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Model Risk Management: An Overview

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By Michele Bourdeau

The Modeling Platform

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Publication Schedule
Publication Month: April 2017
Articles Due: Jan. 24, 2017

Letter from the Editor

By Phil Schechter

We are up to our fourth newsletter and find our attention fairly evenly split between model governance, model efficiency and the nuts and bolts of the actual models.

Trevor Howes, in his final note as council chair, discusses modeling and professionalism, comparing the emerging standards in the United States and Canada.

Michele Bourdeau lays out a structural framework for model risk management, starting from the beginning (what is a model and how is it used?) through three lines of defense within an insurance organization.

Mary Pat Campbell gives an overview of the sessions sponsored by our section at the 2016 Life & Annuity Symposium. These sessions dealt with model governance, model risk management and model efficiency—a topic that merited two sessions.

Model efficiency continues to occupy our thoughts, as Bob Crompton suggests a practical method to implementing a cluster model approach independent of modeling platform.

Linda Chow, Jillian McCoy and Kevin Kang are contributing a serialized article on long-term care; the first installment appears in this issue. As an editor, I am pleased to have articles pledged in advance, and, as a section member, I appreciate the deep dive into this topic.

I penned an article on some of the basics of asset modeling—even if you never need to open up that side of the model, a good understanding of both sides of the balance sheet can help make sense of an integrated asset-liability management model.

And my co-editor, Tim Cardinal, takes a cold, hard look at the VM-20 scenarios and their impact on reserve requirements.

With the new council comes some reorganization of the roles; Tim, who was instrumental in getting this newsletter off the ground, is leaving the masthead, to be replaced by Mary Pat Campbell, who has already been deeply involved as an author and an editor.

We look to continue expanding our list of authors—a reminder that if you've worked on something full-time for a few months, you most probably have some insights that would help others. I encourage you to share. ■

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Chairperson's Corner

Modeling Professionalism, or Aren't We Modeling Pros Yet?

By Trevor Howes

Two remarkably similar events impacting the North American actuarial profession occurred this past summer: the twin Actuarial Standards Boards (ASBs) serving the Canadian and United States professions both released revised exposure drafts of intended guidance relating specifically to modeling (or *modelling*, as we Canadians prefer to spell it).

Let's start with the most fundamental and significant similarity: Both standards boards are treating the use and reliance on models as worthy of explicit guidance for professionals and, in particular, offer guidance on understanding, mitigating and communicating how model risk impacts the quality of their work. Despite some resistance in both national communities to yet more guidance (threats of discipline? unnecessary work of no benefit?), both ASBs insist this guidance is needed and persist with repeated drafts to get it right. There are a number of interesting aspects to these developments beyond their notable similarities and differences in approach and style.

This work has been in progress for a while. Canadians started in 2011 with a notice of intent leading now to a second exposure draft, while the American body started work a year earlier and now offer a third exposure draft. The Brits finalized their professional guidance on this topic in April 2010, about the time we were just getting going.

Why the delay in North America?

A lot of the discussion and debate may be driven by conflicting interpretations and usages of the word "model." For example, models to many actuaries mean software. This then implies the ASBs are trying to regulate the creation and use of software, including third-party modeling tools and simple spreadsheets.

This focus on software as a modeling tool leads to a discussion of whether simple programs or spreadsheets performing simple calculations, often reflecting a standard "method," should require this much professional effort and mandated compliance.

The teams drafting these new standards want them to apply to actuaries of all kinds doing actuarial work that might be quite different in nature; the fundamental principles being applied are sound and useful guidance. Getting the right wording that communicates clearly to this wider audience is not an easy task.

The latest drafts in both countries clearly reflect these concerns, both in modified guidance wording and in the accompanying comments by the issuing bodies. The U.S. exposure draft now explicitly defines a "simple model" and excludes it from the scope of the standard. The Canadian draft similarly states that "some models are so simple or otherwise have such low model risk that the actuary is able to exercise appropriate diligence without formal documentation or reporting."[1]

The drafts in both cases repeatedly use phrases such as "heavily relied on," "material financial effect" and "professional judgment" to qualify the application of prescriptive guidance and emphasize the proportionality concept that requires effort and benefit to be aligned.

When should guidance for professional practice resort to such painstaking efforts to justify itself? Some objectors in both countries have pointed to the overarching rules of conduct that require the actuary to use professional skill, care and judgment, and to consider the practical benefit in relation to the additional documentation and disclosure that new standards are feared to be mandating.

As a life insurance actuary, I agree with the overall need for more detailed and explicit guidance on the use of models and specifically with the need for appropriate care and diligence in the maintenance and use of our increasingly complex software tools, which can mitigate model risk that may arise from errors in the implementation and operation of modeling tools.

However, I hope actuaries from all practice areas reading and reacting to these new standards take note of the care taken in defining models and their essential characteristics. Models are "simplified representation of relationships among real world variables, entities or events" used "to help explain a system, to study the effects of different parts of a system, and to derive estimates and guide decisions."[2] Models always have a conceptual component as well as an operational, calculation-driven aspect.

Model risk is "the risk of adverse consequences resulting from reliance on a model that does not adequately represent that which is being modeled or that is misused or misinterpreted."[3] Thus calculation errors arising from the ongoing maintenance of a model or the selection and definition of model data, assumptions and parameters are only part of the concern. Equally important is the consideration and validation of the underlying simplification of reality inherent in the model, and whether any limitations of the model from that simplification, by design or by errors in implementation and operation, have inappropriately impacted the ultimate work product of the actuary.

If actuaries remember this fundamental goal of understanding and mitigating the model risk and apply reasonable judgment in considering the significance and materiality of the models used to those who are relying on their work, the semantic differences and practice-specific interpretations of the standards cease to be roadblocks. We can then move on to adopting and applying this new guidance in a reasoned proportionate manner to improve the quality of our work as modeling professionals.

By the time this column is published, I expect to have passed the gavel as chair of the Modeling Section to Bruce Rosner, and hopefully he will be writing this column in the next newsletter. I am remaining on council for the rest of my term and look forward to working with Bruce as he leads the section forward.

Trevor Howes, FSA, FCIA, MAAA, is vice president and actuary at GGY AXIS in Toronto. He can be reached at *Trevor.Howes@ggy.com*.

ENDNOTES

1 Canadian Institute of Actuaries, Second Exposure Draft for Standards of Practice—Use of Models, Section 1535.03, July 2014.

2 Actuarial Standards Board, Third Exposure Draft of the Proposed Actuarial Standard of Practice on Modeling, Definition 2.7, June 2016.

3 *Ibid*., Definition 2.9.

Model Risk Management: An Overview

By Michele Bourdeau

Model risk management (MRM) has become an area of increased focus in recent years for banks, both from a good risk management practice perspective and because of enhanced regulatory guidelines and scrutiny. Insurance companies are slowly catching up, as their models and businesses have become gradually more complex. In addition, regulatory pressure is driving insurers to reconsider and enhance their processes around the use of models. Examples of models used for supporting the decision-making process include asset liability management (ALM), stress testing, investments pricing, planning and capital adequacy models.

This article gives an introduction to model risk and sound model risk management processes and controls. It starts with providing a definition of a model and what models are used for. It goes on to describe the various sources of model risk and why one should be concerned. The controls appropriate around the use of models—the model risk governance process—are then detailed.

WHAT IS A MODEL AND WHAT ARE MODELS USED FOR?

What models should be considered for a robust model risk management process? Let's start with a definition of a model. According to U.S. federal bank regulators,[1,2] a model is "a quantitative method, system or approach that applies statistical, economic, financial or mathematical theories, techniques and assumptions to process input data into quantitative estimates."

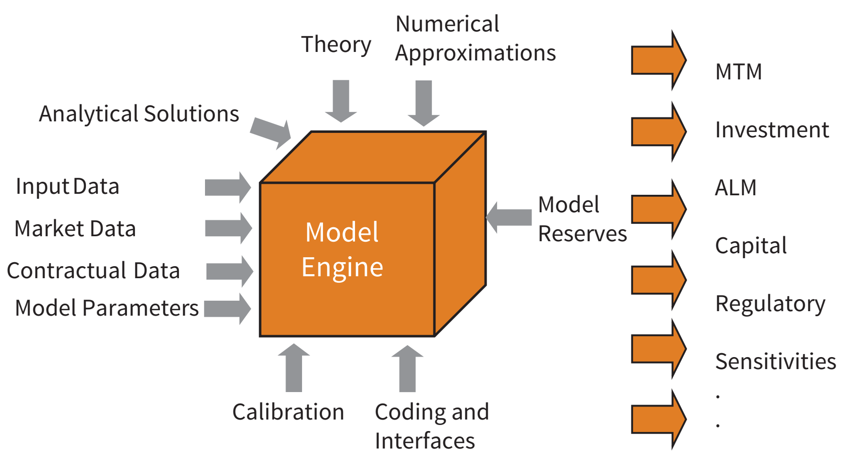
A model has three components: model inputs that include the assumptions and data that go into a model, a processing component that transforms inputs into estimates, and model outputs that transform estimates into useful business information, including any reporting component.

Model inputs include data that itself may originate from another model, and model parameters, such as volatility or interest rates. The processing component includes the model design and theoretical assumptions behind it, analytical or numerical methods and approximations used, the coding and interfaces, and the calibration of the model. Examples of model outputs can be a mark-to-market (MTM) value, a capital calculation, the price of a bond (for an investment decision), and sensitivities and stress-testing analysis results. Reports based on model outputs are used for informing decisions based on the model.

Figure 1 can help to visualize a model.

Models may be used for informing business decisions, measuring risks, valuing exposures (MTM), conducting stress testing, measuring compliance with internal limits, assessing adequacy of capital (ALM), managing client assets, meeting financial or regulatory reporting requirements and issuing public disclosures. Models are used in many areas of an organization, such as finance, securities or assets pricing, risk management, actuarial, asset or investment management, and for the management of client's assets.

Figure 1
What Is a Model?



A good model is a trade-off between replicating the business or market exactly and over modeling. Models should be developed such that they capture the most important aspects of a particular business. Models should be easy to calibrate and use. Models may need to be fast to operate if used for rapid decision-making. Model results should be easy to interpret and understandable by every user through model reports.

WHAT IS MODEL RISK, WHAT ARE ITS SOURCES AND WHY SHOULD WE BE WORRIED?

All three components of a model (input, engine and output) can be sources of model risk. Examples that lead to model risk can be errors in model methodology, errors in model implementation, models not used for their intended purpose, model outputs being misinterpreted, model errors feeding into downstream systems, obsolete models, new complex products for which the model risks are not understood and models used in illiquid markets.

In addition, there could be a breakdown in the model control culture and processes.

