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Data Visualization for Model Controls

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One of the critical components of model risk management is effective model controls. The Committee of Sponsoring Organizations of the Treadway Commission (COSO) defines a control as follows:

"Internal control is broadly defined as a process, effected by an entity's board of directors, management and other personnel, designed to provide reasonable assurance regarding the achievement of objectives relating to operations, reporting and compliance."[1]

Examples of controls commonly used in model risk management include the following:

- Formalized approvals for model changes and updates
- Reconciliation of data
- Review and sign-off of model results
- Trending
- Ratios
- Roll-forward of accounts

Although actuaries are familiar with these types of controls, as a profession we have spent significantly more time thinking about constructing models than controlling them. Controls for actuarial models are currently full of "low hanging fruit"—that is, items that can quickly and easily be improved for a significant benefit to model risk management. One way in which we can harvest this fruit is by adding visualization to the controls we currently use.[2]

THE PROBLEM WITH CONTROLS

Many controls provide extensive numeric results from a model. These numeric results contain the potential for effective controls, but this potential is not always realized. Many controls fail to distinguish exceptions from anticipated results. They give no indication of the bounds of reasonableness and fail to provide the reviewer with indicators of where the model might be out of control.

They rely on the reviewer to make judgments regarding which items are exceptions and which are normal. Actuarial judgment is a fine thing, but it is not uniformly distributed throughout the profession. The model reviewer may not have developed sufficient actuarial judgment, or the reviewer might not be an actuary.

Furthermore, controls are often formatted in such a way that it is difficult to read and interpret the data, and even more difficult to maintain sufficient focus to apply the necessary judgments. Some controls need their own controls!

To illustrate this, a specimen control is shown in Table 1 (below).

This is from a roll-forward of universal life account values in which each of the components is shown as a change from the prior period. Even though just looking at this makes my eyes start to cross, it's clear that there is a lot of good information here, but it is difficult to tell what is what.

Table 1

Plan Code	Change COI	Change Load	Change Interest	Change AV on Surrender	Change AV on Death	Change Premium	Unallocated as % of Fund
1001	0.006	0.012	0.019	0.093	0.067	0.115	0.009
1002	0.015	0.013	0.024	0.077	0.000	0.050	0.007
1003	0.014	0.040	0.042	0.062	0.036	0.081	0.007
1004	0.022	0.039	0.027	0.006	0.060	0.017	0.017
1005	0.013	0.012	0.038	0.016	0.004	0.093	0.006
1006	0.004	0.023	0.034	0.013	0.072	0.009	0.015
1007	0.014	0.051	0.046	0.072	0.042	0.008	0.008
1008	0.004	0.051	0.039	0.086	0.033	0.032	0.008

Can we do better than subject model reviewers to such a painful exercise?

DATA VISUALIZATION ADDRESSES THE PROBLEM

The best controls provide immediate and effective feedback on potential model exceptions. Table 2 (below, top) is based on the data in Table 1. However, it presents the data in a binary manner—green for Exception and gray for No Exception.

Usually the simpler a control is, the more effective it becomes. Compare the ease of scanning the control in Table 2 with a more nuanced control similar in format, but with a *Consumer Reports*-style ranking shown in Table 3 (below, bottom).

Although this format provides more information than the green/gray format, it underperforms as a control because it is not as easy nor as efficient to scan.

The key to making such controls effective is understanding the normal range of results as well as what typically causes outliers. The model owner will need to articulate this understanding in such a way that the quantification of the range of normal results is possible. As an example, the model owner for the roll-forward model shown above may have determined through experience that any unallocated amount of fund change greater than ±2 percent of the fund is indicative of an outlier. On the green/gray control above, any unallocated amount more than ±2 percent would show up as a green light.

Both the green/gray control and the *Consumer Reports*-style control were created in Excel, using conditional formatting.

SOME GENERAL RULES FOR VISUALIZATION IN CONTROLS

The difference in the efficiency between the two ranking controls above points us to some of the rules for data visualization controls. Since visualization is more of an art than a science, these rules are stated in general form. The practitioner must decide how these are best applied in any situation.

