Canadian Institute of Actuaries

Institut canadien des actuaires

# *Report*

# Risk Assessment Models

## Solvency Framework Sub-Committee Model Working Group of the Committee on Risk Management and Capital Requirements

### August 2008

# Memorandum

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

**From:** Jacques Tremblay, Chairperson
Practice Council

William Beatty, Chairperson
Solvency Framework Sub-Committee Model Working Group of the Committee on Risk Management and Capital Requirements

**Date:** August 15, 2008

**Subject:** **Report – Risk Assessment Models**

The Solvency Framework Sub-Committee Model Working Group has prepared a report on risk assessment models. The report describes considerations relevant to all risk assessment models. The stimulus for its drafting is the current move towards advanced capital models and away from prescribed factor and formula-based approaches. Individual companies are developing internal models involving economic scenario generators, cash flow models based on company data and experience, and often stochastic processing.

The purpose of this paper is to provide guidance to actuaries and insurance regulators/supervisors regarding risk assessment model practices primarily for the purposes of capital assessment. The objective of this guidance is to promote: accuracy of results; comparability between companies; consistency between valuation dates and between risks; transparency of models; reliability of results; and practicality of the model's implementation and use.

In accordance with the Institute's Policy on Due Process for Approval of Practice-Related Material other than Standards of Practice, this report has been unanimously approved by the Solvency Framework Sub-Committee Model Working Group and has received final approval for distribution by the Practice Council on January 16, 2008.

The members of the working group are William Beatty, Ronald Harasym, Trevor Howes, Jean-Guy Lapointe, Steven Prince, Sylvain St-Georges and Stuart Wason.

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## 1.    EXECUTIVE SUMMARY

This paper describes considerations relevant to all risk assessment models. The stimulus for its drafting is the current move towards advanced capital models and away from prescribed factor and formula-based approaches. Individual companies are developing internal models involving economic scenario generators, cash flow models based on company data and experience, and often stochastic processing.

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### MODEL DESIGN

In order to ensure a model is appropriate for its intended use, the following topics may be considered early in the model building process.

### Model Definition

Models can vary dramatically in terms of: what elements are standardized versus company-specific; the degree of sophistication; the layout of contributory sub-models; and the probabilistic approach (stochastic, deterministic or closed form).

### Model Risk

A model is an imitation and simplification of a real world system: a tool that provides estimates and not exact results. Model risk is a general term referring to the possibility of error and/or loss resulting from the use of models. Model risk can be mitigated through the use of strong governance practices, a good understanding of the model's limitations and the judicious use of risk margins.

### Risk Assessment Framework

A clear definition of what the model will measure is required. A risk assessment framework includes the financial element being stressed (reserves, capital, etc.), the risk horizon (one year, life-time, or somewhere in between), the statistical measure (CTE, VaR, etc.), the confidence level (80%, 99%, etc.), and, if applicable, the terminal provision at the end of the risk horizon.

### Capital Model Considerations

Capital models may differ from the more familiar reserve and planning models in several ways including that capital models: will be run under more extreme scenarios; may require more approximations to practically implement; and often measure risks individually and so need an aggregation process.

**Resources**

It is desirable to achieve a balance between the available resources and the degree of sophistication of the model. If resources cannot be secured to produce a sufficiently accurate and robust model, then consideration could be given to using a standard model.

**Approximations**

The use of approximations is a necessary component of any model, and their selection involves judgment and perspective.

**Risk and Model Integration**

If risk assessments are performed on individual risks or blocks of businesses, then the results would be aggregated reflecting: diversification benefits; dependencies between risk elements and asset segments; and concentrations of risks.

**Stochastic Model Design**

Stochastic modelling requires risk element scenario generators as input to the insurance cash flow models. The selection and design of these generators is critical to the accuracy of the results.

**Regulatory Capital versus Internal Risk Assessment**

Although regulatory capital and internal assessment models ideally would share a common chassis, the regulatory capital models are subject to constraints that may not be desirable for internal risk assessment.

**MODEL IMPLEMENTATION**

**Development and Use of Model Inputs**

A key process in model implementation is the development of model inputs, which include assumptions, parameters and business data, each of which requires individual consideration.

Assumptions correspond in general to each of the risks inherent in the business being modelled that have a financial impact. Expected assumptions require the appropriate blend of company specific and industry experience, according to the credibility and relevancy of available data. The granularity of the model may impact the granularity of the assumptions applied. Validation of the assumptions, as well as the implementation of the selected assumptions in the actual model, are both important. Assumption validation techniques include backtesting in various forms, and rationalization compared to industry practices and other benchmarks, if known.

Typically setting assumptions involves application of explicit margins as may be appropriate for the model type and purpose. In stochastic models, however, provision for random variation is handled through risk measures selected. Special considerations apply

to the setting of margins and reflecting the interaction of assumptions under extreme scenarios required for capital and risk assessment modelling.

Parameters are critical inputs that can significantly impact the results of using the model, and as such are generally set by calibration techniques, or selected on a standardized or prescribed basis to ensure comparability.

Business data reflect the actual insurance contracts and actual invested assets. Actual business data may need to be simplified or compressed for practical run-time reasons, with appropriate documentation and validation of techniques applied. Utilizing common business data sources reduce the risk and effort, but control total validation is still useful. Additional considerations apply when analysis occurs off the reporting date.

**Information Technology (IT) Implementation**

IT issues are inherent in advanced models. Key objectives are transparency of methodology, assumptions and parameters, and integrity with theoretical model design, while achieving economically viable performance. The model implementation could facilitate the management and validation of approximations in data representation or in the application of assumptions, and could clearly separate assumptions from data.

Whether through proprietary or outsourced solutions, it may be beneficial that the IT implementation anticipates appropriate change control procedures, as well as the review and replication of results for audit, and the establishment of back-up and recovery processes, including business continuation plans. The ability to smoothly incorporate future technology improvements may also be planned for.

**Processes**

The model implementation could anticipate a variety of processes beyond the basic risk analysis and calculation of a primary result, including validation tests, sensitivity tests, stress tests, calibration of mathematical models that generate economic scenarios, archiving and replication of prior runs, documentation of assumptions, and detailed results. Flexibility of use has many advantages, if it can be achieved.

**Results and Analysis**

Flexibility in reporting may be balanced with reliability and validation concerns, while considering the risk of misinterpretation or misuse of results.

**Stochastic Model Implementation**

Complex stochastic modelling often demands thousands of scenarios significantly straining hardware resources unless processing shortcuts such as representative scenarios or predictive modelling techniques are used. Careful validation of these approximations is necessary to control the increased model risk and operational risk.

## MODEL VALIDATION AND CALIBRATION

### Model Validation

Models can be very complex and the process of checking them is likewise so. Models would usually be validated at both a conceptual level (that is, the theoretical basis is valid) and an implementation level (that is, the model accurately implements the theory). Model validation could consider the following:

#### Techniques

Several techniques can be used in this validation, including: validation that the individual components on their own are reasonable; that simple test cases work as expected; that incremental additions of complexity produce explainable changes in results; that extreme cases produce explainable results; that results have a rational relationship to other models or published standard factors; and the various levels of aggregation of results produce appropriate diversification benefits.

