Deferred Annuity Liability Compression Methods

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Cell compression terminology and example

Cell - An inforce model data point.

Seriatim - A set of cells without grouping, categorization, or remapping. One cell = one policy.

Grouping - A set of inforce data aggregated across certain elements defined by an algorithm. One cell has ≥1 policies.

Categorization - A process by which data elements are systematically and deliberately summarized to prepare for compression. Ex: Summarizing Issue Month into Issue Quarter.

Remapping - A data summarization technique whereby data elements are possibly altered. Ex: Products {A, B, C} are remapped to {A, C, C}.

Compression - Grouping process by which policies with similar characteristics are aggregated together, generally for actuarial modeling. Compression involves grouping, categorization, and/or remapping. A compression is done to reduce model runtime by reducing model points via similar groupings. A compression is defined by rules, formal or not.

Compression Bias - Model error due to inappropriate or excessive categorization or remapping. Ex: creates an unintentional *benefit of aggregation* which reduces model accuracy. Compression bias could overstate or understate results and may be nonlinear.

Compression Ratio - Average number of policies found in a cell. Higher compression ratio leads to model efficiency, at the possible cost of introducing compression bias. Ex: Depending on purpose a VA model could have a compression ratio between 10:1 and 2000:1.

Multiplier Effect - For each additional grouping selection utilized, this multiples the cell count by the number of elements in the group. Ex: if a model compresses policy to nearest issue year, and it is now desired to compress to nearest issue month, there will be 12 times as many cells. (This example assumes independence of variables.)

Cell compression example

Seriatim Data

Policy Number	Product Type	Issue Month	Issue Year	NAR Ratio	AV
10000001	Victory	4	2005	113%	100,000
10000002	Pinnacle	5	2005	108%	50,000
10000003	Victory	6	2005	98%	75,000

Categorized Inforce Data

Policy Number	Product Type	Issue Quarter	Issue Year	NAR Band	AV
10000001	Victory	2	2005	1.05-1.15	100,000
10000002	Pinnacle	2	2005	1.05-1.15	50,000
10000003	Victory	2	2005	0.95-1.05	75,000

Categorized and Remapped Inforce Data

Policy Number	Product Group	Issue Quarter	Issue Year	NAR Band Midpoint	AV
10000001	Victory	2	2005	1.05-1.15	100,000
10000002	Victory	2	2005	1.05-1.15	50,000
10000003	Victory	2	2005	0.95-1.05	75,000

Compressed Inforce Data

Policy Count	Product Group	Issue Quarter	Issue Year	NAR Band Midpoint	Sum of AV
2	Victory	2	2005	1.05-1.15	150,000
1	Victory	2	2005	0.95-1.05	75,000

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Why is understanding compression methods important?

Understand how and where to review models

The compression process can be a source of error and/or efficiency in a model.

Ex: What products are grouped together for compression purposes? Is the grouping appropriate for the product features?

Understand model attribution analysis

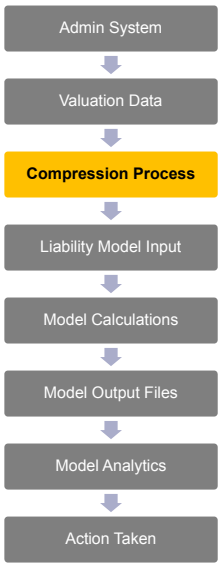
Changes in compression should be separately attributed when changing, refining, or updating models. Is it?

Ex: How do you attribute changes in your compressions? Do you test appropriate alternatives?

Evaluate compression bias

It's helpful to be aware of the consolidation process to understand how it works to understand how the actuarial liabilities are reported.

Ex: Have you recently evaluated the impact of compression on modeled results?



