Catastrophes and Workers Compensation Ratemaking

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Abstract: The CAS Statement of Principles Regarding Property and Casualty Insurance Ratemaking states that "Consideration should be given to the impact of catastrophes on the experience, and procedures should be developed to include an allowance for the catastrophe exposure in the rate."

For the first time in many years, NCCI has modified the methodology used to determine a state's overall average loss cost or rate level indication for workers compensation. The aggregate ratemaking methodology was modified specifically to handle two general categories of large events for which workers compensation exposure exists. They are: a) large individual claims, and b) catastrophic events related to the perils of industrial accidents, earthquake, and terrorism. NCCI actuaries worked with a well-known modeling firm to determine provisions for catastrophic events on a state basis.

This paper describes the new methodology NCCI has developed, implemented, and filed in many of its states. It discusses in detail how the traditional areas of aggregate ratemaking were modified: loss development, the tail factor, trend, selection of loss limits by state, and application of excess provisions.

The paper also documents for the first time in CAS literature how computer modeling was applied in workers compensation to determine a loss cost by state. Consideration was given to the protection of proprietary trade secrets of the EQECAT modeling firm, with whom NCCI partnered.

Keywords: workers compensation; NCCI ratemaking; NCCI loss cost filings; catastrophic events; large losses; TRIA.

1. INTRODUCTION

For the first time in many years, NCCI has modified the methodology used to determine a state's overall average loss cost or rate level indication for workers compensation insurance. The aggregate ratemaking methodology was modified specifically to handle two general categories of large events for which workers compensation exposure exists. They are: a) large individual claims, and b) catastrophic events related to the perils of industrial accidents, earthquake, and terrorism.

This paper describes the new methodology NCCI has developed, implemented, and filed in many of its states. It discusses how the traditional methods for aggregate ratemaking were modified, as well as how advanced modeling techniques were used to quantify loss cost provisions by state for those perils. The large loss ratemaking procedure can be described as one that uses reported losses capped at a given dollar threshold and adds a provision for expected losses excess of this threshold. The details underlying the specifics of the approach and the decision making process are documented in the pages that follow.

1.1 Research Context

The focus of this research is two-fold. It addresses the use of modeling outside of personal lines, as well as providing an update on current workers compensation ratemaking methods. Current CAS literature that addresses some of the same issues include "Workers Compensation Ratemaking" by Sholom Feldblum, and "Issues in the Regulatory Acceptance of Computer Modeling for Property Insurance Ratemaking" by Rade Musulin.

1.2 Objective

This paper updates the CAS literature on workers compensation ratemaking techniques, with particular attention to recent modifications in the NCCI ratemaking methods for handling large claims and very large events. To address its absence in the current CAS literature, this paper also discusses the use of computer modeling in workers compensation ratemaking. Class ratemaking considerations will not be addressed in this paper, as the considerations of large losses on class relativities is currently being reviewed at NCCI.

1.3 Outline

The remainder of the paper proceeds as follows. Section 2 will discuss the reasons and impetus for the changes made, the thought process NCCI followed, the research approach and results, and specific aggregate ratemaking methodology changes. Section 3 documents the modeling approach used for several catastrophic perils, and how the modeling of large events was used to estimate loss costs.

2. BACKGROUND AND METHODS

Prior to the 1970s, the workers compensation rates promulgated by NCCI included a 1-cent catastrophe provision in every rate. This provision was eventually removed from ratemaking.

The events of September 11, 2001, which caused the greatest insured loss in property-casualty history to date (that may or may not have been exceeded by Hurricane Katrina), brought into focus the potential that large events may have on workers compensation. Previous NCCI estimates of the insured loss for the workers compensation line of insurance due to the events of September 11th range from $1.3 – $2.0 billion on a direct (of reinsurance) basis. As with so many other lines of insurance and perspectives about risk-taking, the events of that day created a compelling reason to take a fresh look at how workers compensation ratemaking could fund such large, infrequent events prospectively. It was clear that funding large events is an issue in workers compensation, and is no longer just an issue confined to personal and commercial property insurance.

2.1 Overview of the Methodology Change

NCCI revised its aggregate ratemaking approach in 2004 to more closely resemble basic limits ratemaking. Limited losses are calculated by subtracting the actual loss dollars for each claim that are excess of a given dollar threshold from the aggregate unlimited losses for a state. Next, the limited aggregate losses are multiplied by limited loss development factors (discussed later) to obtain ultimate limited losses. Trends (loss ratio and severity) are then calculated using these limited losses and benefit changes are applied (to the limited base of losses).

Finally, the trended ultimate limited losses are divided by a factor (1 -XS), where XS is the Excess Ratio (described later) for the appropriate dollar threshold, resulting in total projected ultimate losses, for use in ratemaking.

In the sections below the details of the large loss procedure will be described and how the different aspects of the ratemaking process and the overall rate filing are affected. The terms "limited" and "capped" will be used interchangeably.

2.2 How Were Large Events Handled in the Past?

Historically, NCCI actuaries occasionally encountered one or more large individual or multi-claim occurrences in past loss cost and rate filings that impacted a state's overall loss cost or rate level indication. The methods of handling these claims varied from state to state. Treatments in filings of historical experience that included large claims or occurrences in a filing included the following ad hoc approaches:

- Making no adjustment to the reported experience for the state
- Selecting a longer experience period (for example, three policy years in lieu of two

years)

- Allowing the large claim(s) to remain in the base losses, without applying loss development factors to the specific large losses
- Removing the large claim completely from the experience period, without building back any excess provision

Similar decisions were made for loss development and loss ratio trend selections. It made sense for NCCI to develop an approach that was standardized and uniformly applicable across its states.

2.3 Goals and Objectives

The goal of this research was to develop an aggregate ratemaking methodology, which would provide long-term adequacy of loss costs, rates, and rating values while recognizing the need for rate stability, particularly at a state level. It also aided in standardizing the methodology for handling individual large claims in aggregate ratemaking.

2.4 Defining a Large Event

Beginning in 2002, NCCI began working with EQECAT, a division of ABS Consulting. EQECAT is a modeling firm that has performed modeling for the California Earthquake Authority, a large earthquake pool, and has performed modeling extensively used in windstorm filings. The perils EQECAT modeled specifically for NCCI included the following:

- Terrorism
- Earthquake
- Catastrophic Industrial Accidents

Naturally, only injuries and losses resulting from the simulated events that related to workers compensation were a priority from NCCI's perspective.

It soon became clear to NCCI actuaries that the most practical approach for treating large catastrophic events in a ratemaking context was to exclude entirely from the NCCI ratemaking data any actual catastrophic events that occurred in the past due to these perils. The reasons for doing this included:

1. Actual catastrophic events of this nature that impact the workers compensation line of insurance have rarely occurred. Thus, they would not be predictive by their nature.

2. Actual catastrophic events would create volatility for a state's loss cost structure.
3. Direct carriers cannot put per-claim or per-occurrence limits on workers compensation policies. Therefore, events such as these would not be able to be excluded from workers compensation coverage without statutory actions by legislators.
4. Reporting and aggregating information from such large events would create difficult data reporting issues, conceivably involving multiple employers with multiple claims involving multiple insurance carriers.
5. Very few catastrophic events of this nature ever occurred, and thus, it was easy to remove data for these perils from NCCI's historical databases, provided the loss limitation dollar amount chosen was significantly large.
6. State of the art modeling techniques could be used to better estimate the cost of large events directly caused by one of the named perils.

After much discussion both internally at NCCI, and with external parties including carrier representatives and regulatory authorities, NCCI selected a threshold of $50 million for the specific perils of terrorism, earthquake, or catastrophic multi-claim occurrences. This threshold applies per occurrence, across all states for which claims arise from a single occurrence.

The entire ground-up amount of losses generated from a catastrophic multi-claim event is removed from the ratemaking data, not just the portion excess of $50 million. The loss costs derived from the modeling for the named perils include the cost of the first $50 million layer, as well as the excess.

NCCI removes the catastrophic occurrences first, and then caps individual claims secondly. The $50 million limit applies to individual claimant large losses that occur in workers compensation, but a more stringent limiting approach is applied. Large individual claims are treated state-specifically and the loss limitations are applied based on 1) the size of the state, and 2) the maturity of the claim. This procedure is described in more detail under the section entitled "Selecting a Threshold by State".

2.4.1 Capturing the Detail on Large Individual Claims and Events

For use in workers compensation ratemaking, NCCI collects the Policy Year Call (#3) and Calendar-Accident Year Call (#5), amongst other calls. The data calls are due by April 1 each year, and provide a year-end snapshot of twenty individual years of cumulative data and certain aggregate data on prior years. NCCI collects the data by carrier and by state, and it is reconciled to each carrier's Annual Statement. Because this data is reported on a summarized basis, large individual claims are not identified.

A review of the other databases NCCI maintains showed that a new call would be required to provide the information needed to implement the new large loss procedure.

NCCI designed Call #31, considering input from NCCI's Actuarial Committee and Data Collection Procedures Subcommittee, to capture detail on large individual claims greater than $500,000, and multi-claim occurrences from large catastrophic events. Extraordinary loss events that may involve multiple insurance lines of business, states, or data collection organizations are synchronized with the already existing catastrophe numbering system administered by the Insurance Services Office (ISO) for the property casualty industry. Consideration was given to having a large occurrence data call, but was not pursued due to practical considerations of the data providers.