#### Calibration

Model calibration ensures that all assumptions and parameters are appropriate to the situation at hand. Periodically the calibration would be reviewed to ensure the model remains current with changing situations and operating environments.

## GOVERNANCE

### Roles, Responsibilities, Resources

It is advisable that the key roles and responsibilities of the Board of Directors for the approvals, and Senior Management (CEO, CFO, CRO and AA) for the management process, development and use of risk assessment models be well defined. Appropriate policies would cover risk management, documentation, controls, compliance, etc. The level of expertise available is an important consideration, and specialized tools could be needed. This could call for reliance on external resources.

### Risk Management Policy and Practices Characteristics

Robust governance requires the pervasive use of the capital model in the risk management practices, including risk/capital management, capital allocation and planning, and performance measurement/compensation. The level of risk exposure is typically managed against pre-established risk limits.

### Review Process

An important part of controls is the review process. It rests on three components: internal review; external review; and regulatory/supervisory review. It would encompass all aspects of the risk assessment model and framework in place. A full model review would normally be undertaken when a model is implemented. In case of substantial changes, additional reviews might become necessary.

**Documentation**

Model documentation is useful for review and control purposes. Many details may be documented, from the principles on which the models are built, to the approximations used. Different styles of documentation with varying levels of details could be used, according to the stakeholders and the importance of the information.

**Compliance**

Models are subject to compliance requirements. Examples include regulatory/supervisory rules, internal policies, and professional guidance.

**REPORTING**

The results of a risk assessment model would generally be reported in a manner and with a level of detail appropriate for the target audience and for the purpose of the report. Transparency and comparability of internal models across the industry is best facilitated by the public disclosure of methodology. Reports can fall within the following categories:

### Results and/or Prescribed Capital Reports

These are prepared for senior management and board, examiners and regulators, or the public on an annual basis and would typically present the final numbers on required capital and target capital. Reporting normally would state that the models used conform to the company's policies, industry practices and regulatory/supervisory requirements. The level of details on model controls and validation, assumptions and risk sensitivity would depend on the specific needs of the different stakeholders.

### Risk Analysis Reports

These would be prepared on an ad-hoc basis and would address the potential impact of a proposed transaction or of a change in policy or risk mitigation strategy. Reporting would focus on the particular and specific purpose of the analysis.

### Model Development and Implementation Progress Reporting

Reports would be prepared to provide stakeholders with information about the model development project. Reporting could be fairly specific and concentrated on a few issues while referring to more generalized status and update reporting. Reporting could be used frequently and for each step to keep interested people up-to-date and to ensure there is a good coordination at the company level.

### Approval Reporting

This would be prepared for the Board and/or regulators/supervisors for initial approval of the models to be used by the company. The application package for approval would document, by section, how the institution is complying with

different criteria. Specific emphasis may be placed on the management of risk exposures and the use of internal models in the measurement of such risks. The application could include, as appropriate, information on the frequency of audits and model reviews along with documentation and samples of reporting.

## 2.    CONTEXT

This paper describes considerations relevant to all risk assessment models. However, the stimulus for its drafting is the current move towards advanced capital models and away from prescribed factor and formula-based approaches. Individual companies are developing internal models involving economic scenario generators, cash flow models based on company data and experience, and often stochastic processing.

### 2.1    Global Move Towards Advanced Capital Models

The international insurance industry is moving towards advanced capital models for internal risk management, regulatory/supervisory reporting requirements, and rating agency assessments. Examples of regulatory/supervisory requirements using advanced models include: Solvency II in the Europe Union; Individual Capital Assessment in the UK; and the Swiss Solvency Test. The international banking industry has already largely moved to advanced models as Basel II will be adopted in many countries around the world in 2007.

Advanced models may take various forms but generally are designed to ensure the following.

- Risks are measured consistently, and at the same level of confidence.

- Each company's own risk profile is reflected, better than can be achieved with a general factor approach.

- Risk drivers and risk mitigators (including diversification benefits) are recognized and understood.

- Sound risk management is encouraged as capital levels reflect the consequences of management decisions and actions.

- The solvency framework is principle-based and so models evolve with changes in the environment.

It is expected that advanced capital models will lead to more appropriate levels of capital held by individual companies and support optimal risk-based business decisions.

### 2.2    Canadian Initiative

Canada is now actively moving towards advanced models to determine capital requirements. Compared with other regulatory capital frameworks, Minimum Continuing Capital and Surplus Requirements (MCCSR) for Life Insurance Companies is already reasonably sophisticated. Current requirements vary by risk, ranging from the use of company-specific advanced internal models to simplistic factor approaches. The vision is to continue to evolve the MCCSR requirements risk by risk but under a consistent

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framework going forward. Ultimately, it is anticipated that advanced modelling approaches will be developed for most risks, along with one or more, simpler, standardized approaches for each risk.

This initiative is being led by the MCCSR Advisory Committee (MAC). The MAC includes representation from the insurance industry, the actuarial profession and the supervisors. The development work is being performed by the CIA Committee on Risk Management and Capital Requirements – Solvency Framework Subcommittee and its various working groups. Details of the overall solvency framework, as well as methodologies for specific risks, can be found in the references listed in Appendix B.

### 2.3    Need for Risk Assessment Model Guidance

The Canadian insurance industry has been modelling its business for years. The Canadian Asset Liability Method (CALM) and Dynamic Capital Adequacy Testing (DCAT) models are already quite advanced. These models are typically company specific, capture all material risks, integrate assets and liabilities, and often use full seriatim data.

However, there is a need for guidance relating to risk assessment model practices, since:

- There is currently limited Canadian professional modelling guidance available (other than on segregated funds);

- There are some considerations that are particularly relevant to capital models as opposed to reserve and planning models, as described in Section 4.4; and

- The application and use of stochastic methods in modelling is still evolving.

### 3.    PURPOSE

The purpose of this paper is to provide guidance to actuaries and insurance regulators/supervisors regarding risk assessment model practices primarily for the purposes of capital assessment. This report attempts to address all aspects of the operation and use of these types of models.

The objective of having minimum standards for the use of risk assessment models is to ensure the following.

- Accuracy: Establish controls to ensure each risk is reasonably reflected and the results are meaningful.

- Comparability: Ensure externally disclosed results are comparable between companies.

- Consistency: Ensure results are consistent between valuation dates and between risks.

- Transparency: Ensure that models are documented and that their capabilities and limitations are well understood by all users.

- Reliability: Ensure that the process of generating results is robust.

- Practicality: Recognize cost and time constraints and appropriate trade-offs between theoretical accuracy and materiality.

## 3.1   Scope of Paper

This paper is intended to cover all aspects of model design, implementation and validation, the model's role in risk governance, and the reporting of model results. This paper is neither a regulatory/supervisory guidance note nor a professional standard, although it may become a useful starting point for such documents.