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Basic compression features

How are the compression calculations typically done?
- Excel via pivot tables, or
- In admin system directly via a subroutine, or
- In an Access or Oracle database

Simple variable annuity compression example
- SELECT FROM Current Month Valuation Data
- GROUP BY Issue Year, Net Amount at Risk (NAR) Band, Benefit Type, Attained Age Group
- SUM Policy Count, Policy AV, Gross Remaining Benefit (GRB), NAR$
- AVERAGE Attained Age $_{\text{Weighted by AV}}$

Grouping vs. Calculation Elements
- Grouping. In this example they are Issue Year, NAR Band, Benefit Type, Attained Age Group
- Calculation. In this example they are Policy Count, Policy AV, GRB, NAR$ and Attained Age

Two ways to reduce model points
- First, use a simple "Group By" function. This reduces seriatim to a compression level with very little compression bias
- Second, introduce remapping. This changes the values of the grouping elements, and *begins to introduce compression bias.*

Basic compression features, continued

Is every policy uniquely assigned to a single cell?
- In simple compressions, yes
- Policy division may be required or desired
  - Depends on modeling purpose
  - Depends on product features
- Ex: fund regression calculations

Incremental evolution vs. generational
There may not be a formal process to adjust the compression. It could be done ad hoc, in reaction to a new product or modeling feature. It may be done only after something seriously breaks.

Compression Validations
- At minimum confirm the control totals for key calculation fields match before and after the compression process
- May indicate incorrect valuation data or erroneous calculations
- Possibly add filtering elements, ex: select only policies with AV > 0
- We'll discuss this in more depth later in the presentation

Top Level Adjustment
- Occasionally implemented as a way to overcome previously identified and quantified compression bias
- May be a linear adjustment to fix a non-linear issue
- Need to make sure the top-level adjustments are validated, documented, and refreshed appropriately

Basic compression features, example

Types of data elements
- Modeled – used in the compression process and required by the calculation model
- Filtered – used in the compression process but not required by the calculation model

By crossing modeled/filtered classification of elements with the grouping/calculation, we can create a simple grid where every element is accounted for:
- We listed nine elements in our simple VA example.
- All data elements are accounted for below:

	Calculation	Grouping
Modeled	Account Value Policy Count Attained Age Gross Remaining Benefit	Issue Year Benefit Type
Filtered	Net Amount at Risk $	Net Amount at Risk Band Attained Age Group

Control total validations

Separate Validations for Calculation Elements and Grouping Elements
- For calculation elements, review the control totals before and after compression
- For grouping elements, review the distribution totals before and after groupings and/or remapping

Validation of Calculation Elements
The element summary statistic (sum, count, weighted average) is the same before and after compression.

	Operation	Seriatim Value	Compressed Value
Account Value	Sum	1,000,000,000	1,000,000,000
Policy Count	Sum	15,000	15,000
Attained Age	WA on AV	63.45	63.45
GRB	Sum	1,200,000,000	1,200,000,000
NAR ($)	Sum	300,000,000	300,000,000
Cell Count	Count	15,000	3,000

Validation of Grouping Elements – Without Remapping
Note the total and categorical distribution of AV by Attained Age Category is the same before and after compression.

Attained Age	Seriatim Value	Compressed Value
00-39	50,000,000	50,000,000
40-49	90,000,000	90,000,000
50-59	200,000,000	200,000,000
60-69	350,000,000	350,000,000
70-79	250,000,000	250,000,000
80-89	50,000,000	50,000,000
90+	10,000,000	10,000,000
Total	1,000,000,000	1,000,000,000

Control total validations, continued

Validation of Grouping Elements – With Remapping
In this example a contract has a 10-year CDSC period. The account value for issue years 10+ is compressed into the 2001 model year.

Issue Year	Seriatim Value	Compressed Value
1998	30,000,000	0
1999	30,000,000	0
2000	30,000,000	0
2001	50,000,000	140,000,000
2002	80,000,000	80,000,000
2003	150,000,000	150,000,000
2004	120,000,000	120,000,000
2005	120,000,000	120,000,000
2006	120,000,000	120,000,000
2007	120,000,000	120,000,000
2008	100,000,000	100,000,000
2009	40,000,000	40,000,000
2010	10,000,000	10,000,000
Total	1,000,000,000	1,000,000,000

If the model used the Valuation Date, Issue Year, and Issue Age to determine Attained Age, then this remapping would be inappropriate because the attained age would be understated for contracts beyond the CDSC period.