A copy of Call #31 (i.e. Large Loss and Catastrophe Call) is included in Appendix C.

2.4.2 Selecting a Threshold by State

In order to perform the large loss limitation procedure in aggregate ratemaking, a threshold is needed at which individual claims will be limited.

Thresholds are state-specific. They were initially calculated based on a given state's on-leveled and developed experience period Designated Statistical Reporting (DSR) level premium from the previous year's filing. The initial dollar threshold is calculated as one percent of this premium figure—after all currently approved expense provisions have been removed—rounded to the nearest one million dollars. As an example, in a full rate state, this would mean standard premium at DSR level less all expenses multiplied by 0.01. This includes all policy (or accident) years in the experience period used in the most recent previous filing.

Essentially, a large individual claim is defined as one for which the impact of the claim under the prior methodology would result in an overall average statewide loss cost level change of at least one percent. Depending on the state, two or three years of experience will generally be used for the experience period. The advantages of this approach are that loss limitation thresholds:

1. Reflect the actual loss volume in each state,
2. Are inflation sensitive,

3. Temper the impact that one large claim may have on the overall statewide loss cost level indication, and
4. Install a standardized approach across states

As will be described in a later section, a lower threshold results in more claims being limited (and losses removed), but also results in a greater expected excess factor being applied. Conversely, if a larger threshold was selected, fewer losses are limited and removed from ratemaking, but the magnitude of the expected excess factor is smaller. NCCI had considered a two percent of DSR pure premium threshold, but after considering the two thresholds and observing the hypothetical results of previous loss cost filings for many states under both thresholds, a one percent threshold was chosen. One of the main reasons for selecting the one percent threshold was to provide stability.

2.5 Limited Loss Development

Historically, NCCI workers compensation aggregate ratemaking was based on using unlimited loss development factors applied to unlimited losses. The new methodology revised the loss development procedure to use limited loss development factors and apply them to limited base losses from the state's experience period. Thus, the ultimate losses derived are limited to a given threshold, analogous to the concept of basic limits losses, commonly found in other property - casualty lines of insurance. In other lines of insurance, the insured makes the decision as to how much coverage to purchase, and increased limit factors are computed and applied to derive the proper loss estimate for the limit sold on the policy.

The important difference that separates the workers compensation line of business from those other lines of insurance is that the benefits the coverage provides is based on statutory provisions, and essentially workers compensation provides unlimited medical benefits. In some jurisdictions, wage replacement benefits are also unlimited as to their duration. (One exception to that general statement is employers' liability coverage, with a basic limit of $100,000, and the employer has the option to purchase higher limits if desired.) Therefore, the unique coverage differences that workers compensation presents for NCCI actuaries is that the limited ultimate losses must be brought to an unlimited ultimate basis. This is addressed by the application of the excess ratio, which will be discussed in a later section of the paper.

NCCI computes loss development factors separately for indemnity and medical benefits. The large claims that are subject to loss limitation almost always have both an indemnity and medical component. Therefore, by limiting individual claims, a procedure had to be determined for capping the two components. The procedure NCCI uses to cap individual claims is discussed in a later section of this paper.

A difficult hurdle the NCCI actuaries had in implementing a new methodology based on limited loss development was how to handle the workers compensation tail factor, which is a 19th report to ultimate factor based on incurred losses including IBNR. In addition to the many well-documented, difficult challenges that exist estimating the tail factor in workers compensation was the challenge of answering the question, "How does one cap a bulk reserve?" A subsequent section of this paper is devoted to the details underlying the modifications made to the NCCI tail factor methodology.

2.5.1 De-Trending Loss Thresholds for Loss Development

The maturity of the claim is considered in the loss limitation that is applied. This is achieved through a process NCCI calls de-trending. De-trending is a procedure that progressively reduces the thresholds in historical periods to remove the distortion inflation has on loss development triangles. A detailed example may be found in the Appendix. Thresholds are de-trended each year by the corresponding change in the annual state-specific CPS wage index. This procedure was chosen for the following reasons:

1. State-specific wage changes will reflect indemnity inflation, and, through actual testing, provided a very reasonable proxy for medical inflation over a long period,
2. For consistency, as annual state-specific wage information is already used in other areas of the filing such as the wage adjustment used in loss ratio trend calculations, and
3. The medical CPI commonly used to approximate medical inflation is only available on a countrywide or regional basis rather than a state-specific basis.

NCCI performed actual data testing of the differences that would result in thresholds based on de-trend factors using annual medical CPI percentage changes in lieu of de-trend factors using CPS wage changes. The overall differences in loss cost level indications that resulted by state between the two de-trending approaches tested were hardly discernable. Thus, it was not clear that the countrywide medical CPI would better represent state-specific medical inflation than the state-specific CPS wage index.

Another very important, yet subtle, point to clarify is that the de-trending percentage does not represent, nor was intended to quantify, the total loss severity trend that occurred from year to year. It represents an inflationary amount to recognize the change in the average nominal costs of a claim over time. A loss severity trend in workers compensation measures much more than inflation. It measures changes such as the following:

- Changes in the utilization of benefits such as longer or shorter claim durations, or the propensity of claimants to return to work sooner or later than in the past,
- Changes in medical utilization, such as increased usage of more expensive treatments, medical procedures, pharmaceuticals with no generic equivalents, etc.,
- Changes to a state's administration of its workers compensation system, which may increase or reduce adjudication delays, alter dispute resolution processes, increase or decrease attorney involvement, etc.

If the de-trend percentage selected was the total loss severity trend that was incurred (which is very difficult to isolate and quantify), then it would be difficult for NCCI to accurately forecast loss costs. The historical data (adjusted for de-trending) used for loss development and to forecast the trend would be adjusted in such a way that the projected loss costs would be inaccurate by some implicit amount. Actuaries at NCCI tested two possible indices for de-trending, namely CPI inflation and changes in total claim severity. By developing simple models, it was demonstrated that the de-trending index should be based on inflation because it produces more predictive loss development factors than using claim severity for the de-trending index.

Using the simple models, the actuaries separately tested the impact on loss development factors and resulting ultimate losses of de-trending the cap using both an inflation index and a severity index. De-trending by an inflation index preserved the value of the age-to-age link ratios when average claim size is increasing due to inflation, which is what one would expect. When severity increases due to changes in claim duration, using inflation to de-trend preserved the value of the age-to-age link ratios for early reports, but link ratios for later reports would need to be adjusted to reflect lengthening durations. The alternative de-trending index, claim severity, resulted in distorted age-to-age link ratios at every age, making the resulting ultimate losses less predictive. In conclusion, the resulting ultimate losses were more predictive using an inflation index to de-trend large loss thresholds.

The initial state-specific thresholds were rounded to the nearest million for the policy year effective period when the new methodology was first implemented. For example, if the experience period DSR pure premium volume is $525M, a 1.0% threshold would imply a (rounded) large loss limitation of $5.0 million for the midpoint of the rate effective period. The rate effective period is also known as the "base year". The thresholds for each of the years prior to the effective period are not rounded.

Because NCCI actuaries develop a range of indications using policy year and calendar/accident year data, NCCI must de-trend large loss thresholds applicable to both sets of data. NCCI calculates the accident year de-trended thresholds first, and then calculates the de-trended policy year thresholds second. This is accomplished by weighting together two adjacent calendar/accident year thresholds using the state-specific distributions of premium writings by month. The reason for de-trending accident year thresholds first is that the CPS wage changes are on a calendar year basis, which is a better match with calendar/accident year data. A detailed example of the de-trending approach used may be found in Appendix A.

Once de-trended thresholds are computed for individual years, they are fixed at those dollar amounts going forward. In this way, the limited loss development factors will not vary from year to year due to revisions to the thresholds. In subsequent loss cost filings, the base year threshold will be trended forward utilizing actual CPS wages to the extent possible and then projected CPS wage changes. For example, if the AY 2006 threshold is $5,000,000, the newly calculated AY 2007 threshold will be $5,000,000 multiplied by the expected 2006-2007 CPS wage change.

In the future if a state grows or shrinks such that the threshold seems too high or low, NCCI may consider recalibrating the threshold at that time. Thresholds in years subsequent to the base year will not be rounded.

NCCI uses the same threshold and excess ratio for loss cost level indications based on paid and "paid+case" losses. Since large losses are reported to NCCI only for those claims with "paid+case" loss amounts greater than $500,000, the minimum de-trended threshold used in a state is $500,000, despite the fact that de-trending could generate a lower threshold.

Due to the size of DSR pure premium in the states of Florida and Illinois, and hence, the very large indicated threshold, the large loss procedure was not filed in those jurisdictions.

2.5.2 Applying the Loss Limitations to Individual Claims

In workers compensation ratemaking, losses are separately analyzed by type of benefit; namely, indemnity and medical losses. This impacts the method one chooses to limit a large claim. Further complicating loss limitation is that the traditional chain-ladder loss development techniques project ultimate losses using cumulative paid losses as the base (i.e. "paid" methods), as well as cumulative paid losses plus case reserve amounts (i.e.

"paid+case" methods).

In a given state, the NCCI actuaries review a range of indications based on both "paid" and "paid+case" methodologies. Therefore, capping large claims was more challenging than expected. After reviewing several loss limitation possibilities, the decision was made to use a methodology that limited payments first, followed by limiting the case reserves. The capping would be applied to individual claims within the experience period as well as within the historical loss development triangles. The myriad of other options considered by NCCI for capping claims is not included in this paper for sake of brevity.

