Canadian Institute of Actuaries
Institut canadien des actuaires

Educational Note

Use of Models

Modelling Task Force

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Members should be familiar with educational notes. Educational notes describe but do not recommend practice in illustrative situations. They do not constitute standards of practice and are, therefore, not binding. They are, however, intended to illustrate the application (but not necessarily the only application) of the Standards of Practice, so there should be no conflict between them. They are intended to assist actuaries in applying standards of practice in respect of specific matters. Responsibility for the manner of application of standards of practice in specific circumstances remains that of the members.

MEMORANDUM

To: All Fellows, Affiliates, Associates, and Correspondents of the Canadian Institute of Actuaries

From: Pierre Dionne, Chair
Practice Council

Bob Howard, Chair
Modelling Task Force

Date: January 26, 2017

Subject: **Educational Note—Use of Models**

A revised draft educational note was released to members on July 26, 2016. The task force thanks those who submitted comments. Based on the comments, there are a few clarifications and corrections in the final educational note below, but there are no major changes in thrust.

The subject that was commented on most frequently related to the definition of what is and what is not a model. Some objected to the classification found in section 1.2. The task force acknowledges that there is necessarily some vagueness in the definition of a model and that actuarial judgment is required, particularly near the border of what is and what is not a model. The task force believes that the main distinction contained in the definition is whether there is a simplification of reality as opposed to a calculation of reality itself.

In accordance with the Canadian Institute of Actuaries' (CIA) Policy on Due Process for the Approval of Guidance Material Other than Standards of Practice and Research Documents, this educational note has been prepared by the Modelling Task Force, and has received final approval for distribution by the Practice Council on January 24, 2017.

As outlined in subsection 1220 of the Standards of Practice, "*The actuary should be familiar with relevant Educational Notes and other designated educational material*." That subsection explains further that a "practice that the Educational Notes describe for a situation is not necessarily the only accepted practice for that situation and is not necessarily accepted actuarial practice for a different situation." As well, "Educational Notes are intended to illustrate the application (but not necessarily the only application) of the standards, so there should be no conflict between them."

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1 Background

1.1 Reference to Exposure Draft

This educational note is being released at the same time as a change to the General Standards on the use of models. This educational note is intended to be read along with the new standards. The standards address the main principles involved in an actuary's use of models. The educational note expands on the principles to set out more specifics of how an actuary can ensure that good practice is being followed in the use of models. The intent of this educational note is to be principles-based rather than rules-based. The examples are intended to illustrate the principles rather than to describe a single correct way to do things.

The definitions in the Standards of Practice related to models are repeated here for convenience.

.31.1 Model is a practical representation of relationships among entities or events using statistical, financial, economic, or mathematical concepts. A model uses methods, assumptions, and data that simplify a more complex system and produces results that are intended to provide useful information on that system. A model is composed of a model specification, a model implementation, and one or more model runs. Similarly for "to model". [*modèle*]

.31.2 Model implementation is one or more systems developed to perform the calculations for a model specification. For this purpose "systems" include computer programs, spreadsheets, and database programs. [*implémentation du modèle*]

.31.3 Model risk is the risk that, due to flaws or limitations in the model or in its use, the actuary or a user of the results of the model will draw an inappropriate conclusion from those results. [*risque de modélisation*]

.31.4 Model run is a set of inputs and the corresponding results produced by a model implementation. [*exécution d'un modèle*]

.31.5 Model specification is the description of the components of a model and the interrelationship of those components with each other, including the types of data, assumptions, methods, entities, and events. [*spécifications du modèle*]

1.2 Examples of Models

In most cases, it is clear what is and is not a model, but in some cases there can be uncertainty. However, the distinction is not necessarily important. An actuary ensures that all calculations are done with "due skill and care". It would not be good practice to use any computer program without considering whether it was sufficiently accurate and suitable for the task.

The main distinction in the standards between a model and a calculation that is not a model is in the documentation required. The standards normally require some documentation for choosing and using a model. There is no requirement in the standards of practice that an actuary keep any particular documentation of a calculation that is not a model, but for more significant or complex calculations, it may be prudent to retain some documentation.

Whether a model or not, the same standard of care in accuracy applies.

The two lists below are intended to give some examples of what is or is not a model, but neither list is definitive nor exhaustive. Their purpose is to clarify the definition, but ultimately classifying as a model or not will require judgment.

Examples that are not Models

1. Adding a column of numbers. There is no simplification of reality. The sum is reality itself. The same is true whether there are a few numbers or so many that they could not possibly be added manually.
2. Calculating a least-squares regression line. A regression line may be used in a model, but calculating a regression line itself is not a model.
3. Spreadsheets used to summarize and reformat information, typically for reporting purposes. The input may come from models, but the summarizing is not a model.
4. Calculating a life annuity factor where the formula and assumptions are prescribed, for example, by standards or regulation. This is not a model because the calculation does not allow for any discretion.