Compression tradeoffs and externalities

Reasons for More Compression

- Appropriate for high policyholder optionality
- Increased model accuracy in key scenarios
- Trace model results to policyholder cell drivers

More compression

More model points

Reasons for Less Compression

- Reduces model runtime; allows for more scenarios or faster results
- Control over infrastructure costs: hardware vs. software investment tradeoff
- May be required by model software or hardware constraints

Externalities

Incorrect valuation data

Model calculation bias

Scenario selection bias

Analysis bias

Failure to understand or take appropriate action based on model results

Illustrative effect of compression on model results

Situation

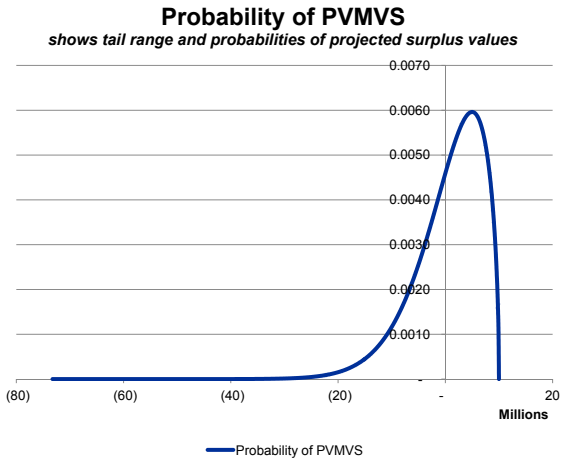
You have a generic asset adequacy analysis model, designed to calculate the present value market value of surplus (PVMVS).

Product and Risks

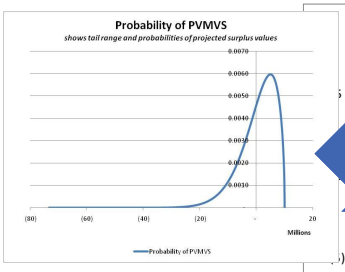
For illustrative purposes, the product and risks are not very important, just important that there is a distribution.

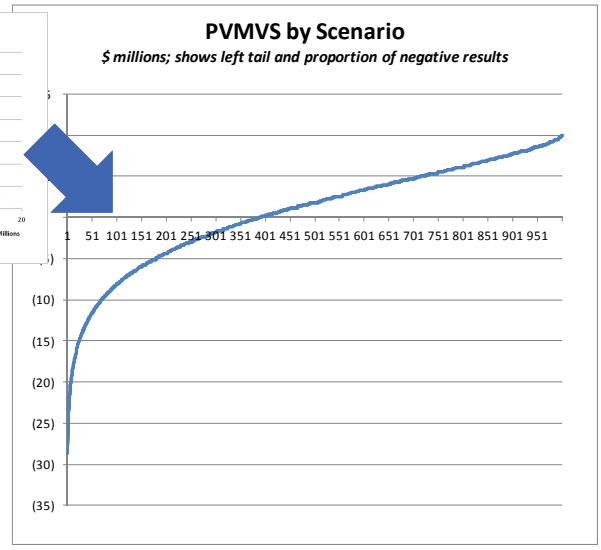
There is a positive expected value, an upper limit limited by premium collected; and a long left tail due to insured risks.

This illustrates the seriatim run.



Translating the probability distribution to scenario results





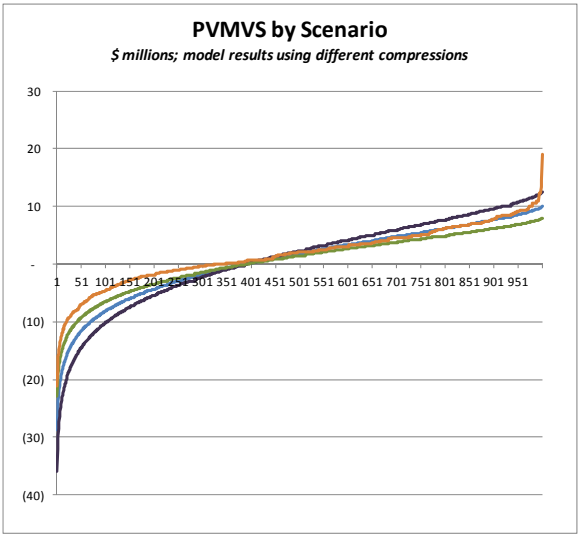
Scenario Results

The scenario results are ranked and displayed from smallest to largest PVMVS.

