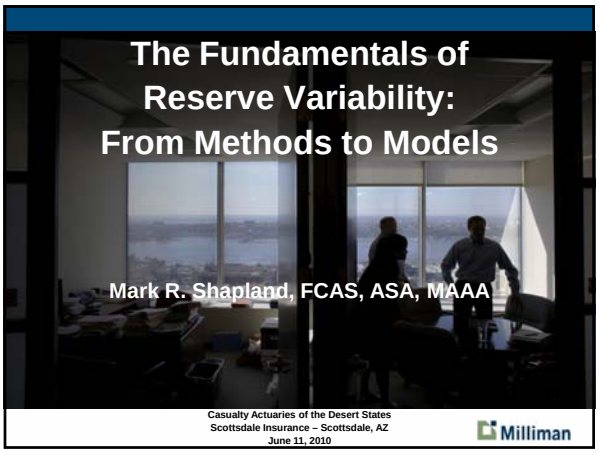
The Fundamentals of Reserve Variability: From Methods to Models

Casualty Actuaries of the Desert States

June 11, 2010



Overview

- Definitions of Terms
- Ranges vs. Distributions
- Methods vs. Models
- Types of Methods/Models
- What is "Reasonable"?
- What is a "Reserve Range"?
- Model Evaluation

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Definitions of Terms

- **Reserve** – an amount carried in the liability section of a risk-bearing entity's balance sheet for claims incurred prior to a given accounting date.
- **Liability** – the actual amount that is owed and will ultimately be paid by a risk-bearing entity for claims incurred prior to a given accounting date.
- **Loss Liability** – the *expected value* of all estimated future claim payments.
- **Risk** (*from the "risk-bearers" point of view*) – the uncertainty (deviations from expected) in both timing and amount of the future claim payment stream.

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Definitions of Terms

- **Process Risk** – the randomness of future outcomes given a *known* distribution of possible outcomes.
- **Parameter Risk** – the potential error in the estimated parameters used to describe the distribution of possible outcomes, assuming the process generating the outcomes is *known*.
- **Model Risk** – the chance that the model ("process") used to estimate the distribution of possible outcomes is incorrect or incomplete.

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Definitions of Terms

Measures of Risk from Statistics:

- Variance, standard deviation, skewness, average absolute deviation, Value at Risk, Tail Value at Risk, *etc*. which are measures of dispersion.
- Other measures useful in determining "reasonableness" could include: mean, mode, median, pain function, *etc*.
- The choice for measure of risk will also be important when considering the "reasonableness" and "materiality" of the reserves in relation to the capital position.

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Ranges vs. Distributions

- A "Range" is not the same as a "Distribution"
- *A Range of Reasonable Estimates* is a range of estimates that could be produced by appropriate actuarial methods or alternative sets of assumptions that the actuary judges to be reasonable.
- A *Distribution* is a statistical function that attempts to quantify probabilities of all possible outcomes.

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Ranges vs. Distributions

A Range, by itself, creates problems:

- A range can be misleading to the layperson – it can give the impression that any number in that range is equally likely.
- A range can give the impression that as long as the carried reserve is "within the range" anything is reasonable.

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Ranges vs. Distributions

A Range, by itself, creates problems:

- There is currently no specific guidance within the actuarial community (e.g., +/- X%, +/- $X, using various estimates, etc.).
- A range, in and of itself, needs some other context to help define it (e.g., how to you calculate a risk margin?)

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Ranges vs. Distributions

A Distribution provides:

- Information about "all" possible outcomes.
- Context for defining a variety of other measures (e.g., risk margin, materiality, risk based capital, etc.)