Examples that are Models

1. Calculating a life annuity factor where the actuary makes assumptions or where the actuary makes decisions about simplifications. This stands in contrast to example 4 above.
2. Dynamic Capital Adequacy Testing. This is a very complex model that may contain several submodels.
3. Generating a series of random events. The generation of a series of pseudo-random numbers is the application of an algorithm and not a model, but when those numbers are used to represent reality, the whole would be considered a model.
4. Creation of loss development factors (LDFs, also known as chain ladder) to estimate the ultimate incurred losses. While a simple model, the estimation of the age-to-age factors and the application of the ultimate factors are considered a model.
5. Generalized linear model (GLM) techniques used for segmenting an automobile book of business.

1.3 Use or Development

This educational note and the associated standards deal with the use of models but not with the development of models. There are robust bodies of knowledge around coding practices, change management, and process management that are typically employed in developing and modifying systems (including models), and actuaries will want to be assured that good practices for model development and changes have been followed. However, this note focuses instead on tasks such as what is an appropriate model to use in a particular case, what assurance is there that there are no material errors in the model results, and how is the knowledge from the model best communicated to the user.

1.4 Model Risk and Risk Rating a Model

The concept of model risk is key to using a model effectively. Because a model is a simplification of reality, there is always risk in using a model. Model risk is focused not so much on the output of the model as on the inferences, opinions, and decisions that flow from the modelling.

Various strategies would be employed to mitigate model risk. These strategies are employed when actuaries do the following:

- Choose a model for a task;
- Use the model (one-time or ongoing) or oversee its usage; and/or
- Communicate results of that model.

In determining the potential mitigation activities, the actuary would consider the level of risk that the model poses; i.e., use a risk-based approach. Model risk exposure can be considered along two scales: severity and likelihood of failure in a model.

The first is the potential severity of a model failure, or "how bad can it be?" While it is difficult to quantify this, we can provide guidance in terms of looking at the following:

- The financial significance of the results that the model produces. Severity is greater for a model that is used for a major balance sheet item than for a model that is used to decide if a particular strategy is directionally correct.
- The importance of decisions being made using this model and how much the results of this model contribute to that decision. For example, one could be using several models to make a key decision, and in this case, each model's individual contribution to the exposure is lower.
- Frequency of use. A model that is used frequently will have a much larger potential total severity than one used very infrequently because the same failure could be repeated many times until found. Conversely a model that is used infrequently is more subject to being misunderstood or misused than one that is used frequently.
- The non-financial impact. There could be a reputational impact and/or opportunity cost of getting it wrong. Even if there are no immediate financial outcomes, a model failure could lead a company to jeopardize its standing with regulators, competitors, and customers. A model failure could lead the company to miss a potential opportunity.

The second metric to consider is the likelihood of a model failure. This will generally be based on looking at the following:

- The complexity of the model. More complex models have greater potential for misuse and misunderstanding of the results, and there are many more calculations that need to be checked.
- Required level of knowledge and expertise of users. Inadequate knowledge and training of users could contribute to failures in the processing of the model, e.g., wrong inputs or failure to deal appropriately with known limitations. There could also be cases where the users misunderstand the model's purpose and try to use it for another purpose for which it has not been tested.
- Adequacy of documentation.
- Sufficiency of testing.
- The degree of independence of the one validating the model from the developer of the model.
- Adequacy of peer review.

Typically, the actuary has limited control over severity. Also typically, the actuary can exert considerable control on likelihood through matters such as choosing better models, exercising greater care in validation, and employing tighter controls for model runs. Both the severity and the likelihood of potential model errors would be considered in risk rating the model.

(This educational note assumes that a risk rating is done, but there are acceptable alternatives. The essential point is to assess the risk of the model and determine the effort expected in validating and other model related tasks. When there are many models within a firm, a risk-rating scheme promotes efficiency and consistency. When there are few models, a risk-rating scheme may not be of benefit.)

Appendix 1 presents examples of risk rating a model out of many that are acceptable. The actuary is encouraged to follow an approach to risk rating that works well in his or her business. It is important to have a consistent approach to risk rating. The amount of effort in choosing, testing, validating, documenting, and controlling a model would reflect the risk rating. All models require some work to ensure that they are being used appropriately and accurately; those with higher risk ratings require more extensive work to mitigate model risk. When the risk rating is very low, little effort is warranted; when the risk rating is high a great deal of effort is warranted. In the extreme, a model may be unacceptable because its risk-rating is too high.

A protocol for periodically updating the risk-rating would normally be part of the risk-rating approach. The following considerations may guide the decision to update a risk-rating:

- Reassess if a model fails;

- Reassess on a regular cycle, e.g., every five years;
- Reassess when model use changes; and
- Reassess if the impact of results change greater than [some tolerance level set in advance].

2 Choice of Model

2.1 New (or Substantially Changed) Model

Before using any model, an actuary would become comfortable that it is well suited to the use that the actuary intends, that the model works correctly, that available data conform to the model requirements, and that the output is in a form that the actuary can use. The actuary would be alert to limitations in the model that may prevent it from providing reliable results under certain circumstances. The model's risk rating is a key factor in determining the extent of the effort performed in deciding whether a model is acceptable. In particular, what is described below in this subsection is not to be taken as the minimum standard for all models. The amount of effort in each area would vary according to the risk rating.