- Make controls as simple as possible, but as complex as necessary
  - Controls should provide only the information needed to determine the control decision
- Provide immediate indications of actuals versus expectations
- Emphasize the critical data
- Changes in output values are often more informative than either the beginning or ending values

Table 2

Plan Code	Overall Rank	Change COI	Change Load	Change Interest	Change AV on Surrender	Change AV on Death	Change Premium	Unallocated as % of Fund
1001	●	●	●	●	●	●	●	●
1002	●	●	●	●	●	●	●	●
1003	●	●	●	●	●	●	●	●
1004	●	●	●	●	●	●	●	●
1005	●	●	●	●	●	●	●	●
1006	●	●	●	●	●	●	●	●
1007	●	●	●	●	●	●	●	●
1008	●	●	●	●	●	●	●	●

Table 3

Plan Code	Overall Rank	Change COI	Change Load	Change Interest	Change AV on Surrender	Change AV on Death	Change Premium	Unallocated as % of Fund
1001	◕	●	●	●	◔	◔	◔	◕
1002	●	◕	●	●	◑	●	◕	●
1003	◕	◕	◑	◑	◑	◕	◑	●
1004	◕	◑	◑	◕	●	◑	●	◔
1005	●	◕	●	◑	●	●	◑	●

- Orient the data in the most user-friendly way
- Color draws the eye quicker than black and white
- Use a visualization style suitable to the purpose—for example:
  - Line graphs work well for trends
  - Bar charts work well for rankings
  - Maps work well for geographical data

The goal is to make the data visualization work as a process control chart—a tool that quickly tells the model reviewer whether results are outside of the boundaries of reasonableness.

> Make controls as simple as possible, but as complex as necessary.

WHEN REASONABLENESS BOUNDS CANNOT BE EASILY ARTICULATED

In some instances, the modeler will have difficulty articulating what the bounds of reasonableness are for modeled items. This may be due to the multifactorial nature of the item, or it may be due to the nonlinearity of the item. It could be due to both the multifactorial nature and nonlinearity.

Whatever the reason for the difficulty, the modeler will usually only have a rough sense of how modeled values will emerge from the model.

A typical example of this sort of model item is the reserve per $1,000 of in force that is often used as a control for valuation models. There are various forces that affect the reserve/$1,000 for any particular valuation cell, including:

- Number of policies in the cell
- Amount of in force in the cell
- Type of benefit
- Premium paying pattern

So this is definitely a multifactorial item. In addition, the slope of reserves is usually nonlinear, adding to the difficulties in determining the bounds of reasonableness.

Not only is it hard for the model owner, it is also difficult for the auditor. The PCAOB has come down very hard on auditors for not giving sufficient scrutiny to this sort of control, and for not documenting their analysis of the effectiveness of the control. The following quote from Helen Munter, director of the Division of Registration and Inspections of the PCAOB emphasizes this point:

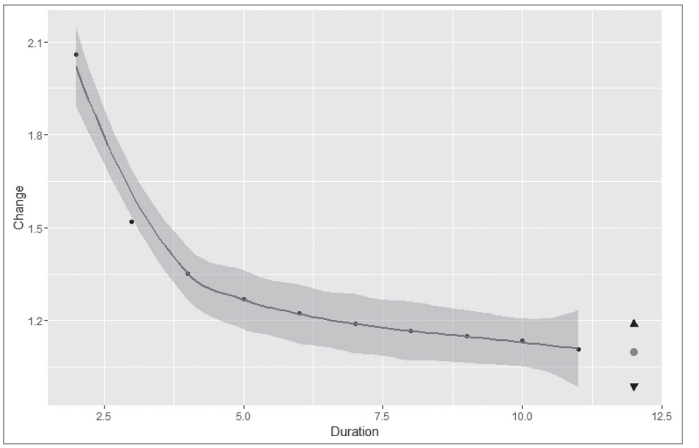
> "Over the last few years, the audit of internal control has topped the list of deficiencies in the audit work we have reviewed."[3]

When the required articulation is not possible, it is still possible to develop visualizations for the bounds of reasonableness. We require a general fitting method combined with predictions of the model item in question. Figure 1 shows one such approach.

In Figure 1, the dots in and around the shaded area are historical actual reserve change ratios. The line inside the shaded area is the curve fitted to the data. The shaded area is the fitted curve plus/minus one standard error.

This approach used loess regression (a nonlinear approach in which a series of polynomials is fitted to the data) for the first 11 policy durations, and a prediction interval for the 12th duration is given as the point estimate ± one standard error. These bounds of reasonableness are shown as triangles, while the actual result is shown as a circle. In this example, we see that the actual result falls comfortably within the bounds of reasonableness.

Figure 1



It is possible to programmatically chart a series of such reserve progressions. It is also possible to export the results into a Red/Green indicator type spreadsheet in addition to (or in place of) charting the results as in Figure 1.