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Ranges vs. Distributions

A Distribution can be used for:

- Technical Provisions / Unpaid Claim Estimates
  - IFRS: Discounted Best Estimate + CoC Risk Margin
  - GAAP / Statutory: Undiscounted Best Estimate
- Economic / Risk-Based Capital / Solvency II
  - Reserve Risk
  - Pricing Risk
  - Duration Risk

  → Allocated Capital
- Pricing / ROE
- Reinsurance Analysis
  - Quota Share
  - Aggregate Excess
  - Stop Loss
  - Loss Portfolio Transfer

  → Risk Transfer
- Dynamic Risk Modeling (DFA) → Parameterize ANY Model
- Strategic Planning / Performance Management / ERM
- Regulatory & Rating Agency Support
- Compare Expected vs. Actual Variability / Back Testing
- Mergers & Acquisitions

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Ranges vs. Distributions

Should we use the same:

- criterion for judging the quality of a range vs. a distribution?
- basis for determining materiality? risk margins?
- selection process for which numbers are "reasonable" to chose from?

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Methods vs. Models

- A **Method** is an algorithm or recipe – a series of steps that are followed to give an estimate of future payments.
- The well known chain ladder (CL) and Bornhuetter-Ferguson (BF) methods are examples.
- The search for the "best" pattern.

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Methods vs. Models

- A **Model** specifies statistical assumptions about the loss process, usually leaving some parameters to be estimated.
- Then estimating the parameters gives an estimate of the ultimate losses and some statistical properties of that estimate.
- The search for the "best" distribution.

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Methods vs. Models

- Many good probability models have been built using "Collective Risk Theory"
- Each of these models make assumptions about the processes that are driving claims and their settlement values
- None of them can ever completely eliminate "model risk"

"All models are wrong. Some models are useful."

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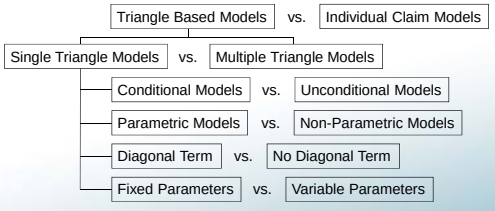
Types of Models



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Types of Models

- Processes used to calculate liability ranges can be grouped into four general categories:

1) Multiple Projection Methods,

2) Statistics from Link Ratio Models,

3) Incremental Models, and

4) Simulation Models

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What is "Reasonable"?

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What is "Reasonable"?

Premise:

- We could define a "reasonable" range based on probabilities of the distribution of possible outcomes.
- This can be translated into a range of liabilities that correspond to those probabilities.

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What is "Reasonable"?

A probability range has several advantages:

- The "risk" in the data defines the range.
- Adds context to other statistical measures.
- A "reserve margin" can be defined more precisely.
- Can be related to risk of insolvency and materiality issues.
- Others can define what is reasonable for them.

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What is "Reasonable"?

Comparison of "Reasonable" Reserve Ranges by Method

	Relatively Stable LOB			More Volatile LOB		
Method	Low	EV	High	Low	EV	High
Expected +/- 20%	80	100	120	80	100	120
50th to 75th Percentile	97	100	115	90	100	150

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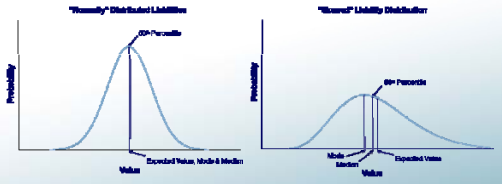
What is "Reasonable"?

Comparison of "Reasonable" vs. "Skewed" Liability Distributions



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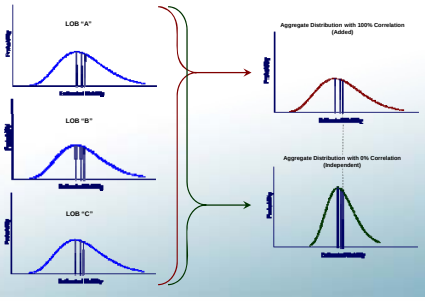
What is "Reasonable"?

