Article from

The Modeling Platform

April 2018
Issue 7

A System-based Approach to Cell Testing

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"Let us dismiss the question, 'Have you proven that your model is valid?' with a quick NO. Then let us take up the more rewarding and far more challenging question: 'Have you proven that your model is useful for learning more about . . . ?'"

—James B. Mankin Jr., electrical engineer and computer scientist

Model validation and model risk management have been hot topics in recent years for many actuaries. Single cell testing is a fundamental process of model validation. In this article, we discuss a system-based approach for integrating the various parts of the cell testing process.

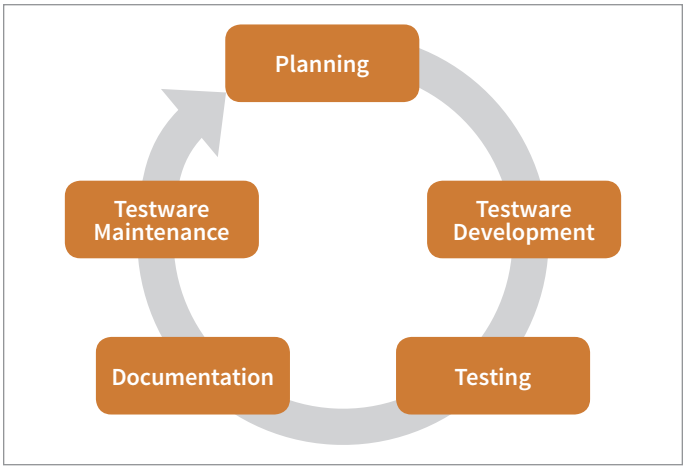
WHY A SYSTEM-BASED APPROACH?

Actuarial models and their corresponding test tools are necessarily interrelated and interdependent. The cell testing process is dynamic, ranging from a simple, time-dependent roll forward to a complex attribution of model changes. This process may include testers from several internal departments and possibly even vendor companies, consulting groups and auditing firms.

A system is defined as a group of interacting, interrelated, or interdependent elements forming a complex whole. In this article, we propose categorizing the cell testing process as a system and argue that cell testing as a system is beneficial for model validation and model risk management.

We'd like to introduce a new term: *testware*. This is comprised of a user guide, test plan, test cases, result summaries, and one or more test tools. Figure 1 illustrates the five deeply connected elements of the cell testing system in our paradigm: planning, development, testing, documentation and maintenance. *Planning* involves drafting a solid test plan to guide the testing process. *Development* includes the writing of the testware, which should conform to the approved test plan. *Testing* consists of a comparison of the model and test tool results and the resolution of any unexplained differences. *Documentation* is written by the model testers so that actuaries may review details about the testware, including simplifications, limitations and testing results. *Maintenance* of the testware rounds out the system and ensures that the testware remains in sync with the model throughout the production cycle.

Figure 1
Cell Testing System Elements



PLANNING

Planning is the initial stage of the system-based approach to cell testing. A test plan is the pivotal component in this phase. Enumerating the components of the testing process by drafting a test plan and allocating dedicated testing resources are the first steps to a successful and meaningful testing exercise. All stakeholders should discuss and agree on the following components.

- **Test plan.** Model owners, model users and model testers should agree on a test plan that delineates the roles and responsibilities of all dedicated resources. Ultimately, the parties need to identify the goals of the testing exercise and tie the company decision-making process to the testing goals.

- **Scope.** This specifies what is tested and what is not tested. Setting scope requires experience with the model and is a necessary prerequisite for budget planning.

- **Sampling.** A sufficient number of cells should be selected to test a large set of model variations. Sample cells should be carefully chosen and the key characteristics of the business should be considered. A coverage ratio may be calculated to reflect the scale of the sample. The sample should be reviewed periodically to accommodate new business and changes to the in-force census.

- **Table and code reviews.** The nature of the model will drive whether a table and code review should be included in testing. Some code can be prewritten and repetitively used by vendors or third parties and could be thoroughly tested in

other applications. If those canned codes are used repeatedly in the model, previous testing evidence may be leveraged.

DEVELOPMENT

Test tools should be built from first principles. Complexities regarding the cell testing process require actuaries to design system-based testing strategies with functional testware.

In recent years, insurance companies have been implementing several actuarial model conversions that require extensive testing on new models. For black box models, reverse engineering and vendor support may be needed to sufficiently understand the model's calculations. For glass box models, technical specifications may assist in describing the model. The reconciliation process depends on the transparency of the calculations. If disagreements arise between modelers and testers, methodological differences should be reconciled during the testing process. In some cases, an existing model with similar functionalities may be leveraged as an alternative to developing a test tool from scratch.

TESTING

The Actuarial Standards Board (ASB) Modeling Task Force provides the following guidance on the use of cell testing:

> The actuary should determine the appropriate degree of checking of formulas and table mapping that is needed (for example, breadth, depth, complexity, etc.), given the intended purpose, context and nature of the model, including its operating environment and controls, and whether there may have been any changes to the model and its environment.[1]

The concept of separation of duties is familiar to actuaries, but we argue further that the testing of the model should be independent from the development of the testware. Single cell testing is comprised of input testing, output testing and calculation testing.

Input Testing

Input testing is critical in the cell testing process. Following the big data trend, a greater number of data management packages are now available, and we foresee input testing becoming more important.