While the paper is intended to cover all types of risk assessment models, it is predominantly aimed towards advanced capital models. The focus is on considerations to ensure the model results are reasonable and consistent with the previously described objectives, as opposed to prescribing methodologies.

A solvency or risk assessment framework is the starting point of any model design. It is assumed that this is known and that the practices described herein will apply to any framework. The solvency framework being discussed in Canada is described in the references listed in Appendix B.

This draft of the paper was written fairly early in the Canadian initiative. It is intended to evolve with the development of other aspects of the solvency framework. For example, specific details in this draft focus on life insurers. The paper will be reviewed by the P&C sub-committee of the Committee on Risk Management and Capital Requirements to ensure that it adequately captures the important features of the property and casualty context. Furthermore, the International Actuarial Association (IAA) and the International Association of Insurance Supervisors (IAIS) are working on similar papers currently titled, "Guidance Paper on the Use of Internal Models for Risk and Capital Management Purposes by Insurers" and "Guidance Paper on the Use of Internal Models for Insurers" respectively, that may influence this paper.

## 3.2   Audience

This paper is primarily written for those individuals developing, maintaining and reviewing risk assessment models. However, it may be useful to any stakeholder who relies on and wants a better understanding of the model results.

Stakeholders can be categorized as follows:

- Internal Management:  Senior Management, Board, risk managers;
- Examiners: Regulators/Supervisors, auditors, peer reviewers, rating agencies; and
- Public: Shareholders, market Analysts, policyholders.

Additional audiences of initial drafts of this paper are those working groups that are developing advanced methodologies for capital determination.

## 3.3   Structure of Paper

The remainder of this paper has five sections as follows:

- Model Design: Description of the high level overall considerations in selecting and designing risk assessment models;

- Model Implementation: Description of the detailed considerations in building and running a risk assessment model;

- Model Validation and Calibration: Recommended procedures to validate the model's framework, the implementation of that framework and the ongoing evolution of the model;

- Governance: Description of the oversight of the risk assessment models, and their role in enterprise risk management; and

- Reporting: Description of considerations of what could be reported and how that varies by stakeholder.

The building of a risk assessment model is not a linear process. All of the above elements are important to consider before embarking too far on the building process. Furthermore, there will necessarily be iterations between these five elements as the model evolves.

## 4.   MODEL DESIGN

In order to ensure a model is appropriate for its intended use, it would be advisable to address the following questions during the model design stage:

- What is the risk assessment framework? That is, what is the model being built to quantify?

- What considerations are unique to a risk assessment model, in particular a capital model, as opposed to reserve valuation models?

- What resources are available and are they sufficient? If insufficient, should additional resources be secured or should a simpler modelling approach be employed?

- What approximations will provide reasonable results and make the modelling exercise easily worked, shaped, or otherwise handled?

- How will different model components (possibly split by risk, product, geography, etc.) be integrated into one result?

- Should the model be stochastic, and if so, what are the associated considerations and potential consequences?

- How do regulatory capital models differ from internal risk assessment models?

This section defines and describes a range of model types, defines model risk, and then addresses each of the above questions.

### 4.1   Model Definition

A model may be defined as any approach of approximating reality for the purpose of understanding observed experience and predicting possible future outcomes.

Risk assessment models generally estimate the distribution of (or specific points on the distribution of) one or more financial measures (earnings, internal rate of return, projected surplus, etc.). Capital models generally quantify how much a financial institution's capital may be depleted over a specified time horizon at a certain confidence level.

There is a considerable amount of variation between the types of risk assessment models in use. Some of the aspects along which model types vary are as follows:

- Degree of Standardization: Risk assessment models may include a combination of company specific and industry standard features. Examples include:

  - Standard factors applied to company data;

  - Standard method and assumptions using company specific models and data;

  - Standard method using company specific models, data and assumptions; and

  - A standard framework with everything else set internally by the company.

With respect to regulatory capital models, it is anticipated that companies will have a choice among a range of standard and advanced approaches, subject to meeting defined requirements, similar to the Basel II framework for banks.

- Degree of Sophistication: All models, by definition, involve approximations but the degree of sophistication varies dramatically.

- Model Layout: A risk assessment model may be made up of several contributory models. For example, it is typical that economic scenario generators will be distinct from insurance cash flow models. Risk assessment models may also be split by line of business and/or by risk.

- Probabilistic Approach: All risk assessment frameworks involve some statistical level of certainty. In rare situations, and under certain assumptions, the level can be determined from closed form solutions. However, given the complexity of insurance liabilities with embedded options as an example, it will often be determined stochastically or approximated from carefully selected deterministic scenarios.

The degree of sophistication, the degree of standardization, and model layout, representing three of these dimensions, are illustrated in the following diagram. The model adopted for each risk may be a different point on the spectrum of model sophistication and company specificity.
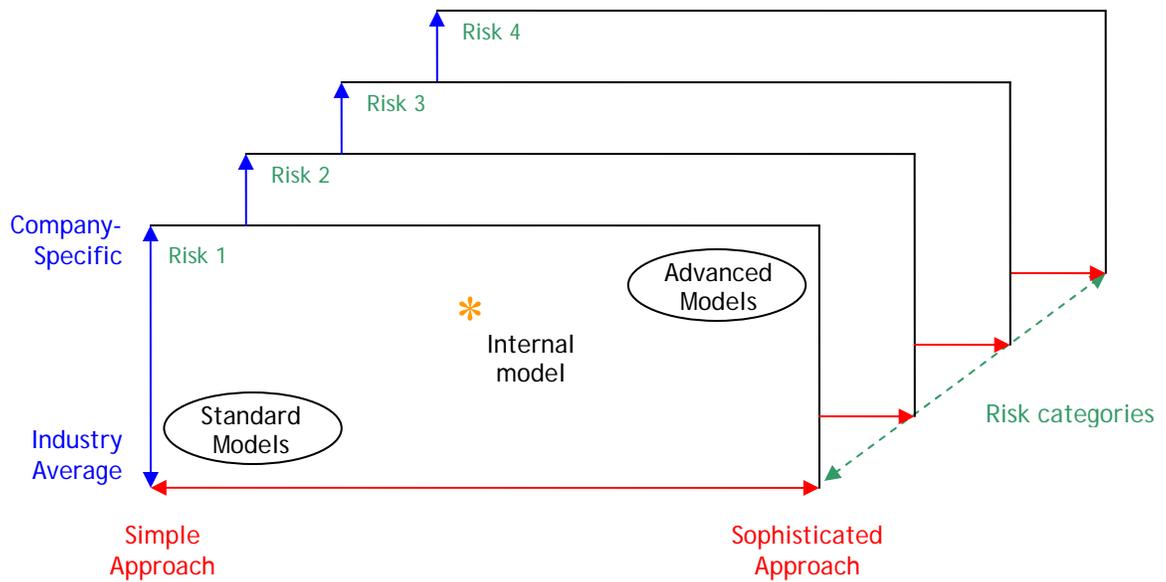
Internal model, advanced model, and standard model are three descriptions commonly used for risk assessment models. These terms are used broadly in the industry but are defined for the purpose of this paper as follows.