Comparison of Aggregate Liability Distributions



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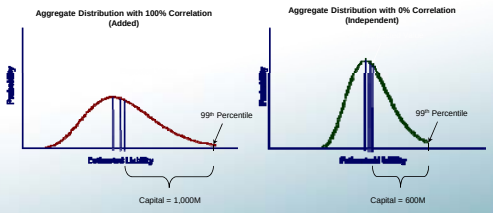
Comparison of Aggregate Liability Distributions



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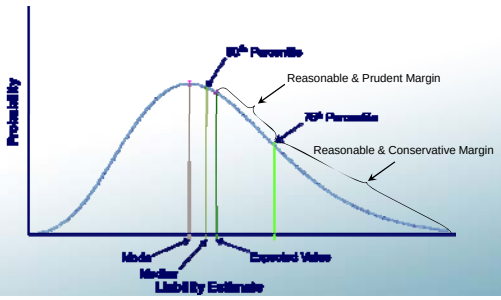
What is "Reasonable"?

Others can Define Reasonability



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What is "Reasonable"?

Comparison of "Reasonable" Reserve Ranges with Probabilities of Insolvency

"Low" Reserve Risk

		Corresponding Surplus Depending on Situation					
Loss Reserves		Situation A		Situation B		Situation C	
Amount	Prob.	Amount	Prob. Of Ins.	Amount	Prob. Of Ins.	Amount	Prob. Of Ins.
100	50%	80	40%	120	15%	160	1%
110	75%	70	40%	110	15%	150	1%
120	90%	60	40%	100	15%	140	1%

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What is "Reasonable"?

Comparison of "Reasonable" Reserve Ranges with Probabilities of Insolvency

"Medium" Reserve Risk

		Corresponding Surplus Depending on Situation					
Loss Reserves		Situation A		Situation B		Situation C	
Amount	Prob.	Amount	Prob. Of Ins.	Amount	Prob. Of Ins.	Amount	Prob. Of Ins.
100	50%	80	60%	120	40%	160	10%
120	75%	60	60%	100	40%	140	10%
140	90%	40	60%	80	40%	120	10%

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What is "Reasonable"?

Comparison of "Reasonable" Reserve Ranges with Probabilities of Insolvency

"High" Reserve Risk

		Corresponding Surplus Depending on Situation					
Loss Reserves		Situation A		Situation B		Situation C	
Amount	Prob.	Amount	Prob. Of Ins.	Amount	Prob. Of Ins.	Amount	Prob. Of Ins.
100	50%	80	80%	120	50%	160	20%
150	75%	30	80%	70	50%	110	20%
200	90%	-20	80%	20	50%	60	20%

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What is "Reasonable"?

Satisfying Different Constituents:

- **Principle of Greatest Common Interest** – the "largest amount" considered "reasonable" when a variety of constituents share a common goal or interest, such that all common goals or interests are met; and the
- **Principle of Least Common Interest** – the "smallest amount" considered "reasonable" when a variety of constituents share a common goal or interest, such that all common goals or interests are met.

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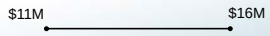
What is "Reasonable"?



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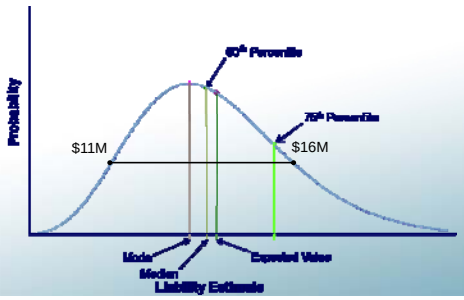

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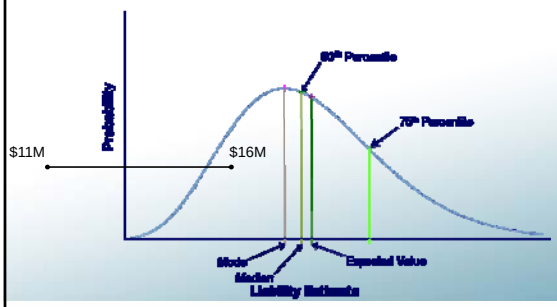