Review Specification

The actuary will want to understand the model specification to verify that the methods used are sound, that assumptions that are embedded are appropriate, that the data can be provided in the form required, and that the model design contemplates all the necessary assumptions. For example, if valuing pension plans, the model needs to allow for a variety of forms of benefit, both immediate and deferred, and support the desired valuation method. The model would need a facility for adjusting the base mortality table, and it is desirable to support a two-dimensional improvement scale.

If using a third-party model, the actuary may have no access to the full specification. In this case the actuary will want to perform the appropriate tests to assess any important aspects not covered in the user's documentation.

It is important to ensure that the format and interpretation of data available to use with the model coincides with or can be made to coincide with what is contemplated in the model specification. For example, some systems use sex codes 1=male and 2=female, but others use 1=female and 2=male. Some interest rates may be assumed to be effective annual, but others may be semi-annual compound.

Validate Implementation

The actuary cannot simply assume that the model correctly implements the specification. The actuary tests the model and ideally compares it with other tested models to verify the calculations. The greater the financial significance of the work for which the model is to be used, the more thorough the testing. It is good practice to keep documentation on the testing done. It is also good practice to maintain a set of test cases that can be run through the model or a new version of the model to verify that the model is still correct. For a model with a higher risk-rating, it may be wise to run an entire live file through successive versions of the model.

There are many techniques that can be used in validation; not all techniques are appropriate to all models. Sensitivity is discussed at greater length in subsection 2.5. Backtesting may be helpful in some cases. Comparison to other models is useful when feasible.

The actuary would ensure that an adequate review was conducted on the model code and parameters used in the implementation. In many cases the actuary will have no access to the code, but the actuary can often ask the developer to describe what review was done to ensure that the code and hard-coded parameters are correct.

An actuary who is validating a model may consider having another actuary peer review his or her work.

Dealing with Limitations

Understanding limitations of models is important but rarely easy.

Actuaries would be aware of which events are independent of each other and which are correlated. For example, the mortality of individuals is normally independent, but lapse rates may be correlated to interest rates.

Actuaries would be alert to assumptions that are fixed or embedded in a model. For example if the income tax rate is hard-coded, the model cannot be used to assess sensitivity to changes in the tax laws.

Some approximations are not robust over a full range of potential outcomes. For example, if a mortality improvement scale which is two-dimensional is approximated by a one-dimensional improvement scale, the approximation may not be good enough for a pension plan of mostly young lives with long deferral periods, but it may be fine if most of the liability is for retired lives.

The actuary would understand the range of potential circumstances and uses for which the model was designed and tested. The model may appear to work correctly for all test cases, but it may not handle the full range of situations in the real world. A model may be appropriate for pricing, but it may not be able to handle all cases needed in valuation.

Documentation[1] of Model Choice

It is good practice for the actuary to keep documentation on why he or she decided a particular model to be suitable, how it was determined to be sufficiently accurate, and what limitations, if any, were found.

[1] *Documentation* refers to the actuary's working papers and is distinct from internal or external user reports. Although documentation may not be made generally available, it is important that the documentation be available to those reviewing an actuary's work and to those who later assume responsibility for the actuary's work.

2.2 An Existing Model Used in a New Way

This subsection assumes that the steps in subsection 2.1 were previously followed for the model.

In this case, the actuary can be confident that the calculations are accurate, but the new application may be affected by limitations in the model that were not relevant in the initial application. Therefore, the actuary would consider what limitation, if any, is to be reviewed, perform appropriate testing, and document this work. The actuary would also consider whether the risk rating for the model has changed and, if it is higher, more validation work may be required. Completing this work effectively expands the range of standard applications for the model.

2.3 Models Approved for Use by Others

It commonly happens, particularly within a large firm, that one team validates a model that is to be used by others. It is generally appropriate for an actuary using a model to use the work of the others who validated the model, provided that the actuary agrees that the validation process was adequate.

The team doing the validation will typically disclose, at least in summary, that the steps in section 2.1 were followed. The actuary using the model would review the report on validation and retain evidence to show that the actuary is aware of the work done and is satisfied that the work was sufficient.

In some cases, an actuary may choose to rely on the validation done by others outside his or her firm. Unless the actuary has access to the documentation of the validation, the burden of proof for accepting such a validation would be higher than for a validation done within the firm.

2.4 Models Outside an Actuary's Area of Expertise

Actuaries may need to use and/or rely on models outside of their expertise: for example, credit-scoring models, economic capital models, or enterprise risk management models that contain features and components outside the expertise of the actuaries using the models.

In these circumstances, the actuary would determine the appropriate level of reliance on other experts. In doing so, the actuary would consider the following:

- If the individuals on whom the actuary is relying are considered experts in their field of practice;
- The extent to which the model has been reviewed by experts in the applicable field; and
- The risk rating associated with the model.

The actuary would make a reasonable attempt to understand the following:

- The basic workings of the model including its inputs, outputs, and general approach;
- The testing and validation work that was completed; and
- The model's complexity and the control framework used.

