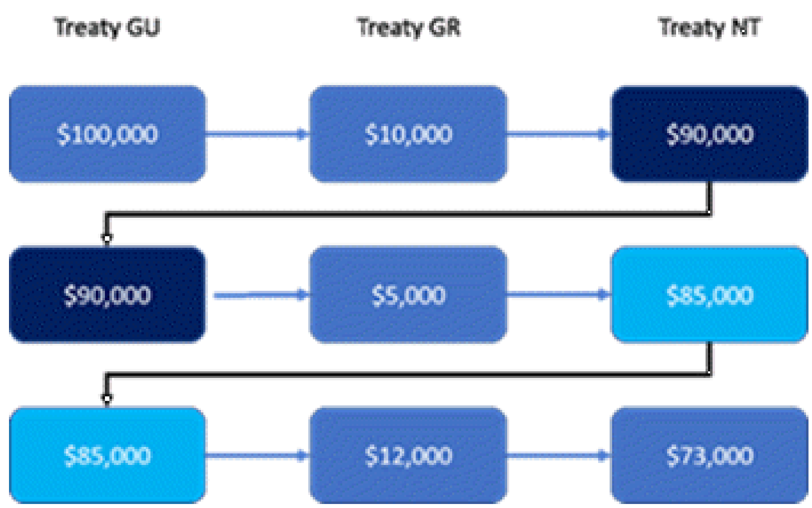


Figure 41. Treaties in series

When multiple treaties have the same inuring order, those treaties are said to be applied in parallel, meaning simply that the input (or ground up) to the treaty is the same across the tier and that each treaty is applied independently. For each treaty within a tier, the net loss is calculated. Additionally, the gross losses per risk are accumulated across treaties within the tier and this accumulation is used to calculate the tier net loss per risk, which is used as the ground up loss to the next tier of reinsurance. Any facultative certificates at this same target type can be thought of as an unspecified inuring order zero within the treaty reinsurance program and the propagation of loss from facultative loss to the first tier of treaty reinsurance then follows the same rules as described above.

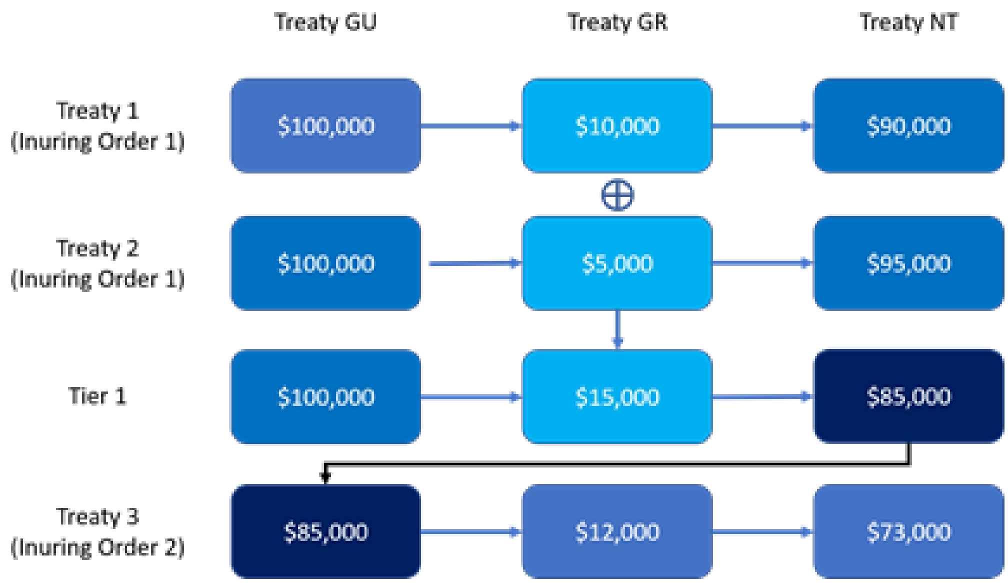


Figure 42. Treaties in parallel

Across treaty (and facultative) target types, the general order of application is first location, then layer, and finally contract. The net loss of the highest inuring order treaties of the previous target type becomes the ground up loss for the lowest inuring order treaties after one additional step; the accumulation from one target type to another. For example, after all location reinsurance is applied, all locations need to be grouped by contract (or layer) and accumulated to that risk type before the next set of risk reinsurance can be applied.

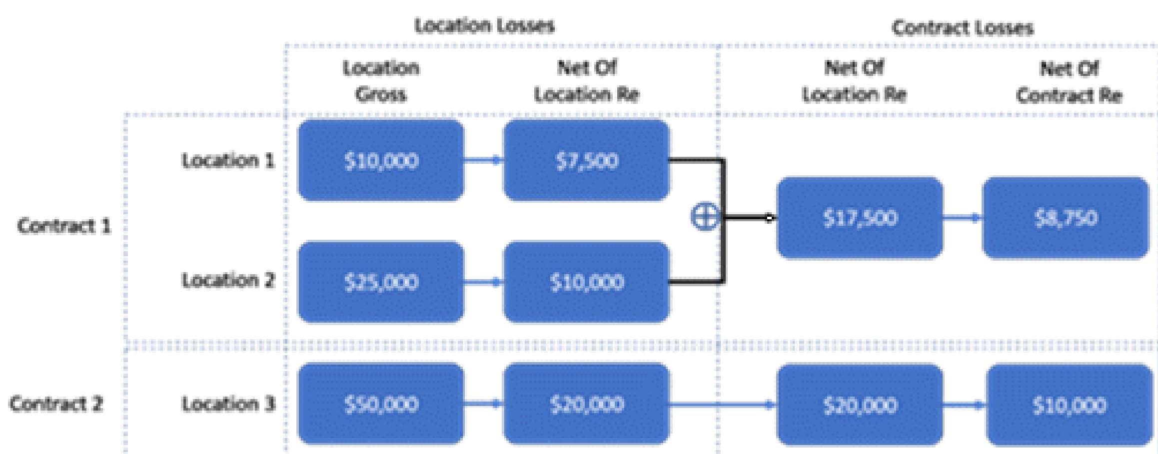


Figure 43. Risk type propagation

Location reinsurance with policy layers

The financial engine includes updates to how location-level treaty insurance is applied.

Location-level facultative reinsurance on a policy with layers is referred to as spot facultative. Such policy terms are typically used to reduce the loss to the layer by using facultative insurance for individual locations (typically those of high value/risk). This policy condition applies location-level deductibles and limits first, then applies the location facultative terms, and finally applies the layer terms. Similarly, the NGM framework allows location-level treaty reinsurance, which is applied immediately after location facultative reinsurance and before any layer terms. That is, all location-level reinsurance is applied before layer level insurance or reinsurance. Losses are produced and reported within the gross perspective instead of within the Net perspective that is common for reinsurance policy conditions.

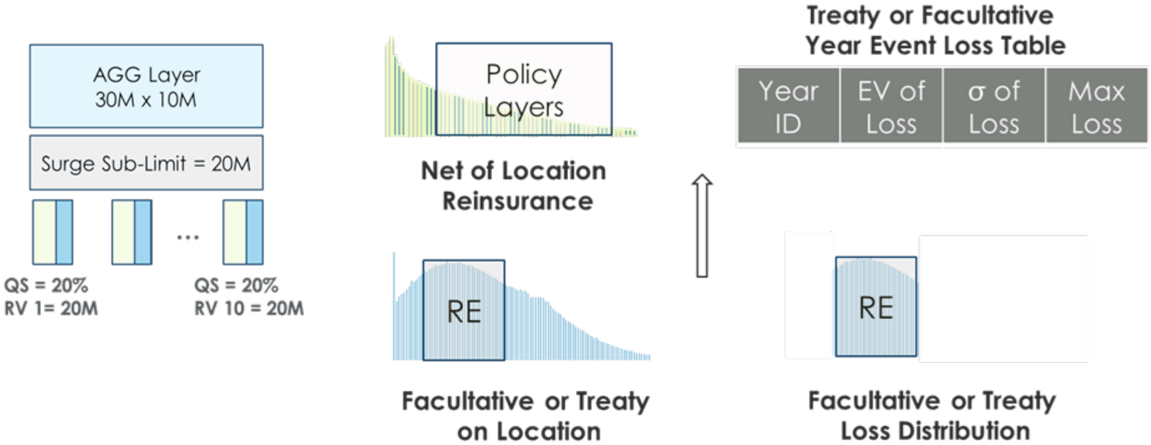


Figure 44. Location reinsurance with policy layers

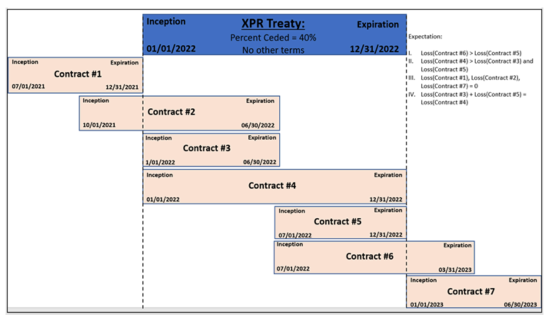


Figure 45. Example of attaching risks to trigger types

Probabilistic loss computation

Distributions and probabilistic loss in Touchstone.

The financial engine uses distributions through every stage of application and therefore, loss computations are fully probabilistic. Loss computation is accomplished almost entirely through methods shared with the fully probabilistic insurance module with the notable addition of the probabilistic computation of net loss through comonotonic subtraction. Probabilistic computation of net loss generates distributions for the insurers view of the resulting loss from a tier of reinsurance application, which can then be used to report distribution statistics (mean loss, max loss, and standard deviation of loss) and which can be propagated to a subsequent tier or reinsurance terms.

Terms and conditions for reinsurance

Support for new terms and conditions in Touchstone reflects the growing complexity in treaty and reinsurance underwriting.

The financial engine has expanded support; all applications of terms and conditions are now fully probabilistic:

- All loss accumulations are performed with probabilistic distributions with correlation factors
- All reinsurance terms and conditions applied on probabilistic distributions
- All net of reinsurance losses are modeled through probabilistic distributions
- All modeled uncertainty is propagated to the parameters of standard deviation, max of loss in year event loss tables

Supported reinsurance terms and conditions

Support for reinsurance terms and conditions in Touchstone.

The following table presents the supported reinsurance terms and conditions in order of application from top to bottom.

Table 23. Supported reinsurance terms and conditions

Order of application	Facultative	Quota Share	Surplus Share	XoL PR
Percent Placed		Y	Y	Y
Percent Ceded (SS/QS)		Y	Y	
Risk Occurrence Retention	Y		Y	Y
Risk Aggregate Retention	Y		Y	Y
Risk Occurrence Limit	Y		Y	Y
Risk Aggregate Limit	Y		Y	Y
Percent Ceded (Fac/XOL)	Y			Y
Treaty Occurrence Limit		Y	Y	Y
Treaty Aggregate Limit		Y	Y	Y

Treaty and facultative loss results

Reinsurance results perspectives (views) in Touchstone.