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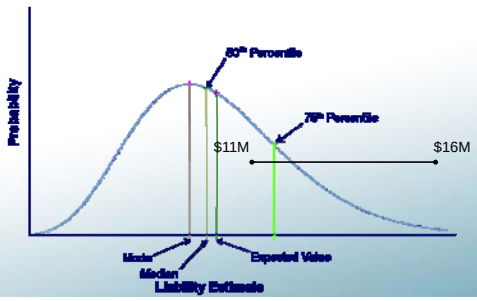

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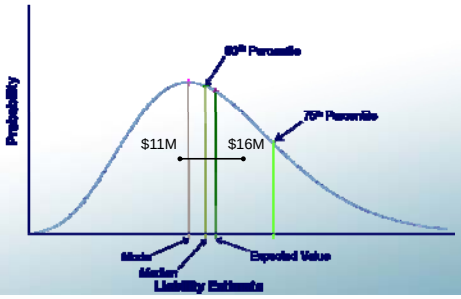

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What is a "Reserve Range"?

- A "range" is generally considered to be either a subset of the "possible outcomes" or a subset of "central estimates".
- A "possible outcome" will generally include random movements in the incremental values (e.g., calendar period payments within each accident period).
- For a "central estimate" the incremental values will essentially have the random movements "averaged" or "smoothed" out.

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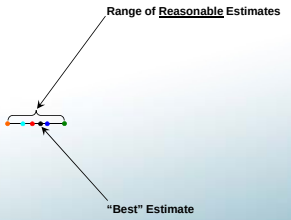
What is a "Reserve Range"?



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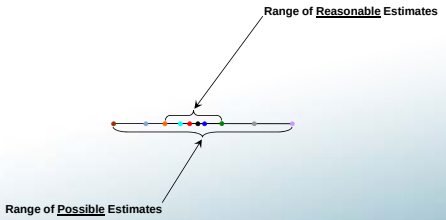

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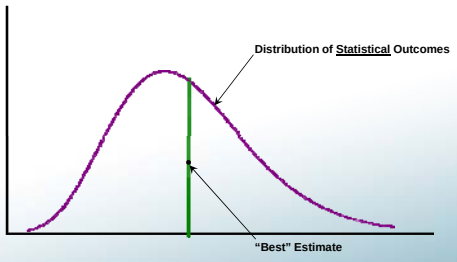

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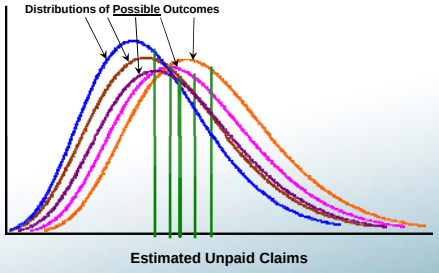

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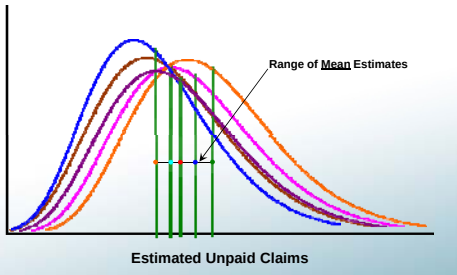

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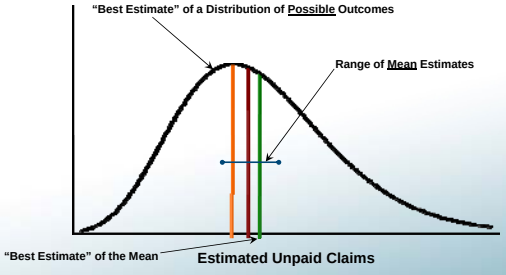