How do you know when a compression is good? Or good enough?

Which of these compressions is the best one?

Are any adequate for the modeling purpose?



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Evaluating a compression quantitatively

The baseline run is seriatim. Note the increasing pattern of compression bias:

(in $ millions)

CTE Value	Baseline	Compression A	Compression B	Compression C
50	(4.0)	(3.9)	(3.8)	(3.6)
65	(6.0)	(5.9)	(5.7)	(5.4)
70	(7.0)	(6.9)	(6.7)	(6.3)
80	(9.0)	(8.8)	(8.6)	(8.1)
90	(13.0)	(12.7)	(12.4)	(11.7)
Cell Count	**15,000**	**8,000**	**4,000**	**1,000**

Measuring compression bias (as a percent of the baseline):

CTE Value	Baseline	Compression A	Compression B	Compression C
50		-1.0%	-3.2%	-6.2%
65		-1.3%	-3.9%	-7.4%
70		-1.8%	-4.2%	-8.7%
80		-2.0%	-4.8%	-9.5%
90		-2.1%	-5.1%	-10.3%
Cell Count	**15,000**	**8,000**	**4,000**	**1,000**

In practice you may not have the information conveniently available to make this tradeoff decision.

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Compression requirements and recommended practice

C3 Phase II Practice Note – 9/2006

Q4.2 What granularity of models is usually appropriate?
A: For large blocks of business, the actuary may choose to employ grouping methods to in-force seriatim data in order to improve model run times. The actuary normally uses enough model points that the VA RBC result would not materially change with additional model points (model cells). Grouping methods usually retain the characteristics required to model all material risks and options embedded in the liabilities. The actuary may wish to consider describing the degree of granularity chosen in the supporting memorandum.

VACARVM Practice Note – 7/2009

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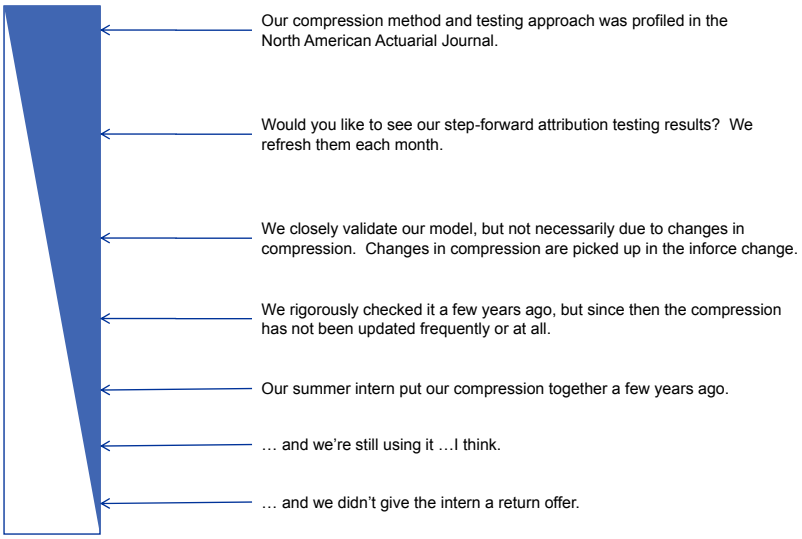
Results

Compression is very much a judgment call. Disclosure of the high level method is required, but disclosure of the testing approach is not required.

Comfort level

How have you validated your inforce compression?



Compression testing and other validation methods

Full seriatim categorization test
The most comprehensive method is to run each cell through the model individually. This method is the AG43 Standard Scenario test. This involves categorization, but not necessarily grouping or remapping. If this is possible, it's generally the best validation method.