Touchstone has enhanced all existing reinsurance results views to include new loss perspectives and all of the distribution statistics that are common in insurance results views (mean loss, max loss, and standard deviation). Those existing result views have been renamed and the new names are listed below with a brief description of what they show and when they will be generated.

- LOSS_ByTreaty - The total losses for each treaty - Always generated when a reinsurance program is included in the analysis
- LOSS_ByTreatyExposureAttribute - The losses by Line of Business for each treaty - Generated when results are saved by Line of Business
- LOSS_ByTreatyExposureAttributeGeo - The losses by Line of Business and geography (Country, Area, Subarea, or Postal) for each treaty - Generated when results are saved by Line of Business and a Geography
- LOSS_ByTreatyGeo - The losses by geography (Country, Area, Subarea, or Postal) for each treaty - Generated when results are saved by any risk other than Line of Business and a Geography

All reinsurance results views have the following loss perspectives:

- Ground Up - Input distribution to the treaty.
- Recovery - The loss after risk terms (without treaty limits).
- Gross - The loss after all treaty terms (risk terms and portfolio terms).
- Net - Same as treaty gross.

5 Determining event level loss

How policy terms affect event-level losses in Touchstone

In addition to the peril models, Touchstone relies on location and layer terms and policies to generate loss estimates.

This section provides several use cases that specifically address the effect of policy terms on loss.

Policy terms effect losses in a variety of ways including (but not limited to):

- Order of application of policy terms
- Single versus multiple coverages per location
- Single versus multiple location policies
- Use of location groups
- Use of nested sublimits
- Inclusion of sub-perils
- Application of reinsurance terms

The following discussion covers examples of loss calculations:

- Policy loss calculation workflow examples for common structures
- Actuarial methodologies for applying certain types of insurance or reinsurance terms
- How back allocation is used in calculating losses for reporting

Additional details on how the new terms introduced with NGM are calculated can be found in a supplement *NGM Policy Term Calculation Examples.*

Order of application of policy terms in Touchstone

In Touchstone, policy terms are applied in a particular order to determine losses.

When applying policy terms, Touchstone **first applies any demand surge factors** to the ground-up loss. It then applies policy terms as follows:

1. Location participation 2
2. Location coverage occurrence deductibles
3. Location site occurrence deductibles
4. Location site aggregate deductibles
5. Location coverage occurrence limits
6. Location site occurrence limits
7. Location site aggregate limits
8. Location participation 1
9. Location-level reinsurance
10. Location group deductibles
11. Location group limits
12. Location group reinsurance (facultative)
13. Sublimit occurrence deductible
14. Sublimit aggregate deductible

15. Sublimit occurrence attachment amount
16. Sublimit aggregate attachment amount
17. Sublimit occurrence limit
18. Sublimit aggregate limit
19. Sublimit participation
20. Layer occurrence deductible
21. Layer aggregate deductible
22. Layer occurrence attachment amount
23. Layer aggregate attachment amount
24. Layer occurrence limit
25. Layer aggregate limit
26. Layer participation
27. Layer reinsurance terms (facultative, then surplus share, then quota share)
28. Excess of Loss (XOL) policy conditions

Reinsurance

1. Fac/Surplus Ceded Amount
2. Fac/Surplus Occurrence Retention
3. Fac/Surplus Aggregate Retention
4. Fac/Surplus Occurrence Limit
5. Fac/Surplus Aggregate Limit
6. Fac/Surplus Reinstatement
7. Treaty Percent Ceded
8. Treaty Risk Occurrence Retention
9. Treaty Risk Occurrence Limit
10. Treaty Risk Aggregate Retention
11. Treaty Risk Aggregate Limit
12. Treaty Occurrence Retention
13. Treaty Occurrence Limit
14. Treaty Aggregate Retention
15. Treaty Aggregate Limit
16. Percent Placed
17. Coinsurance

Contract loss calculation examples

Calculate losses for a single location and one coverage

This example describes how Touchstone calculates event-level losses for a single location and one coverage.

This is the most basic workflow and can be used to understand the Touchstone method for estimating gross losses based on ground-up distributions.

A probability distribution underlies each coverage and location for a given event. The figure below illustrates a probability loss distribution for a single location and one coverage—loss is represented as quantities on the X-axis and probability of loss as the 0 to 1 value on the Y-axis. This discrete probability loss distribution is divided into several bins and represents the ground-up loss distribution. Each bin represents the probability of having a loss in the given range.

For example, in the distribution, there is a 0.35 probability of a loss in the $30-$40 million range.

Bin	Ground-Up Loss (millions), x	Probability
0	$0 = x < 10$	0.05
10	$10 \leq x < 20$	0.1
20	$20 \leq x < 30$	0.2
30	$30 \leq x < 40$	0.35
40	$40 \leq x < 50$	0.3

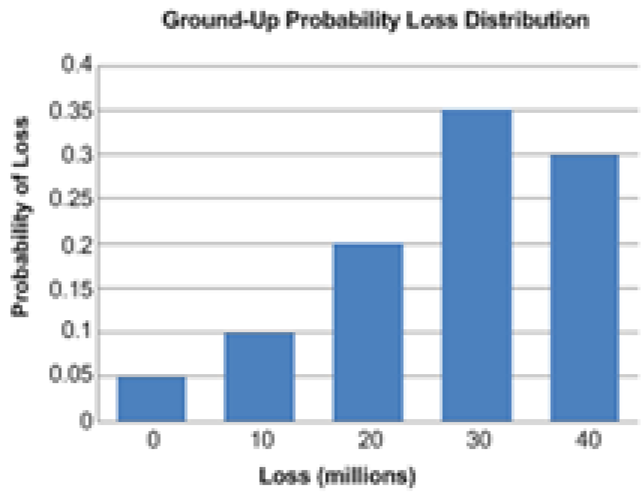


Figure 46. Ground-up probability loss distribution for single location and one coverage

The mean of the ground-up loss distribution is the sum of the product of the loss for each bin and its associated probability, calculated as follows:

$$Mean\ \ GUP\ \ loss\ = \sum_{i=1}^{n} l_i \times P(l_i)$$

Using the example in the figure above:

$$Mean\ \ GUP\ \ loss = (0*0.05) + (10*0.1) + (20*0.2) + (30*0.35) + (40*0.3) = 27.5$$

When a $10 million coverage deductible is applied, the distribution shifts to the left by a distance equal to this deductible and is measured as retention. The probabilities that cross the Y-axis will now stack on top of the first bin (representing zero loss), as seen in the figure below.

$$Mean\ \ Gross\ \ loss\ = \sum_{i=1}^{n} l_i \times P(l_i)\ \ Mean\ \ Gross\ \ loss$$

$$= max\{0, (0-10)*0.05\} \ + \ ((10-10)*0.1) + ((20-10)*0.2)$$

$$+ ((30-10)*0.35) + ((40-10)*0.3)$$

$$= (0 \times 0.15) + (10 \times 0.2) + (20 \times 0.35) + (30 \times 0.3) = 18$$

Bin	Gross Loss (millions), x	Probability
0	$0 \leq x < 10$	0.05
0	$0 = x < 10$	0.1
10	$10 \leq x < 20$	0.2
20	$20 \leq x < 30$	0.35
30	$30 \leq x < 40$	0.3

Bin	Gross Loss (millions), x	Probability
0	$0 = x < 10$	0.15
10	$10 \leq x < 20$	0.2
20	$20 \leq x < 30$	0.35
30	$30 \leq x < 40$	0.3

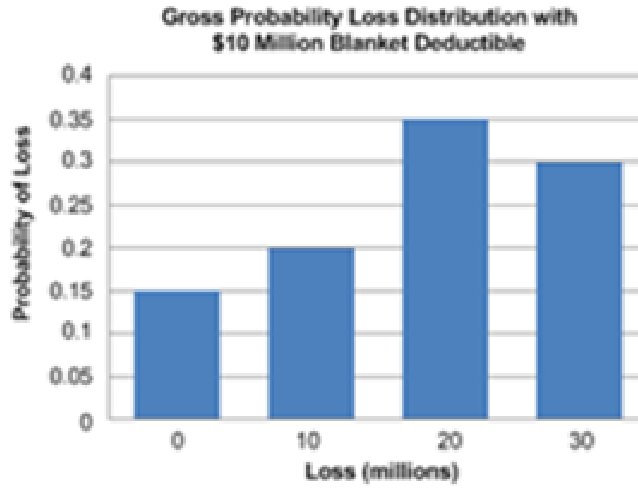


Figure 47. Gross probability loss distribution for single location and one coverage

with $10M coverage amount deductible

Calculate losses for a single location with multiple coverages

This example describes how Touchstone calculates event-level losses for a single location with multiple coverages. It can thus be used to understand the Touchstone method for convolving loss distributions and applying site or coverage-level terms.

This example can be used to understand the Touchstone method for convolving loss distributions and applying site or coverage-level terms.

Touchstone uses the same method to apply coverage-level terms. Coverage-level terms, such as coverage limits and deductibles, are applied to the ground-up coverage loss distribution for each coverage per location. If location-level per coverage terms exist, the Touchstone financial module applies them first, and then combines the individual coverage loss distributions per location and event, to create the total loss distribution for that location for that event. However, if the terms are applied by site, or across a subset of coverages at a location, Touchstone accumulates the coverage distributions first, using the mixture method, and then applies the site term to the accumulated distribution of loss.