Model risk is the loss resulting from misspecified, misapplied or wrongly implemented models. One could argue that all models are wrong by design because they are simplifications of reality. Model risk could arise from incorrect estimates of risks, leading to incorrect business and management decisions. Model risk could also give rise to reputational risk.

MODEL RISK GOVERNANCE

Model risk management should be approached as a multidisciplinary subject, and the responsibilities and standards for the three lines of defense need to be clearly defined and established, usually through a model risk management policy and standard operation procedures. The three lines of defense normally consist of the first line of defense or the line of business (LOB) model owners, the second line or risk management (including model risk management) and the third line or internal audit. Good communication between all relevant parties is essential. It is also essential to ensure a robust model control framework with clear audit trails evidencing all aspects of the framework. In practice, controlling model risks involves a trade-off between the level of model risk and the necessary costs of controlling the risk.

Models are subject to a model lifecycle that entails:

- All models are captured in a model inventory.
- All models are documented in detail, including their design, assumptions, limitations and the testing performed.
- Models can be tiered and the controls prioritized according to their perceived inherent risk.
- Models should be regularly subject to testing and validation (review by the LOB and/or independent validation).
- Model controls, including information technology controls, should be in place.
- Change management processes should be defined for material model changes.
- Ongoing performance monitoring of the outputs should be established.

Audit has responsibility for due diligence around these processes.

Line of Business

The first line of defense responsibilities is the line of business.

Model Development and Testing

LOBs are responsible for model development. As such, they need to define the model's purpose, develop the model's design (including the assumptions that go into the model and the model's methodology, including analytical, numerical or other tools used), write the code and/or customize a third-party vendor model. The LOBs need to implement the model, covering model inputs, coding and outputs, and make sure all components of the model work and interact smoothly and correctly with each other. The model then needs to be calibrated and tested to make sure it works as expected. This can cover sensitivity analysis, benchmarking to other models and stress testing. All aspects of the model also need to be documented and business continuity provisions put into place.

Model Documentation

Documentation of the design and operational details of the model is required to ensure business continuity and transparency of models used. Granularity of documentation takes into account the level of management or key function at which it is intended to be used. Documentation should be sufficiently detailed and complete to enable a third party to form a sound judgment on the suitability of the model for the intended purpose. The theory, assumptions, methodologies, software and empirical bases should be explained, as well as the data used in developing and implementing the model. Relevant testing and ongoing performance testing need to be documented. Key model limitations and overrides need to be pointed out so that stakeholders understand the circumstances under which the model does not work effectively. End-user documentation should be provided and key reports using the model results described. Major changes to the model need to be shared in a timely manner and documented, and IT controls should be in place, such as a record of versions, change control and access to model. Third-party vendor documentation should be subject to similar requirements, with the understanding that the methodology may not be accessible and testing is performed using sensitivity and stress-testing analysis (inputs/outputs).

Change Management

The LOB needs to establish and document processes around model releases and model change management (as an example, regression testing when a model is being changed or released). The model documentation needs to be updated to reflect major changes. In addition, clear controls around access to input data and access to code/spreadsheet or vendor where model resides need to be established.

Ongoing Performance Monitoring

LOBs need to establish a process for ongoing testing and evaluation of the model performance to make sure the model continues to work in its current operating environment. Higher risk models and those used most frequently are expected to be tested more often. Models are also expected to evolve and improve with time.

Risk Management

The second line of defense responsibilities is risk management.

Model Risk Management Policy

The second line usually establishes, with input from the first and third lines, the MRM policy and the standard operating procedures for implementing the MRM framework. Roles and responsibilities around each component of the model lifecycle need to be clearly defined and articulated.

Independent Model Validation

Model validation is typically a second line of defense activity. It can, however, be performed by the first line with oversight from the second line (peer review). In fact, among the actuarial community, there is a strong culture of model peer review. The model controls currently in place are of varying strengths and would need to be formalized and expanded to satisfy enhanced regulatory and risk management requirements. Model validation serves as an independent check on the models and controls put in place by the first line. Validation and testing activities need to take place when the model is first developed, when any significant changes to the model are made, or when the operational environment changes; for example, if the model needs to be applied to a new business or product. Validation of a particular model should be updated on a periodic basis depending on the level of changes to the model or the environment in which it operates.

Validation activities should be prioritized. Models deemed to be more risky to the organization should ideally be tested and validated more often. Model riskiness can be defined based on the complexity (quantitative or operational) of the model, the reliance on the model outputs or the financial or reputational impact of a model error. Validation activities are primarily there to assess whether the model is fit for its intended purpose and whether the first line has performed its due diligence. As such, all components of the model need to be examined, including the assumptions, inputs, data quality used, implementation and model limitations. Validation activities will depend on the nature of the model but can include sensitivity and stress-testing analysis, individual cell testing, code or spreadsheet review, reimplementation using an alternate model or benchmarking to other models, and a review of the controls around the model. Third-party vendor models are expected to be subject to the same type of scrutiny, understanding that the exact methodology and implementation are not accessible to the user and that sensitivity analysis, stress testing and benchmarking are the preferred methods for assessing the model.

The validation should be documented in detail, particularly for the higher risk models. Documentation can include a summary of the model and its assumptions, a review and assessment of the testing performed by the first line, as well as additional testing performed by the second line and evaluations on other aspects of the model such as model limitations, overrides and model reports. An overall assessment of whether the model is fit for its purpose should be included in the report.

Independent validations can results in findings. These need to be confirmed and their materiality established with input from the LOBs and other stakeholders. Material findings would need to be addressed in a relatively short time. Remediation timelines need to be set. Remediation may include redeveloping parts of the model, addressing missing documentation and adding controls around model use; for example, limiting the model use in certain conditions.

Internal Audit

The third line of defense is internal audit.

Audit's Role

Audit is responsible for the oversight over all aspects of the model control process, including the model inventory, model testing and validation, change management, and the responses and timelines of the LOBs to findings resulting from the validation of the model. As part of their review of the first and second line, audit may perform targeted reviews of model inventory, testing, validation and controls.

SUMMARY

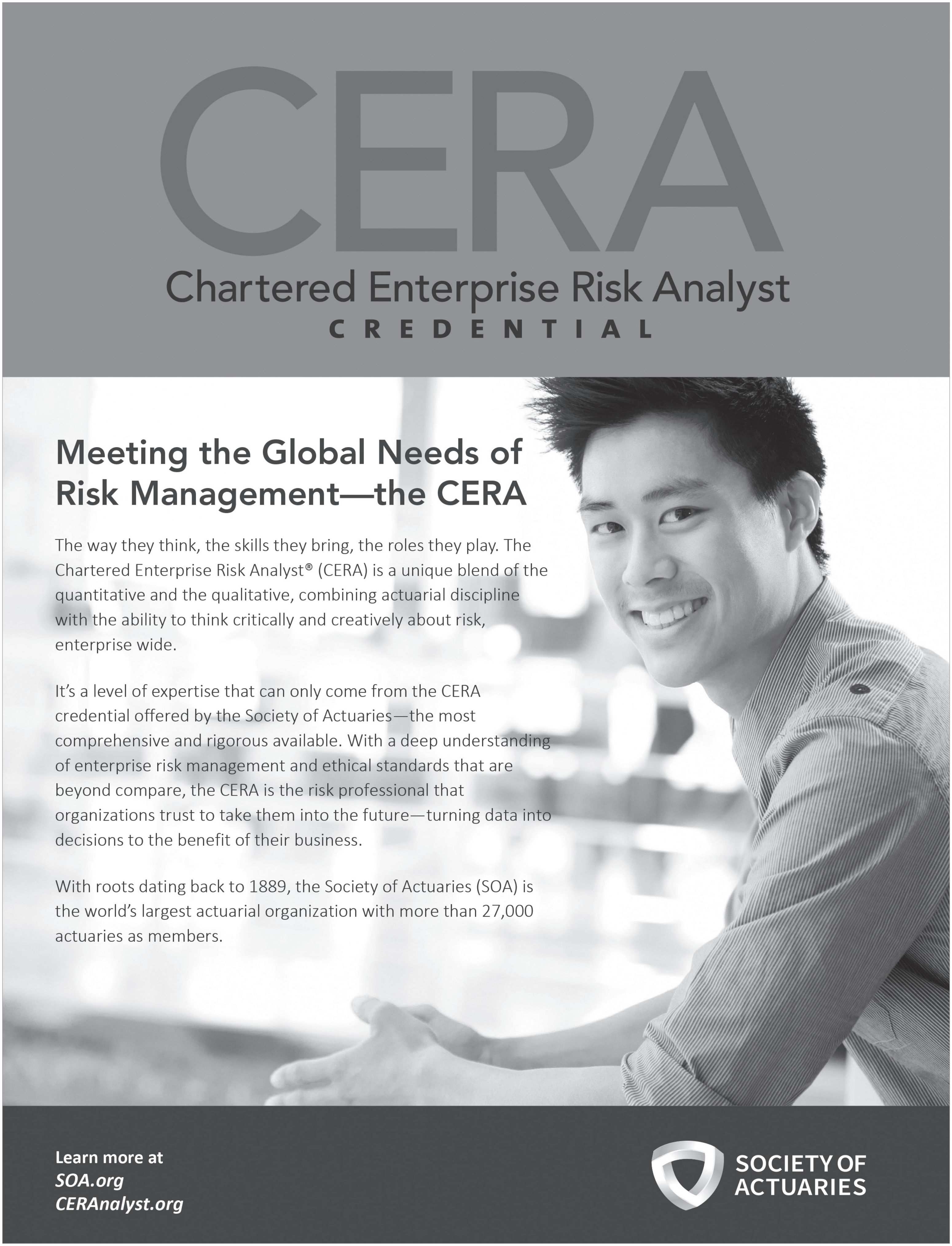
A robust model risk management framework is good practice. Roles and responsibilities need to be clearly established around the use of models. This article presents some guidance and foundations for developing an effective model risk framework. ■

Michele Bourdeau is a managing director and head of model risk management at TIAA, where she was hired to create and implement the model risk management function. She can be reached at *mbourdeau008@gmail.com.*

ENDNOTES

1 Board of Governors of the Federal Reserve System and Office of the Comptroller of the Currency, "Guidance on Model Risk Management," SR 11-7, April 4, 2011, *https://www.federalreserve.gov/bankinforeg/srletters/sr1107.htm.*

2 Ibid., "Supervisory Guidance on Model Risk Management," SR 11-7 attachment, April 4, 2011, *https://www.federalreserve.gov/bankinforeg/srletters/sr1107a1.pdf.*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Summary of Modeling Sessions at the 2016 Life & Annuity Symposium

By Mary Pat Campbell

At the 2016 Life & Annuity Symposium held in May in Nashville, the Modeling Section sponsored the following four sessions:

- Session 15: Model Governance
- Session 49: Model Risk Management
- Session 57: Model Efficiency, Part 1
- Session 70: Model Efficiency, Part 2

The four sessions ranged from idealized states of model management to the art of taking the ideals and transforming them into practical approaches. From best practices to getting it done rapidly, there was something for all actuaries, in all lines of business.