Further, the actuary would disclose, in the appropriate documentation and disclosures, any reliance on models created by other experts.

In cases where an actuary is required to use a model built using software in which he or she is not expert, the actuary would attempt to gain such understanding as to be convinced that the validation and control framework followed is sufficient to provide confidence in the results produced by the model.

2.5 Sensitivity Testing

Sensitivity testing is useful for validating a model, for understanding relationships between inputs and outputs, and for developing a sense of comfort with a model.

The actuary would consider the assumptions that will be input into the model. The actuary would test and observe the impact of varying these assumptions in validating the model.

The actuary would also consider testing a range of assumptions that may be outside the expected or currently observable range. The actuary can then observe if the model continues to operate soundly under these "what if"-type conditions. A simple example might be using zero or negative interest rates and ensuring the model result is theoretically correct.

The actuary would also ensure that the interplay between related assumptions is considered. For example, in a life insurance valuation model, a change to death rates impacts the mortality charge but also impacts the persistency of the block and may therefore have second-order impacts on the actuarial present value of the maintenance expense cash flows. The actuary would consider sensitivity testing assumptions singly and then in combination to ensure that the model works correctly and that he or she understands these interactions.

The actuary would be alert in the sensitivity testing to cases for which the relationship between input and output is non-linear or linear only over a limited range. In either case, the actuary would test a wider range of inputs so that the impact on output is more thoroughly understood.

Sensitivity testing is sometimes used to enhance the results produced by the actuary. In that case, the actuary may consider not only reporting on the chosen assumption but also on the sensitivity around that assumption. Aggregate risk models sometimes require dependency assumptions to model how different types of risk interact. The actuary usually would have to employ judgment in the choice of assumption to reflect dependency. Thus the actuary may produce results under one correlation matrix but disclose what happens under alternative correlation matrices.

The range of values tested would reflect the range of assumptions that is reasonably expected to be found in practice. Particularly in the case of stochastic models, it is important to test a range wide enough to cover the cases that would be generated randomly.

2.6 Preparing to Use the Model

Having chosen which model to use, the actuary will typically follow a set of steps before it can be used.

The model may require some customizing to fit the particular situation. Any changes to the specifications would be recorded, and any changes to the implementation would be tested.

Particularly in the case of a model that is used repeatedly and with a high-risk severity, it is good practice to document the process to be followed. Subsection 1540 provides relevant guidance on the control process. A process document might include the following:

1. Instructions for obtaining input data;
2. What authorization is required for setting input assumptions;
3. Step-by-step instructions on how to run the model;
4. Checks to be applied to model inputs and outputs;
5. Reconciliations required from prior runs; and
6. A flowchart of the process.

3 Minor Changes to a Model

When a model is changed, either section 2 or this section will apply. It is a matter of actuarial judgment which is more appropriate. If in doubt, it may be better to apply section 2.

Models are rarely static over time. A model may be changed to fix a bug, to change a hard-coded parameter, to handle a new situation, to reflect regulatory changes, etc.

Each time that a model is changed there is risk that the new feature will be implemented incorrectly, that something not planned to be changed will stop working correctly, that the documentation will be rendered inconsistent with the model, or that the change will not be correctly communicated to those who use the model.

At a minimum the actuary using a model that has been changed would be wise to run test cases through both the original and the changed model to verify that the differences, if any, are reasonable. If the changed model can handle cases not handled before, it may be useful to compare a new case handled by the changed model with a similar case handled by the previous version of the model.

The actuary may choose to rely on work done by others in validating a changed model in a manner similar to that described in section 2.3.

4 Use of Models

It is typical for an actuary to use the same model for a variety of cases, whether for valuation, pricing, or other purpose. Doing so makes good use of the actuary's time and is economical for the client. To use the terms in the standard, the actuary produces many model runs (possibly varying data input and assumptions) with the same model specification and model implementation.

4.1 Validation of Data Input

Data need to be "sufficient and reliable". It is assumed that there is a proper control process in place for obtaining the data to be used by the model. Subsection 1530 is directly relevant for data used in a model. The presence of faults in the input data represents a limitation in the model which may need to be disclosed. If the actuary does not assume responsibility for the data, then he or she would so report. Model risk increases when there are flaws in the data and may increase when the actuary assumes no responsibility for the data.

For example, if an insurance company is obtaining input to a valuation model for a material line of business, the actuary might consider the following:

Sufficiency

1. Do the data meet the requirements of the model specification?
2. If the model will be used repeatedly, are the data in a consistent format every time?

Reliability

1. Reconciliation to other sources (preferably audited):
    - For example, does an asset file reconcile to the balance sheet?
    - For example, do the total benefit/premium/records, etc., reconcile to data in other financial records of the company?
2. Summarize and compare input data to prior periods, if applicable.
3. Check and investigate data points that are outliers for possible errors. Examples are age 115, zero benefit, zero premium.
4. How are missing data handled? Is a data assumption made or is an error generated? Is it flagged?
5. Data assumptions would be reviewed periodically to assess their appropriateness.
6. Is the size of the data file consistent with prior periods?