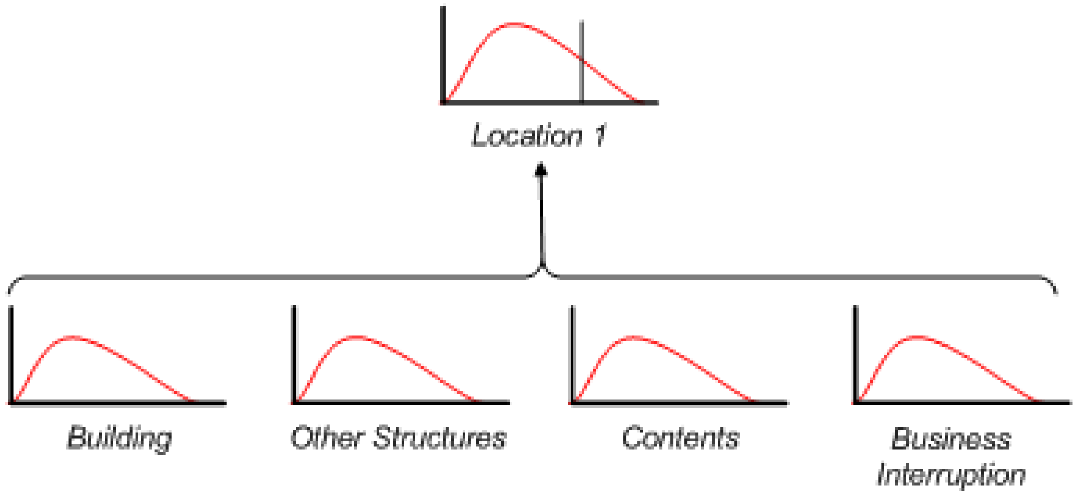
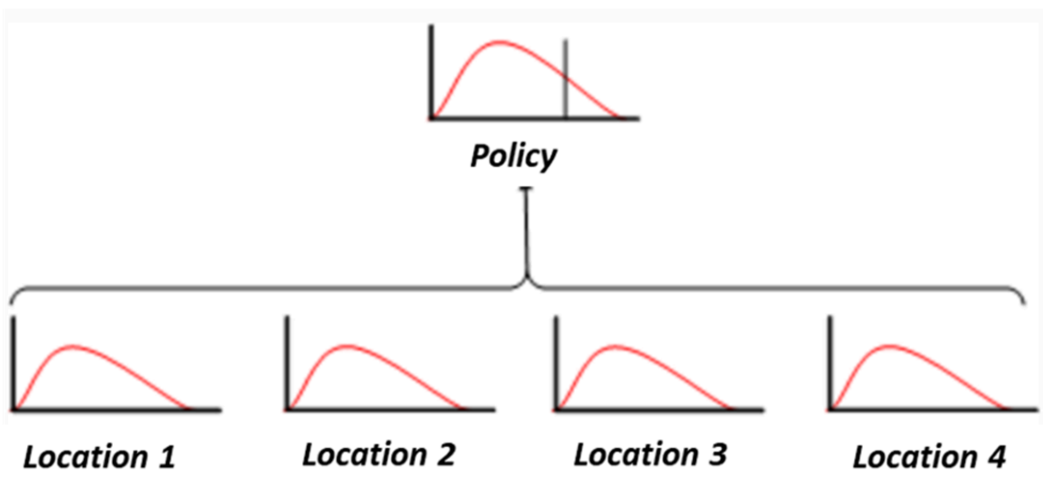


Figure 48. Single location with multiple coverages

Calculate losses for a single policy with multiple locations

This example demonstrates Touchstone;s method for accumulating loss distributions from location to policy level.

In cases with more than one location within a policy, the individual location terms are processed first. This includes any individual coverage, combined coverage, or site (all coverage) level limits, deductibles, and participations, which are applied and aggregated as described in the previous section. Once coverage and location terms are applied, each location's distribution of loss is combined using the mixture method to impose spatial correlation between risks, with risks in closer proximity seeing higher levels of correlation. For more information on this process, refer to the section Modeling uncertainty. Once all location loss distributions are combined, per the figure below, the policy level limits, deductibles, and participations (referred to in Touchstone as "layer terms") are combined to the joint distribution of loss across all impacted locations for a given event.



Calculate losses for a policy using location groups

This example demonstrates Touchstone's method to apply terms for policies that contain location groups.

In some cases, policy conditions are applied to multiple locations; for example, a limit could be applied to locations within a campus. This is referred to as *campus structures*. In this situation, the conditions are applied to multiple locations where each location may have different geocodes/construction/occupancy/age/height/replacement values, but not have individual, location-specific policy terms. Policy terms covering the locations exist in the location group, which is called the *primary location*.

Another policy condition can be applied that limits loss to a collection of locations within a certain region, for example the group of locations, as well as to other locations combined.

Finally, an overall layer limit can be applied that limits the total loss across all locations in all regions. Touchstone can also apply *spot facultative reinsurance* to the primary location; however, applying the spot facultative terms *after* applying the location terms (the primary location terms in this case), which affects the Gross loss.

The figure below illustrates the structure of a location group:

- Six locations in a policy (locations 3, 4, 5, and 6 in California, locations 8 and 9 in Oregon).
- Three California locations (locations 3, 4 and 5) each have different geocodes/ construction/occupancy/age/height/replacement values. They also have a $1 million limit and $50,000 deductible applied to all three locations combined.
- Sublimit deductible of $100,000 covers Shake losses to all California locations.
- $20-million-layer limit and $1-million blanket deductible covers shake losses for all six locations.

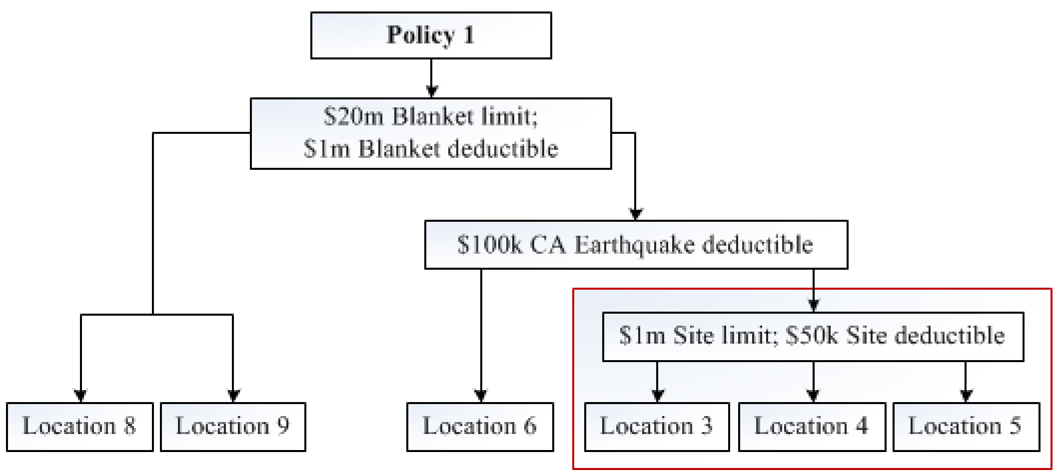


Figure 49. Location group structure

In this example, the location group comprises locations 3, 4 and 5. For a given event the Touchstone applies the terms as follows:

1. Accumulates the loss from each location within the location group (locations 3, 4, 5).
2. Applies policy terms to the loss from step 1.
3. Accumulates loss results from step 2 with the loss from the other location within the region (location 6).
4. Applies the sublimit deductible.

5. After applying the sublimit deductible, accumulates the total loss results from the California locations with the loss results from the Oregon locations (locations 8 and 9) and then applies the layer deductible and limit.

Calculate losses to multiple locations under a single policy with sublimits

This example demonstrates how sublimits can be used to limit the losses to a set of locations or to a coverage within a set of locations in Touchstone.

Sublimits in Touchstone are employed to group location losses and limit them by geography, peril, and insurance coverage.

When calculating gross loss to a policy with multiple locations and sublimits the application of sublimit terms takes place after all coverage and location terms have been applied. To limit or apply a deductible to losses for the sublimited group of locations, all the loss distributions to which the sublimit applies are accumulated using the mixture method, then the sublimit terms are applied. After the sublimit terms are applied, the non-sublimited locations distributions of loss are combined with the sublimited result, again using the mixture method, and then any policy-level terms are applied as required.

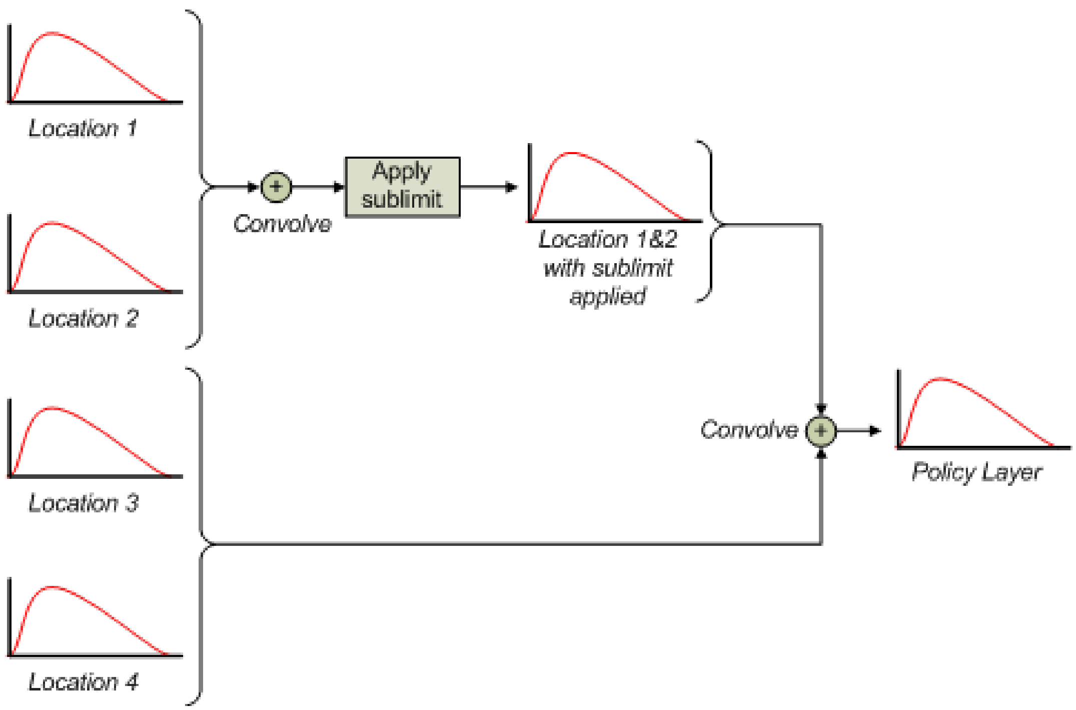


Figure 50. Multiple locations under a single policy with a sublimit

Applying sublimits to a single coverage

Sublimits can also be used to limit loss for an individual coverage, such as contents. In such a case, the content losses for each location are combined and the sublimit terms are applied. The result is paired with the remaining coverage losses for all locations and then enters the layer.

What is final contract gross loss

For layered commercial contracts, gross loss is defined as the accumulation of all layered gross loss in each contract.

Gross loss is computed with the fully probabilistic methodology of comonotonic accumulation of the layer gross loss distributions. In natural catastrophe modeling this methodology is used for accumulation of fully dependent risks. Multiple excess policy layers in the same contract applied on the same GUP-to-layer loss meet this definition of full dependency. For single layered contracts the final contract gross loss becomes simply the single layer gross loss.