NCCI uses proportional capping to allocate limited claim amounts. Limited loss amounts for claims above the threshold will be allocated to layers and to indemnity and medical in the proportion that their values contribute to the total value of the claim and the threshold. NCCI limits paid losses first, then limits the case reserves until the per claim threshold is reached. The remaining excess losses are subtracted from the aggregate unlimited losses in order to calculate limited losses for use in ratemaking. In order to understand the mechanics of how claims are limited, the following hypothetical illustrative examples are included:

Illustration 1. For claims that have pierced the threshold on a "paid" basis; State threshold = $1M:

UNLIMITED LOSSES ($Millions)	Paid	Case	Total
Indemnity	0.4	0.6	1.0
Medical	4.8	2.2	7.0
Total	5.2	2.8	8.0

In this situation, the resultant limited amounts are as follows:

LIMITED LOSSES ($Millions)	Paid	Case	Total
Indemnity	0.077	0	0.077
Medical	0.923	0	0.923
Total	1.0	0	1.0

The formula for deriving the limited paid amounts for indemnity and medical is:

(Indemnity paid/total paid) x threshold = (0.4 / 5.2) x 1.0 = 0.077

(Medical paid/total paid) x threshold = (4.8 / 5.2) x 1.0 = 0.923

Illustration 2: A claim that has not pierced the threshold on "paid" basis, but has pierced the threshold on a "paid+case" basis; State threshold = $1M:

UNLIMITED LOSSES ($Millions)	Paid	Case	Total
Indemnity	0.1	0.8	0.9
Medical	0.3	6.8	7.1
Total	0.4	7.6	8.0

In this situation, the resultant limited amounts are as follows:

LIMITED LOSSES ($Millions)	Paid	Case	Total
Indemnity	0.1	0.063	0.163
Medical	0.3	0.537	0.837
Total	0.4	0.6	1.0

In Illustration 2, the limited paid amounts are identical to the unlimited paid amounts. The "remainder of threshold" is computed as follows:

"remainder of threshold" = (threshold – total paid) = (1.0 – 0.4) = 0.6

The formula for limited case reserve amounts for indemnity and medical:

(Indemnity reserve/total reserve) x "remainder of threshold" = (0.8 / 7.6) x 0.6 = 0.063

(Medical reserve/total reserve) x "remainder of threshold" = (6.8 / 7.6) x 0.6 = 0.537

It is possible to have negative development on a limited basis for individual claims when the uncapped claim value increases. Usually this results from a shift in the proportion of paid losses and/or case reserves between indemnity and medical claim benefits from one evaluation to the next. This is simply a situation to be aware of, and should not significantly impact the limited loss development factors.

2.5.3 Tail Factor Adjustment

A limited tail factor (referred to as a capped tail factor in the terminology that is being introduced in this section) is needed to properly develop capped "paid" and "paid+case" losses to an ultimate basis. The previous NCCI tail methodology generates uncapped (i.e., unlimited) tail factors. Because claims with accident dates prior to 1984 are not reported on Call #31 (Large Loss and Catastrophe Call), it is not possible to adjust the state uncapped tail to a capped tail by removing the effect of losses excess of the state threshold. In order to convert the uncapped "paid+case" tail factor to a capped "paid+case" tail factor, we use a tail adjustment.

In general terms, the tail adjustment considers the relationship between a countrywide capped "paid+case" tail factor and a countrywide uncapped "paid+case" tail factor, and applies that relationship to individual state uncapped "paid+case" tail factors to generate state-specific capped "paid+case" tail factors.

First, a countrywide capped tail factor $CLDF_T$ is derived for the threshold T from countrywide uncapped tail factors, countrywide excess tail factors, and countrywide excess ratios, using the formula:

$$CLDF_T = \frac{1 - XS_T}{\left[\frac{1}{ULDF} - \frac{XS_T}{ELDF_T}\right]} \tag{2.1}$$

Where,

$CLDF_T$ = Capped "paid+case" tail factor, 19th - to - ultimate, for threshold T

$ULDF$ = Uncapped "paid+case" tail factor, 19th - to - ultimate

XS_T = Excess ratio for threshold T, i.e., the ratio of losses excess of T to total losses at an ultimate report.

$ELDF_T$ = Excess "paid+case" tail factor, 19th - to -ultimate, for threshold T

All of the above factors are on a countrywide basis for medical and indemnity benefits combined, across all injury types. Thresholds are de-trended to the 19th prior report.

The numerator of the right hand side of (2.1), $1\text{-}XS_T$, is the proportion of total ultimate losses that are below the dollar threshold T. The denominator is the proportion of total ultimate losses below the threshold T reported at 19 years of maturity. To see this, note that $1/ULDF$ is the proportion of total unlimited losses reported at 19 years, and $XS_T/ELDF_T$ is the proportion of total losses that are excess losses reported at 19 years. The difference is the proportion of total losses less than the threshold reported at 19 years. The ratio of the numerator and denominator is the loss development factor. The adjustment factor F_T is

$$F_T = \frac{CLDF_T - 1}{ULDF - 1} \tag{2.2}$$

where $CLDF_T$ and $ULDF$ are as described above. The state capped tail factor is derived as follows:

$$SCLDF_T = 1 + F_T(SULDF - 1) \tag{2.3}$$

Where,

$SCLDF_T$ = State-specific capped "paid+case" tail factor, 19th - to - ultimate, for threshold T

$SULDF$ = State-specific uncapped "paid+case" tail factor, 19th - to - ultimate.

The state-specific uncapped "paid+case" tail factor, $SULDF$, is the state uncapped incurred (including IBNR) tail factor times the ratio of uncapped incurred (including IBNR) at 19th report to uncapped "paid+case" at 19th report. This is computed separately for medical and indemnity losses.

In practice, the factor F_T is applied to the uncapped medical and indemnity "paid+case" tail factors separately, to produce separate capped "paid+case" medical and indemnity tail factors.

An additional step is necessary to convert to a state-specific paid tail factor on a capped basis. The state-specific capped "paid+case" tail factor, $SCLDF_T$, is divided by the ratio of capped "paid" losses to capped "paid+case" losses at 19th report, separately for medical and indemnity losses. The de-trended dollar thresholds are used in the calculations of the "paid" to "paid+case" ratio for each state.

Unlimited "paid+case" tail factors, SULDF, will not be adjusted (i.e. reduced) if the unlimited "paid+case" tail factor is less than or equal to 1.000.

NCCI used Reinsurance Association of America (RAA) data [2] to calculate countrywide excess loss development factors (ELDFs). Data is submitted to RAA by reinsurers on an accident year de-trended basis. The RAA excess loss development factors are available only for combined "paid+case" losses (not "paid" losses) for five attachment point ranges (in thousands of dollars: $1-150, $151-350, $351-1500, $1500-4000, $4001 and greater) through an 18th report. NCCI fit curves through average period-to-period development factors for the lowest four ranges to extrapolate 19th-to-ultimate tail factors for each of the ranges (reported development for the highest range was deemed too volatile to provide a reliable base for extrapolation). A curve was fit through these four tail factors to extrapolate tail factors for higher attachment points. RAA produces excess loss development data every two years, which will allow NCCI to update the underlying factors periodically.

NCCI class ratemaking is generally not impacted by the new procedure at this time. NCCI concluded that it is appropriate for class ratemaking development factors to be unlimited for the following reasons: 1) The excess ratios are computed using the same 5th-to-ultimate factors as are applied to the loss dollars on serious claims, and 2) The first through fifth report link ratios derived from the Workers Compensation Statistical Plan data are currently based on unlimited losses. This is an area that is being explored in class ratemaking research.

An alternative considered was to apply the tail adjustment only to medical tail factors since it is believed that most development after 19th report, especially for large claims, occurs on medical rather than indemnity. One reason why this procedure was not followed is that adjustments to indemnity factors are usually small, since the uncapped indemnity factor is generally small, so most of the impact of the tail adjustment is to the medical tail factor. For states whose indemnity tail factor is large, it is likely that large loss development occurs on indemnity claims as well as medical, in which case it is appropriate to adjust indemnity tail factors.

A future consideration might be to incorporate state-specific excess ratios and unlimited "paid + case" tail factors, which are inputs into the tail adjustment calculation, in lieu of countrywide excess ratios and tail factors.

2.6 Application of the Excess Ratios

Adjusted per claim excess ratios will be used in calculating unlimited ultimate losses from limited ultimate losses. Excess losses are defined as the sum of the excess portion of claims above a given per claim threshold. NCCI produces proposed excess ratios with each loss cost or rate filing.

The excess ratio, XS_T, for a given threshold T, is defined as:

$$XS_T = \frac{\text{Expected Excess Losses Above Threshold } T}{\text{Expected Total Unlimited Losses}} \tag{2.4}$$

The ratio of excess losses to total unlimited losses is at an ultimate value. The excess ratio applied in the large loss procedure is on a per claim basis and varies by state as well as by threshold. This differs from an excess loss factor as excess loss factors are on a per occurrence basis, and also may include a provision for expenses.