This article provides high-level summaries of these sessions, which have all been recorded. You can get recordings of the audio, synchronized with the slide presentations, at the archived event page: *https://www.soa.org/Professional-Development/Event-Calendar/2016/las/Agenda-Day-2.aspx*.

SOA members can order these recordings for free; nonmembers can purchase access for $299. In addition, everyone can download the slides in PDF format for free.

SESSION 15: MODEL GOVERNANCE

Model governance has received growing interest with the increasing importance of actuarial models in valuation, pricing and risk management. Moderator Jason Morton was joined by speakers Robert Stone and David Beasley in looking at model governance from the scope of the activities to the individual components to change management in the process.

Scope of Model Governance: Jason Morton, FSA, MAAA

Jason kicked off the session with the importance of model governance for actuarial work. We want results to be accurate, to be able to be relied upon for decision-making, and to be delivered in a timely fashion so that effective decisions can be made. He discussed some current leading practices to achieve those goals. Figure 1 explains what model governance involves.

Jason also explained that an update to an SOA survey on actuarial modeling controls was being conducted, driven by the need to get ready for principles-based reserving in life insurance in the United States. The survey was first conducted in 2012, and the new survey has most of the same questions as the previous one. There was a sneak peek of results at the Valuation Actuary Symposium in August 2016, and the completed survey statistics will be published later.

Components of Governance: Robert Stone, FSA, MAAA

Robert added another goal of model governance: that results from actuarial models become trusted by decision-makers. If the results aren't trusted, they won't be used to make decisions; sometimes the lack of trust comes from a lack of understanding of how the models operate and how to interpret results.

Robert's talk was broken up into three parts: the modeling environment, governance control and model industrialization. All of these pieces focused on the goal of having trusted model results. In each of the parts, he looked at a structure for understanding the components, and what elements need to be in place for successful model governance.

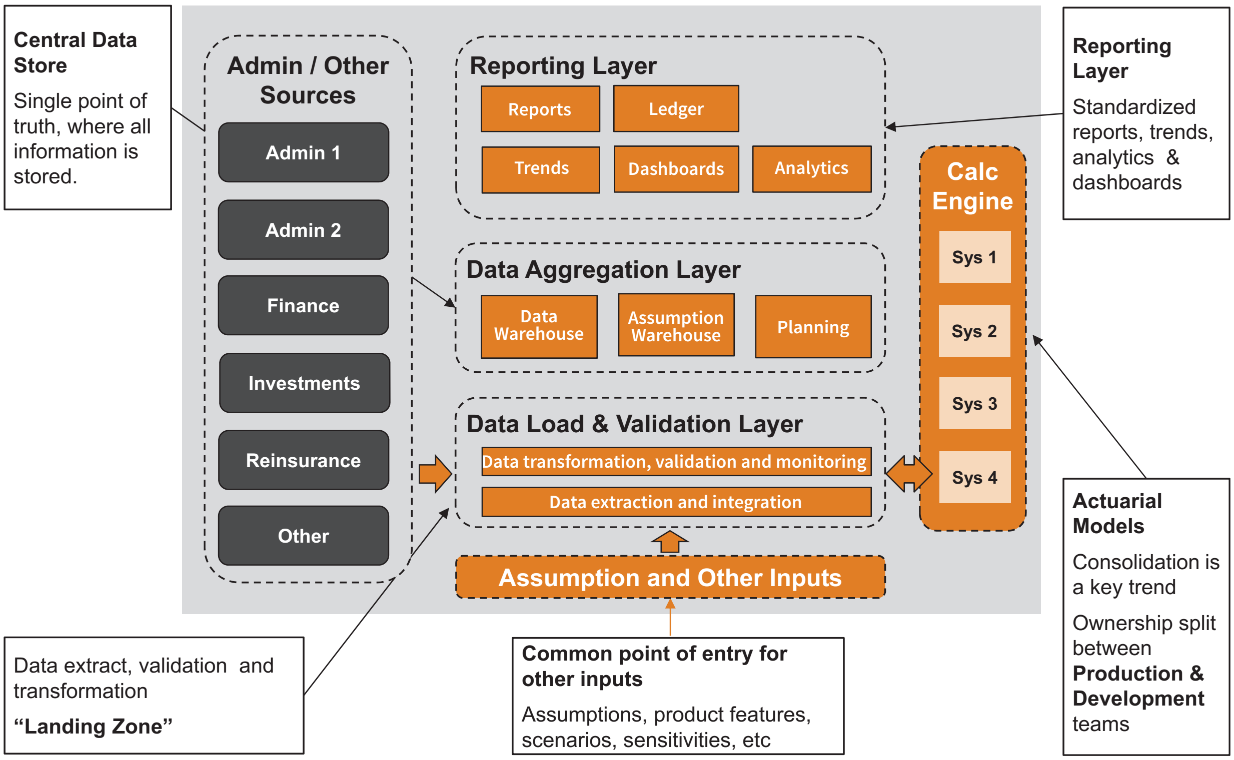
One key point made by Robert, beyond the need for building trust of model results, was the need for a model governance culture, and that the most difficult part of setting up a good structure is to get people to actually follow it. Robert talked about some of the practical issues of trying to get people to hew to a controlled environment in which models are both developed and executed. This involved some loss of personal control for the individual modeler but is key to the integrity of the model.

The last portion of the talk, model industrialization, was about having a complete, well-defined process, where you know the end-to-end flow from raw data to results, with as many steps as possible being automated. This is to create a mind-set that the "models are right," via testing to destruction, and presenting results with clear communication of drivers of those results. Much of the industrialization is reducing the amount of direct human "touch" on the whole process. Again, one key aspect is getting buy-in to this culture, and putting people in appropriate roles and structures.

Change Management: David Beasley, FSA, CERA, MAAA

David covered model governance in an overlapping manner with Jason and Robert, but reflecting his personal perspective and experience as a model owner for a large block of universal life with secondary guarantees. He came to the model ownership just after a large validation project had been completed; one focus was how he had to manage changes to the model. His talk focused on having to deal with practical constraints while making model changes and satisfying the needs of a variety of stakeholders.

Figure 1
Span of Model Governance: Typical Target State Architecture



David walked through the change management steps he used as part of annual planning when he was the model owner. His prioritization was to take care of errors first, then look at model control issues. The potential impact on key metrics also factored into the prioritization, to focus efforts on the most material issues.

When focusing on changes to be implemented, David looked at the effort to make the change in terms of hours of staff, the expected impact on model validation and the expected impact on a key metric. He also talked about the 11 testing techniques he used, where most of these were implemented in parallel for timely results. These 11 were a toolbox, where the specific tests would be chosen depending on the change being made. The key is to maximize efficiency in applying the tools. Model risk is partly managed through documentation of the changes, to provide enough information for the change management team to evaluate the change.

SESSION 49: MODEL RISK MANAGEMENT

Moderator Mark Mennemeyer kicked off this early morning session by noting the universality of interest in model risk management. Actuaries have many different functions (pricing, valuation, risk management, etc.) but almost all use models in some way. There were a few survey questions for the audience with regard to model risk management, showing that, indeed, pretty much everyone has dealt with models and model risks.

Motivations and Challenges: Mark Mennemeyer, FSA, MAAA

Mark provided his own definition of model risk: the possibility that inadequate modeling leads to adverse outcomes. There are many potential sources of such model risk: improper model design, incorrect model production, model misuse and poor communication of model results. There are both internal and external drivers toward implementing model risk management in your own work.

Mark covered some of the challenges to model risk management: complexity of the models and modeling process, increasing external and internal demands on reporting results (whether regular or ad hoc), corporation organizational issues in preventing a unified approach, inefficient modeling processes and lack of clarity or ownership in terms of model risk.

Model Validation Best Practices: Kristen Dyson, FSA, MAAA

In laying out the challenges in model risk management, Mark set the stage for the next portion of the session. Kristen Dyson spoke on best practices for model validation. She covered definitions of model validation, the importance of validating models to improve the model process and reliability of results, and the best practices approach to methodically validate models.

The best practices include developing a test plan, creating a baseline report before validation, categorizing findings while doing reviews of the model, and continued monitoring of models once the validation foundation has been laid down. For each of these steps, Kristen provided practical details.

She noted this thorough approach does take a great deal of time to set up and implement, but, once it has been established in enough detail, there is less effort in fixing problems going forward. The continued monitoring can be easy once the model validation baseline review has been done.

Case Study: Daron Yates, FSA, MAAA

While Kristen talked about best practices, Daron Yates explained Allianz's development of approaches and their own practical experiences within the United States. He started with the evolution of model risk management he has seen from the early 2000s to today. This covered not only actuarial-specific software and models but also spreadsheet standards.

> It can be difficult to get senior management and regulator buy-in for some of the techniques.

Daron talked specifically about getting models compliant with the Solvency II Directive, as Allianz is an EU-domiciled company. Pitfalls included a lack of resources, the need to greatly increase the amount of documentation and controls to a potentially onerous level, and to adjust a system set up for financial reporting to be workable for Solvency II. There was also the issue with regard to validation, and how much is too much—this takes a great deal of time to do.

Ultimately, the U.S. branch of Allianz got a reprieve—there is a temporary equivalence of U.S. standards to be used for reporting U.S. business under Solvency II. However, in many ways, this effort was good preparation for developments going on with U.S. regulations as well as international capital standards. Allianz created its own model risk and governance standard used within the organization. This section, showing the practical challenge of taking current business closer to best practices, gives an idea of the challenges and opportunities actuaries have with these pressures.

SESSION 57: MODEL EFFICIENCY, PART 1

Two back-to-back sessions were devoted to model efficiency, looking at it through different lenses, culminating in a full-bore case study showing the power of modeling efficiency techniques. As speaker and moderator for the model efficiency sessions, Tony Dardis noted the core concept in model efficiency is to have one's models run as quickly as possible without giving up too much with regard to accuracy of numerical results.