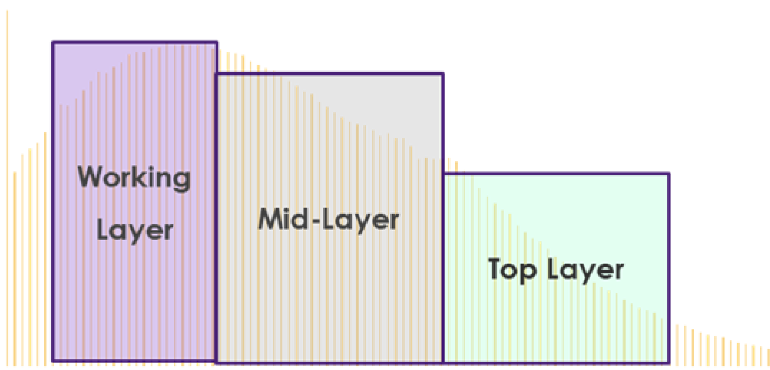


Figure 51. Distribution of GUP-to-layer

In Touchstone, gross losses from locations with peril codes not included in the layer peril code set are not included in the final contract gross loss. The final contract gross loss is defined purely as accumulation of layer gross losses in the case of multiple layers, and as a single layer gross loss in the case of a single layered contracts.

In the example below we have a contract coded for three perils – hurricane, earthquake, and wildfire. The contract has two layers – hurricane layer and an earthquake layer. The contract has six locations coded in pairs for one of the three peril codes.

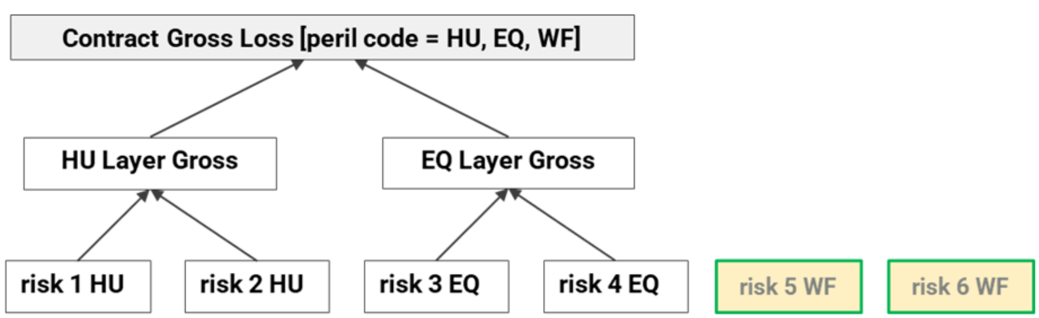


Figure 52. Example of gross loss: two layers and three perils

In Touchstone 2023 (11.5) the final contract gross loss is the fully probabilistic comonotonic accumulation of the hurricane layer gross loss and the earthquake layer gross loss. The gross loss from the two locations coded for wildfire does not participate in the final gross loss. In earlier versions of Touchstone (11.0, Technical Preview , 10.0, and 9.0), the gross loss from these two locations participated in the final contract gross loss. In addition, the accumulation of layer gross loss is no longer capped to layer-GUP as it was done in the previous generation of the financial module. To conclude, we can generalize the deterministic versions of the actuarial formulas for contract gross loss as follows:

- Touchstone 2023 (11.5):

  Contract Gross Loss = ∑ Layer Gross Loss

- Touchstone 2023 (11.0) and the Technical Preview:

  Contract Gross Loss = ∑ Layer Gross Loss + (non/layered location-peril Gross)

Apply multiple locations to a policy

Event losses in Touchstone for one policy, multiple locations.

In some cases, policy conditions are applied to multiple locations; for example, a limit could be applied to locations within a campus. This is referred to as "campus structures. In this situation, the conditions are applied to multiple locations where each location may have different geocodes/construction/occupancy/age/height/replacement values, but not have individual, location-specific policy terms. Policy terms covering the locations exist in the location group, which is called the *primary location*.

Another policy condition can be applied that limits loss to a collection of locations within a certain region, for example the group of locations, as well as to other locations combined.

Finally, an overall layer limit can be applied that limits the total loss across all locations in all regions. The financial engine can also apply *spot facultative reinsurance* to the primary location; however, applying the spot facultative terms *after* applying the location terms (the primary location terms in this case), which affects the Gross loss.

The figure below illustrates the structure of a location group:

- Six locations in a policy (locations 3, 4, 5, and 6 in California, locations 8 and 9 in Oregon).
- Three California locations (locations 3, 4 and 5) each have different geocodes/ construction/occupancy/age/height/replacement values. They also have a $1 million limit and $50,000 deductible applied to all three locations combined.
- Sublimit deductible of $100,000 covers Shake losses to all California locations.
- $20-million-layer limit and $1-million blanket deductible covers shake losses for all six locations.

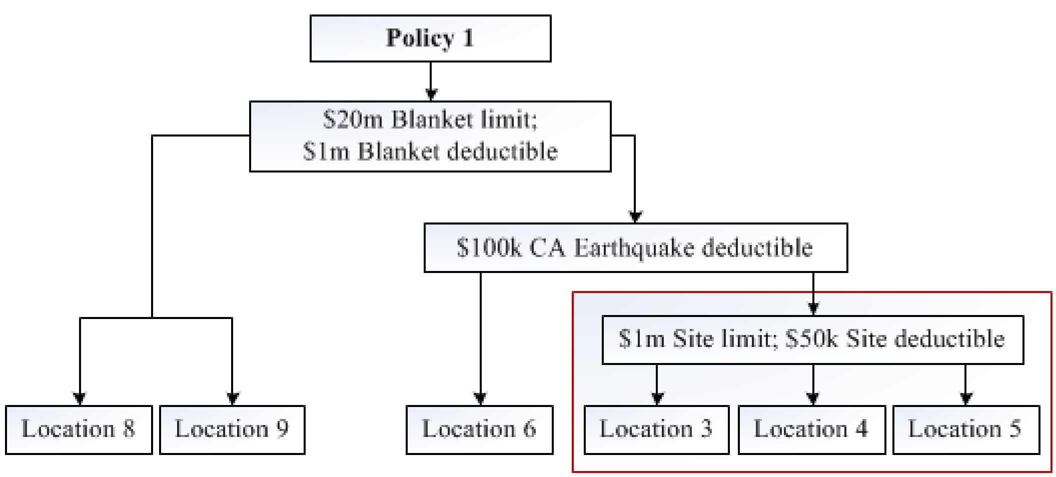


Figure 53. Location groups structure

In this example, the location group comprises locations 3, 4 and 5. For a given event the financial engine applies the terms as follows:

1. Accumulates the loss from each location within the location group (locations 3, 4, 5).
2. Applies policy terms to the loss from step 1.
3. Accumulates loss results from step 2 with the loss from the other location within the region (location 6).
4. Applies the sublimit deductible.
5. After applying the sublimit deductible, accumulates the total loss results from the California locations with the loss results from the Oregon locations (locations 8 and 9) and then applies the layer deductible and limit.

Financial modeling with dependent sub-perils

Use of dependent sub-perils in Touchstone.

This section describes how the application of policy terms when there are sub-perils can be different for some earthquake models compared with wind models.

Accumulation and back allocation of dependent sub-peril probabilistic distributions

Another application of dependent sub-perils in Touchstone.

Another scenario when modeling an earthquake is to have terms for both shake damage and fire following damage. In this scenario, Touchstone applies an accumulation and back allocation of dependent sub-peril probabilistic distributions method; this method more accurately applies the terms to the combined PES +PEF distribution. To do this, the combined PES+PEF distribution is scaled into two distributions using the proportion of contributing PES loss for one distribution and the proportion of contributing PEF loss on the other. The distributions are scaled on probability, which means that the loss points are the same on the two distributions and the original distribution combined PES+PEF distribution. Scaling the distributions on probability ensures the max values are preserved; if Touchstone scaled on loss, the max values would be less than the total insured value. After deriving the two distributions from the PES+PEF distribution, Touchstone applies the PES and PEF terms to their respective distributions. Then it combines the parameters from the resulting distributions.

$$\mu_{COMBINED} = \mu_{PES_{AFTER\ TERMS}} + \mu_{PEF_{AFTER\ TERMS}}$$

$$\sigma_{COMBINED} = \sqrt{\sigma^2_{PES_{AFTER\ TERMS}} + \sigma^2_{PEF_{AFTER\ TERMS}} + 2\,(\sigma_{PES_{AFTER\ TERMS}}\,\sigma_{PEF_{AFTER\ TERMS}})}$$

$$MAX_{COMBINED} = MAX_{PES_{AFTER\ TERMS}} + MAX_{PEF_{AFTER\ TERMS}}$$

After combining the parameters, Touchstone fits a transformed beta distribution using the new combined parameters, which results in the post-terms location gross distribution.

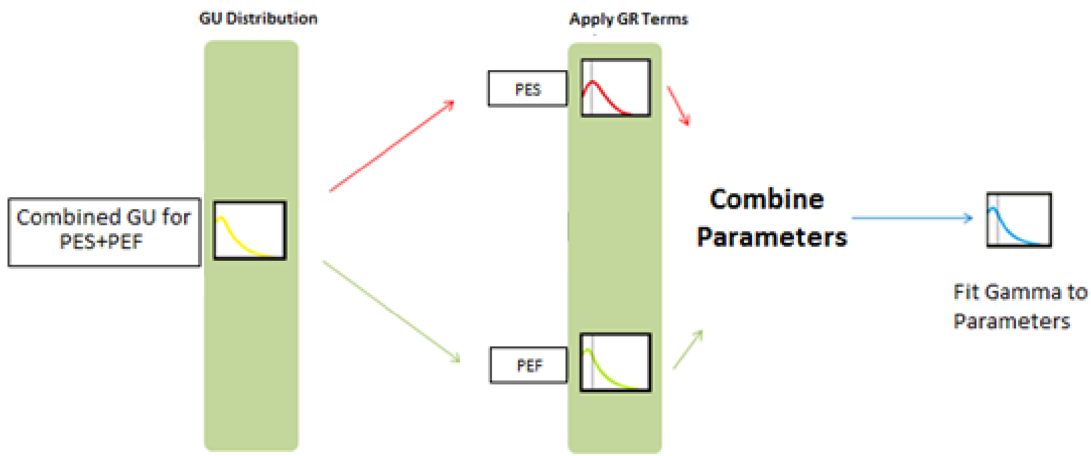


Figure 54. Accumulation and back allocation of dependent sub-peril probabilistic distributions

Financial modeling with wind, storm surge, flood, and precipitation

Combined peril analysis in Touchstone.

When the wind and storm surge or wind and precipitation flood perils are run as a combined analysis, the Hazard model sends one combined mean damage ratio (MDR) discrete probabilistic distribution to Touchstone. Touchstone normalizes the MDR of wind and storm surge/flood such that the combined MDR does not exceed 100% damage to TIV. At the location level, only one set of terms can be applied on this distribution. That is, if there is a wind set of terms and a storm surge set of terms, Touchstone applies only the first set of terms, ignoring all subsequent sets of terms. When there are second-tier financial structures on single perils such as layers, or sublimits on wind and storm surge/flood separately, Touchstone applies financial terms on the single distribution from the Hazard model with a combined MDR for wind and storm surge/flood.