Excess ratios are <u>not</u> adjusted when applied to different experience period years for purposes of calculating experience period loss ratios for ratemaking or for trend calculations. Therefore, in a given filing, the same excess ratio is applied to each year in the experience period. This is due to the fact that the dollar thresholds applicable to historical years are de-trended. By de-trending the threshold in the loss development and trend calculations, the proportion of losses above the threshold is preserved. Consider the following simple example. If a state's threshold is $5.0M in 2005, and that corresponds to a 2.0% excess ratio, then a $4.8M threshold in 2004 would also correspond to a 2.0% excess ratio, assuming that the 1.042 (1.042 = $5.0M/$4.8M) change in threshold values is solely due to inflation and correctly measures the actual rate of claim inflation in the state.

The adjusted, per claim excess ratio is applied as a factor, 1/ (1 -XS), to limited ultimate losses that have been on-leveled and trended to the midpoint of the proposed filing effective period. Similarly, the excess ratio applied has also been trended to the midpoint of the proposed filing effective period. Each policy period in the experience period has the same 1/ (1-XS) factor applied to both indemnity and medical losses, since the size-of-loss distributions are on a combined indemnity and medical basis. The excess ratios for aggregate ratemaking are a weighted average across hazard groups using expected losses as weights, and are based on the values contained in the state's latest approved filing.

2.7 Loss Ratio Trend

Indicated exponential loss ratio and severity trends, as well as econometric trends, are based on the losses that are derived from the large loss procedure. That is, trend indications are based on ultimate limited losses, where the limit is determined using the same de-trended thresholds by year as those used for loss development. This is consistent with the general approach that the ratemaking analysis is done on a limited basis, and is consistent with the fact that the excess ratio used in the filing implicitly contains inflationary trend over time.

2.8 Defense, Cost Containment and Adjusting and Other Expenses (formerly Loss Adjustment Expenses)

No changes to the calculation of Loss Adjustment Expense (LAE) factors were made as a result of using the aggregate large loss limitation procedure. This is a potential area of future study.

2.9 Summary of Filing Results for the Large Loss Methodology

NCCI filed the new large loss procedure for the first time in the filing season with effective dates from October 1, 2004 through July 1, 2005. The new procedure was filed in 32 states and it coincided with NCCI's revised excess loss factor procedure. Most state regulatory officials were satisfied with the implementation of NCCI's new methodology and its long-term advantages, and NCCI staff tracked results for each state on both an "unlimited" basis (i.e. the previous methodology) and the newly filed large loss procedure.

In the implementation year of the large loss procedure, the overall limited rate/loss cost level change was the same as would have been filed using the prior unlimited loss procedure when averaged across the 32 states where it was filed by NCCI. The indicated loss cost/ rate level change approved across individual NCCI states ranged from 0.973 to 1.028, indicating that the difference between the new methodology and the previous one, even at the extreme ends of the spectrum, were relatively modest and generally symmetric around 1.00.

In summary, as of May, 2006, the large loss methodology was adopted in 30 of the 32 states where it was filed. Colorado and Virginia have not adopted the change in methodology, and it has not been filed in Nevada, Illinois, or Florida.

3. THE USE OF CATASTROPHE MODELING IN WORKERS COMPENSATION

A secondary, but very important, goal of this paper is to discuss how modeling was used to derive loss cost provisions for catastrophic events due to terrorism, earthquake, and industrial accidents. In late 2002, NCCI filed Item B-1383, which was a national item filing proposing new loss cost/rate provisions by state for events that result from acts of foreign terrorism. This filing was designed to align with conditions of the Terrorism Risk Insurance Act (TRIA) passed by Congress in 2002.

In 2004, NCCI filed Item B-1393, which was a national item filing proposing new loss cost/rate provisions by state for events that result from the following perils: acts of domestic terrorism, earthquake (and tsunami, in certain states), and catastrophic industrial accidents.

Almost all states approved the voluntary loss cost and assigned risk rate provisions that NCCI filed, and many workers compensation insurers now apply these values to payroll in hundreds of dollars to determine the premium it generates. As part of Item B-1393, this premium is applied after standard premium is determined, and is not subject to any other modifications including, but not limited to, premium discounts, experience rating, retrospective rating, and schedule rating. It is an additive amount applied in the calculation of a policy's estimated annual premium initially charged to an employer, which is subject to a final audit when payroll is finalized at policy expiration.

3.1 Definition of the Perils

Terrorism, earthquakes, and catastrophic industrial accidents can result in losses of extraordinary magnitude for workers compensation. While the exposure is real, the absence of a large event in recent history within the data means that the current loss costs and rates do not provide for this type of exposure. NCCI's new approach is to exclude losses resulting from these major catastrophes once a provision for their exposure is contained in the loss costs and rates. The threshold for each of these exposures is $50 million. The modeling results described below assume that all events exceeding $50 million of loss for workers compensation would be removed from ratemaking on a first-dollar basis.

For purposes of the modeling, the following definitions apply:

- ***Acts of Foreign Terrorism:*** All acts of terrorism within the scope of TRIA with aggregate workers compensation losses in excess of $50 million. This is defined as:
  a. Any act that is violent or dangerous to human life, property, or infrastructure; and
  b. The act has been committed by an individual or individuals acting on behalf of any foreign person or foreign interest, as part of an effort to coerce the civilian population of the United States or to influence the policy or affect the conduct of the U.S. Government by coercion
- ***Domestic Terrorism:*** All acts of terrorism outside the scope of TRIA with aggregate

workers compensation losses in excess of $50 million.

• ***Earthquake:*** The shaking and vibration at the surface of the earth resulting from underground movement along a fault plane or volcanic activity where the aggregate workers compensation losses from the single event are in excess of $50 million.

• ***Catastrophic Industrial Accident:*** Any single event other than an act of terrorism or an earthquake resulting in workers compensation losses in excess of $50 million.

Note that for workers compensation, obligations to pay benefits are dictated by state law, and exclusions of these perils are not possible without statutory changes. Because TRIA has a unique mechanism for triggering federal reinsurance, separate statistical codes were created to capture premium credits or debits reported to NCCI for the Foreign Terrorism catastrophe provision and the catastrophe provision covering the other three perils, commonly referred to as DTEC (Domestic Terrorism, Earthquake, and Catastrophic Industrial Accidents).

3.2 Overview of the Approach to Determining Loss Costs Using Modeling

Beginning in 2002, NCCI began working with EQECAT, a division of ABS Consulting. EQECAT is a modeling firm that performed modeling for the California Earthquake Authority, a large earthquake pool, and performed modeling extensively used in windstorm filings. Serving the global property and casualty industry, EQECAT is known as a technical leader and innovator in the development of analysis tools and methodologies to quantify insured exposure to natural and man-made catastrophic risk. EQECAT developed three models for NCCI. These models address the potential exposure to workers compensation for terrorism, earthquake, and catastrophic industrial accidents. The models are described in detail in the following sections.

The framework of determining loss costs/rates using the modeling can best be described in the following manner:

1. Events are simulated for specific states using qualitatively defined thresholds. Some events modeled may actually result in no losses. The qualitative thresholds used by peril were:

- Large industrial accidents likely to cause at least two worker fatalities or at least ten worker hospitalizations,
- Terrorist attacks with the potential to cause at least $25M in workers compensation

losses according to the magnitude of physical event, and

- All possible earthquakes are modeled

2. Expected Annual Losses (EAL) were calculated for every state and peril analyzed. These losses were obtained using the casualty counts generated from the simulated events and by using state-specific benefit payments by injury type by state provided by NCCI.

3. Using the loss exceedance distribution underlying the EAL estimates, NCCI actuaries remove from the distribution events that do not exceed the selected dollar threshold of $50M. See Appendix B for more explanation.

4. The modified EAL was divided by the number of full-time-equivalent (FTE) employees and divided by the annual wage per employee (based on Current Population Survey or CPS) to derive a pure loss cost per $100 of payroll.

5. This was computed by peril and summed to determine the catastrophic (DTEC) provision. (Note: the foreign terrorism provision was computed similarly except for a final adjustment to remove the portion of losses from events that exceeded the federal backstop provided under TRIA.)

3.3 Modeling the Three Perils: Terrorism, Industrial Accidents, and Earthquake

Separate EQECAT models have been utilized to provide estimates of the risks to workers compensation insurers due to the following perils:

- Terrorism events
- Industrial accidents
- Earthquake ground shaking

All three models consist of the following primary components:

- Definition of the portfolio exposures
- Definition of the peril hazards
- Definition of the casualty vulnerability
- Calculation of loss due to casualty

Each of the above components is described separately below.

3.4 Portfolio Exposures Within the Models

The location, number, and types of employees are needed to characterize the risk exposures to all three perils listed above. Business information databases were used to obtain the addresses of businesses and the estimated number of employees assigned to each location. For the perils of terrorism events and industrial accidents, the exposures were aggregated to the census block level (typically a city block). This aggregation level was suitable for terrorist events and industrial accidents that span hundreds of meters. Since the definition of seismic hazard data is rather refined, the exposure data at each work site were used.

The number of workers at each aggregate level (census block or work site) was prorated to approximately account for part-time workers, workers absent for various reasons, and the self-employed. The workers were then grouped into five NCCI industry groupings: Manufacturing, Contracting, Office & Clerical, Goods & Services, and All Others. Certain government classifications not covered by workers compensation were excluded.

In addition to the employee information, required exposure data for the earthquake peril include information on the buildings where the employees are located. Building information consists of the structure type and age.