4.2 Validation of Assumptions

In some cases, assumptions are not set through the model specification process but vary with each model run. In these cases, the input assumptions need to be as well controlled as the input data. Section 1700 is relevant for the assumptions required for a model run. The following considerations may be useful:

- Regular peer review (internal and external) of the assumptions.
- Are the intended assumptions the ones used in the model? Care should be taken with models used repeatedly that the assumptions are updated as needed on each model run.
- Are model assumptions unchanged unless they were meant to be changed?

4.3 Validation of Results

At a minimum, the actuary would ensure that the results of a model run are reasonable in light of the input. For models with higher risk rating, there would be stronger controls on the output. For many models, the following checks may be applied:

- Are outputs consistent with inputs? For example, do the output totals agree with the totals of input for number of lives or policies and the amount of insurance or income?
- How many errors were generated and what amount was involved? Is it within an established tolerance? Has the root cause of errors been identified and rectified to an acceptable tolerance?
- Are results as expected, both in direction and magnitude?
- If there are several model runs at different dates, are the latest results consistent with the trend?
- Are the results consistent with the impacts obtained from any sensitivity analysis that was conducted?
- Attribution analysis—has the change in the results from the prior period been explained?
- Testing the predictive value of the model using test data separately from data used for the parameterization.

4.4 Documentation

It is good practice for the actuary to retain documentation on the version of the model used and the inputs and outputs of the model. The model would not normally be mentioned in the user report. The actuary would not need to repeat in the documentation for a model run the issues dealt with when choosing that model.

4.5 Periodic Validation

It is good practice for the actuary to repeat the validation of a model periodically even if it has not been changed. (If the model has changed, see section 2 or 3.) A model with a higher risk-rating would be validated more frequently. A periodic validation can identify where assumptions or approximations, validated initially, are no longer appropriate and relevant in the current environment. An actuary new to a role in which an existing model has been routinely used would be wise to review the model and review the documentation of the model from the actuary's predecessor.

4.6 Stochastic Models

In many respects, a stochastic model is the product of performing numerous runs of a deterministic model. As such, the recommendations of the other subsections of section 4 would generally continue to be followed. However, as indicated by 1540.09, when a stochastic model is used, additional consideration would be given to certain other elements.

When the model inputs and/or assumptions vary with each run, the actuary would ensure that the distribution of such inputs and/or assumptions is reasonable (e.g., in a model that forecasts pension valuations, is the distribution of valuation discount rates reasonable), paying particular attention to items such as the trend, mean, median, symmetry, skewness, and tails of such distributions. The actuary would also ensure that the correlation between each of the inputs and/or assumptions is appropriate. For example, in a model that forecasts pension valuations, is the correlation between valuation discount rates and government long bond yields appropriate? In an economic capital model, is the correlation between the unemployment rate and the gross national product appropriate?

Another question that could be addressed is the potential change of the correlation between variables at the mean as compared to the tail ends of the respective distributions. For example, for property and casualty (P&C) exposures, P&C lines of business are usually considered to be moderately correlated at the mean. However, in catastrophic and infrequent situations, the dependency assumption between casualty and property lines of business increases significantly.

In validating the results of a stochastic model, it is impractical and infeasible to review the results from every simulation. Instead, the actuary might typically review the following:

- The results from a carefully chosen sample of realized deterministic scenarios, covering an appropriate range of inputs and/or assumptions (e.g., a median-type scenario, a high-inflation-type scenario, a low-inflation-type scenario, etc.).
- The distribution of output results for reasonability, again paying particular attention to items such as the trend, mean, median, symmetry, skewness, and

tails of such distributions (e.g., in a model that forecasts pension valuations, is the distribution of forecasted funded status reasonable).

- Whether the results of the chosen deterministic scenarios are consistent with the distribution of stochastic results (e.g., are the results of the median-type deterministic scenario consistent with the median of the distribution of stochastic results).
- The relationships, or distributions of relationships, between certain inputs, assumptions and/or output results to ensure they are appropriate and internally consistent (e.g., in a model that forecasts pension valuations, is the distribution of the relationship between discount rates and funded status appropriate).
- Scenarios that lie near a boundary that is particularly important to the application; for example, a calculation of CTE99[2] would be more concerned with scenarios in the far tail.

The actuary would be mindful that the result of a stochastic model is usually itself a statistical estimate that has its own mean and variance. The variance can be lessened by running more scenarios, but it cannot be eliminated. For example, if the purpose of the model is to estimate CTE99, two successive runs (with different random seeds) will usually give different results due to random fluctuation. Neither is the true answer; both estimates are equally valid. The fact that there is no single right answer presents challenges in communicating the results.

5 Reporting

The actuary is referred to section 1800 of the Standards of Practice for general guidance on user reports, both internal and external. The nature of the engagement (or assignment) will determine whether the model is mentioned in an actuary's user report. In most cases, an actuary is engaged to express a professional opinion, such as an actuarial liability associated with a pension plan or the price for an insurance product. The actuary may use a model to inform the opinion, but it is not relevant to the user how the opinion was formed as long as it was done in accordance with accepted actuarial practice (i.e., modelling is incidental to the engagement). In other cases, an actuary is engaged to model a particular situation or to assess a model (i.e., the engagement involves modelling), and in those cases explicit comments on the model and its results would be relevant to the user.