Calculate losses to multiple locations under a single policy with sublimits

This example demonstrates how sublimits can be used to limit the losses to a set of locations or to a coverage within a set of locations in Touchstone.

Sublimits in Touchstone are employed to group location losses and limit them by geography, peril, and insurance coverage.

When calculating gross loss to a policy with multiple locations and sublimits the application of sublimit terms takes place after all coverage and location terms have been applied.
To limit or apply a deductible to losses for the sublimited group of locations, all the loss distributions to which the sublimit applies are accumulated using the mixture method, then the sublimit terms are applied. After the sublimit terms are applied, the non-sublimited locations distributions of loss are combined with the sublimited result, again using the mixture method, and then any policy-level terms are applied as required.

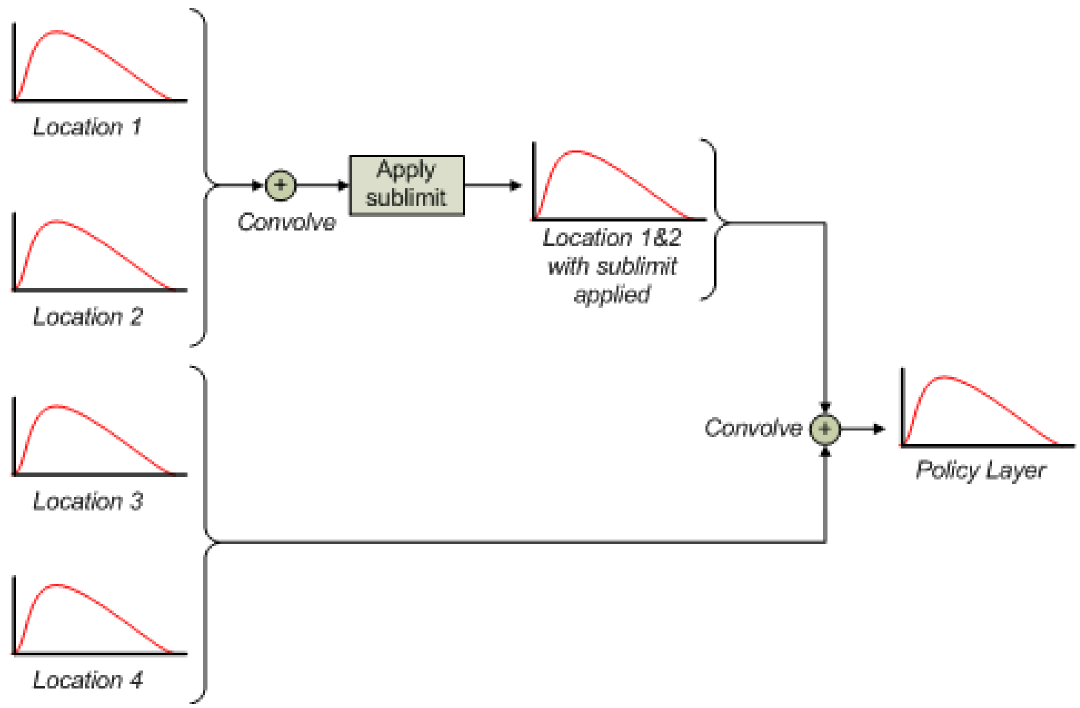


Figure 55. Multiple locations under a single policy with a sublimit

Applying sublimits to a single coverage

Sublimits can also be used to limit loss for an individual coverage, such as contents. In such a case, the content losses for each location are combined and the sublimit terms are applied. The result is paired with the remaining coverage losses for all locations and then enters the layer.

Apply reinsurance terms to a multiple-location policy

Reinsurance terms can be applied at the location, layer, and contract level in Touchstone.

At the location level, reinsurance is applied after location terms; at the layer level they are applied after layer terms. Reinsurance can also be applied at the contract level where, if there are multiple layers, these layer losses are combined, and reinsurance is applied to this total loss distribution. Such contract-level reinsurance is applicable only to Quota Share (QS) and Per-Risk Excess of Loss (XPR) treaties. For layer-level reinsurance, the reinsurance terms are applied to the Gross Loss probability distribution for all coverages combined for each location for each event. The Reinsurance Recovery Amount (RRA), which is the portion of the loss that is ceded to the reinsurance contract, is computed. The difference between the Gross loss and RRA is calculated by event and displayed as the Net loss in Touchstone.

Figure 56 provides an example of a $2.5 million XS $2.5 million Per Risk Excess of Loss treaty applied to each location in a contract. The replacement value of each location is $8 million; as a result, the probability loss distribution varies from $0 to $8 million. The terms are applied to each location with the result that losses are ceded to the treaty within the range of $2.5 to $5 million as specified by the treaty. Touchstone computes the ground-up losses for each location, applies the location terms, and determines the Gross losses.

Touchstone then applies the Per Risk Excess of Loss treaty to each location's Gross loss distribution and subtracts the portion shown in blue from the Gross loss distribution to give the Net loss to the treaty (shown in green). For the first-tier of treaty reinsurance contracts in the inuring chain and all facultative contracts, Touchstone uses the same numerical methods and precision, including interpolations, as for the application of location and contracts terms. If the Treaty option is selected when a user views loss results, then the displayed ground-up loss represents the ground-up loss to the treaty and, therefore, policy terms have been applied; the ground-up loss in all other circumstances has no policy conditions applied.

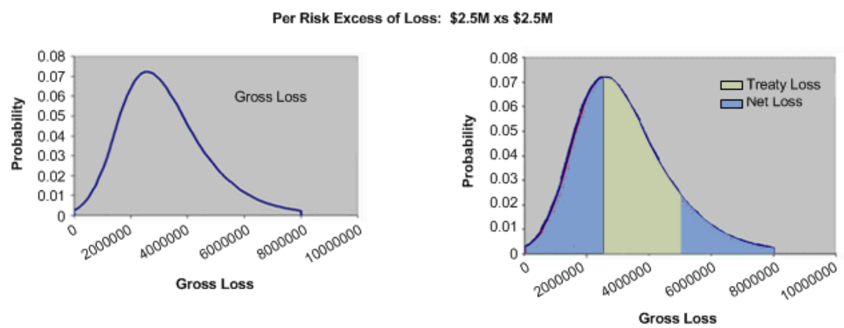


Figure 56. Reinsurance terms in Touchstone

Apply location-level reinsurance to layered policies

Location-level reinsurance on a policy with layers is referred to as *spot facultative* in Touchstone`.

Such policy terms are typically used to reduce the loss to the layer by using facultative insurance for individual locations (typically those of high value/risk). This policy condition applies location-level deductibles and limits first, then applies the location facultative terms, and finally applies the layer terms. That is, location-level reinsurance is applied *before* layer-level reinsurance. Losses are produced and reported within the *Gross* perspective instead of within the *Net* perspective that is common for reinsurance policy conditions.

`'Refer to the document *Using Reinsurance in Touchstone* for additional information about applying reinsurance in Touchstone.

Excess of loss reinsurance contracts

Catastrophe and aggregate excess of loss reinsurance contracts can be modeled in Touchstone.

Note that all loss calculations are deterministic, where the means of pre-CAT net losses are passed to the excess of loss contracts and policy terms and conditions are applied only to these mean losses.

Catastrophe excess of loss programs

Catastrophe excess of loss (XOL) in Touchstone is an excess contract type with multiple reinstatements.

Catastrophe excess of loss losses in excess of the reinsured's loss retention from events within a year are incurred until the total per event limit and any reinstatements of the limit for the year have been exhausted. The occurrence retention is first applied to all events, then the occurrence limit and events will incur a loss to the contract insofar that the aggregate limit has not been exhausted.

Example: Catastrophe XOL

Example of applying CAT XOL in Touchstone.

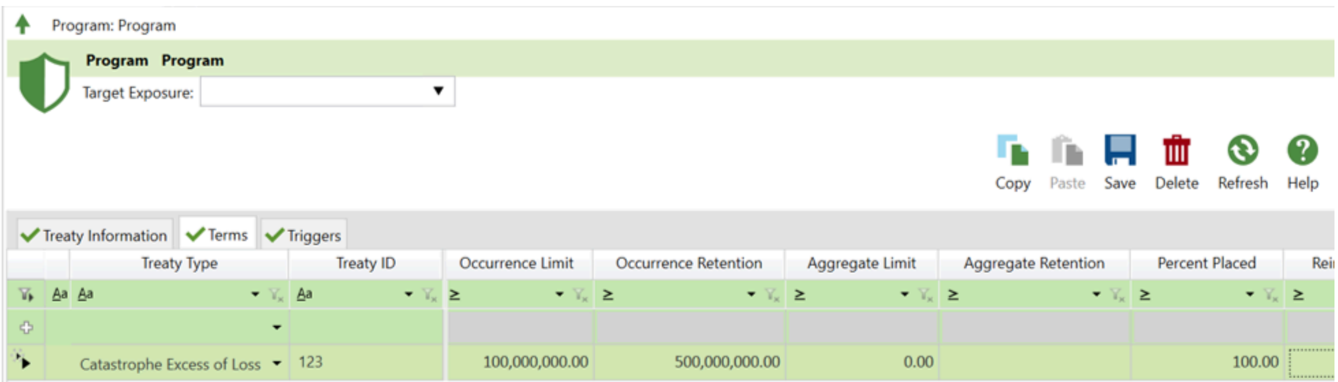


Figure 57. Example of catastrophe excess of loss terms

The following table illustrates the limits and losses for catastrophe excess of loss policies.

Table 24. Catastrophe Excess of Loss example (USD thousands)

Event	Year	Company Loss (GR_0)	Apply Occurrence Retention (r)	Apply Occurrence Limit (L)	Applicable Aggregate Limit (Agg_{LT})	Contract Loss (GR_3)
220075976	1856	$503	$3	$3	$300[7]	$3
280012594	1856	$888,851	$888,351	$100	$297	$100
280012596	1856	$324,694	$324,194	$100	$197	$100
220075977	1856	$21,291	$20,791	$100	$97	$97
220075978	1856	$310,575	$310,075	$100	$0	–
220075979	1856	$79,866	$79,366	$100	$0	–
280012597	1856	$408,552	$408,052	$100	$0	–
220075980	1856	$129,476	$128,976	$100	$0	–
220075981	1856	$90,990	$90,490	$100	$0	–

Equations for calculating losses

- Company Loss (GR_0) = GR_0
- Apply Occurrence Retention (r) = GR_1 – Max (Company Loss – Occurrence Retention, 0)

7 Derived from occurrence limit plus two reinstatements.

- Apply Occurrence Limit (L) = GR_2 – Min (After Occurrence Retention, Occurrence Limit)
- Applicable Aggregate Limit (Agg_{LT}) = Max [(Number of Reinstatements + 1) x Occurrence Limit - Total Limit already applied, 0)
- Contract Loss (GR_3) = Min (After Occurrence Limit, Applicable Aggregate Limit))

Catastrophe XOL: mathematical application

Notation used during the mathematical application of the CAT XOL in Touchstone.