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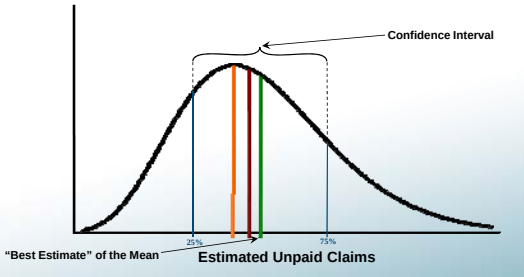

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Model Selection and Evaluation

- Actuaries Have Built Many Sophisticated Models Based on Collective Risk Theory
- All Models Make Simplifying Assumptions
- How do we Evaluate Them?

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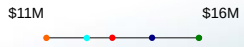
How Do We "Evaluate"?
(Point Estimates)



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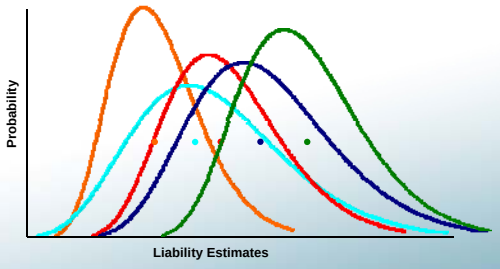
How Do We "Evaluate"?
(Multiple Distributions)



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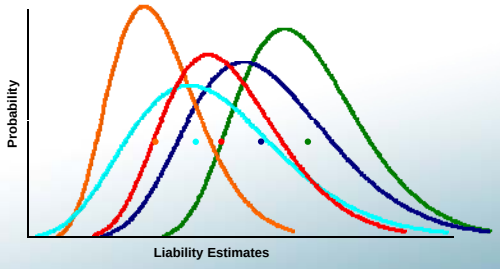
How Do We "Evaluate"?
(Eliminate "Weaker" Models)



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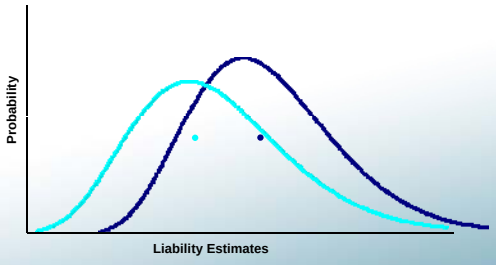
How Do We "Evaluate"?
(Competing Distributions)



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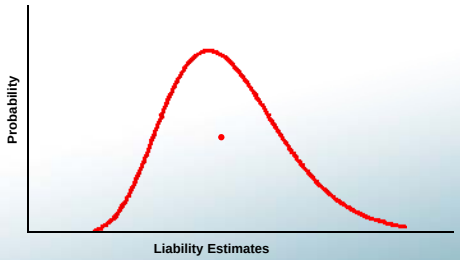
How Do We "Evaluate"?
("Weight" into Single Distribution)



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Fundamental Questions

- How Well Does the Model Measure and Reflect the Uncertainty Inherent in the Data?
- Does the Model do a Good Job of Capturing and Replicating the Statistical Features Found in the Data?

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Modeling Goals

- Is the Goal to Minimize the Range (or Uncertainty) that Results from the Model?
- Goal of Modeling is *NOT* to Minimize Process Uncertainty!
- Goal is to Find the Best Statistical Model, While Minimizing Parameter and Model Uncertainty.

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Model Selection & Evaluation Criteria

- Model Selection Criteria
- Model Reasonability Checks
- Goodness-of-Fit & Prediction Errors

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Model Selection Criteria

- **Criterion 1**: ***Aims of the Analysis***
  - Will the Procedure Achieve the Aims of the Analysis?
- **Criterion 2**: ***Data Availability***
  - Access to the Required Data Elements?
  - Unit Record-Level Data or Summarized "Triangle" Data?