- **Source files.** Inputs, including assumption data, should be validated through comparison with the source files. Stakeholders should agree whether full validation is required or if spot checking is sufficient.

- **Hidden data.** In black box models, inputs and data parameters are often hidden, such as the mortgage prepayment model calibration and logic. These parameters may even include proprietary information, which could be protected from the tester. Some assumptions may be set by departments within the company. In each of these cases, the model testers may need to rely on testing performed by vendors or other departments.

- **Usage.** The correct usage of assumptions needs to be examined. The application of assumptions should be consistent with their development. For example, if lapse assumptions are developed on an end-of-month basis but the model applies lapses at the beginning of the month, it may be necessary to adjust lapse rates prior to their implementation.

- **Assignment.** The correct assignment of assumptions needs to be reviewed, such as what plan code uses what assumptions. This could be done by feeding source inputs and parameters into the testware.

- **Scenarios.** Some models obtain scenario data as an input item, whereas others use an internal scenario generator. In either case, scenarios should be checked for reasonableness and the tester should understand their utilization within the model.

- **Calibration.** Input testing may include checks and balances against other sources, such as the calibration of key assumptions in different departments of the company or in different models.

Output Testing

Output testing in the cell testing process shares many similarities with user acceptance testing (UAT). For single cell testing, additional output testing could be used to accelerate the testing process before releasing the model to end users. This preliminary testing could be used to help explain observations made during the UAT process.

- **Reasonableness.** Running reasonableness checks provides the tester comfort that the output makes sense. Whereas user acceptance testing typically checks model results in aggregate, single cell testing could assess reasonableness at the seriatim level.

- **Sensitivity testing.** Performing sensitivity analysis on a cell basis across key assumptions assists in the validation of assumptions and logic, especially across highly sensitive variables.

- **Attribution analysis.** Completing an attribution analysis at the cell level helps validate the impact of model changes to identify elements contributing to unresolved differences.

- **Trend analysis.** Trend analysis is a time-series comparison. Back-testing can provide valuable information about the model.

- **Actual-to-expected testing.** Obtaining checks and balances with other sources, such as a seriatim-level, actual-to-expected analysis, is often valuable to better understanding the output.

Calculation Testing

Development of test tools from first principles is a key element of calculation testing. Independence between model developers and testware developers ensures that the test tools serve as a solid benchmark for the model.

- **Proof-of-concept tool.** For complex calculations on a block basis, it may not be practical to build testware as that may require building another complete model. In such situations, a simplified proof-of-concept test tool could be developed.
- **Scenarios.** Different scenarios should be tested in the calculation process, especially when the calculation is sensitive to the scenarios.
- **Acceptance criteria.** The testing result threshold should be discussed upfront, such as the absolute dollar difference, percentage difference or present-value measure.
- **Testware performance.** The run-time of the testing process should be considered when building the testing strategy. Single cell testing that runs in Excel could require significant runtime for complicated calculations. Iterations may be very long if the testing process needs to be repeated.

DOCUMENTATION

Testing documentation includes the test plan, testware user guide, testing results summary, approvals and supplemental information, such as slides prepared for management presentations. Model testers should confirm that deferred items, model enhancements and bug fixes are documented in ongoing project plans. Documentation should be reviewed with all the stakeholders and periodically reviewed to ensure it is up-to-date.

The test plan should clearly articulate the scope of the testing. All considerations leading to the decision of a reasonable test scope need to be clarified and agreed upon among stakeholders and management. Either a follow-up test plan or a risk analysis is encouraged to help prioritize testing.

The testware itself should include instructions on how to use the test tools. A version log should contain a summary of updates in each version and the impact of these changes on results.

MAINTENANCE

Testware maintenance depends on the significance of updates to the model and inputs. For a production model, the accompanying testware needs to go through the change management process concurrently. Periodic review of the testware is encouraged.

Maintenance could also improve the efficiency of the testing process. For example, different scenarios or product groupings could be rotated in each round of testing during the maintenance stage to test the model more efficiently. A robust sampling technique is important in this case.

Periodic code reviews are also encouraged, especially during model or assumption changes.

INTEGRATION OF CELL TESTING ELEMENTS

In summary, we discussed the elements in a dynamic system-based cell testing approach. This system-based approach provides a holistic view of the cell testing process and model risk management. We explored the elements of a cell testing system, but actuaries should not only thoroughly consider each element of the system but also be cognizant of the interdependence of the planning, testware development, testing, testware documentation and maintenance.

Actuaries should consider the maintenance of the testware during its development. Important questions such as the efficient use of the testware and its change management process may lead actuaries to choose one form of development over another. Also, when actuaries perform testing during frequent model releases, documentation of these releases will assist in the testware development. Documentation could also guide future development of the testware and testing process.

Overall, we argue that important knowledge from tacit to explicit could be gained through the cell testing process. Thinking through the testing process from a system perspective will help organizations retain and make better use of the information and improve the efficiencies of the model testing. ■

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ENDNOTE

1 Actuarial Standards Board. 2012. Discussion draft regarding Modeling in Life Insurance and Annuities, *http://www.actuarialstandardsboard.org/asops/modeling-life-insurance-annuities/* (accessed February 21, 2018).