GR_0^i	Gross before occurrence retention
GR_1^i	Gross after occurrence retention
GR_2^i	Gross after occurrence limit
GR_3^i	Gross after occurrence retention, occurrence limit, and reinstatements (if any) of limit
r	Occurrence retention
L	Occurrence limit
R	Number of reinstatements
AGG_{LT}^i	Applicable aggregate limit

For first event i=1 in year j:

1. Apply occurrence retention.

   $$GR_1^i = Max[GR_0^i - r, 0]$$

2. Apply occurrence limit L.

   $$GR_2^i = Min[GR_1^i, L]$$

3. Apply applicable aggregate limit GR_0^i.

   For the next events in the same year, the same occurrence policy terms are applied to the loss insofar that there is some amount of limit remaining. The total amount of the limit is given by (R + 1) × L and, thus, policy terms are applied to the next event because only a maximum of L was used in the first event. The process continues until the applicable aggregate limit is exhausted. In other words, losses can be incurred for more events than the number of reinstatements plus one since events can incur loss once there is some aggregate limit remaining.

   $$AGG_{LT}^i = Max\left[(R+1) \times L - \sum_{j=0}^{j} GR_2^{i+j}, 0\right]$$

4. Calculate final loss.

   The occurrence retention and limit are applied again, as above, for event I + 1 in the same year and the process repeats until the entire aggregate limit (R + 1) × L has been exhausted for that year.

   $$GR_3^i = Min[GR_2^i, AGG_{LT}^i]$$

Gross loss vs. ground-up loss in Touchstone

Relationship between gross losses and ground-up losses in Touchstone.

Depending on the location of exposure and policy terms, it is possible for mean ground-up losses to *decrease* while Gross losses increase.

The figure below reveals the shapes of the damage distributions for two different locations with similar mean damage. As you can see, there are significant differences between the distributions for damage ratios less than 0.35. Then the damage distributions are very similar out to damage ratio of 1.00, except for a small rise at the tail of the distribution (see inset). This seemingly insignificant rise in the distribution for high damage ratios can increase the Gross loss, as there is a higher probability of loss at high damage ratios.

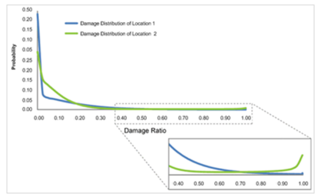


Figure 58. Ground-up loss damage ratio distributions

Given the damage distributions above, it is expected that as the location deductible increases the difference in Gross losses between the two locations will increase as well. An example of the effect of varying the location deductible on the Gross losses is shown below.

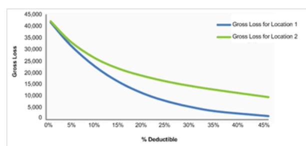


Figure 59. Varying Location Deductibles on Gross Loss

It should be clear that Gross loss changes are not solely a function of the changes in ground-up losses. Changes in the shape of the ground-up loss distributions and the policy terms applied are large contributors to the changes seen in Gross losses.

Claims count in Touchstone

Claims count in Touchstone represents the expected number of claims produced for a given location and event.

Claims count uses the number of risks field in its calculation. Here is the formula:

$$Claims\ \ count\ \ for\ \ a\ \ single\ \ location\ \ and\ \ event = number\ \ of\ \ risks \times P(Loss > (0.5 \times deductible))$$

Note

Claims count is valid only for U.S. locations, and for all perils except for Terrorism.

Example: Claims count

Determining a claims count in Touchstone.

To illustrate how the claims count formula works, imagine that there were 100 risks for one location with no deductible and we ran it over one event. If the event produced a loss for that location, intuitively we would expect that the number of claims would approximately equal the number of risks. This is approximately true; however, the probability distribution of damage includes some probability of zero loss. Since there would be no claims with zero loss, we need to exclude this from the calculation.

The figure below shows a single location with 100 risks over a single loss-causing event and no policy terms. You can see that there is a 0.89 probability (1- 0.11) of there being some loss; hence the claim count for this location is 89.

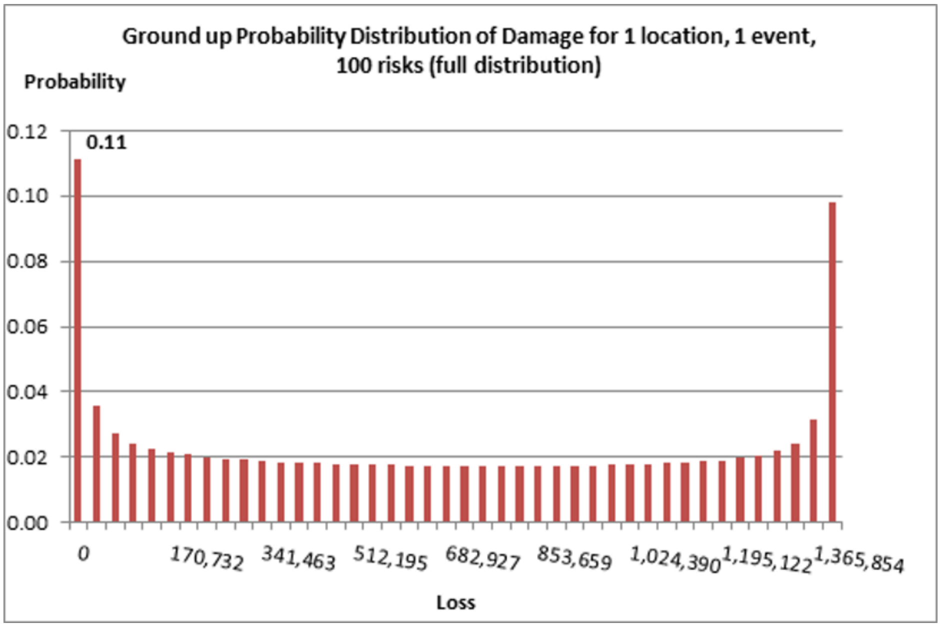


Figure 60. Probability distribution of loss for one location and event

Now imagine that there is a single location with a deductible of $100,000. According to the preceding formula, the claims count for this location is the probability that the loss is greater than $50,000. As you can see from the distribution below, this probability is 0.85; in fact, the claims count for this location and event is 85.

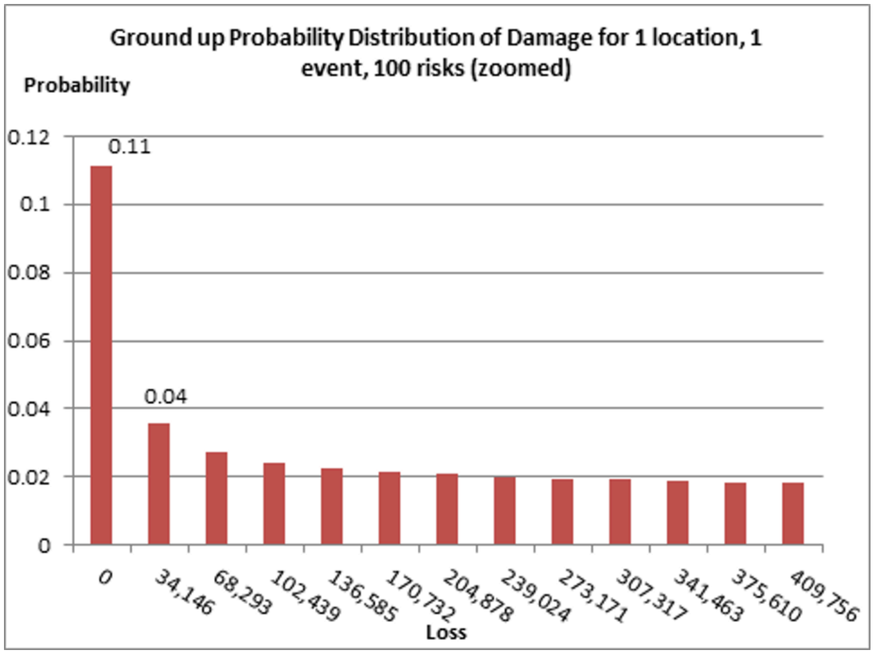


Figure 61. Zoom of probability distribution of loss for one location and event

6 Financial and policy terms

Policy terms

Policy terms in Touchstone.

The following summarizes the policy terms Touchstone supports and which combinations are valid for running detailed loss analyses.

Term types

Touchstone financial terms fall into categories.

Each of the financial terms (e.g., limits and deductibles) that Touchstone supports for layers, sublimits, and locations falls into one of the categories indicated below.

Key for term types

Touchstone term keys.

ABCD	This category of financial terms refers to terms that are split by coverage type (Limit A, Limit B, Limit C, Limit D). In very general terms, property exposure data treats these coverages as follows: • A Building • B Other Structures • C Contents • D Time Essentially this will mean that the user will import a separate replacement value for each of those and a separate limit to the amount of financial relief the insurance company will provide for each of those specified coverage types.
ABC-D	This category of financial terms refers to insurance coverage that is split only between Building and Time coverage, where the building accounts for the Other Structures and Contents together (Limit A, B, C, - then Limit D). This means that only a replacement value and a limit will be specified for A and for D separately, because B and C are being aggregated into A.
Total	This category of financial terms refers to insurance coverage that combines all exposure into a single replacement value and a single limit to the financial relief that the insurance company will provide.

Layer terms

Layer occurrence limit types

Touchstone policy terms: layer occurrence limit types.

Code	Description	Term Type
B	Blanket limit	Total
E	Excess limit	Total
CB	Combined, excluding time	ABC-D
CT	Combined including time limit	ABC-D
C	Limit by coverage	ABCD
CSL100	Combined single limit 100% participation	ABCD
CSLAI	Combined single limit assured interest	ABCD
N	No limit	N/A

Layer aggregate limit types

Touchstone policy terms: layer aggregate limit types.

Code	Description	Term Type
AGGL	Annual aggregate limit	Total
N	No limit	N/A

Layer occurrence deductible types

Touchstone policy terms: layer occurrence deductible types.

Code	Description	Term Type
AP	Attachment point	Total
FR	Franchise deductible	Total
B	Blanket deductible	Total
MA	Maximum deductible amount	Total
MI	Minimum deductible amount	Total
MM	Minimum and maximum	Total
PL	Percent of loss	Total
CB	Combined excluding time	ABC-D
CT	Combined including time	ABC-D
C	Deductible by coverage	ABCD
N	No deductible	N/A

Layer aggregate deductible types

Touchstone policy terms: layer aggregate deductible types.