Often this test is impossible, impractical, or undesirable:
- Many projection models have an effective upper limit on number of model cells.
- The calculation could take too long or generate too much output to store.
- Aggregate or dynamic modeling features may not work correctly; ex: reinsurance treaty modeling.

Should additionally test impact of grouping, then of remapping.

Point validations
A good substitute for a full seriatim categorization test is to chose a subset of cells or scenarios.
- Can run single cells as a categorization, or choose cells with one policy.
- Desirable to run several calibration scenarios of same cell.
- Desirable to run several cells through same scenario.
- Develop a fixed set of "test cells" which test common and extreme values.

An alternative approach is to run all cells through a subset of scenarios
- This subset should adequately model the tail and also the shape of the entire distribution

Static & dynamic validation
- This should be designed to reveal model biases, independent of the compression used.

Compression testing and validation methods, continued

Improve Until Good Enough
Test different compressions until the refinements don't result in any material output changes.
- Depends on definition of materiality.
- Must be sure to test "non local" solutions.

Remember, you may observe model biases independent of the compression.

When the behavior regime changes, do your bands?
Suppose in 2006 a company banded NAR ratio by the following groups:
{0-0.5, 0.5 – 0.8, 0.8 – 0.9, 0.9 – 1, 1-1.15, 1.15 – 1.25, 1.25+}

Then after the financial crisis the policyholders average NAR ratio increases to 1.2. The model must have redefined bands to account for new expectations of tail behavior.

Modeling the tail
The tail can refer to the model output tail – the worst scenarios by the key measures – or those cells which result in the worst model output. Reviewing tail values is important to understand what compression results trigger extreme behavior; then can calibrate your bands.

Scoring methods
May have a predefined evaluative criteria to select among different compressions.
Evaluations should be independent of model results.
May consider cell count; some sort of intraband measures.

Advanced compression features

Version control features
- Compression owner will track changes to the compression calculations
- Adds capability to reproduce prior compression results
- Log all the elements used, the qualitative method (sum, WA on AV, etc) and remapping rules

Default categorization feature
- Runs each policy into one cell without grouping but with remapping
- Facilitates compression validation and single-cell testing

Cell IDs with traceable inputs
- In simple compressions, it may be difficult or impossible to tell exactly which policies compose a cell
- This becomes more difficult if policies are subdivided across several cells
- An advanced compression will 'tag' each policy with an compression cell ID

Nonlinear banding / clustering
- Example of a linear banding: issue quarter
- What happens if 75% of your business was sold in 2Q and you require monthly projections?
- Might make sense to redefine issue date bands as: {1Q, April, May, June, 3Q, 4Q}

- Greatest granularity for bands with highest risk or modeling interest
- Helps better identify and model policyholder behavior in the tail

Advanced compression features, continued

Multi-stage compressions
- May apply different grouping and calculation rules sequentially
- Goal is to reduce the number of cells with few cell points
- *Generally model runtime is a function of cell count, not compression ratio*

Behavior review / prediction analysis
- Advanced compression technique where prior policyholder behavior is used to categorize
- Ex: Has the policyholder taken irregular partial withdrawals in past few years?
- Ex: Is this policy a lapse risk by some predefined criteria?

Asset compression methods
- Not widely used, yet.
- Asset call and prepayment schedules are generally unique and significantly influence market values.
- Asset diversity is generally greater than liability diversity for a given block.
- Simplistic asset compression may be appropriate if low invested asset balances, such as term life.
- Would not be appropriate for spread based insurance products.

Sampling Methods and Advanced Modeling Techniques
- An emerging actuarial practice

Compression best practices

- Compression algorithm is clearly documented and change history is maintained.
- Compression is validated by:
  - Control totals
  - Distribution checks for grouped elements
  - Distribution checks for remapped elements
- Changes to compression are appropriately tested using one or more of the following methods:
  - Seriatim categorization
  - Test cells
  - Test scenarios
  - Attribution tested on model results
- Static and dynamic validations are performed
- Tail scenarios are reviewed to understand sources/drivers
- Sources of compression bias on model results are understood, monitored, and adjusted if appropriate
- The degree of granularity and choices for grouping are supported by appropriateness testing, refreshed periodically.