REVIEW AND SIGN-OFF CONTROLS

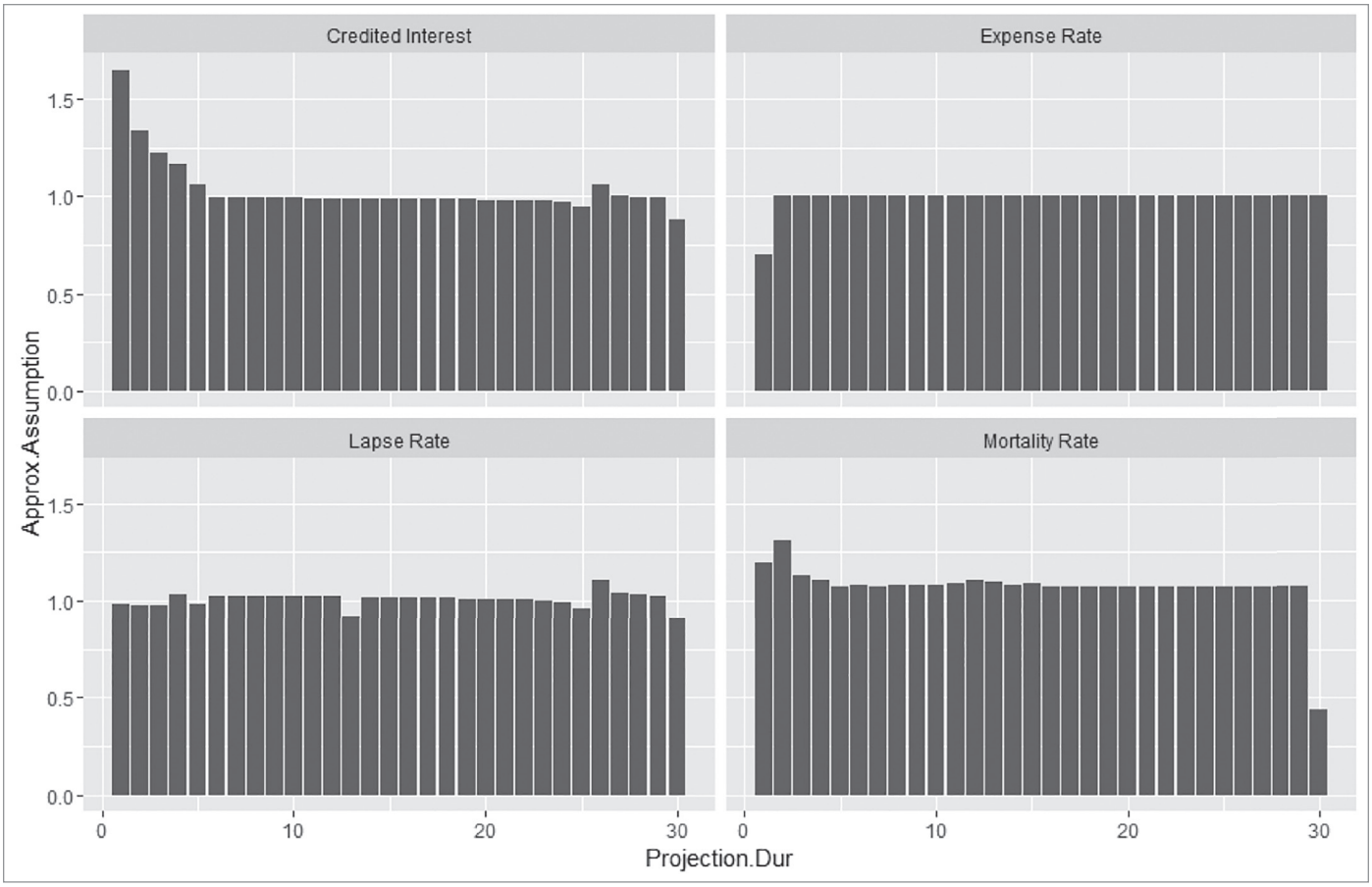
Review and sign-off controls are subject to several difficulties. Sometimes the sign-off form merely states that the model has been reviewed for reasonableness. (Occasionally there will be sign-off forms that merely assert that a review has been performed, but most companies seem to have realized the true value of this assertion.)

A simple assertion of reasonableness is troublesome from several aspects. The first is that it might not be clear precisely what model output has been scrutinized for reasonableness. It is possible that several items could be effectively reviewed for reasonableness, yet a critical model output might not be scrutinized. Such an oversight could easily go undetected until there is a material model problem.