Code	Description	Term Type
AGGD	Annual aggregate deductible	Total
N	No aggregate deductible	N/A

Sublimit terms

Sublimit occurrence limit types

Touchstone policy terms: sublimit occurrence limit types.

Code	Description	Term Type
B	Blanket limit	Total
CB	Combined, excluding time	ABC-D
CT	Combined including time limit	ABC-D
E	Excess limit	Total
C	Limit by coverage	ABCD
C100	Limit by coverage 100% participation	ABCD
CAI	Limit by coverage with assured interest	ABCD
N	No limit	N/A

Sublimit aggregate limit types

Touchstone policy terms: sublimit aggregate limit types.

Code	Description	Term Type
AGGL	Annual aggregate limit	Total
N	No limit	N/A

Sublimit occurrence deductible types

Touchstone policy terms: sublimit occurrence deductible types.

Code	Description	Term Type
FR	Franchise deductible	Total
B	Blanket deductible	Total
PL	Percent of loss	Total
MA	Maximum deductible amount	Total
MI	Minimum deductible amount	Total

Code	Description	Term Type
MM	Minimum and maximum	Total
CB	Combined excluding time	ABC-D
CT	Combined including time	ABC-D
C	Deductible by coverage	ABCD
N	No deductible	N/A

Sublimit aggregate deductible types

Touchstone policy terms: sublimit aggregate deductible types.

Code	Description	Term Type
AGGD	Annual aggregate limit	Total
N	No limit	N/A

Location terms

Location occurrence limit types

Touchstone policy terms: location occurrence limit types.

Code	Description	Term Type
S	Site	Total
EF	Earthquake fire expense insurance	Total
C	Limit by coverage	ABCD
EE	Extra expense	ABCD
N	No limit	N/A

Location aggregate limit types

Touchstone policy terms: location aggregate limit types.

Code	Description	Term Type
AGGL	Annual aggregate limit	Total
N	No limit	N/A

Location deductible types

Touchstone policy terms: location deductible types.

Code	Description	Term Type
AA	Florida annual amount	Total

Code	Description	Term Type
FR	Franchise deductible	Total
ML	Max of deductible amount or percent loss	Total
MP	Mini policy deductible	Total
PL	Percent of loss	Total
S	Site deductible	Total
CB	Combined - excluding time	ABC-D
CT	Combined - including time	ABC-D
CPL	Coverage percent of loss	ABCD
C	Deductible by coverage	ABCD
N	No deductible	N/A

Location aggregate deductible types

Touchstone policy terms: location aggregate deductible types.

Code	Description	Term Type
AGGD	Annual Aggregate Deductible	Total
N	No limit	N/A

Location min/max deductible types

Touchstone policy terms: location min/max deductible types.

Code	Description	Term Type
MI	Minimum deductible	Total
MA	Maximum deductible	Total
MM	Minimum and maximum deductible	Total
N	No min/max deductible	N/A

Financial terms

Financial terms, including limits and deductibles, and the combinations of terms and term types that Touchstone supports for layers, sublimits, and locations.

When working with policy terms in Touchstone, it is important to understand the financial terms that are supported, and the combinations of the financial terms that are valid for running detailed loss analyses.

Keys for financial terms

Keys for Touchstone financial term fields, coverage types, and other terminology.

Table 25. Key for data format

-	Field is not available
$	Field value is >1
%	Field value is <1
✓	Valid combination

Table 26. Coverage type key

b	Blanket - all coverage
c	Combined coverage
y	By coverage

Table 27. Terminology key

AA	Florida annual amount
AGGD	Annual aggregate deductible
AGGL	Annual aggregate limit
AP	Attachment point
B	Blanket
C	Limit by coverage -or- deductible by coverage
CAI	Limit by coverage with assured interest
CB	Combined excluding time
CPL	Coverage percent of loss
CT	Combined including time
C100	Limit by coverage 100% participation
E	Excess
EE	Extra expense
EF	Earthquake expense fire insurance
FR	Franchise
MA	Maximum
MI	Minimum
ML	Max of deductible amount or percent of loss
MM	Minimum and maximum
MP	Mini policy
N	None
PL	Percent of loss
S	Site -or- site combined limit amount

Layer terms overview

Touchstone financial terms layer terms.

Note

Refer to Keys for financial terms for details.

Layer limit fields

Coverage type indicated in superscript.

Limit Type >	B^{b}	E^{b}	C^{y}	CSL10(	CSLAI^{y}	CB^{c}	CT^{c}	AGGL^{b}	N
v Field									
Limit 1	$	$ >= L1	$	$ >= L1	$ >= L1	$	$	-	-
Limit 2	-	$ >= L2	$	$ >= L2	$ >= L2	$	$	-	-
Limit 3	-	-	$	-	-	$	$	-	-
Limit 4	-	-	$	-	-	-	$	-	-
Attachment point 1	$	$	$	$	$	$	$	-	-
Attachment point 2	-	-	$	-	-	-	-	-	-
Attachment point 3	-	-	$	-	-	-	-	-	-
Attachment point 4	-	-	$	-	-	-	$	-	-
Aggregate Limit	-	-	-	-	-	-	-	$	-
Aggregate Attachment Point	-	-	-	-	-	-	-	$	-

Layer deductible fields

Coverage type indicated in superscript.

Deductible Type >	AP^{b}	B^{b}	FR^{b}	MA^{b}	MI^{b}	MM^{b}	PL^{b}	CB^{c}	CT^{c}	C^{y}	AGGD	N
v Field												
Deductible 1	$	$	$	-	$	$ < D2	%	$	$	$	-	-

Deductible Type >	AP[b]	B[b]	FR[b]	MA[b]	MI[b]	MM[b]	PL[b]	CB[c]	CT[c]	C[y]	AGGD	N
v Field												
Deductible 2	$	-	-	$	-	$ > D1	-	$	$	$	-	-
Deductible 3	-	-	-	-	-	-	-	$	$	$	-	-
Deductible 4	-	-	-	-	-	-	-	-	$	$	-	-
Aggregate Deductible	-	-	-	-	-	-	-	-	-	-	$	-

Layer limit/deductible combo

Deductible >	AP	B	FR	MA	MI	MM	PL	CB	CT	C	N
v Limit											
B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
E	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CSL100	-	-	-	-	-	-	-	-	-	-	✓
CSLAI	-	-	-	-	-	-	-	-	-	-	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Sublimit terms overview

Touchstone financial terms sublimit terms.

Note

Refer to Keys for financial terms for details.

Sublimit limit fields

Coverage type indicated in superscript.

Limit Type >	B[b]	C[y]	E[b]	C100[y]	CAI[y]	CT[c]	CB[c]	AGGL[b]	N
v Field									
Limit 1	$	$	$ >= L2	$	$	$	$	-	-
Limit 2	-	$	$ >= L1	$	$	$	$	-	-

Limit Type >	B^b	C^y	E^b	$C100^y$	CAI^y	CT^c	CB^c	$AGGL^b$	N
v Field									
Limit 3	-	$	-	$	$	$	$	-	-
Limit 4	-	$	-	$	$	-	$	-	-
Attachment point 1	$	$	$	$	$	$	$	-	-
Attachment point 2	-	$	$	$	$	-	-	-	-
Attachment point 3	-	$	-	$	$	-	-	-	-
Attachment point 4	-	$	-	$	$	-	$	-	-
Aggregate Limit	-	-	-	-	-	-	-	$	-
Aggregate Attachment Point	-	-	-	-	-	-	-	$	-

Sublimit deductible fields

Coverage type indicated in superscript.

Deductible Type >	B^b	FR^b	PL^b	MA^b	MI^b	MM^b	CB^c	CT^c	C^y	$AGGD^b$	N
v Field											
Deductible 1	$	$	%	-	$	$ < D2	$	$	$	-	-
Deductible 2	-	-	-	$	-	$ > D1	$	$	$	-	-
Deductible 3	-	-	-	-	-	-	$	$	$	-	-
Deductible 4	-	-	-	-	-	-	-	$	$	-	-
Aggregate Deductible	-	-	-	-	-	-	-	-	-	$	-

Sublimit limit/deductible combo

Deductible >	B	FR	PL	MA	MI	MM	CB	CT	C	N
v Limit										
B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
E	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Deductible >	B	FR	PL	MA	MI	MM	CB	CT	C	N
v Limit										
CSL100	-	-	-	-	-	-	-	-	-	✓
CSLAI	-	-	-	-	-	-	-	-	-	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Location terms overview

Touchstone financial terms location terms.

Note

Refer to Keys for financial terms for details.

Location limit fields

Coverage type indicated in superscript.

Limit Type >	C^{y}	EE^{y}	EF^{b}	S^{b}	AGGL^{b}	N
v Field						
Limit Building	$	$	$	$	-	-
Limit Other	$	$	-	-	-	-
Limit Contents	$	%	$	-	-	-
Limit Time	$	-	-	-	-	-
Participation 1	%	%	%	%	-	%
Participation 2	%	%	%	%	-	%
Aggregate Limit	-	-	-	-	$	-

Location deductible fields

Coverage type indicated in superscript.

Limit Type >	AA^{b}	C^{y}	CB^{c}	CT^{c}	FR^{b}	ML^{b}	MP	PL^{b}	CPL	S^{b}	AG	N
v Field												
Deductible Building	$	$ / %	$ / %	$ / %	$	$	%	%	%	$ / %	-	-
Deductible Other	$	$ / %	$ / %	$ / %	$	%	-	%	%	$ / %	-	-
Deductible Contents	-	$ / %	$ / %	$ / %	$	-	-	%	%	$ / %	-	-
Deductible Time	-	$ / %	-	$ / %	$	$	-	%	%	$ / %	-	-

Limit Type >	AA^{b}	C^{y}	CB^{c}	CT^{c}	FR^{b}	ML^{b}	MP^{b}	PL^{b}	CPL	S^{b}	AGG	N
v Field												
Aggregate Deductible	-	-	-	-	-	-	-	-	-	-	$	-

Location min/max deductible fields

Coverage type indicated in superscript.

MixMax Deductible Type >	MA^{b}	MI^{b}	MM^{b}
v Field			
MinMax Deductible 1	-	$	$ < D2
MinMax Deductible 2	$	-	$ > D1

Location limit/deductible combinations

Coverage type indicated in superscript.