[2] Conditional Tail Expectation at 99 percent probability. That is, the mean of all scenarios that represent the worst 1 percent of results.

5.1 When Modelling is Incidental to the Engagement

The actuary would not normally mention the model unless there are limitations that need to be disclosed. The purpose of the model is to inform the actuary, who informs the user. The model is not intended to inform the user directly.

In cases where the model is not communicated to the user, one might say that the actuary bears the entire model risk.

5.2 When the Engagement Involves Modelling

In this case, the actuary would typically refer directly to the model. Whether the model is primary or secondary in the report would depend on whether the engagement was to model or assess a model or to form an opinion supported by modelling. As appropriate, the actuary's disclosure could range from describing the model and its results in considerable detail to comprising only a brief overview. The actuary may explain why the model was considered appropriate, but the work done in validation would not likely be mentioned. The actuary may have completed hundreds of model runs, but only those most relevant to the engagement would be mentioned in the report.

The actuary would disclose any relevant limitations in the model.

If model results are miscommunicated or misunderstood, it could lead to poor decision-making or other adverse consequences. Therefore, it is important to have clear and audience-specific communication of the intended use of the model, any limitations, and key approximations.

5.3 Limitations

In some cases the model may have limitations that bear directly on the ability of the actuary to fulfil the engagement. In such cases, regardless of the terms of the engagement, the actuary would disclose that a model was used and that the limitations of the model could materially impact the results. For example, if the actuary had any concerns with the quality of the data used in the model, the actuary would disclose those concerns, or if the model ignores or simplifies the treatment of a factor that the actuary considers relevant, the actuary would disclose that fact.

6 Hypothetical Examples

The following examples are not real but represent some typical situations that actuaries face. They are constructed by actuaries who have been in a similar situation and have given consideration to what would represent good practice in using a model. As with any example, these cannot be taken as prescriptive. Rather, they are intended to give actuaries a framework for addressing their own situations.

6.1 Life Insurance Valuation Using AXIS

Amy Anders has worked on the quarterly valuation of a block of non-par term insurance policies for the last two years. The company has just updated to a new version of AXIS.

The company has standard change management practices in place. Amy's work related to the valuation model involves the following steps:

1. The model risk-rating is moderately high for several reasons: the potential impact on the company's financial statements, amount of user customization in the model, and the level of expertise required to understand the model.
2. There have been control practices in place within the operating unit, in terms of change management practices, layers of documentation, and model review.
3. Her work with the new version of AXIS is therefore to do the following:
    a. Review the list of changes since the earlier version and establish an expectation of impact on the model. Identify if there is a need to isolate the impact on particular blocks of policies beyond some standard breakdowns.
    b. Convert the model and understand the impact on key outputs from the valuation. She decides to use the prior quarter-end data set per her company's change management protocol. She reruns the batches from beginning to end and reviews the impact by plan, term structure, as well as a few other key product features. She notes that the overall impact was immaterial, but the impact was concentrated to a small plan that was newly introduced last year.
    c. This was consistent with her expectation, as there was a bug fix in the new version related to certain commission tables.
    d. She documents the changes in the company's model version control system and puts comments in the data set notepad.
    e. She shares her documentation with teams who might use the model for dynamic capital adequacy testing (DCAT), Canadian asset liability method (CALM), economic capital, and other items in the future. She also shares the information with the pricing team.

6.2 Pension Valuation Using Third-Party Software

Paul Penny is a pension practitioner doing a regular valuation for a pension plan using his firm's valuation software that is licensed from a third party. Paul has been with his firm for 10 years and did the previous valuation of this plan using the same third-party software, although it was using a prior release. Paul understands that the software was thoroughly vetted by an internal team of actuaries when it was initially licensed by his firm and that this team also vets subsequent releases, but this will be the first time he will personally be using the current release. Paul's work related to the valuation model (distinct from doing the valuation itself) involves the following steps:

1. Paul considers whether the third-party software is the appropriate model for performing the valuation, and determines that it is.

2. Paul assesses the risk rating of the choice of model and comes to the conclusion that it is high, owing to the financial significance of the results to the users, the regulatory nature of the valuation filing, and overall reputational risk associated with the work.
3. Paul reviews the documentation provided by the third party to assess the extent of the changes between the release Paul used for the previous valuation and the current release. He pays particular attention to changes that could be applicable to the plan he is working on. Based on this assessment, Paul considers whether the principles of section 2 or section 3 would be most applicable.
4. In Paul's opinion, the principles of section 3 are most applicable in this case. He is also of the opinion that this release revision represents a moderately-low risk activity.
5. Paul contacts his firm's internal team that is responsible for licensing and vetting the software. They provide Paul with the quality control report from the third party, and he satisfies himself that appropriate regression testing was applied to the current release (and intermediate releases) and that the third party has rigorous controls for approving each release. The internal team also directs Paul to a source for internal working papers that indicates that they have reviewed the third-party's reports and performed their own independent testing on a control group of plans.
6. Based on step 5, Paul is comfortable that the validation process for this release was adequate.
7. Paul retains a copy of the documentation noted in step 5 and evidence of his review in his working papers.
8. Paul proceeds with the valuation of the pension plan using the new release.