> Data visualization is limited mostly by our imaginations rather than our software capabilities.

Another troubling aspect of such a review is that there is no definition of what constitutes reasonableness or of where the boundaries of reasonableness lie. If the reviewer has different judgments on reasonableness compared to the model designer or the model owner, then we should expect either false model exceptions or missed model exceptions.

Figure 2



A final difficulty with such a simple assertion is that if it is time sensitive, the depth and extent of the review could be subject to variability.

In order for a sign-off control to work uniformly, there needs to be a structure provided in which the review takes place. Often what is wanted in a reasonableness review is a review of the directional changes in model output compared to the directional changes in model assumptions. One way to address this is to put a visualization of the ratio of stated directional changes versus approximated directional changes into a quickly and easily assimilated visualization. The example in Figure 2 (pg. 21) shows the ratio of the documented assumption versus the approximation of the assumption calculated from model output.

In this visualization, the significant drivers of model output are shown together in order to ease the reviewer's job. The reviewer would need to decide if the early-duration and late-duration variations are true exceptions or if they are artifacts of the approximation methodology.

Another item that may be of interest is model composition such as in force by issue age or underwriting category. One way to quickly display such information is in an ordered bar chart such as Figure 3 (below).

For model control visualization, we can put together a historical series of charts for some selected number of past model cycles in order to provide an additional dimension to the visualization.

WHEN VISUALIZATIONS GO WRONG

One of the more popular forms of visualization found on many websites is the "mosaic plot." A mosaic plot display of the information in the In Force Composition from above is shown as an example.