A Wander Through the Model Efficiency Countryside: Tony Dardis, FSA, CERA, FIA, MAAA

In this session, and Session 70, Tony gave some details from an article he wrote for the April 2016 issue of *The Modeling Platform*, "Model Efficiency in the U.S. Life Insurance Industry." In this first part, Tony covers a model efficiency taxonomy, developed from the American Academy of Actuaries' Model Efficiency Work Group (MEWG) that came into being to support principles-based reserves and capital projects in U.S. life/annuity regulations. The modeling efficiency taxonomy splits into two large areas: actuarial/modeling techniques and technology solutions. The first is more about conceptual model design, compressing or simplifying models in some way, such that the numerical results one gets may be somewhat different compared to a "full" model. In contrast, technology solutions are methods of designing software and/or hardware to optimize model implementation. The calculated results do not change—the issue is more runtime as well as development time.

Tony covered some of the history of model efficiency in the actuarial world, with a specific focus on the U.S., starting from the 1980s into present day. There is a model governance issue with model efficiency techniques—these are often mathematically complicated, and it can be difficult to get senior management and regulator buy-in for some of the techniques.

Clustering and Variable Annuity Case Study: Tung Tran, ASA, MAAA

Tung Tran looked specifically at clustering techniques, which fall into the actuarial/modeling technique portion of the model efficiency taxonomy. Tung covered the general approach to clustering. One needs to decide what variables are being used for clustering—"location" (will be used to determine "distance") and "size" (weighting of a model point)—and the amount of compression to be attempted. He went through a simplified example, to show how clustering was determined, and then looked at the results from a more complicated variable annuity example. Specifically, there was a runtime improvement of 95 percent, with fair value fit of 98 percent. This was in exchange for one day's work to create the clusters. The clusters here were for liability cells, but the technique can be applied on either the scenario or liability side.

Of course, in compressing the model to these clusters, some accuracy was given up. Other drawbacks of clustering include increased difficulty in explaining the model and the lack of seriatim results.

The payoff, however, is improved runtime, which allows for more sensitivity analysis. While the clustering may not be appropriate for certain applications, like seriatim valuation, it can be very helpful in making estimates of financial impact in assumption changes.

Model Efficiency Through Technology Solutions: Trevor Howes, FSA, FCIA, MAAA

While Tung looked at a mathematical process to simplify a model, Trevor Howes focused on software and hardware approaches in making models run more efficiently. There are three layers to the model implementation to consider: the application software in which the model "lives," the system software (operating systems, etc.) the application runs in and that deals with interfaces and, finally, the hardware being used. Trevor detailed the efficiency opportunities in each of these three layers. The kind of improvements one can get from each layer differs greatly, with different pros and cons and different impacts on model governance.

In addition to these layers, Trevor covered some specific approaches in breaking up the modeling job into smaller pieces. He looked at two approaches to task distribution: one that can be done "manually" (which doesn't require extra programming necessarily) and automated task distribution mediated by application software. The concept is to use grid computing, with segments and scenarios distributed across the grid to be executed in parallel. However, it may not be effective for complex situations with nested stochastic processes, due to a coordination issue. This works well when there are non-interacting pieces that can be easily distributed and then consolidated.

SESSION 70: MODEL EFFICIENCY, PART 2

Session 70 continued the topic of model efficiency, focusing heavily on the use of proxy models to improve runtime with good accuracy.

The Family of Proxy Modeling Methodologies: Case Studies: Tony Dardis, FSA, CERA, FIA, MAAA

Tony finished up covering his *Modeling Platform* article in this session, looking specifically at proxy modeling. This is part of the actuarial/modeling technique aspect of model efficiency taxonomy.

A proxy model is like a "light" model, where one has something very easy to calculate from a simplified set of drivers. You use the full or "heavy" model to develop what the fitting and validation points are. As Tony mentioned, proxy models are not replicating portfolios. He covered the pros and cons of proxy models, with both theoretical and practical issues.

He talked about three approaches—plain curve fitting, least squares Monte Carlo and radial basis functions. These are often multidimensional, and fitting can be quite complex and require a lot of up-front calculation.

Forecasting Stochastic Required Capital: Ron Harasym, FSA, CERA, FCIA, MAAA, and Andrew Ng, FSA, MAAA

In this presentation, Ron Harasym and Andrew Ng talked about their work at New York Life, using a real life case study (with some altered numbers) of capital forecasting for a life/annuity block of business. They combined multiple techniques to achieve a great amount of compression, noting the scenario reduction was 50,000 down to 50 scenarios. Ron mentioned this approach wouldn't be appropriate for valuation, but could be appropriate for their capital forecasting. In their capital forecasting, they had a one-year horizon, with their risk metric being conditional tail expectation (CTE) of the run-off at one-year from the in-force date as the metric being calculated. The highly compressed approach could be used to test sensitivity of required capital to changes in interest rates, equities and credit market dynamics in an efficient manner.

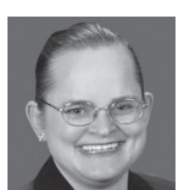
The main issue was that their project was considered impossible, in-house, because a brute force simulation approach would not have been practical, using too much time and calculation to get good results. They used a variety of approaches on the problem to get it into a tenable size for computation: least squares Monte Carlo, scenario stratification, stress scenario selection and then LSMC proxy fitting. They started with 50,000 scenarios for their CTE calculation and got it down to 54 simulation runs for each stochastic required capital calculation.

Ron and Andrew talked about the technology aspects—being able to use modular apps to hack away at different parts of the problem to improve efficiency—as well as the organizational aspects, such as having a team with diverse skills to attack the problem.

DISCUSSION AND THE FUTURE

In each of these sessions, there was active audience participation, sometimes in the middle of the talk to provide clarification. Many of these techniques and concepts are still being developed.

If you weren't able to attend, you should check out the recordings of the sessions. Have any reactions to these concepts? Have other modeling-related meeting sessions to relate or your own practical experience to share? Why not write about it for our newsletter?



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Roll Your Own Cluster Model

By Bob Crompton

Model efficiency is an important area of model management, and model compression is one of the dimensions of such efficiency. Model compression improves efficiency by creating a significantly reduced number of model points compared to a seriatim model. Cluster modeling is a model compression methodology that has been successfully implemented for a number of years.

A good introduction to cluster modeling can be found in the article "Cluster Analysis: A Spatial Approach to Actuarial Modeling."[1] For simplicity, this article is referred to as "the Milliman article." Some actuarial software incorporates cluster modeling; if yours doesn't, this article is for you.

SOFTWARE USED

The clustering in this article is performed with the open source software R.[2] In addition to the software included in the standard installation, I used two additional packages—**xlsx** and **fpc**—to perform some of the tasks discussed in this article. To install these packages, use the R console commands:

```
install.packages("xlsx", dependencies = TRUE)

install.packages("fpc", dependencies = TRUE)
```

Since these packages are not part of the home library, they will need to be added. They can be manually loaded as follows:

```
library(xlsx)

library(fpc)
```

CREATING A CLUSTER MODEL

I obtained from a colleague an in-force file of universal life (UL) policies. There are five plan types in the file and 1,347 records.

The broad steps we need to create a cluster model are:

- Generate synthetic policy attributes.
- Apply weighting to the attributes as appropriate.
- Split data into segments.
- Import the file of in-force attributes to R.
- Apply the clustering algorithm.
- Export results.
- Reconfigure in-force files for the reduced number of cells and rerun the model.

These steps are considered in this article.

GENERATE SYNTHETIC POLICY ATTRIBUTES

One of the most interesting aspects of the Milliman article is the use of synthetic policy attributes—that is, policy attributes that are not found either in the in-force file or are not simple transformations of data found in the in-force file. Quinquennial ages are examples of simple transformations of in-force data.

The development of clusters uses attributes associated with projected cash flows in addition to the attributes found in the in-force file. For example, the life/health model used in the Milliman article includes the following synthetic attributes:

- Present value of proxy profits
- Present value of proxy profits through 10 projection years
- Present value of proxy profits through 20 projection years

There are three other attributes used in this model, of which two are synthetic. The only native attribute is beginning reserve.

It is instructive to review the synthetic attributes for the term life model included in the Milliman article:

- Beginning reserve
- Cumulative present value of proxy cash flows
- Present value of proxy cash flows
    - Years 1–5
    - Years 6–10
    - Years 11–15
    - Years 16–20
    - Years 21–25
    - Years 26–30
- Projected death benefits
    - Years 1–5
    - Years 6–10
    - Years 11–15
    - Years 16–20
    - Years 21–25
    - Years 26–30
- Projected premiums
    - Years 1–5
    - Years 6–10
    - Years 11–15
    - Years 16–20
    - Years 21–25
    - Years 26–30

This is 20 attributes, of which only one is native, with all the rest being synthetic. Why are there so many? The complexity of reserving for level term, combined with the mortality patterns during and after the level term period, mean extensive information is required if we want a well-fitting cluster model.

The attributes I used for my model were those used in the Milliman article for the traditional life/health model with one exception. I did not include the present value of total proxy profits because my original projections only went for 20 years. The information contained in the early years' proxy profits and the later years' proxy profits overlaps the information contained in total proxy profits.

APPLY WEIGHTS TO ATTRIBUTES

Weights adjust the relative importance of the various attributes used for clustering. Weighting affects both the selection of the representative cell for a cluster as well as the cells assigned to the cluster.

Consistent with the cluster attributes, the weights I used for my model were those used in the Milliman article for the traditional life/health model.

CREATE SEGMENTS

The in-force file needs to be split into segments. The Milliman article describes segments as follows:

> You divide the business into segments, which instructs the program not to map across segment boundaries. Segments might include plan code, issue year, GAAP [generally accepted accounting principles] era or any other dimension of interest.

So clustering is applied at the segment level. In my example, the entire file is treated as one segment. If I had used multiple segments, they would have been based on plan code.

IMPORTING THE DATA INTO R

For the import operation, I am demonstrating how to import from Excel because Excel is ubiquitous. I will demonstrate two possibilities because there is more than one way to skin a cat. (I don't actually know this from personal experience, but generations of folk wisdom attest to the truth of this statement. Who am I to question generations of folk wisdom?)

Importing Directly from Excel

For the first import operation, I use the `read.xlsx` function. The `read.xlsx` function is from the **xlsx** package.

Use the following console command:

```
MyInforce <- read.xlsx("c:/Inforce.xlsx", 1)

#  2nd parameter indicates which tab to import
```

MyInforce, the variable containing the output from the `read.xlsx` operation, is a data frame. Data frames are formatted matrix-like data structures. They are convenient since they can be used in many built-in functions that require matrix input.

Importing From a Comma-Separated File

For this import operation, I use the `read.table` function:

```
MyInforce <- read.table("c:/Inforce.csv", header
= TRUE, sep = ",")
```

The `read.table` operation yields a data frame, the same as the `read.xlsx` operation.

Comments on Excel vs. CSV Files

The `read.xlsx` function has the obvious benefit of convenience. You are working directly from Excel so you don't have to reformat. In addition, if you put each segment in a separate tab, it is easy to loop through the tabs with the `read.xlsx` function.