6.3 P&C Valuation Using the Chain Ladder Method

Claude Cousteau is valuing a block of automobile claim liabilities using the chain ladder method. His company developed software for implementing this method several years ago, and the software continues to be used without modification. Claude's work related to the model involves the following steps:

1. Considers whether the current model is applicable, and decides that no modifications are required. The model is rated medium to high owing to the importance on the financial statements.
2. Updates the incurred loss triangles to include an additional valuation period.
3. Selects the types of averages (high/low, three year, five year, others) to be used for the age-to-age estimation.
4. Determines if the data has sufficient credibility to be used on its own or if benchmarks are required to supplement to historical data.
5. Reviews the historical age-to-age factors for anomalies and extremes.

6. Smooths and/interpolates the resulting age-to-age factors as required.
7. Selects the age-to-age factor based on the results of the model.
8. Reviews the tail factor and makes a determination of the tail factor value based on a documented methodology.
9. Runs the model to calculate the loss development pattern, which will be used to project the ultimate incurred losses.
10. Prints the result of the evaluation in appendices of the report, documenting the whole valuation of the liabilities.

6.4 Determination of the Value of Lost Wages for a Suit Involving Personal Injury

Ed Evans is an actuarial evidence actuary who has been engaged to determine a present value. Ed wrote the software for the model three years ago and tested and documented it thoroughly at that time. Ed recognized the model as important to his business because it is used for a significant proportion of his work. He has repeated the validation each time there has been a major change such as a new version of operating system or a new mortality table. He has used the model for dozens of similar cases and it remains valid. Ed's current work related to the model involves the following steps:

1. Decide whether his standard model is applicable in this particular case, and determine that it is.
2. Enter the file reference for the case, the date of birth, the date of the accident, salary, and other parameters on the input screen for the program.
3. Run the model to calculate the present value.
4. Print the screen (showing input, output, and timestamp for the run) and file it.

6.5 Forecasting Capital Requirements Using a Spreadsheet Model

Ruth Rock has been assigned the task of forecasting quarterly capital requirements for a small reinsurer. In order to improve on the method used in prior years, Ruth decided to develop a new model using a spreadsheet, which will take inputs from the entity's valuation output and finance department, as well as current yield curves and investment analysis. Ruth's work related to the model involves the following steps:

1. Ascertain the risk-rating of the proposed model by considering what the model will be used for, financial significance, frequency of use, complexity, inputs, and outputs. In this case, a moderately high risk rating was assigned. Document the result.
2. Gather the inputs.
3. Confirm the inputs with other sources: e.g., capital form submitted to the regulator, income and balance sheet data, Bank of Canada website.
4. Decide on assumptions to be used regarding sensitivity of required capital to interest rate changes:

a) Sensitivity analysis; and

b) Review actual impacts from prior periods.

5. Build the model using the prior year-end as the starting point, to forecast the next quarter (which is already past, but is being used as the initial validation of the model).
6. Validate and refine the model using several prior quarters. Highlight and document any limitations.
7. Document the process for updating the model.
8. Run the model in parallel with the prior method for a few quarters, and reconcile model output to actual results. Refine the model and update documentation if necessary.
9. Revalidate the model after year-ends, updating assumptions and documentation if necessary.

6.6 Using a New Economic Scenario Generator in an Internal Capital Model

Nigel Nyambi is the actuary in charge of the implementation of a new third-party vendor economic scenario generator (ESG) model for use in the economic capital calculation for segregated fund guarantees. Nigel's project plan includes the following tasks:

1. Review the model features, limitations, controls, parameters, and outputs and document any concerns.
2. Review the scenarios produced by the vendor under various parameters to assess whether they are reasonable and meet the needs of the company; e.g., do the risk neutral scenarios produce market values that are consistent with Canadian market prices? Document the outcome of the assessment.
3. Risk rate the ESG model and document the outcome and rationale. The model is rated as high risk because of the following:
    a. There is a high variability of the segregated fund capital to different ESG scenarios;
    b. The ESG model is used for senior management and board reporting of capital;
    c. Although the reserves are currently small, this product is a key user of capital for the company; and
    d. The third-party software code is open and can be changed by a user.
4. Set up and parameterize the ESG model to produce risk-neutral and real-world scenarios with the prior quarter's assumptions and parameters. Review the results produced.

5. Have the model validated by another person/team with the requisite knowledge and experience who is not part of Nigel’s reporting chain. Review the model validation report and fix any material issues.
6. Prepare for implementation, e.g., update process and controls documentation.
7. Implement model.