Deductible >	AA	FR	ML	MP	PL	S	CB	CT	CPL	C	N
v Limit											
S	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Location min/max deductible/location deductible combinations

Location Deductible >	AA	FR	ML	MP	PL	S	CB	CT	CPL	C	N
v Location MinMax											
MI	-	-	-	-	✓	✓	✓	✓	✓	✓	✓
MA	-	-	-	-	✓	✓	✓	✓	✓	✓	✓
MM	-	-	-	-	✓	✓	✓	✓	✓	✓	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Location aggregate deductible/location deductible combinations

Location Deductible >	AA	FR	ML	MP	PL	S	CB	CT	CPL	C	N
v Aggregate Deductible											
AGGD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Location aggregate deductible/location min/max deductible combination

Location MinMax Deductible >	MI	MA	MM	N
v Aggregate Deductible				
AGGD	-	-	-	✓
N	✓	✓	✓	✓

Limit combinations

Touchstone financial terms limit combinations.

Note

Refer to Keys for financial terms for details.

Location sublimit limit types

Sublimit >	B	E	C	C100	CAI	N
v Location						
S	✓	✓	✓	-	-	✓
EF	✓	✓	✓	-	-	✓
C	✓	✓	✓	✓	✓	✓
EE	✓	✓	✓	✓	✓	✓
N	✓	✓	✓	✓	✓	✓

Location layer limit types

Sublimit >	B	E	C	C100	CAI	N
v Location						
S	✓	✓	✓	-	-	✓
EF	✓	✓	✓	-	-	✓
C	✓	✓	✓	✓	✓	✓

Sublimit >	B	E	C	C100	CAI	N
v Location						
EE	✓	✓	✓	✓	✓	✓
N	✓	✓	✓	✓	✓	✓

Deductible combinations

Touchstone financial terms deductible combinations.

Note

Refer to Keys for financial terms for details.

Sublimit layer deductible types

Layer >	AP	B	FR	MI	MA	MM	PL	CB	CT	C	N
v Sublimit											
B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MI	✓	✓	✓	-	-	-	✓	✓	✓	✓	✓
MA	✓	✓	✓	-	-	-	✓	✓	✓	✓	✓
MM	✓	✓	✓	-	-	-	✓	✓	✓	✓	✓
CB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Location layer deductible types

Layer >	AP	B	FR	MI	MA	MM	PL	CB	CT	C	N
v Sublimit											
AA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Layer >	AP	B	FR	MI	MA	MM	PL	CB	CT	C	N
v Sublimit											
ML	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
S	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CPL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Sublimit location deductible types

Layer >	AA	FR	ML	MP	PL	S	CB	CT	CPL	C	N
v Sublimit											
B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓	✓	✓	-	-	-	✓	✓	✓
N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes on Touchstone terms

Considerations for Touchstone financial terms.

- Only one level of policy min-max deductible is supported in Touchstone.
  - If an exposure is imported that has a sublimit within a layer, with both coded for MM, the sublimit MM deductible is converted into a blanket deductible.
  - Similarly, if multiple tiers of sublimit have MM deductibles, the deductible on the lower tier will convert to a blanket deductible.

- Multiple levels of aggregate terms are supported.

7 Selected references

Documents to supplement concepts and information used in Touchstone.

- *Matheson, J. E., & Winkler, R. L. (1976). Scoring Rules for Continuous Probability Distributions. Management Science, 22(10), 1087–1096. https://doi.org/10.1287/mnsc.22.10.1087*
- *-Venter, G. (1983). Transformed beta and gamma distributions and aggregate losses. Proceedings of the Casualty Actuarial Society, Vol. LXX. https://www.casact.org/sites/default/files/database/proceed_proceed84_84026.pdf.*
- *Wójcik, R.; Liu, C.W.; Guin, J. Direct and Hierarchical Models for Aggregating Spatially Dependent Catastrophe Risks. Risks 2019, 7, 54. Available online: https://www.mdpi.com/2227-9091/7/2/54/pdf (accessed on 17 March 2020).*
- https://www.air-worldwide.com/support-and-training/next-generation-models-ngm/

8 Appendices

Impact of terms and conditions in Touchstone

Touchstone financial module uses these terms and conditions to assess and manage losses. Terms and conditions are grouped into three categories: location terms, policy & layer terms, and facultative & treaty terms. These are summarized in the table below.

Table 28. Terms and conditions

Items in **bold** are new with the NGM release

Location terms	Policy & layer terms	Facultative & treaty
Coverage and site deductibles	Blanket occurrence layer	Occurrence risk retention
Coverage and site limits	Excess occurrence layer	Occurrence risk limit
Combined deductibles	Min-max deductible	Aggregate treaty limit
Combined limits	Franchise deductible	**Aggregate risk retention**
Franchise deductible	Blanket deductible	**Aggregate risk limit**
Step functions	Blanket occurrence sublimit	**Aggregate treaty retention**
Min-max deductible	Coverage occurrence sublimit	
Aggregate deductible	**Aggregate attachment excess**	
Aggregate limit	**Aggregate limit**	
Percent of coverage loss deductible	**Participation on Aggregate Limit**	
	Sublimit by sub-peril	
	Second/third tier of sublimits	
	Coverage deductibles	
	Combined deductibles	
	Coverage occurrence limit	

Applying insurance term limits

In Touchstone term limits are applied differently at the location level and the layer level.

Both location and layer insurance terms include limits, step functions, and deductibles. Limits serve to cap the losses to an insurer at a particular maximum value, while deductibles reduce losses by a given amount (or by the amount retained by the insured).

Apply term limits at the location level

At the location level, terms are applied to coverage loss or location loss. Coverage terms are applied individually to each of the four modeled coverages available in Touchstone. Depending on the risk classification, modeled coverages represent different “characteristics” of the risk. The table below identifies the risk characteristic by coverage for the three specific risk types (classification).

Table 29. Risk coverage by risk types

	Risk Classification		
Coverage	Onshore Properties	Offshore Properties	Personal Accident
A	Building	Physical Damage (PD) Structural damage from the combination of wind and waves.	Minor (U.S.) Outpatient (Japan)
B	Other Structures	Removal of Debris (RoD) Includes debris fallen from the topside as well as platform wreckage, even if the platform is still standing.	Moderate (U.S.) Hospitalization and Surgery (Japan)
C	Contents	Operator’s Extra Expense (OEE) Includes making wells safe, pollution cleanup, and the cost of restoration and/or re-drilling.	Major (U.S.) Disability (Japan)
D	Business Interruption	Business Interruption (BI) and Contingent Business Interruption (CBI) BI is also known as the loss of production income and CBI is due to downtime of pipelines and/ or hub platforms.	Fatal (U.S.) Death (Japan)

When applying coverage terms, limits and deductibles are applied to separate coverages (deductibles can be added as percentage of limits or replacement values) or to several coverages combined, which in the latter case applies to an entire location (known as a site term). Location terms are applied to the combined coverage losses for a location. The figure below illustrates the application of terms by coverage and location.

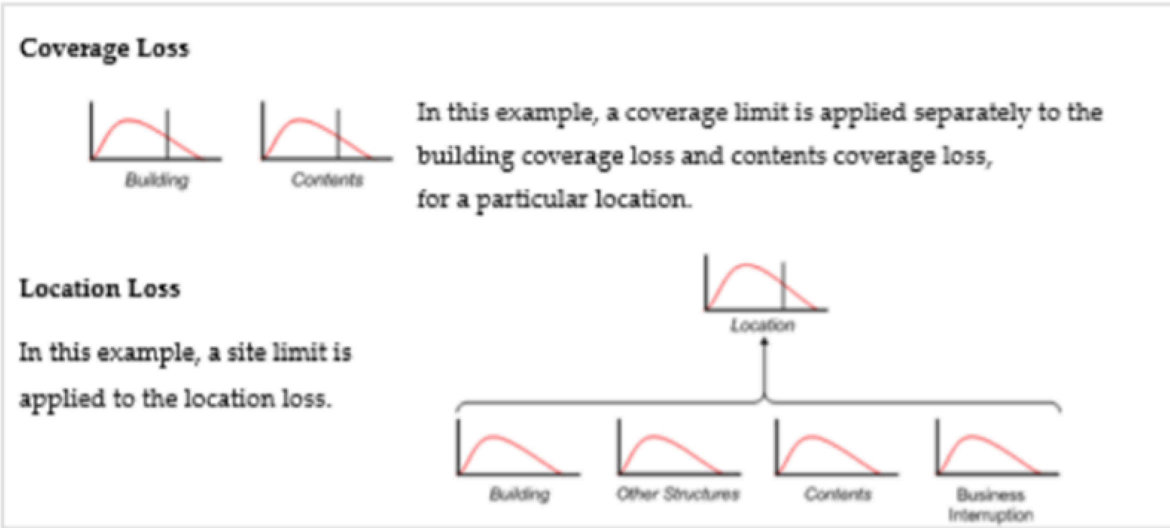


Figure 62. Application of terms by coverage and location

Apply term limits at the layer level

At the layer level (also called policy or contract level), limits and deductibles can be applied to separate or combined coverages. A common layer type includes Excess policies for which the insurer is liable for losses greater than the attachment amount and can sustain losses no greater than the limit amount.

It is common for there to be a participation amount on Excess policies, where the insurer is responsible for a percentage of the loss to the Excess policy. Limits can also be applied in a user-specified priority order, where the Buildings Coverage loss is applied first to the limit, after which the Contents Coverage loss is applied, and so forth. These are referred to as Combined Single Limits and are commonly used in the offshore energy market.

Another policy term, the sublimit, is used to limit loss to a group of locations or to limit loss to a particular coverage. For example, a sublimit can restrict Contents loss to a certain amount, such as $75 million, before the loss enters the layer. After location and layer policy terms are applied, reinsurance terms, such as from facultative certificates and treaties, are applied in the inuring order specified by the user. The reinsurance types can be proportional (Quota Share, Surplus Share, and Proportional Facultative Certificates) or non-proportional (Excess of Loss treaties and Non-Proportional Facultative Certificates).

Finally, the insurer's portfolio comprises all the policies written by an insurer and, in Touchstone, users can run analyses for separate policies individually or for all the policies combined. Touchstone's financial module performs all these calculations

About Verisk

Verisk Analytics (Verisk) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, a Verisk subsidiary founded the catastrophe modeling industry and today models the risk from natural catastrophes, terrorism, pandemics, casualty catastrophes, and cyber incidents. Insurance, reinsurance, financial, corporate, and government clients rely on Verisk's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, longevity modeling, site-specific engineering analyses, and agricultural risk management. Verisk (Nasdaq:VRSK) is headquartered in Jersey City, New Jersey with many offices throughout the United States and around the world. For information on our office locations, visit https://www.verisk.com/about/locations/.

Contact Information

Verisk Analytics
Lafayette City Center, 2nd Floor
Two Avenue de Lafayette
Boston, MA 02111
USA

Tel: (617) 267-6645
Fax: (617) 267-8284

Verisk welcomes feedback on its documentation. If you need assistance in using the software or understanding the information in this document, please email us at Documentation-Air@verisk.com.