> DIY clustering is an easy and straightforward process using existing code.

However, there are some serious drawbacks to using the `read.xlsx` approach:

- It's s-l-o-w! An Excel file with 10,000 records took about 35 minutes to load using `read.xlsx`.
- It's memory intensive. My computer was unable to load a file of 25,000 records because the Java back-end to **xlsx** ran out of memory.

Unless all of your segments are less than 2,000 or so records, reading directly from Excel may not be in the cards. Note that the R manual on data import/export has the following warning:

> The most common R data import/export question seems to be "how do I read an Excel spreadsheet."
>
> … The first piece of advice is to avoid doing so if possible! If you have access to Excel, export the data you want from Excel in tab-delimited or comma-separated form, and use `read.delim` or `read.csv` to import it into R.[3]

However, if you are committed to using Excel as your data source, the manual contains a description of a few other R packages that provide Excel import capability. Experiment with some or all of these to see if they work any better than the **xlsx** package.

CSV files don't have either of these problems. I was able to load a file of 100,000 records in less than 5 seconds using the `read.table` function. The only issue I have noted with CSV files is that if you forget to reformat comma-separated numeric values, chaos and darkness will result.

APPLY CLUSTERING ALGORITHM

Once the data is in R, it is simple to create clusters. There are a number of cluster functions available. I used the `pam` function because the output contains the information we need to create the clusters. `Pam` is based on a version of the K-means approach to clustering. The following code is for the cluster model with 13 cells. Note that the data is standardized by setting one of the function parameters shown. Standardization often gives better results when using clustering algorithms.

```
fit <- pam(MyInforce, 13, stand = TRUE)
```

The output variable `fit` is a list containing, among other things, the index number of the representative cells for each cluster in the component `id.med`, and the cluster assignment of each of the in-force records in the component `clustering`. So the component `id.med` is a vector with length equal to the number of clusters (in this instance, 13), and the component `clustering` is a vector with length equal to the number of in-force records.

Table 1
Comparison of Policy Attributes ($1,000s)

Attribute	Original	Clustered	Ratio
Initial reserve	522,352.9	523,339.7	100.2%
Projected first-year premiums	77,247.2	79,570.8	103.0%
Projected first-year benefits	38,000.4	40,133.5	105.6%
Present value proxy profits, years 1–10	125,481.3	128,489.8	102.4%
Present value proxy profits, years 11–20	(104,775.4)	(109,964.9)	105.0%

We pass these back from R using the following export code:

```
write.table(fit$id.med, "c:/Cluster_index.csv",
sep = ",")

write.table(fit$id.clustering, "c:/Cluster_
assignment.csv", sep = ",")
```

It is possible to use the `write.xlsx` approach to write directly to Excel files; however, the same caveats regarding speed and memory mentioned in the discussion of importing the data will apply to exporting the data as well.

RECONFIGURING THE IN-FORCE FILE

Once the cluster assignments and the cluster representative cells are determined, reconfiguring the in-force file is straightforward. Static items such as issue age, sex, plan code and similar items are set equal to these items from the representative cell.

Dynamic items such as initial reserve, initial fund, amount of insurance and similar items are summed over all the in-force records belonging to the cluster.

RESULTS OF THE TEST FILES

The results from the test clustering are shown in Table 1. I compare the clustered vs. unclustered results for the total net cash flows and the totals of the synthetic attributes.

Observations on Cluster Model Fit

Given that this model has a 99 percent compression ratio (13 cells compared to 1,347 in the original model), the fit is reasonable.

Model projections for premiums, benefits and distributable earnings are shown in Figure 1.

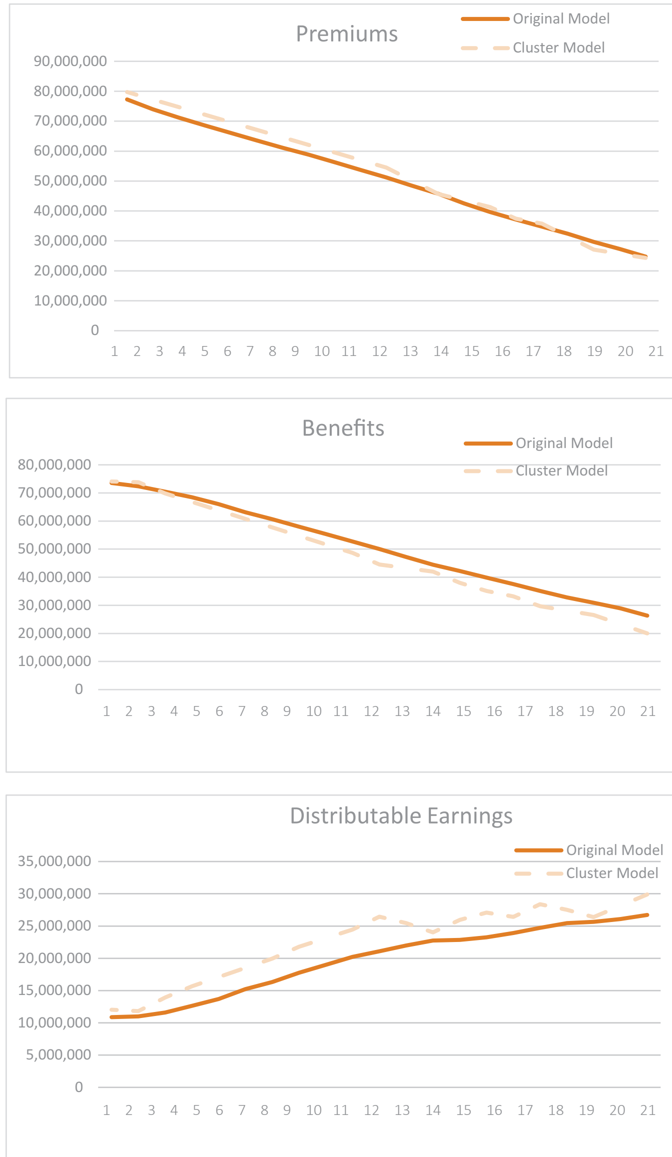
Although the purpose of this article is merely to show how to create cluster models, a brief discussion of how to improve the fit might be helpful. There are two obvious possibilities. The first is to adjust the weighting factors. For example, the weightings for both early and late proxy profits could be increased. This would likely improve the fit for first-year benefits as well as for proxy profits.

The second obvious adjustment is to split the model into three or four segments, rather than just one segment. Three segments with four cells each might perform better at fitting the original data since the different UL plans have differing patterns of cash flows and profit emergence.

OTHER THINGS TO CONSIDER

In addition to simply generating and identifying clusters, there are several other things we can consider as we create cluster models.

Figure 1
Model Projections for Premiums, Benefits and Distributable Earnings



Optimal Number of Clusters

What is the optimal number of clusters? If we don't care much about model fit, and are mainly concerned about processing time, then obviously one cluster is optimal. In that case, we simply define the cluster based on the average policy number. (This is technically known as "humor." It is not intended to be taken seriously.)

The function `pamk` in the package ***fpc*** estimates the optimal number of clusters based on "optimum average silhouette width." A cluster silhouette is a measure of how close each point in one cluster is to points in the neighboring clusters. The further away the points are, the better.

Interestingly, using the `pamk` function to investigate the optimal number of clusters in the range of two to 100 results in an optimal cluster count of three. That seems to explain how the 99 percent compression model performed as well as it did. Of course, silhouette optimization is not what actuaries are really interested in, so this result does not mean we should automatically choose three clusters.

Testing for Sensitivity to Order of Attributes

Many K-means algorithms used for clustering seem to be based on the expectation-maximization algorithm. There are some anecdotes that these algorithms are sensitive to the order in which the attributes are presented. The documentation for the `pam` function claims it is "a more robust version of K-means."[4] It is not clear if this means it does not exhibit sensitivity to the order of attributes. I did not bother tracing back to the source reference for the algorithm, but it is something users can easily test.

I tested for this sensitivity by running `pam` with two additional input files that differed only in the column order of the data. Both additional files produced clusters identical to the original in-force file.

CONCLUSION

As presented here, DIY clustering is an easy and straightforward process using existing code. As my father-in-law used to tell me, "It's easy once you know how." In R, once you know how, many things are insanely easy. The difficult part of R is that it is so extensive, finding the right package to do just what you want is a time-consuming task.

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ENDNOTES

1 Avi Freedman and Craig Reynolds, "Cluster Analysis: A Spatial Approach to Actuarial Modeling," Milliman Research Report, August 2008, *http://www.milliman.com/uploadedFiles/insight/research/life-rr/cluster-analysis-a-spatial-rr08-01-08.pdf.*

2 R Core Team, R: A Language and Environment for Statistical Computing (Vienna: R Foundation for Statistical Computing, 2016), *https://www.R-project.org/.*

3 This can be accessed at *https://cran.r-project.org/.*

4 The pam function is contained in the package cluster: Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., Hornik, K. (2015). cluster: Cluster Analysis Basics and Extensions. R package version 2.0.3. The quickest way to access the documentation for pam is to enter "??pam" at the command prompt in R. You can also access the documentation at *https://cran.r-project.org/web/packages/cluster/index.html.*

Long-Term Care Modeling, Part I: An Overview

By Linda Chow, Jillian McCoy and Kevin Kang

The private long-term care (LTC) insurance industry continues to face significant challenges with low demand and low supply of stand-alone products. Many carriers have exited the market due to a mix of low interest rates, poor product performance and uncertainty in future product risks. Effective financial and risk management have become the primary focus for the industry. A robust financial model is the first line of defense to effectively manage this business.

Actuarial models can be used for a number of financial management activities in managing both in-force and new business, including setting premiums and analyzing profits for new business; evaluating reserves needed to fund future claims, cash-flow projection and asset adequacy testing; business planning; capital management; rate increase analysis; and reinsurance analysis.

> Companies should carefully evaluate which financial modeling approach would best fit their LTC block management strategy.

Modeling LTC products can be daunting due to the wide range of product features and components to capture, such as elimination periods, benefit periods, inflation options, benefit payout options, waiver of premium and shared care benefits. With higher capital requirements than many other insurance products, LTC insurance financial results are driven by variances in key assumptions including morbidity, mortality, lapses and investment earnings. An effective LTC model should be able to accurately project these key assumptions and their interactions over all durations of a policy (at least 50 years in many cases).

Although the industry continues to add an increasing amount of claims experience, the LTC industry is still relatively young. How experience will emerge is still largely unknown as historical experience is not always an indication of the future—even more so for a relatively short history. However, one of the indisputable trends is increasing claim costs.