- Internal Model: An internal model is built by an insurer for its own risk management purposes. Internal models may be simple or sophisticated, based on industry average or company-specific risk profiles and may utilize components built internally or purchased from an outside vendor. The term internal model is sometimes used to imply a more advanced model.

- Advanced Model: An advanced model reflects a company's risk profile by incorporating some company-specific data, experience, product designs, and/or management practices. Advanced models are typically complex and involve additional effort and expense to develop, so they tend to be used only where there are significant volumes of business.

- Standard Model: A standard model is predominantly based on industry data, experience, product designs, and/or management practices. The term standard model is generally used in the context of capital models. It may be as simple as factors applied to company exposures, or as complex as using a standard methodology with most other model features being company specific. A standardized factor approach is typically developed by working with an advanced model using common industry products and experience.

An advanced model is always an internal model, but the reverse is not necessarily true. Additional and more detailed model definitions are provided in Appendix A.

## 4.2   Model Risk

A model is an imitation and simplification of a real world system: a tool that provides estimates and not exact results. Model risk is a general term referring to the possibility of error and/or loss resulting from the use of models. This risk has a number of components and can manifest itself in many ways, such as the following:

- Model misspecification (correct model, incorrect model set-up);

- Assumption misspecification (correct assumption, incorrect assumption set-up);

- Inappropriate use or application (incorrect model given the intended application);

- Inadequate testing, validation, and documentation;

- Lack of knowledge or understanding by the user and/or management;

- Inadequate systems structure and change management controls; and

- Error and negligence.

End-users of information place considerable reliance in persons, who create the models, run the models, as well as those who vet the information along the way, to validate the output prior to distribution. The incorrect use of models, an overly broad interpretation of model results, or decision maker reliance on erroneous exposure estimates creates not only the potential for economic loss, but also the potential consequence of damage to the reputation of the company. The latter is of particular importance in the eyes of external stakeholders such as regulators and rating agencies.

Model risk exists to some extent in any risk assessment model. Model development is a complex and potentially error-prone process. While many completed models work as planned, some models will inevitably contain fundamental errors. Strong governance practices and processes are integral to controlling and understanding the level of model risk.

Incorporating model risk into a risk assessment framework is discussed in Section 5.1.7.

## 4.3   Risk Assessment Framework

To design and select a risk assessment model, one would normally first have a good understanding of what the model is being built to quantify. It is beyond the scope of this paper to specify possible risk assessment frameworks. The Vision paper developed by the MCCSR Advisory Committee outlines the solvency framework expected to be adopted in Canada. It is briefly summarized below to illustrate how a framework initiates the design of a capital model.

Capital is typically set such that the total balance sheet assets can withstand extremely adverse experience over the risk horizon and have "sufficient assets" left over at the end of the risk horizon to mature policyholder obligations. Elements of a solvency framework include the following.

- Risk Horizon: The risk horizon is the period over which the extremely adverse experience occurs. It is typically set at one year, but also sometimes set to cover the lifetime of the risk.

- Risk Measure: The risk measure is the statistical measure used to quantify the extreme event. Measures often used are Value at Risk (VaR or Percentile) or Conditional Tail Expectation (CTE, TailVaR, Expected Shortfall, or Average Downside Magnitude).

- Confidence Level: The confidence level specifies how extreme the adverse experience is over the risk horizon. A percentile of 99.5% or conditional tail expectation of 99% are common for a one-year risk horizon, with lower confidence levels set for longer time horizons.

- Terminal Provision: The terminal provision defines what "sufficient assets" are at the end of the risk horizon. It depends in part on how a company is assumed to act following an adverse extreme event. For example, whether the company will raise capital and continue operations, continue in a runoff mode, or liquidate the remaining risks.

The following solvency principles have been adopted by the MCCSR Advisory Committee:

- Consider all risks;

- Determine assets and liabilities on a consistent basis;

- Be practical, but technically sound;

- Reflect existing risks on a going concern basis and consider winding-up and restructuring;

- Use measures that are comparable across risks and products;

- Ensure that capital is prudent;

- Encourage good risk management;

- Adopt international principles and best practices;

- Allow comparison of similar risks across financial institutions;

- Be transparent, validated and based on credible data;

- Use reliable processes with assumptions sustainable in times of stress; and

- Be part of intervention levels for supervisory action.

Each of these principles is elaborated on at the Office of the Superintendent of Financial Institutions (OSFI) and Autorité des marchés financiers (AMF) websites provided in Appendix B. Additional Canadian industry solvency framework references are also listed.

### 4.4 Capital Model Considerations

Considerations that are particularly relevant to capital models as opposed to reserve and planning models are discussed in the following subsections.

#### 4.4.1 Extreme Events

Capital is determined to support extreme scenarios in the "tail" of a distribution. Models that work well near the expected scenario may be inadequate at estimating losses under extreme events. Elements that are difficult to estimate in the "tail" include assumptions, correlations, management action, etc. For example, relevant experience data may not exist to objectively determine a 1 in 200 year event. As a result of this subjectivity, consideration may be given to standardizing some model elements across the industry. For further discussion, see Sections 4.9, 5.1, and 6.2.

#### 4.4.2 Practical Implementation Issues

The current direction of the industry is towards a one-year time horizon capital calculation with an appropriate terminal provision. This theoretically implies running stochastic on stochastic[1] (nested stochastic) integrated models that consider all risks simultaneously. Likewise, if a lifetime risk horizon is adopted, stochastic on stochastic calculations may still be theoretically required if solvency is to be confirmed at various points along the risk horizon. Practical implementation may require limiting the calculation to only deterministic scenarios or one single stochastic process and possibly measuring only one risk at a time. For further discussion, see Sections 4.6, 4.7, and 4.8.

#### 4.4.3 Aggregation of Risks

Unlike reserve valuation models, capital models typically measure risks individually and then combine risks recognizing the following.[2]

- Diversification Benefits: Total capital may be less than the sum of the capital determined for each risk to reflect that risks are not perfectly correlated. For example, the likelihood of a 1 in 200 year spike in mortality occurring simultaneously with a 1 in 200 year change in interest rates is a great deal lower than 1 in 200.

- Causal Dependency of Risks: Changes in one risk may influence other risks through a direct causal relationship. Examples include dynamic lapses (i.e., where economic conditions impact lapsation), and anti-selective lapsation that leads to mortality deterioration within the surviving business. Also, when determining credit for pass-through of adverse experience to policyholders in situations where adverse experience in multiple risks can be passed through, it may be difficult to ensure that there isn't any double counting of the pass-through room available.