Figure 3

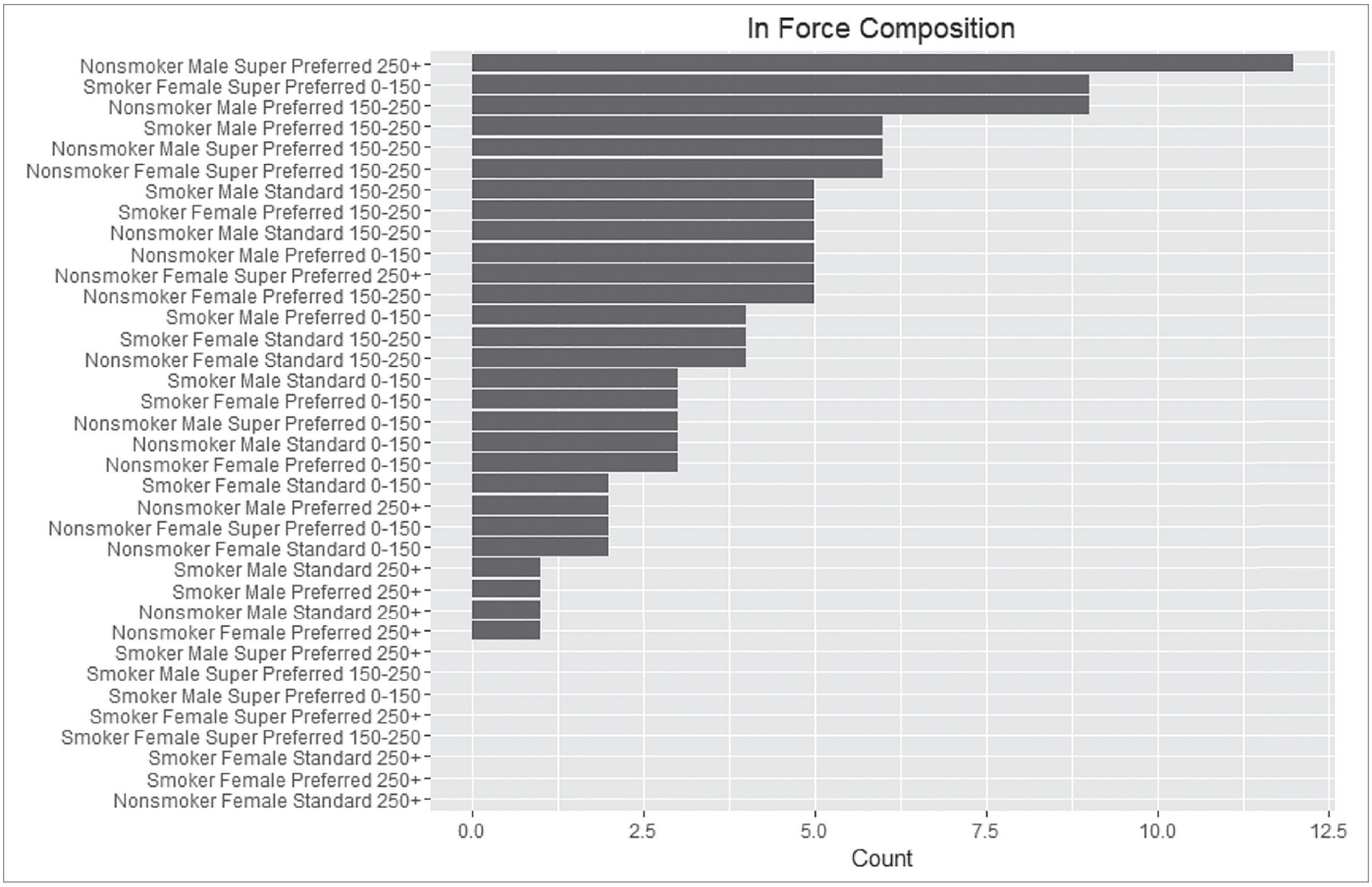
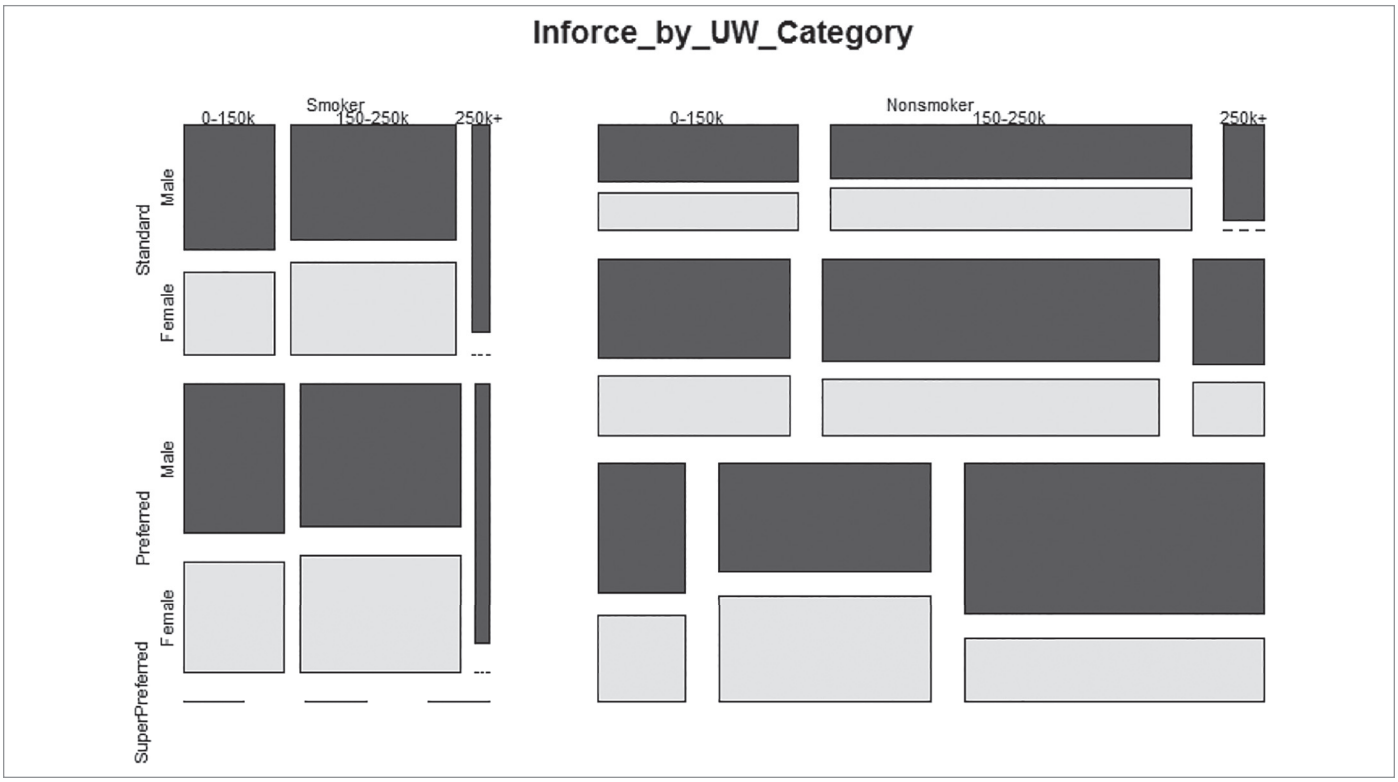


Figure 4



Mosaic plots are interesting and fun to look at, but they don't work as control visualizations. A brief scan of the visualization in Figure 4 shows that it is difficult to make quantitative comparisons between different segments, or even to quickly determine the largest segments of in force.