It's not an easy task to manage an LTC block given the aforementioned uncertainties. Companies should carefully evaluate which financial modeling approach would best fit their LTC block management strategy. This article is the first installment of a three-part series and is focused on providing an overview of LTC modeling approaches and considerations. The second article will provide a deep dive into first principles modeling. The third article will focus on LTC model governance and model validation.

EVOLUTION OF LTC FINANCIAL MODELING APPROACHES

LTC financial models have gone through rapid evolution. Early on, most companies used either a total exposure claims cost or a healthy exposure claims cost approach to modeling. These models projected total expected claims that were pre-calculated and entered as model inputs.

As a result of needing to better manage financial results as well as the advancement of computational power, the next generation of models began to employ a first-principles modeling approach. These models keep track of the state of projected lives, including active (healthy and recovered), disabled [nursing home (NH), home health care (HHC), assisted living facility (ALF) and transfers], group conversions and terminations (active deaths, disabled deaths, lapses and benefit exhaustions). The model can be calibrated to reflect the timing of each event. Conversion from claims cost models to first-principles models for numerous blocks is on the current action list for many companies within the LTC industry.

Driven by regulatory changes (principle-based reserving) and overall insurance industry trends for long duration contracts, the third generation modeling solution of multi-state stochastic models is also on the horizon. These multi-state models are stochastic versions of the first-principles model. While stochastic techniques had historically mostly been reserved for interest-sensitive products, a desire to better understand future risks associated with long duration contracts has resulted in increased efforts to apply stochastic analysis to other risk factors, such as mortality and morbidity.

CLAIMS COST APPROACH

Early generation LTC models primarily used tabular claims cost due to technological limitations. In a nutshell, expected claims cost is the discounted value of expected future claims paid for an incident incurred at a given time period. This includes the probabilities of incurring claims as well as the severity of those claims (characterized by a length of stay and utilization of benefits).

Claims cost models for LTC commonly come in two forms: total-lives claims cost and healthy-lives claims cost. In either

approach, the model projects total exposures using total deaths and lapses as decrements. The total-lives claims cost approach pre-calculates claims cost using incidence rates based on total exposures. These pre-calculated claims costs are applied to the projected total exposures in the model. The healthy-lives claims cost approach pre-calculates claims cost using incidence rates based on healthy exposures. And for healthy-lives claims cost, an external model pre-calculates a set of "J prime" factors (defined as healthy exposure over total exposure). These J prime factors are brought into the projection model to convert projected total exposures to healthy exposures to be consistent with how claims cost is defined.

One modeling consequence of total-lives claims cost is that, even after claim, policies continue to contribute to the aggregate active-life reserves (ALR) in addition to the disabled-life reserves (DLR). Healthy-lives claims cost, on the other hand, takes into consideration the status and only applies to the active population (non-claim) with no ALR for those on claim.

For companies that choose claims cost modeling, the healthy-lives claims cost approach is recommended as there are many disadvantages to a total-lives claims cost approach—namely, that a total-lives approach only works well if the projected population mix is static. The claims cost would be less accurate and continue to deviate as the underlying population experience (claim incidence, claim termination, mortality and lapses) differs from what was assumed. A healthy-lives claims cost approach, if well managed, is a good approach to evaluate the basic financial results of the LTC block. However, neither of these approaches provides carriers with in-depth reporting capability to understand drivers of the modeling results—a first line of defense against risk.

FIRST PRINCIPLES

While a claims cost approach does provide the basic information at a high level, a first-principles approach provides greater granularity of results. In the past five years, there has been a steady theme of converting to models using first-principles components upon which the claims cost tables were originally built. There are varying degrees of specificity and intricacy on first principles to which the model tracks states (active/disabled/recovered, NH/HHC/ALF, state transitions, etc.).

Indeed, there are important reasons for a company to consider a first-principles conversion. Carriers that have never had a sophisticated projection model or have used multiple segmented models for their actuarial functions recognize the need to improve their financial modeling capability given the complexity of LTC projections. Many companies are attempting to improve their ability to understand experience drivers and their financial impacts. For some companies, their existing expected claims cost tables were provided by external resources, and the original claims cost components were not available to allow detailed analysis. Improved operational efficiency, cost reduction, alignment of various actuarial functions, and financial reporting capabilities are achievable as well.

Implementing and maintaining a first-principles approach requires a higher level of sophistication when it comes to systems

and data management. For some carriers, this might imply a small refinement to their current existing organizational structure, while for others this might require significant up-front investment to improve systems and data warehouse or reallocate talent.

Unsurprisingly, implications of model conversions extend outside the model. Relative to claims cost models, first-principles models require an increased level of product and technical competency to support the increase in both the sophistication of modeling techniques and level of assumption detail. Additionally, the data requirements to support these assumptions are more intensive given the level of detail in reviewing the experience for each component and credibility considerations. The models are compared further in Table 1.

MULTI-STATE STOCHASTIC MODEL

A multi-state model is a full-scale first-principles model that allows detailed tracking of a policyholder's state, benefits payable and timing of key events. A multi-state stochastic model uses the probability of transitioning among states as input assumptions and employs techniques (e.g., Monte Carlo method) to simulate the distribution of random events due to the potential variation in assumptions.

A robust stochastic process should include two steps:

1. **Stochastic analysis around the mean on key assumptions by duration.** This assumes the assumptions (the mean) are always correct and would measure the variations around the mean.
2. **Parameterization analysis of the mean.** This helps to understand the probability the mean is incorrect.

To analyze long-term care business, random events can be stochastically modeled. Potential risk parameters to consider are active death, disabled death, incidence rates, claim continuance, claim recovery, inflation, utilization, lapses, benefit exhaustion, conversions, care path and transfers. Although doing so is challenging, rate increase actions and their impact to experience should also be considered in the stochastic process.

Stochastic models can enable better measurement of tail risks and extreme scenarios. However, they certainly add another layer of complexity in terms of model implementation, assumption setting, stochastic scenario selection, probability distribution calibration and technology requirements. The requirement

Table 1
Strengths and Weaknesses of Models

	Claims Cost	First Principles
Strengths	Succinct way to summarize incurred benefits Intuitive summary from valuation models Faster model run time	Possibly greater appreciation of in-force movement Simpler, more direct implementation in models More direct application to metrics and source of earnings Ability to obtain paid claims
Weaknesses	Required calculation as an intermediate step before the model Limitation of incurred claims without paid claims Less direct understanding of underlying metrics and source of earnings Potentially prohibitive number of claims cost tables	Greater focus on assumptions Slower model run time than claims cost Higher complexity (auditability, analysis, etc.) Question of credibility

of principles-based reserves has led to the implementation of stochastic techniques in major modeling platforms for life and annuity business. This evolution has also been brought to the horizon for LTC carriers.

MODEL GOVERNANCE, MODEL RISK FRAMEWORK AND MODEL VALIDATION

The previous sections highlighted increased model capabilities for first-principles models. Yet the constantly increasing intricacies and sophistication of financial models in today's world demonstrate the importance of managing model risk, which may arise from decisions based on the incorrect selection, implementation or usage of models. A model risk management (MRM) framework calls for three lines of defense:

1. **Model owners.** The objective is to manage the organization's model risk by developing, using and maintaining models consistent with enterprise policies. There should be a conscious focus on thoughtful and transparent model development, well-controlled and tested model implementation, rigorous change management procedures and ongoing performance monitoring.
2. **Model governance and validation.** The objective is to manage the organization's model risk by establishing and implementing a model risk management policy. Key roles include maintaining and monitoring model and input files (including assumptions) inventory, performing independent model validation and providing effective push-back challenge throughout the model development process.
3. **Internal audit.** The objective is to assess and validate that the first and second lines of defense comply within the organization's model risk management policies.

A sound model change control process should lay out a framework for an array of change categories for the model including assumptions, new feature implementation and model refinement. This change framework should include principles around choosing appropriate metrics for validation and acceptable tolerances to enable and achieve proper reconciliation.

OVERVIEW OF MODEL VALIDATION

Model validation is an important step of financial model management and covers five pillars across a modeling life cycle: conceptual soundness, data quality assurance, implementation, model performance and integrity, and documentation and governance.

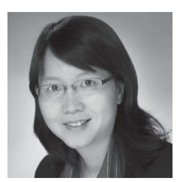
The aforementioned LTC modeling approaches would require different levels of review throughout a model validation process. Generally, model validation should at minimum include:

1. **Model verification.** This includes verification of data source quality, static validation, assumption review and testing, formula review, conceptual soundness, cell level testing and aggregate result review.
2. **Model fitting.** This includes retrofitting and dynamic testing to assess and validate that the model accurately tracks past experience.
3. **User acceptance testing.** Actual users of the model test run the model with realistic assumptions and scenarios to validate that all perspectives of the models are functioning correctly before going into production.

CONCLUSION

Companies should choose a financial modeling approach that best fits their LTC block management strategy. Given the complexity of LTC models, questions remain about what an effective model entails, how a company could make the most of a first-principles model, and what a company should do to properly implement and manage such models. Overall, the conversion process of going from a claims cost regime to a first-principles world is a non-trivial exercise of splitting "aggregated" tables into components with necessary attribution at each step—this can be an expensive exercise for a slow-growing or closed block. But there are many benefits of first-principles models, and we continue to see conversions to first principles.

Stay tuned for the next two installments of our three-part series as we look to discuss first-principles implementation considerations and implications, as well as guiding principles of a robust model risk management framework.



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Modeling General Account Assets: An Introduction

By Phil Schechter

Hedging has turned the modeling of complex interest and equity derivative instruments into a hot topic over the past 15 years and properly so; the effectiveness of a hedging program contributes to the stability of an insurance entity, and any disconnect between assets and liabilities can cause an immediate and significant swing in earnings.

We should not lose sight, however, of the more traditional life insurance company general account (GA) assets—coupon-bearing instruments including bonds, preferred stocks and mortgages. As of 2015, U.S. insurers held about \$3.9 trillion in bonds and \$370 billion in mortgages.[1] These fixed-income assets make up about 75 percent of the GA balance sheet for all insurers combined—and the proportion for life insurers is historically higher. The return on these assets has to make good on the liabilities, drive crediting on interest-sensitive products, and contribute toward company expenses and shareholder value. While investment departments and asset managers should have better insight into asset behavior at the individual security level, it is only within an asset-liability management (ALM) model that the appropriateness of a portfolio can be ascertained for a particular company. So when we populate our models, we've got to get it right.