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[1] The terminal provision at the end of each stochastic path over the time horizon is calculated using a second stochastic process, which is seeded by the first, requiring a computationally intensive level of calculations. For example, if the terminal provision stochastic process contains 1,000 scenarios and is run for each of 5,000 time horizon scenarios, then 5,000,000 scenarios are theoretically required.

[2] If all risks are captured in an integrated model, these issues are still relevant but are generally easier to address.

- Non-Causal Interaction Between Risks: The integrated impact of stressing two assumptions simultaneously will generally differ from the sum of stressing each assumption individually. This is particularly true on products with guarantees, but also has a second order impact on simpler products since the relationship between capital requirements and risks is not linear.

- Risk Concentration: Models may not directly pick up risk concentrations. Examples include insured lives concentrated in a geographical area and credit exposures concentrated in a single counterparty.

Once an aggregate capital result is determined, it is highly desirable to be able to allocate it back to component risks and product lines. For further discussion, see Section 4.7.

### 4.4.4    Anticipated Change in Risk Profile

Advanced capital models are designed to be company specific and to reflect realistic management action along each modelled path. Depending on the circumstances, it may be appropriate to reflect action based on the current risk profile deviating from expected. For further discussion, see Section 4.9.

### 4.4.5    Real World versus Risk Neutral Valuations

Real world valuations are based on historical experience and actuarial techniques while risk neutral valuations are designed to reproduce market prices. Capital models use a real world approach over the risk horizon, but the terminal provision at the end of the risk horizon may follow either a real world or risk neutral approach, depending on the solvency framework and the expected company response to the events occurring over the risk horizon. As current Canadian valuation models are based on real world traditional actuarial approaches, risk neutral techniques are fairly new to the insurance industry. For further discussion, see Section 5.1.

### 4.4.6    All Risks

A principle of most solvency frameworks is to reflect all risks, some of which are not typically reflected in liability valuations. Examples of these include operational risk and liquidity risk. For further discussion, see Section 4.7.

### 4.4.7    Advanced versus Standard Models

Canadian liability valuation models for material risks typically fall into the "advanced" category. However, it is expected that Canadian companies will have a choice between adopting advanced or simpler standard models for capital determination. For further discussion, see Section 4.10.

While most of these issues are discussed in a little more detail in subsequent sections of this paper, solutions are generally not provided. The issues are highlighted as important model design considerations and some guidance is provided on ways to ensure a chosen approach is appropriate.

### 4.5   Resources

The costs of implementation, maintenance and operation of a risk assessment model would normally be commensurate with the purpose and value of the model's use. As discussed in Section 4.10, if adequate resources are not available to properly implement an advanced model, the use of a standardized model may be appropriate.

Costs include the level of both IT hardware resources and staff resources to operate under anticipated frequency of use, volume of data, and reporting time-frames. Resource adequacy considerations include both staff levels and staff expertise. Margin may be allowed in this resource planning for expected growth in business, unanticipated problems requiring repeated runs, and additional uses of the model beyond the original risk assessment purpose.

It would be appropriate to consider the level, source and timing of additional resources which might be required to replicate or recover the model in an operable environment when developing the business continuity plan.

### 4.6   Approximations

Approximations are vital in making the modelling task possible and effective to use. Approximation is a modelling device generally necessitated by either a lack of information about how a process or risk operates, or by the practical limitations presented by a finite amount of available computing power. Simplifications to reality, inherent in a model, may also be necessary to enable that model to be implemented in a practical manner, effectively managed and generally understood. Approximations will generally fall into one of the following categories.

- Formula: Fundamental simplifications or restrictions inherent in the mathematical models or formulas, or the model framework selected, which allow them to be represented by a computer model.

- Assumptions/Parameters: Discretionary simplification of assumptions to reduce the complexity of code for storing, retrieving, and applying them, or to reduce total run-time. For example, a model may assume that mortality rates are always defined on a policy year basis and the timing of the resulting projected deaths is either concentrated at mid-year, or is spread uniformly over that policy year. As another example, yield curves may be assumed to be constant throughout a calendar month or quarter, changing only at the end of that period. Assumptions may also be simplified due to lack of credible experience data at a more granular level.

- Operation: Simplification of model operation to restrict the timing or frequency of modelled processes, the length of the projection period contemplated, or number of stochastic scenarios run. For example, changing the model processing time step from monthly to quarterly might theoretically reduce run-time by up to 67%. Another example is to truncate the modelled time horizon with the addition of a terminal adjustment if appropriate.

- Data: Simplification of the business and investment data so as to remove heterogeneity, and allow faster runtimes through grouping or model compression. For example,

seriatim in force business data might be grouped by issue date or issue age bands, or the age and date bands of grouped data could be widened resulting in fewer data cells.

Approximations in the formula category typically cannot be changed without a major overhaul or replacement of the working model. Approximations of the last three types may be selected as part of the model implementation stage, as opposed to being inherent in the design. As such, they will typically be more easily tested, validated and adjusted as circumstances and available computing power change.

Potential consequences of employing approximations include loss in accuracy, reduction in precision, and the introduction of bias in the results. Accuracy relates to the level of "correctness" while precision is the degree to which "correctness" is expressed. Bias is the extent to which a modelled result consistently under or over estimates the correct result, and may be intentionally built in to an approximation to compensate for uncertainty about the impact on accuracy or precision.

The materiality of the potential impact of approximations on the accuracy and precision of the model, and any resulting inherent bias, would usually be evaluated in light of the practical advantages of each approximation and the available alternatives, considering the intended purpose and uses of the model. It may also be useful to consider the following.

- Consistent Level of Sophistication: A very precise but computationally intensive approach in one facet of a model will not improve the overall results, and may be counterproductive if it forces more compression or other adjustment elsewhere in the model. A better result might be obtained by using a less computationally demanding approximation in this facet and then using the additional computing power elsewhere for more scenarios or more time periods, etc.

- Consistency with Inputs: Similarly, precise formulas are no better than the data that are fed into them. If data are limited or unreliable, there is little point in using a complex formula.

However, model development is more often an evolutionary process. It may be appropriate to be overly precise in one or more facets if there is an intention to improve the other facets, use the model for other purposes, or if the business profile is expected to change.

It is important to recognize, understand and disclose all material approximations used within a risk assessment model. For example, it is important to understand that approximations that work well over one part of the risk distribution or for the company's current risk profile may perform poorly in other situations. This understanding and disclosure is vital to ensure that the model is not used inappropriately.

Any approximations typically would be periodically validated, preferably by specific testing against more precise methods, when possible, to confirm that the impact of the approximation on overall results is immaterial in the context of the purpose and use of the model, and appropriate in light of the benefits gained by using the approximation.

When exact quantification of the impact of an approximation is not possible, or when an approximation introduces a material level of uncertainty with respect to accuracy and precision of the results, it may be appropriate depending on the model's use to incorporate additional margins in the assumptions used, or directly in the final calculated results. Such

margins and their impacts would normally be clearly disclosed and carefully reviewed in combination with the impact of any bias inherent in the approximation.