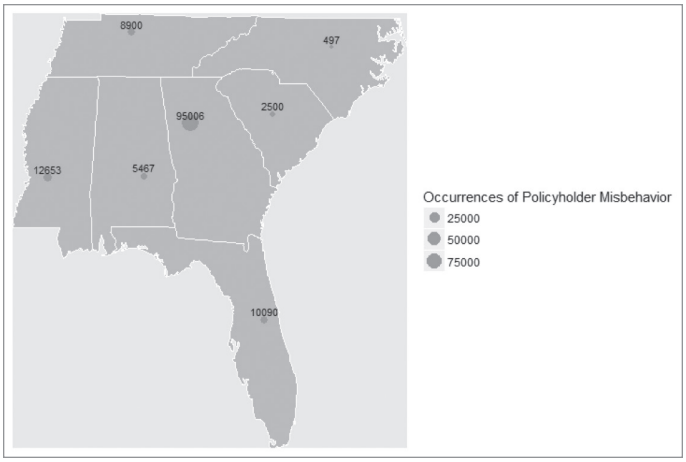
Cells with similar areas sometimes have markedly different dimensions—this issue is so profoundly non-intuitive that it is difficult to conceive of any situation in which a mosaic plot would make an effective visualization for a model control.

Just because we can create a visualization doesn't mean that we should create a visualization.

GEOGRAPHICAL DATA

Whenever a model creates output with a geographical component, maps become an option as a control item. A well designed map provides more information per pixel than almost any other visualization. In the hypothetical example given in Figure 5, I have shown a projection by state of the number of policyholder misbehaviors. Policyholder misbehavior is any activity that results in adverse results for the insurer. The visualization provides a quick relative comparison as well as providing precise information regarding the number of projected occurrences.

Figure 5



CONTROLS FOR WHEN THERE ARE NO BRIGHT LINES

In situations where we are not circumscribed by prescribed methodologies or assumptions, we might be interested in a "better/worse" comparison rather than "reasonable/unreasonable" comparison. Appraisal models and planning/budgeting models might fall into this category.

For such better/worse comparisons, a heat map might provide quick information regarding the relative performance of model output compared to some standard of expectation. Heat maps highlight worse results with "uncomfortable" colors while highlighting better results with "comfortable" colors.

In Table 4, a heat map is used to show how model output compares to projected historical trends.

Table 4

Item	2017	2018	2019
Premiums	3.3%	6.0%	9.3%
Death Benefits	-5.1%	-7.2%	-8.0%
Lapse Benefits	-6.2%	-8.7%	-11.7%
Expenses	20.8%	37.5%	61.5%

- Differs from trend by ± 5%
- Differs from trend by ≥ 5%, < 10% absolute change
- Differs from trend by ≥ 10% absolute change

This heat map was created in Excel, where conditional formatting makes such visualization easy.

There is an interesting issue hidden in the implicitness of numbers used to construct the heat map. The standard for Better and Worse was a linear trend line. Why did I choose a linear trend? Mainly for illustrative purposes. In real life, some nonlinear form of trending might be more appropriate, and might be a better reflection of what is reasonable.

In all of these examples, experience and a firm grasp on reality are important in setting the bounds of reasonableness. As Salvador Dali, the great surrealist, might have said:

> "One person's reasonableness is another person's melting watch."

CONCLUSION

Actuarial model controls are ripe for improvement. One way to greatly enhance the effectiveness of many controls is to include some form of visualization. Visualization can be done with spreadsheets, with R or with some form of commercial data visualization package. Data visualization is limited mostly by our imaginations rather than our software capabilities. Many other forms of visualization are possible and will no doubt come into practice as actuaries focus more on controls. ■

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ENDNOTES

1 From the document "Internal Control—Integrated Framework" on COSO's website at *http://www.coso.org/documents/990025P_Executive_Summary_final_may20_e.pdf.*

2 The visualizations shown in this article were created using R software, except where noted differently.

3 *https://pcaobus.org/News/Speech/Pages/Munter-Audits-Internal-Control-IAG-09092015.aspx*