Furthermore, the number of employees used for the earthquake peril was defined for four different work shifts:

- Day shift
- Swing shift
- Night shift
- Weekends and holidays

Since the number of casualties vary depending on the time of the day and day of the week when the earthquake strikes, it is necessary to determine the number of employees for the different work shifts. The day shift accounts for most of the workers compensation exposure.

The definition of exposure by work shift was only performed for the earthquake peril. Earthquakes are natural disasters and can occur at any time in a random manner. Therefore, it is considered important to "average" the losses from all possible outcomes. Conversely, terrorism events and industrial accidents can be considered to occur most likely during the day shifts when there are more people and activities. Terrorism events are planned to inflict maximum casualties, and industrial accidents are more prone to occur during the peak hours of activities.

3.5 Peril Hazards Within the Models

3.5.1 Peril Hazards for Terrorism Events

EQECAT assembled data on the insurers' exposure and subjected that exposure to a large number of simulated terrorist events. These simulated terrorist events consist of three primary elements:

1. Weapon types
2. Target selection
3. Frequencies of weapon attacks

A brief description of each element follows.

1. Weapon Types

Specific weapons were selected from the range of known or hypothesized terrorist weapons. The selection process considered weapons that have been previously employed, weapons that could cause large numbers of casualties, or weapons that would be more readily available. In some cases a "likely" or "practical" weapon size (or quantity of agent) was selected; in other cases, a range of weapon sizes was selected, in part, to reflect standard quantities that might be available. Some of the selected modes of attack are listed below.

a) Blast/Explosion

b) Chemical

c) Biological

d) Radiological

e) Other

2. Target Selection

A target is the location of a terrorist attack and, in the model, represents the locus of a casualty footprint. An inventory of targets having the following characteristics was created such as:

- Tall buildings—10 stories and higher
- Government buildings—with a large number of employees or serving a critical or sensitive nature (e.g., FBI office).

- Airports—major
- Ports—major
- Military bases—U.S. armed forces
- Prominent locations—capitol buildings, major amusement parks, etc.
- Nuclear power plants—operational
- Railroads, railroad yards and stations—freight lines for railroad cars carrying chemicals
- Dams—large ones near urban areas
- Chemical facilities—emphasizes those with chlorine and ammonia on site

Nuclear power plants, dams, and chemical facilities receive only specific casualty footprints. Other locations are assigned more than one type of terrorist weapon. Some footprints have no specific target but are distributed at regular intervals throughout the urban area. This spreads out the effect to a larger population in the urban area. Mobile release anthrax is not located at any target but located in the general downtown area in major metropolitan areas.

3. Frequency of Weapon Attack

The relative likelihood of a type of attack occurring at a target location is represented by an assigned (annual) frequency. The significance of an attack's frequency is in its relationship to other attacks. Attack frequency is based on the following considerations:

- Availability of weapons
- Attractiveness of target
- Relative attractiveness of the region to other regions based on various theories

For footprints that are atmospheric releases of chemical, biological, and radiological agents, wind direction affects the assigned frequency. The frequency for each wind direction is weighted by the likelihood of the wind blowing in that direction based on historical wind speed and direction measurements for the region.

3.5.2 Peril Hazards for Catastrophic Industrial Accidents

Industrial accidents are characterized by the following elements:

- Facilities where industrial accidents occur

- Accident types
- Frequencies of accidents

Facilities

Facilities capable of large industrial accidents resulting in casualties above a threshold were identified from several public and commercial data sources. The facilities considered as potential sources for large industrial accidents are identified below:

- Refineries
- Chemical plants (oil, gas, petrochemical, etc.)
- Water utilities
- Power utilities
- Other manufacturing plants

Accident Types

Depending on ,the peril, the atmospheric conditions, the plant configuration and location, etc., the footprint of an accident could reach beyond the plant boundaries and affect workers in adjacent facilities and beyond. The perils considered in the study were broadly classified into three categories: chemical releases, large explosions, and all other accidents.

Chemical Releases: Chemicals considered included chlorine, anhydrous ammonia, and other nonspecific chemicals. A range of potential atmospheric releases of chemicals was considered in the analysis. The range encompassed an upper quantity represented by the total amount of chemical stored on site and, in some cases, identified in the facility's Risk Management Program submittal as the worst-case scenario, and a lower release quantity representing the minimum release quantity that could produce consequences to meet the threshold definition of large industrial accidents. A continuous range of release quantities was considered within the range.

All of the scenarios considered were modeled probabilistically and included the likelihood of the releases and their consequences as described above.

Large Explosions: Explosion simulation software is used to estimate blast pressures and consequences of the explosion in terms of casualties. These footprints were varied probabilistically to simulate the variability in the effects of an explosion. The size of the explosion varied by facility. The largest explosions were modeled to occur at oil refineries, where a significant potential for explosions exists.

All Other Accidents: In addition to the above accident types, a smaller event was considered at all modeled facilities to simulate all other industrial accidents such as fires, explosions, confined space accidents, structure and component collapse, and all other random accidents that meet the threshold damage criteria of large industrial accidents.

Frequencies of Accidents: The frequencies of occurrence of large industrial accidents in each of the modeled states were derived based on historical fatality and injury data. Frequencies of extreme events, which are very large and very rare, were based on ABS Consulting expert opinion and historical data.

The relative likelihood of the three categories of perils simulated in the analysis was derived from historical data and varies by state.

3.5.3 Peril Hazards for Earthquakes

Regional Hazard

The calculation of annualized losses requires a probabilistic representation of the location, frequency, and anticipated ground shaking of all earthquakes that can be expected to occur in the region. The characterization of the location and frequency of earthquakes comprise what is commonly known as a seismotectonic model.

One component of the seismic hazard model is the source zonation. Source zonation entails identifying potential seismogenic sources that can affect the site. These sources can either be faults or diffuse zones of seismic activity, commonly referred to as area sources and background seismicity. Each source zone represents a fault or area in which earthquakes are expected to be uniformly distributed with respect to location and size. Background seismicity is distinguished from an area source by the way that earthquake locations are treated. Earthquakes associated with background seismicity are allowed to have recurrence frequencies that smoothly vary over a region. Both area sources and background seismicity can include large earthquakes and are intended to model areas containing hidden or unknown faults or known faults, which are too numerous to be modeled individually. Earthquake source zones are identified from information on the geology, tectonics, and historical seismicity of the region.

The seismic hazard model also integrates the recurrence frequency of earthquakes. For each of the earthquake source zones, an earthquake recurrence relationship is developed. For area sources and background seismicity, this relationship is developed using an appropriate earthquake catalog, which is a listing of historically recorded or documented earthquakes. The catalog is analyzed for completeness by determining the time period over which all earthquakes of a given magnitude are believed to have been reported.

Magnitudes are converted to a consistent magnitude measure (e.g., moment magnitude, MW) for use with the strong-shaking attenuation relationships (described in the next section) and for the determination of earthquake recurrence relationships.

Faults are modeled by a characteristic earthquake model or a Gutenberg-Richter recurrence relationship, or both, depending upon the available geologic information. The characteristic earthquake model assumes that earthquakes of about the same magnitude occur at quasi-periodic intervals on the fault. The characteristic recurrence relationship is consistent with paleoseismic and historical earthquake data on individual faults. For most faults, the recurrence relationships are constrained to be consistent with known geologic deformation along the fault, since there are usually very few historical earthquakes from which to develop a reliable earthquake recurrence relationship.

The maximum magnitude for each earthquake source zone is estimated from the published literature, from comparisons with similar tectonic regimes, from historical seismicity, and from the dimensions of mapped faults.

The seismic hazard model simulates approximately 2,000,000 stochastic events across the United States.

Site Hazard Severity

Attenuation relationships are used to predict the expected amplitude of ground shaking at a site of interest knowing an earthquake's magnitude and the distance from the fault to the site. The ground shaking is characterized by one or more ground-shaking parameters, the most notable of which are peak ground acceleration (PGA), response-spectral acceleration (Sa), and Modified Mercalli intensity (MMI). These predictions are made for a uniform soil condition. Attenuation relationships are chosen to correspond as closely as possible to the tectonic environment of the region, since regional differences in earthquake source characteristics, crustal propagation properties, and site-response characteristics are known to have a significant effect on the observed ground shaking.

Soil amplification factors are used to modify the ground-shaking parameter calculated for a uniform soil condition for the specific soil conditions at the site of interest. These factors are different for each ground-shaking parameter. They are defined in terms of one or more site categories (or classes), each representing a specific set of site-response characteristics.

Soil categories are defined in terms of simple qualitative or quantitative site descriptions, such as surface geology and shear-wave velocity (the speed at which seismic waves travel through the soil deposit, a measure of the strength of the deposit).

The effect of local soil conditions within each individual zip code was taken into account. In general, soft soil sites will experience higher earthquake motions than firm soil or rock sites for comparable locations relative to the earthquake fault rupture zone, thereby increasing the likelihood of damage to buildings on soft soil for a given earthquake.

3.6 Casualty Vulnerability

Casualty vulnerability establishes the casualty levels to various peril event magnitudes. While the casualty vulnerability for terrorism events and industrial accidents are rather similar, the casualty vulnerability for earthquakes is established rather differently.