## 4.7    Risk Integration and Model Integration

Ideally, all material products and all material risks would be modelled simultaneously in one integrated model. However, this is not the current practice. Therefore, in designing the overall model, a framework is needed on how to aggregate the components.

A component approach to risk assessment models is common for the following reasons.

- Historical Influence: Advanced risk assessment modelling is not as developed as reserve modelling.

- Sophistication: As risk assessment models typically focus on the tail of the risk distribution, they are generally more complicated than reserve models. For example, risk assessment models are often stochastic, and stochastically varying all uncertain elements at once, in a correlated fashion, is challenging.

- Risk Specific Results: In order to manage risk and optimize returns on capital, it is beneficial to understand the impact of each risk individually, and how each contributes to the aggregate result. So even if the risk assessment model is fully integrated, there is a need to determine risk specific results. Conversely, while risk margins in reserves can be separated out by risk, the underlying best estimate liability cannot be separated by risk.

Risk assessment frameworks are typically split into model components by risk and/or product line. When risks or products are modelled in pieces, the sum of the component results may not equal the actual aggregate result. Considerations in aggregating the components include the following:

- Model coverage;

- Diversification benefits;

- Implementing correlation assumptions;

- Allocation of diversification benefits;

- Risk dependencies;

- Risk concentration; and

- Surplus versus liability segments.

Each of these considerations is discussed in the following sub-sections.

### 4.7.1   Model Coverage

In designing the model and the aggregation of its components, one would consider what risks are included and how will they be modelled.

It is likely that different risks will be measured at different levels of sophistication and company specificity as illustrated in Section 4.1. This is partly because the move towards

advanced models will evolve over time, tackling one risk or one product at a time. It may also be decided that advanced models are not practical for some risks, possibly operational risk. Therefore, the aggregation method will include the bringing together of different model types. Depending upon the models employed, it may be appropriate to use more than one aggregation approach, for example, aggregate advanced models using integrated scenarios, and standard models using correlation matrices.

Other risks may be measured and analyzed, but excluded from aggregation on the basis that they are well managed and have an immaterial contribution to the overall risk profile. Examples of this may include liquidity risk and financial risks on closed blocks of participating business. However, the rationale for excluding any risks from aggregation would be well documented and the risk would continue to be monitored. A risk that is hedged or otherwise mitigated may not be readily excluded. Rather, both the risk and the risk offset would be modelled including any basis risk (hedge efficiency) and any new risks introduced (hedge counterparty risk).

Depending on the risk assessment framework, the model may include some new business issued after the valuation date. When new business is included, it is important to recognize the additional sources of risk it entails, including but not limited to, uncertainty around production volumes, product mix, and distribution channel. Additional sensitivity testing may be warranted.

### 4.7.2   Diversification Benefits

Diversification is the act or practice of investing in a variety of securities, selling a variety of products, etc., so that a failure in or an economic slump affecting one of them will not be disastrous. The benefit from diversification emerges since all risk drivers are not usually perfectly or 100% correlated. The end result is that the aggregate risk position will be lower than the sum of all the risk positions. As an example, the mortality and interest experience in a 1 in 200 year integrated scenario will be less severe than the experience in each of the 1 in 200 year mortality experience and the 1 in 200 year interest experience.

Correlation assumptions between risks are needed in order to measure diversification benefits. The process of setting assumptions is discussed in Section 5.1. In addition, it is important to note that observed historical correlations may not be representative of how risks behave under an extremely adverse year. For example, while mortality and equity returns generally exhibit no correlation, in a pandemic situation, equity markets would very likely fall.

Observed historical correlations between risk drivers (for example, yield curve changes, equity returns, mortality shocks and changes in future outlook, etc.) may not be directly applicable as correlation assumptions between risk amounts (for example, interest capital, equity capital, mortality capital, etc.). The simplest example of this is when the sign of the correlation flips when a company's exposure to risks is opposite to that of observed correlations. For example, if equity returns and interest rates are 100% positively correlated, but the company is at risk from equity market declines and the yield curve increases, then equity and interest capital would be 100% negatively correlated.

### 4.7.3   Implementing Correlation Assumptions

There are two basic approaches to reflecting correlation assumptions when aggregating risks:

- Correlate stochastic paths using an integrated risk assessment approach; or

- Aggregate risk amounts using statistical approaches.

While the integrated approach is more challenging to implement overall, it does provide a more accurate way to capture the diversification benefits. Instead of estimating correlations between risk amounts, correlations are estimated between the risk drivers which are more readily observable. However, it may be challenging to implement these correlations in the economic scenario generators, depending on their structure. Correlating scenario generator random variable inputs will not necessarily result in the stochastic path sets exhibiting the same correlation. The path sets would usually be reviewed to confirm they are as expected.

If not using an integrated model, then the risk amounts could be integrated using a statistical approach. A correlation matrix approach is the one most commonly used, where the aggregate risk amount is set equal to:

$$\sqrt{\sum_i \sum_j \rho_{ij} \times Risk\_Amount_i \times Risk\_Amount_j}$$

Implicit in the correlation matrix approach are the following assumptions: risk amounts are normally distributed; risk amounts are measured versus the mean; and correlations are valid throughout the distribution.

Another statistical approach to aggregate risk amounts is to use a copula. Copulas describe the relationship between the quantiles (i.e., rankings) of distributions of the risk amounts, as opposed to directly relating the risk amounts themselves. As such, copulas avoid several of the constraints on the risk amount distributions implied by the correlation matrix approach, typically only requiring that the relationship between any risk driver and its risk amount be monotone. However, the copula approach also introduces complexity and the underlying assumption that the relationship between the quantiles is well described by the chosen copula.

### 4.7.4   Allocation of Diversification Benefits

Whether using integrated or stand alone models, in order to make risk/return optimization decisions, it is necessary to drill down and decompose the result into risk and/or product components. For example, the company's aggregate capital would typically be allocated to the business units as the first step towards comparing each unit's contribution to the company's return on capital. Allocating diversification benefits is a subjective exercise, with no single correct approach. Some common approaches include the following.

- Pro rata: Allocate diversification benefits on a pro rata basis in proportion to a component's pre-diversified capital. This approach may understate the

diversification benefits of smaller components, particularly if there are any negative components.

- Pro rata on "Last In" Contribution: For each component, nominal diversification benefits are measured on the basis of that component being the last one included in the aggregation process. Then the actual diversification benefits are allocated on a pro rata basis in proportion to a component's nominal diversification benefit.

- Marginal: Diversification benefits can be allocated such that the resulting post diversified capital for any component, when unitized (that is, divided by the risk exposure) represents how much the total aggregate diversified capital would increase for one additional unit of exposure.

- Retain in Corporate: All diversification benefits may be retained in corporate. If each business unit prices on a pre-diversified basis however, this may lead to uncompetitive pricing.