MODELING INDIVIDUAL SECURITIES: FIXED CASH FLOWS

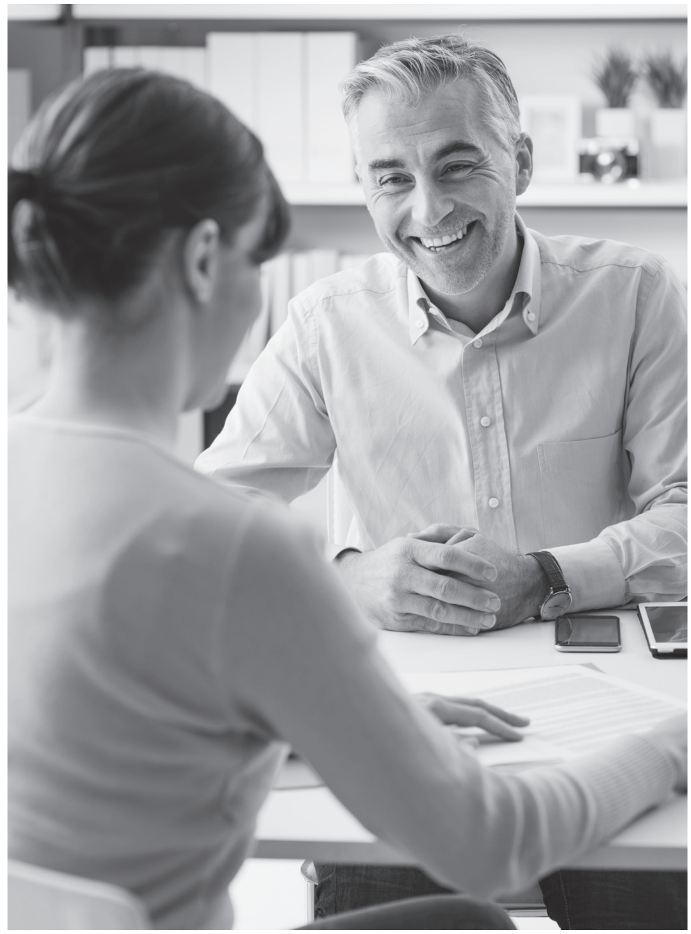
A typical actuarial projection starts from a statutory (stat) point of view. This view determines regulatory capital requirements, distributable earnings, asset adequacy and appropriate benchmarks for crediting interest-sensitive general account products.

Most fixed income assets on the stat balance sheet use the constant yield method of accounting. Under this method, the yield (stat amortizing yield or book yield) is set at issue = IRR (internal rate of return) of the assets using the expected cash flows.

Yield (fixed at issue) = IRR ((– purchase price,) expected cash flows)

The key pieces of information necessary to model this kind of asset are:

- The nominal or par value
- The coupon rate
- The maturity date or schedule



Then, by definition, for each accounting period, the income on this asset is by definition

$$GII_t = BV_{(t-1)} \times \text{Yield}$$

Where:

GII_t is the gross investment income for the asset for time period t
BV_t is the statutory book value at the end of period t

This investment income has three components:

- Cash coupon payment. This is the actual coupon amount paid during the period.
- Change in accrued income. Coupon income is considered to be earned linearly between coupon payments; income is accrued linearly between coupon dates.
- Accrual of discount/amortization of premium.

This last item represents a change in book value. Any difference between the purchase price and the par value is amortized into income over the life of the asset on a schedule that preserves the constant IRR of the asset.

If your model allows you to sell assets to raise funds, or if you need to report market value metrics, you will need to calculate a market value for each security as it rolls forward. In reality, the market value of an asset at any point in time is based on more factors than could realistically be captured in a model, so we use approximations based on the market value as of the inventory date.

Our models will generally calculate market value at any given point in the projection as the present value at that point in time of all cash flows projected beyond that time. The discounting should be based on the spot curve of interest rates at that point in the model, applicable to an asset of similar rating. However, at time 0, frequently this approach will not come acceptably close to the given initial market value (MV). Reasons for this discrepancy include:

- The model may not have yield curves corresponding to every credit quality; for example, a model may have two or three credit classes to which all of the more detailed asset ratings are mapped.
- The market may have different views of sectors or individual issues within a given credit rating, and this may impact the initial quoted market value.
- There is not complete and deep market information for full yield curves by credit rating, and the investment managers may be using different data points and interpolations to the spot curve than the ALM model.

In projecting an initial market value of a security, a common approximation is to calculate a "residual spread" at time 0 in the model. For example, we may find that to match the starting MV for a particular security, we need to discount the projected cash flows at a rate implied by the AA-rated curve + 7 basis points (bp). In this case, each time we calculate a market value for this asset going forward, we would use the AA curve at that point in time and add the 7 bp calculated at time 0.

ASSETS WITH UNCERTAIN CASH FLOWS

Some assets have less certain cash flows than others. For example, bonds may be issued as callable with a call penalty depending only on the date of call. Mortgage-backed securities pay off based on the behavior of the underlying mortgage pools.

In recent experience, payoff of callable bonds seems to be related more closely to credit of the issuer or other issuer-specific factors than to the interest rate environment. However, it is prudent to assume that if you have granted an option, it may be used against you. Your model should reflect that assets are less likely to prepay when you would like them to (i.e., when rates go up) and are more likely to prepay when you want them to stick around—when rates go down. There are two common ways to model this prepayment behavior:

- Compare the coupon on the asset to the comparable coupon on a new asset of similar nature. If the new money coupon is much lower, assume the issuer is more likely to repay the old notes and issue new ones.
- Compare the amount necessary to pay off the asset (par + prepay penalty) to the hypothetical market value of the asset if not prepayable. If the payoff amount is significantly less than the market value of the scheduled cash flows, assume the issuer will prepay.

Given the lack of market data over the last few years to validate modeled prepay behavior, especially dynamic behavior, this would be a good assumption to stress test if your portfolio has significant holding of these assets.

Mortgage backed securities (MBS) and collateralized mortgage obligations (CMOs) are rather difficult to model. The cash flow patterns are dependent on the behavior of the underlying pool (or pools) of mortgages, and it is unlikely that in-house administrative systems will contain a whole lot of information about those pools. CMOs also have many tranches with complex rules governing the cascade of cash flows from the underlying mortgage pools. Two approaches for modeling these assets:

- Use an external vendor (BondEdge, Intex, Wilshire) that collects information on the pools and asset structure. Some may allow control of prepayment assumptions. You can populate these systems with your scenarios, and they will generate projected cash flows, asset balances and even market values, to feed into your ALM model. These models will be wrong and should be stress tested if material; for example, run with different prepay speed parameters to get some kind of confidence interval.
- Create a synthetic model. Calibrate some combination of fixed and floating rate bonds, mortgages or even simple CMOs (if available in your modeling platform) to replicate the yield, average life, duration and (maybe) convexity of your MBS portfolio, as reported in Bloomberg or some other market-pricing tool.

Book values for such assets should ideally reflect an "unlocking" each time the best estimate of the cash flows change; go back to the purchase date, string together the cash flows that have already happened with the projection of future cash flows, and, using this string of values, compute what your current book value should be now (e.g., how much accrual of discount/amortization

of premium should have already been reflected). Our models will generally not go to this level of detail—at each period, we will mostly take the beginning of period BV as a given, and then calculate the string of future book values by looking at the cash flows going forward.

Market prices for interest-sensitive assets would ideally be calculated by generating more paths at each node, modeling the cash flows on each path and discounting. This can slow any computer or grid of computers to a crawl, and should be used sparingly—at least consider how material market values are to your model. A single path at each point, consistent with the current scenario, may be adequate depending on the options built into your portfolio. Other approaches may involve closed-form models (e.g., the Black 76 model) to approximate the value of the option built into these assets at each point.

Some assets may allow for prepayments but with "make whole" provisions, which calculate a prepayment penalty that on some basis should make you indifferent to the issuer prepaying. In these cases, you may be able to justify ignoring the prepay provision in the model.

DEFAULTS

Defaults may typically be modeled as a decrement impacting book, market, par and all future cash flows. For example, a 1 percent default would come through as a proportionate reduction in the amount of the asset you are holding. In this methodology, the default rate assumption should be set to reflect your total expectation of credit losses.

A more complex approach would be to model the incidence of default, combined with some recovery behavior. For example, you may assume there is a 2 percent probability of default at a point in time, but after default, there may be an assumption of a 50 percent recovery of face value after a two-year holding period. In the interim, you may hold the defaulted value of the asset with no coupon. While this mechanism may be closer to reality than directly modeling a default cost, it requires more complex assumptions. It does, however, let you reflect that different categories of bonds may behave very differently upon default, taking into account the legal structure of the bond, the underlying sector and even the economic scenario being run.

Finally, you may want a full credit model, which reflects credit transitions, write-downs and write-ups, as well as modeling cash flows. This would be ideal for risk-based capital (RBC) calculations, and could allow a better reflection of all the events that can change the value of an asset. On the downside, I don't know of any modeling system that can do this out of the box—I would be glad to hear if such a thing exists. I have tried to layer this logic onto model output with a spreadsheet-based approach, but that quickly proved unwieldy beyond a two- or three-year time horizon.

ASSETS WITHIN AN ALM MODEL

A boss early in my career drilled into me this truism, and I've tried to pass it on to everybody who has come through my shop:

$$\Delta BV = NII + CG - CF$$

That is to say, the change in the level of assets (ΔBV) in a model (or in reality!) can be completely explained by

- **Net investment income (NII)**. This is the earnings on those assets, for example, coupon or accrual of discount less investment fees charged.
- **Capital gains (CG)**. In the stat world, this would mean realized capital gains; for example, defaults will decrease the pool of assets.
- **Cash flows (CF)** in and out of the pool. Adding money to the pool will increase your level of assets; pulling money out will decrease it.

This seems like an obvious check on the model but can require considerable investigation into the output variables supplied by your modeling system. For example, in some models, the definition of net investment income may already incorporate capital gains, while in others, these are reported separately. Working through an asset roll-forward is a good exercise in understanding the model as well as validating it.

In an ALM model, the cash flows looked at from the asset side should be the same as those from the liability side, except for the sign. Again, this seems like simple common sense; once you model premiums and deposits, benefits, expenses, taxes and stockholder dividends, any positive cash flow should go into your asset pool, and any shortfall will be provided from your existing asset portfolio. But once again, demonstrating this holds true can be tricky. Complicating factors can include:

- Policy loans. These generate investment income but are usually modeled with the liabilities—they are part of the liability inventory, and assumptions as to their growth and repayment are best applied within the contract from which they arise. Furthermore, while in reality, the growth in policy loans is frequently cashless (policy loan interest is capitalized within the policy up to the point of a policy lapse or claim), the model may model payments in cash.
- Transfers between general and separate account (SA). If you are modeling GA assets, this is a cash event—funds move between the company's general account and the policyholder separate account funds. How explicit is the liability model set up in these terms?
- Modeling simplifications. Some liabilities may be modeled using simplifications; for example, a product feature may be modeled as simply an earned spread rather than a full model reflecting interest and crediting. This may be sufficient for some purposes (e.g., analysis at the product level), but will leave you missing key information when trying to put together a full balance sheet projection for a company.
- I've glibly assumed you can categorize various funds as either GA or SA. However, your generally accepted accounting principles (GAAP) presentation may be different than your stat presentation; there may be funds in your green blank (statutory SA statement) that look, taste and smell enough like GA assets that GAAP includes them as part of the GA. This leaves you the option of performing different projections for each accounting basis or having a layering process to get from one to the other—and this can quickly get rather convoluted.