3.6.1 Casualty Vulnerability for Terrorism Events

The casualty footprint of a weapon is a measure of the physical distribution of the intensity of the agent as it spreads out from its initial target. The effects of each type of weapon will vary with the size of the weapon, with atmospheric conditions, and in some cases with local terrain. If detailed knowledge is available, a correspondingly detailed simulation of the effects is possible, but it would be time-consuming to perform. In a large-scale nationwide analysis with millions of simulated events, where local atmospheric and terrain are only generally known, a simpler, more generalized simulation is necessary. The simplifications necessary to efficiently model footprints of weapons effects are described below.

For conventional blast loading, blast simulation software is used to estimate casualties in various urban settings where the geometry and height of the buildings are varied. The results of these detailed simulations are used to develop simplified blast attenuation functions that vary with distance and with the general terrain.

For conventional blast loading, the footprint is defined as a decreasing function of distance from the source of the blast. The casualties for nuclear blast can be estimated on the basis of empirical data resulting from wartime and nuclear test experience. Casualties are assumed to be a function of distance from ground zero with the source located either at ground level or at a relatively low altitude. A simplified, conservative casualty footprint was created to encompass the range of conditions that could exist. Long-term radiation effects were not considered.

The casualty effects for aircraft impact are very much dependent upon the details of the event, so much so that only a simple, conservative footprint can be employed. A simplifying assumption is made that the extent of the footprint is a function of the height of the building.

For chemical, biological, and radiological agent releases, a plume is formed that is influenced by atmospheric conditions and by the terrain. The footprint of the cumulative dose that is deposited by a plume over time was calculated using the simulation software, MIDAS-AT^{TM} (Meteorological Information and Dispersion Assessment System—Anti-Terrorism^{TM}). Terrain conditions were assumed to be "rough" to conservatively approximate a general urban terrain. The wind direction was assumed to be unchanging. The plume footprint was calculated for low, medium, and high wind speeds and for three different atmospheric turbulence conditions. Any of the footprints could then be oriented in each of eight compass directions. Most of the footprints were truncated after an elapsed time of about two hours to account for successful evacuation.

Casualties due to dam failure are approximated using simple hydraulic relationships and assumptions made about the terrain over which the water will flow. The resulting footprint varies as depth of water (and casualty) decreases with distance away from the dam.

The analysis methodology is to apply a casualty footprint to an assigned target and to calculate the extent of casualties to the covered workers within the footprint. For chemical, biological, and radiological footprints, the dose to each employee is calculated, and a conversion is made to the degree of casualty (outpatient treatment, minor/temporary disability, major/permanent disability, and death). Degree of casualty is then converted to loss based upon the average costs by injury type provided by NCCI. The average costs provided vary by state.

3.6.2 Casualty Vulnerability for Industrial Accidents

As discussed earlier in Section 3.2, three accident types were considered in the Industrial Accidents study: chemical releases, large explosions, and all other accidents. The latter category includes a variety of accidents that are localized in nature and affect workers in a small perimeter, the size of a building. These smaller scale accidents were simulated as small blasts.

The methodology used to model chemical releases and blasts is the same as in the

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terrorism model described earlier.

3.6.3 Casualty Vulnerability for Earthquakes

Workers' casualties due to earthquakes are directly correlated to the damage extent incurred by the buildings in which they work. Therefore, casualties due to earthquakes are estimated in two sequential stages:

- Estimation of building damage
- Estimation of worker casualties based on the building damage

Building Damage at the Workplaces

Individual building vulnerability functions, that is, the probability of building damage given a level of ground shaking at the site, depends of the structure type, the age of construction, and the building height. Vulnerability functions account for variability by assigning a probability distribution bounded by 0% and 100% with a prescribed mean value and standard deviation. The vulnerability functions were based on historical damage data and insurance claims data—including the analysis of over 50,000 claims from the Northridge and other earthquakes.

The probability distributions of ground shaking at the site and vulnerability functions are combined to estimate the probability of building damage for each earthquake event. The probability of damage at the site level is also combined probabilistically, accounting for correlation in ground shaking between zip codes and in damage level between the same and different structure types within and between zip codes.

Note that considerable randomness exists in earthquake damage patterns where randomness denotes the irreducible variability associated with the earthquake event. Randomness as characterized by the following parameters:

- Ground shaking
- Damage to the average structure of a given class at a given level of ground shaking
- Each structure's seismic vulnerability relative to the average structure of its class

Modeling uncertainty, the lack of knowledge in characterizing each element of the model, is statistically combined with randomness and correlation to estimate overall variability in damage and loss to the entire portfolio.

Casualties Due to Building Damage

Workers' casualty data resulting from earthquakes is very scarce in the United States. EQECAT is constantly using data from the most recent earthquakes worldwide to update its casualty functions, which correlate building damage to casualties. Because of differences in building design codes and construction practices, data from earthquakes outside the U.S. are adapted to local U.S. conditions. This adaptation takes into consideration building damage, the state, and its resulting casualties.

EQECAT's proprietary workers compensation casualty rate functions are defined for four injury types: death, severe/major, minor/light, and medical-only.

3.7 Calculation of Loss Due to Casualties

Average costs by injury type were provided by NCCI and used in calculating losses due to workers' casualties. The same average costs were applied to all three perils.

Earthquake exposures were defined for different work shifts. The number of casualties by work shift for each work site and earthquake event is estimated prior to the application of the average costs.

3.7.1 Calculation of Loss Due to Tsunami

Although all coastal states on the West Coast are prone to tsunamis, only Alaska was analyzed for this peril.

Alaska has a higher worker rate near the shore in inundetable zones and its coastline is in close proximity to the subduction zone capable of triggering tsunamis. In addition, in remote locations of Alaska, workers compensation extends coverage after the employee leaves the immediate worksite. Other states such as Oregon and Hawaii can benefit from a warning advantage that would reduce the impact of tsunamis generated far away.

A simplified model was formulated to estimate workers compensation loss due to tsunami inundation. This model is based on tsunami modeling developed for Japan, which makes use of historical data to derive a relationship between earthquake moment magnitude (Mw), distance from the earthquake rupture to the shore, and direct or indirect exposure to the wave to determine the run-up height of a tsunami wave. The quantity of historical data needed to develop such a relationship is not available for Alaska; however, the model adopts the Japanese method where the detailed physics of the wave are not being calculated.

Injury Rate

Casualties due to tsunami run-up are estimated by assuming a simple relationship between depth of inundation and the likelihood of being in one of four NCCI injury classes (medical-only, minor permanent partial /temporary disability, major permanent partial /permanent disability, and death). There is scarce data available and the conditions under which the casualties occur is extremely variable. For this simplified approach, the injury relationships were subjected to the 1964 Mega-Thrust earthquake and the relationships calibrated to produce roughly the casualties suffered in the event.

Earthquake Modeling

The source of tsunami in Alaska is limited to the lengthy subduction zone that lies along the undersea trench that stretches from about Seward to the tip of the Aleutians. This subduction zone produces earthquake magnitudes estimated to be as large as Mw 9.2. Only the larger magnitude events have a potential for causing tsunami. For this analysis, magnitudes down to Mw 7.7 were considered.

Based on the geometry of the subduction zone adopted from the USGS, ruptures of magnitudes between Mw 9.2 and Mw 7.7 were placed along the length of the trench. The frequency of each event, as a function of magnitude, was derived from an analysis of the earthquake catalog for the region.

For each earthquake rupture, the surface distance between any location on the rupture plane and each near-shore business location was calculated.

Tsunami Analysis

The computations were performed for each earthquake rupture and for each site. Given the magnitude of the rupture and the distance from the ruptures to the site, the simplified equation estimates the run-up height. The difference between the elevation above sea level and the run-up height determines the depth of inundation.

Inundation depth is then used to determine the percentage of employees who are in each injury category. From the number of employees at the location, the total casualty cost is estimated using the mean costs for each injury category. The cost is multiplied by the event frequency, and aggregated by NCCI occupation class and by county.

The losses from earthquake shaking and tsunami were combined through summation. This conservative treatment neglects the potential for overlap in casualties caused by shaking and by tsunami.

3.8 Deriving Loss Costs from the Modeling

As described earlier, Expected Annual Losses (EAL) were calculated for every state and peril analyzed. These losses were obtained using the casualty counts generated from the simulated events and by using state-specific benefit payments by injury type by state provided by NCCI. The losses do include self-insured employers.

Using the loss exceedance distribution underlying the EAL estimates, NCCI actuaries remove from the distribution events that do not exceed the selected dollar threshold of $50 million. See Appendix B for a detailed hypothetical illustration of this process.

The modified EAL was divided by the number of full-time-equivalent (FTE) employees and divided by the annual wage per employee based on Current Population Survey (CPS) to derive a pure loss cost per $100 of payroll. Note the number of employees also includes self-insured employers.

This was computed by peril and summed to determine the catastrophic (DTEC) loss cost/rate provision. (Note: the foreign terrorism provision was computed similarly except for a final adjustment to remove the portion of losses from events that exceeded the federal backstop provided under TRIA.)

3.9 Other Insights from the Modeling

The relative magnitude of different catastrophes varies based on the time horizon. In workers compensation, for shorter time horizons, industrial accidents are expected to generate the largest expected losses. However, for very long term horizons, earthquakes generate the largest expected losses.