Under any approach that allocates the diversification benefits to the business units, the post diversified capital for one business unit will change as a result of changes in other business units. For example, the marginal approach will tend to allocate a large share of diversification benefits to smaller business units dramatically improving their capital adjusted returns. As these businesses grow, their share of diversification benefits will decline, and the company may find they have under priced these units' products. Hence, it is advisable to consider the risk and consequence of employing such diversification benefits in a marginal cost pricing manner. For this and other reasons, it may be desirable to use different allocation approaches for different applications. For example, a different approach may be used for inforce return measurement versus new business pricing.

### 4.7.5   Risk Dependencies

In the model design, it is useful to distinguish between those elements that can be modelled separately and then aggregated without any loss of accuracy, versus those elements that necessarily introduce approximations when modelled separately. Two separate product lines may be modelled individually and combined accurately as long as the correlation of the risk drivers is taken into account.

When risks within a product are modelled separately, almost certainly approximations are introduced. These can be relatively minor "second order" type impacts such as one would see if one were to estimate the total provision for adverse deviations (PfAD) by measuring each PfAD individually against the unpadded reserve and summing them up, as opposed to layering each PfAD on top of the last one.

In the case of products with guarantees, the interaction impact can be substantial if, for example, none of the risk drivers analyzed individually would be sufficient to put the guarantees in the money, but they do on an integrated correlated basis. Also, causal dependency of risks (dynamic lapses, mortality deterioration) is missed if risks are analyzed individually, although a common practice is to include these dependencies in the analysis of the risk that drives them.

There are portfolio level risk dependencies as well. For example, tax recoverability on losses depends on the integrated result across all risks within a legal entity. A common approach for taxes is to measure the risks on a before tax basis and then to estimate the tax recoveries in aggregate.

If the actuary is not comfortable that the error introduced by modelling elements individually is acceptable, then the elements may be modelled on an integrated basis or other methods may be used to capture the interaction impacts.

### 4.7.6   Risk Concentration

Reflecting risk concentration is a key consideration of any risk assessment framework. According to the Chief Risk Officer (CRO) Forum, most insurer failures can be traced back to concentration risk. Examples include the following.

- Mortality: Concentration of lives in a physical location.

- Asset Default: Concentration of assets with one entity.

- Deferred Acquisition Cost (DAC) Recoverability: Concentration of business with a small number of clients that could lapse.

First principle models reflect concentration risk directly, but typically, even advanced models start with simplifying assumptions such as insured lives being independent and asset portfolios being well diversified. These simplifying assumptions would typically be validated and if not appropriate, the concentration risk could be picked up directly, or policies and practices could be implemented to monitor and limit the concentrations.

Even if reasonable in aggregate, a simplifying assumption may lead to adequate risk measurement, but may be inadequate for risk optimization analysis. Optimization analysis on a simple model will typically lead to extreme positions (for example, 100% of capital allocated to one business or 100% of assets invested in one class) under which the simplifying assumptions themselves will no longer be valid. It is advisable to review the simplifying assumptions in light of the optimal solution.

### 4.7.7   Surplus versus Liability Segments

Ideally, liability and surplus segments would be modelled in concert with each other. One would solve for the amount of surplus initially required such that the assets in both segments combined would be sufficient at the end of the risk horizon to satisfy the terminal provision. This is difficult for several reasons, including the fact that the investment strategies of the segments likely differ, so if modelled together, would require modelling transfers between the segments. One approach is to model liability segments on their own assuming the cash required to meet the terminal provision will be transferred from surplus at the end of the risk horizon. Then the surplus is modelled separately to determine how much surplus is initially required to meet the cash requirement of the liability segments at the end of the risk horizon. Transfers between segments over the risk horizon are ignored, which is a reasonable approximation if the risk horizon is short. The results of the analysis on the surplus segment can be unitized. For example, 1+x dollars are initially required to ensure 1 dollar is available at the end of the risk horizon under the framework's specified

confidence level. Then 1+x can be used as a gross up factor applied to the requirements determined for the liability segments to derive the combined capital requirement.

When analyzing surplus and liability segments separately, the amount of surplus that is "required" is not known until after the total capital has been determined. This may impact the overall mix of risks and hence impact the diversification benefits. If material, iterations may be required.

### 4.8    Stochastic Model Design

A stochastic model, by definition, has at least one random variable and deals explicitly with time-variable interaction. A stochastic simulation uses a statistical sampling of repeated simulations of the same model. Such simulations are also sometimes referred to as Monte Carlo Simulations because of their use of random variables.

Stochastic simulation models will generally be the most suitable approach for assessing the tail risk related to economic variables such as interest rates and equity returns. This approach may also be applied to insurance risks. A stochastic simulation model requires the generation or selection of a set of economic and insurance scenarios which form a key part in the implementation and operation of such models, and thus deserve special consideration.

A number of different economic and insurance scenario generation (ESG) algorithms have been developed and implemented in commercially available software or by companies in their proprietary models. Each ESG will typically depend on the selection of a number of parameter values according to the mathematical model on which it is based. These parameter values are usually estimated using either historical data (real world approach) or current market values (risk neutral approach), which is a difficult task and depends on the geographic and economic market relevant to the insurance portfolio being modelled.

The projections provided by the ESG are stochastically generated using a pseudo-random number generator. Typically, many projections are done, and the reliability and statistically confirmed quality of the random generator over a very large set of scenarios is an important consideration.

The preliminary steps of generating random numbers and using these to produce scenarios of economic/insurance variables over the required projection period are readily separable from the application of these scenarios in a cash flow model. This provides freedom in the model design, to choose from among available alternatives as to random number generators or economic/insurance scenario generators, or both.

The design of the working risk assessment model may contemplate some flexibility in the choice of ESGs over time, including the allowance for importing pre-calculated scenarios as an option.

In order for an ESG is to be credible from a business application perspective, it would be useable for multiple applications within the company. Ideally, it would be used:

- For capital assessment, pricing, ALM and other strategic decision-making;

- For all lines of business, for all applicable economies, for all time horizons and for both assets and liabilities; and

- For the entire company on an integrated basis.

This implies that the ESG would be integrated across economic variables, integrated across applicable economies, and integrated across asset classes, and that it would be able to capture both short- and long-term dynamics. In practice, a single ESG may be far too complicated to be appropriate in all of the above situations. However, it is important that the rationale for using different ESGs in different situations be sound, validated, and documented.

**4.9    Regulatory Capital versus Internal Risk Assessment**

It is highly desirable that the same base models that are used for internal risk assessment purposes also be used to determine regulatory capital. However, the set-up of the models may vary if, for example, the internal risk measure is based on a different financial measure or is measuring capital at a different confidence level.

Some considerations that differ between regulatory and internal capital assessments are discussed in the following sub-sections.

**4.9.1    Potential Elements for Standardization**

It may be appropriate to standardize across the industry some elements of advanced models. It would generally be appropriate if:

- The model is being used to determine regulatory capital or the model results are being disclosed externally;

- Setting the element is necessarily subjective; and

- The element and its impact are common to all companies.

Possible candidates for standardization include:

- The solvency framework;

- The capital valuation method;

- Economic scenarios; and/or

- Operational risk requirements.