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Model Selection Criteria

- **Criterion 3**: ***Non-Data Specific Modeling Technique Evaluation***
  - Has Procedure been Validated Against Historical Data?
  - Verified to Perform Well Against Dataset with Similar Features?
  - Assumptions of the Model Plausible Given What is Known About the Process Generating this Data?

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Model Selection Criteria

- **Criterion 4**: ***Cost/Benefit Considerations***
  - Can Analysis be Performed Using Widely Available Software?
  - Analyst Time vs. Computer Time?
  - How Difficult to Describe to Junior Staff, Senior Management, Regulators, Auditors, etc.?

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Model Reasonability Checks

- **Criterion 5**: ***Coefficient of Variation by Year***
  - Should be Largest for Oldest (Earliest) Year
- **Criterion 6**: ***Standard Error by Year***
  - Should be Smallest for Oldest (Earliest) Year (on a Dollar Scale)

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Model Reasonability Checks

- **Criterion 7**: ***Overall Coefficient of Variation***
  - Should be Smaller for All Years Combined than any Individual Year
- **Criterion 8**: ***Overall Standard Error***
  - Should be Larger for All Years Combined than any Individual Year

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Model Reasonability Checks

Accident Yr	Mean	Standard Error	Coeffient of Variation
1996	26,416	37,927	143.6%
1997	26,216	38,774	147.9%
1998	50,890	54,508	107.1%
1999	90,705	74,824	82.5%
2000	148,110	99,986	67.5%
2001	186,832	117,230	62.7%
2002	418,461	183,841	43.9%
2003	638,082	268,578	42.1%
2004	607,107	477,760	78.7%
2005	1,521,202	1,017,129	66.9%
Total	3,714,020	1,299,184	35.0%

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Model Reasonability Checks

Accident Yr	Mean	Standard Error	Coeffient of Variation
1996	25,913	37,956	146.5%
1997	25,708	38,846	151.1%
1998	50,043	54,780	109.5%
1999	89,071	74,987	84.2%
2000	145,388	100,373	69.0%
2001	183,864	118,502	64.5%
2002	411,367	185,211	45.0%
2003	628,347	271,722	43.2%
2004	1,113,073	229,923	20.7%
2005	1,263,550	253,596	20.1%
Total	3,936,326	599,048	15.2%

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Model Reasonability Checks

- **Criterion 9**: ***Correlated Standard Error & Coefficient of Variation***
  - Should Both be Smaller for All LOBs Combined than the Sum of Individual LOBs
- **Criterion 10**: ***Reasonability of Model Parameters and Development Patterns***
  - Is Loss Development Pattern Implied by Model Reasonable?

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Model Reasonability Checks

- **Criterion 11**: ***Consistency of Simulated Data with Actual Data***
  - Can you Distinguish Simulated Data from Real Data?
- **Criterion 12**: ***Model Completeness and Consistency***
  - Is it Possible Other Data Elements or Knowledge Could be Integrated for a More Accurate Prediction?

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Goodness-of-Fit & Prediction Errors

- **Criterion 13**: ***Validity of Link Ratios***
  - Link Ratios are a Form of Regression and Can be Tested Statistically
- **Criterion 14**: ***Standardization of Residuals***
  - Standardized Residuals Should be Checked for Normality, Outliers, Heteroscedasticity, etc.

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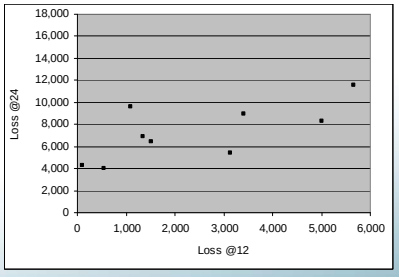
Goodness-of-Fit & Prediction Errors