Appendix 1: Risk-Rating Schemes

There are many valid approaches to risk rating a model. The point is to assess how risky a model is so that the amount of work done to choose, validate, and document a model may be appropriate to the circumstances. Two are presented here as examples.

A Uni-dimensional Approach

For example, a small- to medium-sized direct life insurance company could use a table similar to the following to evaluate its valuation models.

Review each risk factor below and place the score (1 to 4) beside each risk factor. Add up the total score at the end of the table.

Risk Factor	Score (1–4)
A. Size of block valued (percent of total actuarial liability): 1. 0–2 percent 2. 3–5 percent 3. 6–10 percent 4. Greater than 10 percent	3
B. Strategic importance of block valued: 1. Closed to new business, run-off mode. 2. Minimal new business, infrequent re-pricing. 3. Moderate new business or new product line, or occasional re-pricing or product redesign. 4. Significant new business or major product line, frequent re-pricing or product redesign.	3
C. Complexity of model: 1. Simple traditional-type product, few input files, single valuation method, single scenario, infrequent assumption updates. 2. More than one product line or valuation method, more frequent assumption updates. 3. More complex products with more product features (e.g., universal life), or many valuation methods, scenario-based assumptions. 4. Stochastic-type valuation with several scenarios and assumptions, complex products (e.g., segregated funds).	2

D. Expertise of model users and/or key person risk: 1. High level of understanding by model users—understand how the model works, products being valued, expected results. More than two persons capable of running, updating, and analyzing model results. 2. Good understanding of model and products by model user(s) and/or more than two persons capable of maintaining and explaining model results. 3. Some understanding of model and products by model user(s) and/or at least two persons can maintain/explain model. 4. Limited understanding of model and products by model user(s) and/or only one person capable of running, updating, and analyzing results.	2
E. Level of documentation and review: 1. Model fully validated and documented (assumptions, process, limitations, etc.), and documentation updated as needed with appropriate peer review and sign-offs. 2. Good documentation and frequent peer review. 3. Partial documentation and occasional peer review of model. 4. No documentation, model not peer reviewed.	3
Total Score out of 20:	13

Assessment of Score:

1—5 Minimal model risk—keep current practice, little or no changes needed

6—10 Lower model risk—reduce risk factors if possible, focusing on sections D and E

11—15 Moderate model risk—reduce risk factors if possible, focusing on sections D and E, by having more frequent reviews of models, updating documentation and training additional staff if appropriate

16—20 High model risk—high focus, immediate improvements or frequent model validation needed

A Two-Dimensional Approach

A model is assessed separately for severity and likelihood of failure, and the risk-rating is determined by balancing the two aspects.

Risk-Rating for a Model					
		Severity			
		Negligible	Low	Medium	High
Likelihood	Low	Very Low	Very Low	Low	Medium
	Medium	Very Low	Low	Medium	High
	High	Low	Medium	High	Extreme

The following is an example of a worksheet to determine severity and likelihood:

General information

Model:	BBB Model
Owner:	Director, XYZ
Users:	Senior actuarial analyst – ABC
Main Purpose:	Valuation of actuarial liabilities
Other Purposes:	Regulatory capital based on actuarial liabilities

Determining Severity and Likelihood

	Questions	Response	Review & Analysis	Score
Severity	What is the ratio of product line act liabilities/total act liabilities?	20%	High >10% Med 2-10% Low < 2%	High
	What is the main use?	Valuation	Directly impacts general ledger	High
	What are the other uses?	Regulatory capital	Impacts reporting to regulator	High
Likelihood	What platform or software is used?	AXIS	In use for a number of years and well understood by actuarial staff	Medium
	What is the level of expertise of the users?	There is a training program for the senior analysts. There is review by the director	Agreed	Low

	What is the quality of the documentation of the process, methodology and assumptions?	Meets internal audit and S-OX standards	Agreed	Low
	Is there any manual manipulation necessary?	Some manipulation of data for unexpected errors on the quarter-end	Agreed	Low
	Any model failures in the past three years?	None	Agreed	Low

Overall assessment: assessment is *medium* as the high severity is mitigated by the controls to reduce likelihood.

Appendix 2: Bibliography

Actuarial Modeling Controls: A Survey of Actuarial Modeling Controls in the Context of a Model-Based Valuation Framework (2012) https://www.soa.org/Research/Research-Projects/Life-Insurance/Actuarial-Modeling-Control.aspx
Board for Actuarial Standards. Technical Actuarial Standard M: Modelling (2010) https://frc.org.uk/getattachment/3a8825b8-4560-4750-955f-30f740960c7f/TAS-M-Modelling-version-1-Apr-10.pdf
Report from the Actuarial Processes and Controls Best Practice Working Party – Life Insurance (2009) http://www.actuaries.org.uk/research-and-resources/documents/report-actuarial-processes-and-controls-best-practice-working-party
Managing spreadsheet risk (2005) http://www.louisepryor.com/wp-content/uploads/2011/09/managing.pdf
Actuarial Standard of Practice No. 23 – Data Quality (2004) http://www.actuarialstandardsboard.org/wp-content/uploads/2014/07/asop023_097.pdf