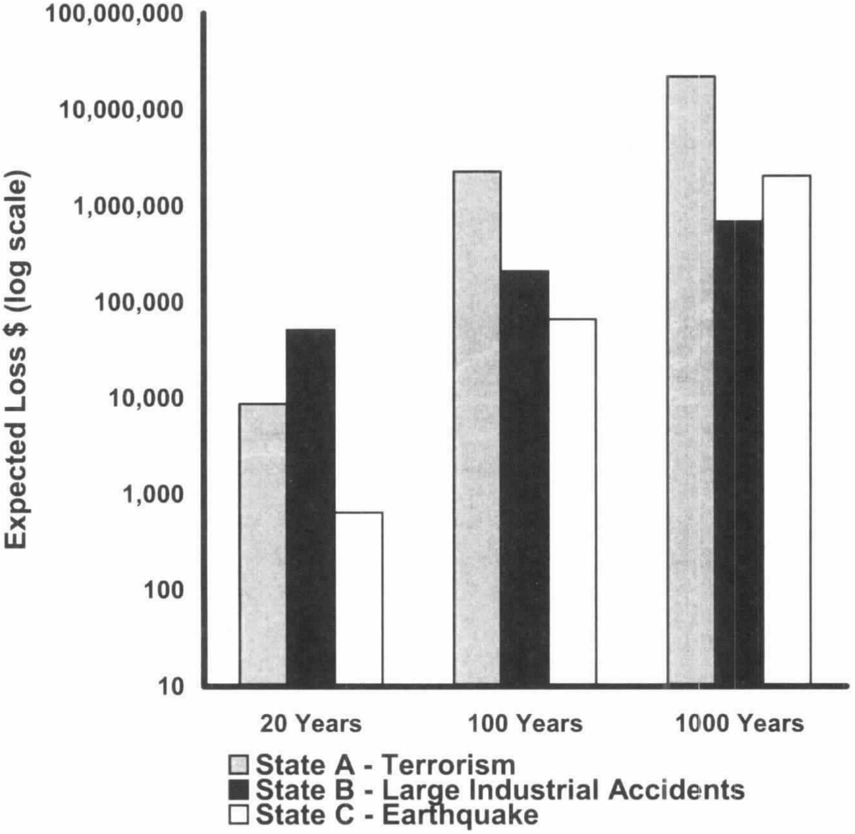
When talking about the relative length of time horizons, one references the return period. The return period for extreme events is defined as the expected length of time between occurrences. It is an approximate measure of frequency per unit of time.

The following bar chart shows that the relative magnitude of perils varies based on the time horizon. Here, we look at the three different perils in three different states: industrial accidents, terrorism, and earthquake. The focus is on the different time horizons.

The first observation is that regardless of peril, over longer time horizons, the expected loss amounts increase. This is because the very largest catastrophic events dominate the calculation of expected loss, despite their very low return period. This is generally true across all states modeled, and all three perils.

The second observation is based on comparing the expected losses by peril relative to each other based on the different time horizons. The following chart shows the differences at a 20-year, 100-year, and 1000-year return period. When taking a 20-year time horizon, industrial accidents are expected to be the largest events in terms of generating expected losses, and earthquake is the lowest. When a 100-year time frame is viewed, industrial accidents rank second, and terrorism events are first. At a time horizon of 500 years or more, terrorism events rank first, followed by earthquakes, and then industrial accidents.

Note the following chart shows results for three different states. This is still representative of the pattern that would likely result in a single state over the same time horizons, but the model results underlying this analysis did not include a single state modeled for all three perils.



Return Period for Extreme Workers Compensation Loss Events

3.10 The Pros and Cons of Using Catastrophe Modeling in Workers Compensation

Catastrophic events are a low frequency occurrence with very high severity, and cannot be adequately addressed through standard actuarial techniques to quantify risk. The data on such events is limited to a very small number of historical events — often without an event having been observed in a state.

Used in conjunction with the actual historical data, stochastic simulations were used in the modeling to provide additional data points. Repeat simulations of an event provide a broader perspective of the possible outcomes. Variations of parameters are also modeled and result in a comprehensive stochastic event set.

Modeling is being used extensively in the insurance and reinsurance industries. State regulators are scrutinizing the models, more fully understanding how they operate, and asking better questions to learn more and more. Over time, there has been a wider acceptance of catastrophe modeling by regulatory officials.

As for disadvantages, there are several parameters with varying levels of uncertainty involved in each of the hazard, vulnerability, casualty, and loss modules which are integrated in these complex models. These uncertainties lead to differences between models and raise questions among regulators who have to determine the validity of these tools which are becoming increasingly used in rate making.

3.11 Possible Future Enhancements to the Catastrophe Modeling

The catastrophe models rely heavily on underlying databases which contain information on the different parameters used in the analysis. To the extent that the refinement and quality of these databases increases, the result may be a reduction in the margin of uncertainty in the final results.

An enhancement to the workers compensation models described earlier would result if a database containing the employment data at each business location and for each work shift were updated regularly. This would improve the estimates of the numbers of workplace injuries and the subsequent modeled loss estimates resulting from events emanating from the perils of terrorism, earthquake, and catastrophic industrial accidents.

Some other examples of information or databases which might improve the estimation of the workers compensation loss estimates follows, organized by peril.

Earthquake Peril

A more refined soil database would be a possible enhancement if used in the earthquake model for workers compensation. It could allow for better estimation of the site amplification of the ground motion, which in turn is used to calculate the building damage, and hence, the resulting casualties among its occupants.

Also, building structure information, if more accurately defined, would allow for the use of a more fine-tuned building vulnerability function. In the absence of such information, assumptions are generally made based on information that could possibly be dated.

The casualty rate functions allow the estimation of the casualties by injury type in different building structures. These functions are developed from limited earthquake casualty data and as more data is collected from future occurrences, loss estimates could be improved as the estimation of casualties improved.

Catastrophic Industrial Accidents and Terrorism Perils

The potential for extreme industrial events needs to be constantly reviewed based on safety regulations and their enforcement, emergency planning, and medical emergency care. These conditions may vary greatly over time and across facilities. This type of information directly impacts the frequency assumption underlying the loss cost. As this information becomes more refined, one should be better able to target the frequency assumption.

Other areas of possible enhancement include obtaining more refined information on the potential target sites. In particular, those sites storing toxic chemicals need to be constantly updated as some plants open or close or change their product lines. The nature and quantities of the toxic chemicals need also be kept current.

For terrorism, the statements above apply with respect to the potential target sites. Also, event frequencies need to be regularly evaluated based on current conditions and the possible threats they may generate. The frequency assumption, as always, is very important to determining the appropriate loss cost levels for all perils.

3.12 Using Models Outside the Actuary's Expertise

The author relied upon the expertise of other NCCI actuaries, whose work product has been described in parts of the modeling discussion presented. Such information has been documented in accordance with ASOP No. 38.

The NCCI actuaries relied upon simulation models supplied by EQECAT for calculating expected losses due to the earthquake perils. The accuracy of these models heavily depends upon the accuracy of seismological and engineering assumptions included.

The NCCI actuaries also relied upon simulation models supplied by EQECAT for calculating expected losses due to the perils of terrorism and catastrophic industrial accidents. The models produce estimated losses due to physical, chemical, and biological terrorist acts. They also produce estimated losses due to chemical releases and explosions at industrial plants, and both perils include the input and opinions from experts in related fields and experts at ABS Consulting. The accuracy of these models heavily depends upon the accuracy of meteorological, engineering, and expert claim frequency assumptions.

4. CONCLUSIONS

This paper documents several important changes that have been implemented in the aggregate ratemaking process used to determine indicated workers compensation loss cost and rate changes by state. The changes NCCI implemented support the long-term goals of adequacy and stability of loss costs and rates based on the explicit consideration of how to treat large events consistently from state to state in the ratemaking methodology.

This paper also serves to document for the first time in CAS literature how computer modeling was used in workers compensation.

Acknowledgment

The author acknowledges the work of Ia Hauck, John Robertson, John Deacon, and numerous other NCCI staff members, whose tireless efforts allowed NCCI to complete the aggregate ratemaking research and testing that allowed for the implementation of the new methodology. The author also acknowledges the contributions to this paper by Jon Evans and Barry Lipton, whose work with EQECAT allowed NCCI the ability to produce the loss cost provisions for catastrophic events, and Omar Khemici, Andrew Cowell, and Ken Campbell of EQECAT, whose insights and work on performing the modeling was the basis for many of the results shown in the paper. I would also like to thank EQECAT, a division of ABS Consulting, for allowing me to disclose an overview of their modeling techniques, much of which is proprietary.