This article has only begun to scratch the surface of asset modeling topics. Reinvestment strategy and portfolio management within a model merit their own articles, and many of topics upon which this piece glances are also worthy of a deeper dive.

If you have any thoughts on future articles, or (even better) would like to share your insights on one of these topics, I would encourage you to get in touch with me to include in a future issue.

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ENDNOTE

1 Capital Markets Bureau, "U.S. Insurance Industry Cash and Invested Assets at Year-End 2015," National Association of Insurance Commissioners (NAIC) Capital Markets Special Report, June 6, 2016, *http://www.naic.org/capital_markets_archive/160606.htm.*

VM-20 Scenarios: An Observation

By Tim Cardinal

Cash flow models have burst on the scene front and center. Models underpin solvency assessments for the major superpowers. These include China Risk Oriented Solvency System (C-ROSS), the EU's Solvency II Directive and Own Risk and Solvency Assessment (ORSA).

In the United States, the National Association of Insurance Commissioners (NAIC) Valuation Manual (VM),[1] including VM-20, has finally arrived in statutory financial reporting.[2] VM-20 is based on three reserves: one formulaic and two modeled reserves—a deterministic reserve based on a single scenario and a stochastic reserve based on stochastic scenarios.

VM-20 prescribes the economic scenario generator. The purpose of this article is not to peer into the black box and see how the innards of that generator works. Rather it's simply to look at some generator output and make an observation pertaining to VM-20. For information on generators in general, the reader is referred to Society of Actuaries' 2016 research paper *Economic Scenario Generators—A Practical Guide.*[3]

There are two primary inputs into the American Academy of Actuaries/SOA generator[4]—the yield curve and the mean reversion parameter as of the valuation date. Additional inputs include the length of the projection period, the number of scenarios (choices are 50, 200, 500, 1,000 and 10,000), and monthly/quarterly/annual rates. Technically, the mean reversion parameter is not an input but is based on historical rates calculated as follows:

- 20 percent of the median 20-year Treasury bond rate over the last 600 months
- + 30 percent of the average 20-year Treasury bond rate over the last 120 months
- + 50 percent of the average 20-year Treasury bond rate over the last 36 months

The parameter is heavily weighted to reflect recent experience.

The VM-20 stochastic reserve is based on a Greatest Present Value of Accumulated Deficiencies methodology, or GPVAD. The discount rates equal the path of 105 percent of one-year Treasury rates. The scenario reserve equals GPVAD plus the sum of the starting asset values. The stochastic reserve is conditional tail expectation (CTE) 70 of the scenario reserves, that is, the average of the highest 30 percent scenario reserves. Thus, the one-year rates across the scenario are of particular interest.

What do our scenario discount factors look like? That is, what is the present value of 1 in year 10, 20, 30, 40 … until there is an immaterial amount of business still in force? How do these factors compare to factors using constant discount rates of 2 percent/3 percent/4 percent/5 percent? We consider projecting the stochastic reserve as of Dec. 31, 2015, at two points in time—Dec. 31, 2016, and Dec. 31, 2024. We assume inter-

Table 1
Dec. 31, 2016, Discount Factors

Policy Year	Percentile						
	5	10	15	20	25	30	35
10	86	84	87	90	84	88	82
20	71	74	66	75	66	68	62
30	57	62	52	57	51	51	46
40	49	54	45	48	41	41	35
50	42	42	37	37	31	34	28
60	34	31	29	27	26	25	24
70	29	20	22	19	20	17	18
80	22	15	16	16	16	12	13
90	18	11	13	13	12	9	9
100	11	8	8	10	9	5	7

Table 2
Dec. 31, 2024, Discount Factors

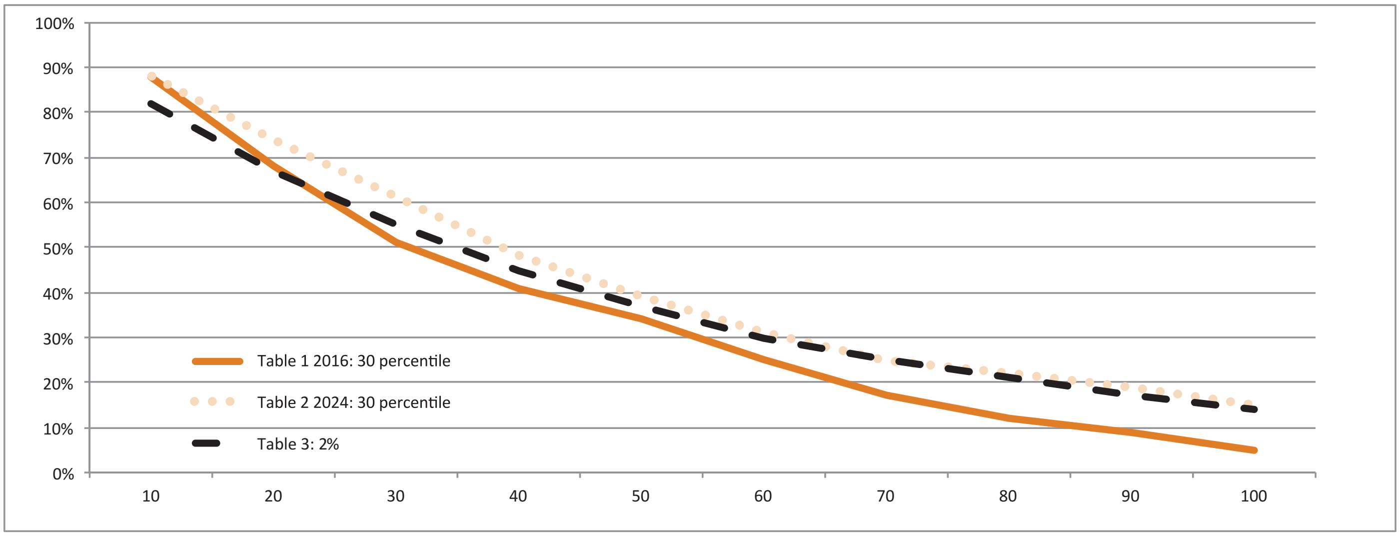
Policy Year	Percentile						
	5	10	15	20	25	30	35
10	87	86	88	88	85	88	88
20	71	66	79	69	74	74	73
30	60	51	67	58	67	61	56
40	53	46	54	48	60	48	47
50	45	44	43	42	48	39	36
60	41	38	35	33	32	31	30
70	35	31	26	29	24	25	26
80	30	24	23	25	20	22	23
90	25	16	19	19	17	19	21
100	20	13	17	14	14	15	18

est rates stay level during the entire projection (i.e., the outer loop). The yield curves are the same at both projection dates; however, the mean reversion parameter is 3.75 percent in 2016 and 3.25 percent in 2024.

For universal life with lifetime secondary guarantees (ULSG), high factors due to low rates exert pressure toward higher reserves. It is not necessarily the case that the highest discount factors correspond one-to-one with the highest reserve scenarios. VM-20 includes a guidance note to use "Lapse Experience Under Term-to-100 Insurance Policies" published by the Canadian Institute of Actuaries in October 2007[5] as the industry table for UL lapse rates[6]—these surrender rates are about 0.3 percent in years 15 and later. Thus, ULSG surrender rates will be zero or near zero after policy years 10 or 20. The higher the discount factor, the higher the present value of death benefits in the later policy years. Tables 1 and 2 present the discount factors corresponding to the lowest one-year rate scenarios based on policy year 60 discount factors.

With a constant 4 percent discount rate, a $1 benefit in policy year 40 is worth $0.21 today but worth $0.41 and $0.48 using 2016 and 2024 VM-20 discounts at the 30 percentile. (See Table 3.) With a constant 5 percent discount rate, a $1 benefit in policy year 50 is worth $0.09 today but worth $0.28 and $0.36 using 2016 and 2024 VM-20 discounts at the 30 percentile.

Figure 1
Discount Factor Comparison (by Policy Year)



As shown in Figure 1, in comparing the Table 1 factors to the Table 3 factors, we see that the 30 percentile lowest rate scenario approximates a 2 percent discount rate—initially VM-20 discount factors are slightly higher, then slightly lower. Table 2 factors are several percent greater than the Table 1 factors.

I will let the reader ponder these numbers further, but the observation is that long-tailed benefits can have high present values.

It should be no surprise that low interest rates exert pressure to increase reserves, but the tables present the cold, hard facts. ■

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Table 3
Discount Factors Using Constant Discount Rates

Policy Year	Percentile			
	2	3	4	5
10	82	74	68	61
20	67	55	46	38
30	55	41	31	23
40	45	31	21	14
50	37	23	14	9
60	30	17	10	5
70	25	13	6	3
80	21	9	4	2
90	17	7	3	1
100	14	5	2	1

ENDNOTES

1 National Association of Insurance Commissioners, Valuation Manual (April 2016), *http://www.naic.org/documents/committees_a_latf_related_valuation_manual_apf_adopted_by_a_cmte.pdf.*

2 The VM operative date is Jan. 1, 2017.

3 Hal Pedersen, Mary Pat Campbell, Stephan L. Christiansen, Samuel H. Cox, Daniel Finn, Ken Griffin, Nigel Hooker, Matthew Lightwood, Stephen M. Sonlin and Chris Suchar, *Economic Scenario Generators—A Practical Guide* (Society of Actuaries and Conning Inc., 2016), *https://www.soa.org/Research/Research-Projects/Finance-Investment/2016-economic-scenario-generators.aspx.*

4 American Academy of Actuaries and Society of Actuaries, "Economic Scenario Generators" (2016), *https://www.soa.org/research/software-tools/research-scenario.aspx.*

5 Canadian Institute of Actuaries, Research Committee, Individual Life Subcommittee, "Lapse Experience Under Term-to-100 Insurance Policies" (Report, Document 207085, October 2007), *https://www.cia-ica.ca/docs/default-source/2007/207085e.pdf?sfvrsn=0.*

6 The Valuation Manual will no doubt be revised to refer to the later version of this study published in 2015.

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