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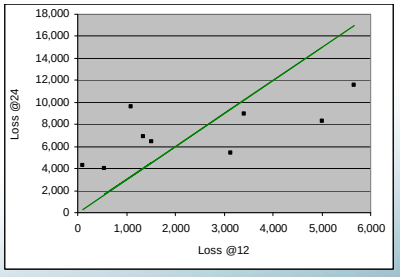
Goodness-of-Fit & Prediction Errors



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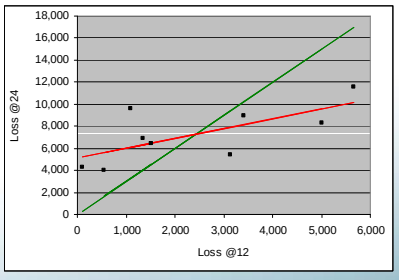
Goodness-of-Fit & Prediction Errors



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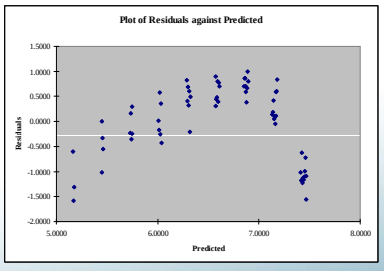
Standardized Residuals



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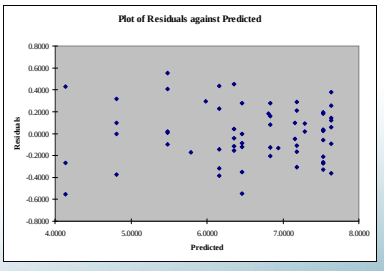

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Goodness-of-Fit & Prediction Errors

- **Criterion 15**: ***Analysis of Residual Patterns***
  - Check Against Accident, Development and Calendar Periods
- **Criterion 16**: ***Prediction Error and Out-of-Sample Data***
  - Test the Accuracy of Predictions on Data that was Not Used to Fit the Model

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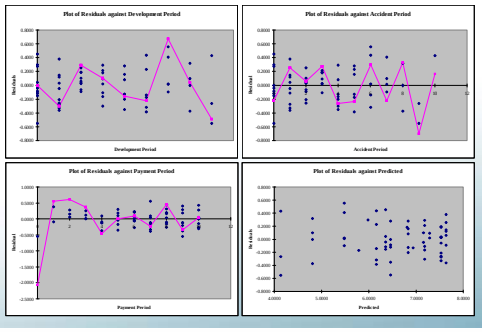
Standardized Residuals



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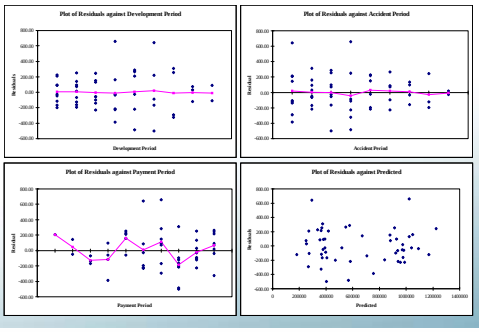

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Goodness-of-Fit & Prediction Errors

- **Criterion 17**: ***Goodness-of-Fit Measures***
  - Quantitative Measures that Enable One to Find Optimal Tradeoff Between Minimizing Model Bias and Predictive Variance
    - Adjusted Sum of Squared Errors (SSE)
    - Akaike Information Criterion (AIC)
    - Bayesian Information Criterion (BIC)

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Goodness-of-Fit & Prediction Errors

- **Criterion 18**: ***Ockham's Razor and the Principle of Parsimony***
  - All Else Being Equal, the Simpler Model is Preferable
- **Criterion 19**: ***Model Validation***
  - Systematically Remove Last Several Diagonals and Make Same Forecast of Ultimate Values Without the Excluded Data

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Questions?

Milliman, Inc.
18119 Bent Ridge Drive
Wildwood, MO 63038 USA
Tel. + 1 636 273 6428
Fax + 1 636 273 4711

Mark R. Shapland, FCAS, ASA, MAAA
mark.shapland@milliman.com

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