Appendix A – Example of De-Trending Procedure

State X - Effective 9/1/2004

Calculation of Base Threshold (Using information from latest approved filing):

Experience Period of Latest Approved Filing	1PY / 1AY
On-leveled, Developed Premium for PY 2001	247,605,878
On-leveled, Developed Premium for AY 2002	240,782,386
Experience Period On-leveled, Developed Premium	488,388,264
Factor to Remove Expenses	1.000
Experience Period On-leveled, Developed Premium Excluding Expenses	488,388,264
1% of the Total Experience Period Premium	4,883,883
Threshold for the Base Year	5,000,000
Midpoint of the Proposed Filing Policy Period (Base Year)	8/13/2005

Calculation of De-trended Thresholds:

(1) Midpoint	(2) CY	(3) Actual CY CPS Wage	(4) Change in Col (2)	(5) Year	(6) AY Threshold	(7) PY Threshold
7/1/1984	**1984**	294.17	1.016	**1984**	2,346,511	2,360,628
7/1/1985	**1985**	298.84	1.010	**1985**	2,384,055	2,393,019
7/1/1986	**1986**	301.72	1.064	**1986**	2,407,896	2,465,839
7/1/1987	**1987**	320.92	1.021	**1987**	2,562,001	2,582,231
7/1/1988	**1988**	327.57	1.063	**1988**	2,615,803	2,677,766
7/1/1989	**1989**	348.30	1.024	**1989**	2,780,599	2,805,691
7/1/1990	**1990**	356.51	1.054	**1990**	2,847,333	2,905,145
7/1/1991	**1991**	375.76	1.101	**1991**	3,001,089	3,115,058
7/1/1992	**1992**	413.85	1.004	**1992**	3,304,199	3,309,169
7/1/1993	**1993**	415.55	1.020	**1993**	3,317,416	3,342,363
7/1/1994	**1994**	423.89	1.030	**1994**	3,383,764	3,421,933
7/1/1995	**1995**	436.46	1.064	**1995**	3,485,277	3,569,147
7/1/1996	**1996**	464.18	1.039	**1996**	3,708,335	3,762,714
7/1/1997	**1997**	482.45	1.021	**1997**	3,852,960	3,883,383
7/1/1998	**1998**	492.61	1.047	**1998**	3,933,872	4,003,391
7/1/1999	**1999**	515.60	1.044	**1999**	4,118,764	4,186,905
7/1/2000	**2000**	538.48	1.049	**2000**	4,299,990	4,379,213
7/1/2001	**2001**	564.63	1.020	**2001**	4,510,689	4,544,609
7/1/2002	**2002**	576.17	1.014	**2002**	4,600,903	4,625,122
7/1/2003	**2003**	584.52	1.026	**2003**	4,665,316	
7/1/2004	**2004**	599.66	1.040	**2004**	4,786,614	
7/1/2005	**2005**	623.80	1.038	**2005**	**4,978,079**	
7/1/2006	**2006**	647.54				

Appendix B – Loss Exceedance Curves and the Catastrophic Event Threshold

Loss exceedance curves are a standard output format from catastrophe models. Table B.1 shows a hypothetical example of output from a catastrophe model. For illustration purposes only 4 points on the loss exceedance curve are shown in Table B.1. Typically, loss exceedance curves will consist of at least several hundred points. The curve is usually represented by loss amounts sorted in descending order along with associated probabilities of exceedance. The probability of exceedance of a given loss amount is the probability that at least one event causing at least as much loss as that loss amount will occur in a single year. The loss exceedance curve is assumed to result from an underlying collective risk model with a Poisson frequency distribution. Based on this assumption, frequencies (exceedance and incremental), return periods, and the severity density can be derived easily.

Table B.1

Hypothetical Example of Various Components of Common Representations of Loss Exceedance Curves

Event Loss	Probability of Exceedance	Frequency of Exceedance	Return Period	Incremental Frequency	Severity Distribution	Severity Density
[1] =Model Output	[2] =Model Output	[3] = - ln (1-[2])	[4] = 1 / [3]	[5] = Difference [3]	[6] =100%-{Shift[3]/ Total [5]}	[7] = Difference [6]
1,000,000,000	0.1998%	0.002	500	0.002	100%	1%
100,000,000	0.9950%	0.010	100	0.008	99%	4%
10,000,000	9.5163%	0.100	10	0.090	95%	45%
1,000,000	18.1269%	0.200	5	0.100	50%	50%
Total	18.1269%			0.200		

For NCCI's large loss procedure, catastrophic losses from events exceeding $50 million dollars are completely excluded from experience used for aggregate ratemaking. A corresponding provision based on catastrophe model results is added to loss costs. Although the catastrophe model assumptions may be designed to only contemplate events likely to cause a large loss, this is only a qualitative threshold. Actual model output will include some events that when simulated with various stochastic assumptions happen to generate a small loss or even no loss at all.

Table B.2 shows the quantitative exclusion of losses exceeding $50 million, on both excess and ground-up bases, from the exceedance curve in Table B.1. Expected values were calculated for the two types of exclusions. Column (12) is used in the derivation of the catastrophe provisions. Note the excess exclusion shown in column (11) of Table B.2 is not used to calculate the replacement provision for catastrophic events in the large loss procedure. However, this is the type of calculation that would be applicable if events greater than $50 million were simply capped, as is done in the large loss procedure with large individual claims exceeding the state's per claim threshold.

Table B.2

Exclusion of Losses Excess of $50 Million Event Losses From Table B.1

$50m Excess	>$50m Ground-up	Expected Ground-up	Expected $50m Excess	Expected >$50m Ground-up
[8]	[9]	[10]	[11]	[12]
= Max(0, [1] 50m)	= if([1] > 50m , [1] ,0)	= [5] x [1]	= [5] x [8]	= [5] x [9]
950,000,000	1,000,000,000	2,000,000	1,900,000	2,000,000
50,000,000	100,000,000	800,000	400,000	800,000
0	0	900,000	0	0
0	0	100,000	0	0
Total		3,800,000	2,300,000	2,800,000

Illustration 3. NCCI 's formula for the calculation of one catastrophe peril's pure loss cost:

Catastrophe Pure Loss Cost (per $100 limited payroll) =

100 x Catastrophe Expected Losses / (# Workers x Limited Average Annual Wage)

So, if the loss exceedance curve in Tables B.1 and B.2 were based on a modeling assumption of 1,000,000 workers and the average annual wage was $40,000 the provision for the excluded large event losses would be:

100 x $2,800,000 / (1,000,000 x $40,000) = 0.007

For the DTEC provision, a similar provision would be computed for the other perils and added to the 0.007. The sum would then be multiplied by a factor to account for loss based expenses (or fully loaded expenses in administered pricing jurisdictions) and then rounded to the nearest penny to produce an additive provision for loss costs/rates.

Appendix C – NCCI Call #31, Large Loss and Catastrophe Call

CALL #31

NATIONAL COUNCIL ON COMPENSATION INSURANCE, INC.
LARGE LOSS AND CATASTROPHE CALL
VALUED AS OF DECEMBER 31, 2003

CARRIER/CARRIER GROUP____CARRIER CODE NUMBER_____________________________
SUBMITTED BY _____________________________TITLE ____________________TELEPHONE NO______________DATE SUBMITTED _________________

Claim	Policy	NCCI	Exposure	Market	Policy		Claim	Accumulated Paid Losses		Case Outstanding		Defense and Cost Containment Expense	
Number (1)	Number (2)	Catastrophe Number (3)	State Code (4)	Type Code (5)	Effective Date (6)	Accident Date (7)	Status Code (8)	Indemnity (9)	Medical (10)	Indemnity (11)	Medical (12)	Accumulated Paid (13)	Case Outstanding (14)

Market Type Code:
3 - Voluntary (not Large Deductible)
2 - Large Deductible
0 - Assigned Risk (not Large Deductible)

Claim Status Code:
0 - Open
1 - Closed
2 - Reopened

5. REFERENCES

[1] Historical Loss Development Study, 2003 Edition, Reinsurance Association of America, 2003.

Abbreviations and notations

AY, accident year
BLS – Bureau of Labor Statistics
CAS, Casualty Actuarial Society
CLDF$_T$- Capped "paid + case" tail factor, 19th to ultimate, for threshold T.
CPI-consumer price index
CPS-Current Population Survey
CY-calendar year
DSR-Designated Statistical Reporting level of NCCI
DTEC-Domestic Terrorism, Earthquake, and Catastrophic Industrial Accident provision
EAL-expected annual loss
ELDF$_T$- Excess "paid+case" tail factor, 19th to ultimate, for threshold T.
EQECAT- modeling company, a division of ABS Consulting Group
F$_T$- Factor to apply to state-specific *ULDF* to get state-specific *CLDF$_T$* for threshold T.
FTE- full-time equivalents
ISO-Insurance Services Office
LAE-loss adjustment expense
M- $millions
MMI- Modified Mercalli intensity
MIDAS-AT- Meteorological Information and Dispersion Assessment System—Anti-Terrorism™
MW- moment magnitude
NCCI- National Council on Compensation Insurance, Inc.
OSHA- Occupational Safety and Hazard Administration
PGA-peak ground acceleration
PY-policy year
RAA-Reinsurance Association of America
Sa-response-spectral acceleration
SCLDF$_T$- State-specific capped "paid+case" tail factor, 19th to ultimate, for threshold T.
SULDF$_T$- State-specific uncapped "paid+case" tail factor, 19th to ultimate, for threshold T.
TRIA -Terrorism Risk Insurance Act of 2002
ULDF - Uncapped "paid+case" tail factor, 19th to ultimate
US – United States
USGS – United States Geological Survey
WCSP- NCCI 's Workers Compensation Statistical Plan
XS$_T$- Per Claim adjusted excess ratio at threshold T

Biography of the Author

Tom Daley is Director and Actuary at NCCI, Inc. He is currently responsible for both applied research and production duties in class ratemaking for all NCCI states, and handling state actuary loss cost and rate filing duties in several other states. He has a B.S. degree in Mathematics from the Pennsylvania State University. He is an Associate of the CAS and a Member of the American Academy of Actuaries.