It would generally be preferable to set economic scenario calibration standards, as opposed to standardizing the paths themselves. Standardized scenarios may not yield appropriate results in all situations, may introduce systemic risk across the industry, and may impede both model development and pervasive use of the model within the company.

**4.9.2    Risk Profile**

Capital models reflect anticipated management action such as reinvestment strategies and Universal Life crediting rate policies. Questions that warrant consideration are:

- Should anticipated management action also reflect action based on the current risk profile being misaligned, or deviated, from expected?

- Should the treatment be the same whether the current risk profile is more or less risky than what is expected?

Examples of anticipated risk profile changes include changes in asset-liability matching, the addition of new hedge programs, and changes in the amount of reinsurance ceded.

Regulatory capital would generally be based on the point in time risk profile since projecting profile changes is subjective and since the market may move before the risk profile changes are implemented. However, there would be no gaming of the rules such as closing out the risk position just before the valuation date and then opening the position up again shortly thereafter.

Anticipated changes in risk profile could, however, be considered in internal risk analysis and disclosed if material. For regulatory capital, anticipated changes in risk profile would form part of the qualitative assessment.

## 4.10  Advanced versus Standard

It is anticipated that regulatory capital frameworks will provide companies, for each risk, a choice of defined methodologies from standard to advanced models. It is likely that companies will strive to evolve towards advanced models on all material risks. In particular it would be appropriate to implement an advanced model when there is reason to expect that the results would be materially different than those of a standard model, whether that difference is higher or lower.

Standard models are intended to cover the majority of products offered in the industry, so they tend to err on the side of conservatism. Reasons not to move towards advanced models include:

- Insufficient resources available to build and maintain advanced models;

- Insufficient company-specific data available to ensure the results of an advanced model are any more reflective of the company's risk profile than the results of a standard model; or

- Insufficient knowledge of the risk behaviour to be able to build an advanced model.

Regulators are expected to develop additional guidance on the selection of advanced versus standard models. Examples include the following.

- Once an advanced model has been developed, it is unlikely that a company will be permitted to revert to using a standard model. An exception would be the case whereby a change in circumstances makes the advanced model no longer suitable, such as defined above.

- Once an advanced model for a given risk has been developed, it likely will be required for all products for which that risk is material.

## 5.    MODEL IMPLEMENTATION

This section discusses issues of model implementation, operation and use, once the appropriate theoretical model(s) have been selected.

### 5.1    Development and Use of Assumptions

Assumptions include a wide variety of model inputs that in general correspond to each of the risks inherent in the business being modelled that have financial impact, either directly or indirectly. Major assumptions to consider for risk assessment purposes are related to future interest rates, growth in equity values, mortality, morbidity, claims level and frequency, expenses, lapses and asset defaults. It is important to keep in mind that this list is not necessarily exhaustive, as the assumptions required would vary with the nature of the situation being modelled.

### 5.1.1    Assumptions versus Parameters

Assumptions are typically not objectively based on actual characteristics, or contractual elements of liabilities or assets being modelled, but rather incorporate some aspects of judgment, estimate, or opinion about future experience. As such, the choice of assumptions as related to expected experience and the selection, incorporation and transparency of risk margins inherent in these assumptions, if required, are primary considerations, according to the model framework.

Contract details such as the volume or current premium levels of insurance policies are considered data, rather than assumptions, and are discussed in a later section.

Parameters are a specific class of inputs to a model that may control some aspects of the model's operation or output. For example, parameters may be used to select from a range of optional values that differentiate between modelling algorithms or customize those algorithms. Accordingly, the issue of risk margins is not generally relevant to the selection of such parameters.

In the case of internal model components that generate financial variables applicable to the model globally for stochastic applications (for example, yield curves or equity market growth rates), parameters may be necessary to tailor the underlying mathematical model used to generate those values. Such parameters are critical inputs that can directly and significantly impact the results of using the model, and as such, are generally set by calibration techniques or selected on a standardized or prescribed basis to ensure comparability. Such parameters act like assumptions and care is necessary to ensure that margins are appropriate and effectively applied in the model application and clearly disclosed in documentation supporting the results.

The risk and potential impact of setting parameters incorrectly would usually be considered and addressed in the model's operation and use, as well as in any operational risk assessment performed by the risk management function of the company.

### 5.1.2   Operational Parameters

Operational parameters may be incorporated in the software model to control such modelling elements as:

- The projection horizon of the model;

- The time step used in model calculations as it moves through a projection period; and

- The frequency with which certain fundamental processes, such as reinvestment and disinvestment of accumulated cash flows, are performed.

Changing such parameters may be tantamount to turning an approximation on and off, in that they can potentially impact calculated results and model run-time in a significant manner. Accordingly, the disclosure of settings used, as well as the regular testing and validation of the impact of setting each parameter, is very important.

### 5.1.3   Selection of Assumptions

The selection and justification of assumptions is a complex and critical process that would normally be guided by actuarial standards of practice and educational guidance specific to those assumptions. Consideration would be given to the solvency assessment and capital requirement calculation purpose of the model, and the specific model type and framework that is being implemented.

While the development of explicit standards and other guidance on assumption setting and margin selection is beyond the scope of this paper, the following general considerations are relevant.

Assumptions would be selected in light of:

- Historical experience (real world) or current market prices (risk neutral), as may be appropriate to the model framework;

- Relevance with respect to the business, investment class, geographic/political environment, etc. being modelled;

- Ability of the model as implemented to accurately apply and reflect the assumption being made; and

- The impact of the assumption and sensitivity of model results to variations in that assumption.

The selection of an assumption would theoretically not be impacted by concerns over the ability to define or implement other independent assumptions. That is, concerns over the validity, relevance, or volatility of one assumption, even one whose impact is judged to be more material, would not be used to justify less care in the selection of another assumption, without appropriate disclosure and justification.

### 5.1.4    Company Experience versus Industry Sources

The derivation of assumptions from historical experience (in the case of real world models) will usually involve some weighted blending between company specific and industry or market experience. Where possible and relevant to projected future experience, historical experience would inform and guide the selection of assumptions.

Where the assumption is one for which future experience is not expected to be materially different between lines of business, or specific portfolios, then appropriate industry experience would be considered to be the most statistically credible because of the greater volume. In this case, industry experience would likely be given the greater weight, perhaps even to the exclusion of company experience.

Where company experience differs from industry experience, or is more detailed, and where such differences can be rationally explained and can justifiably be expected to continue, company experience could be given the greater weight. However, the level of ongoing attention to documentation, disclosure, sensitivity testing and periodic review would be increased.  In order to avoid the appearance of "cherry picking" of experience to the company's advantage, the weighting of company versus industry experience may be rationally supported in a consistent and objective manner on an assumption-by-assumption basis.

Where historical experience that matches the characteristics of the business being modelled, or the environment in which the projected experience is assumed to occur, is not available, reasoned judgment, preferably applied to modify whatever experience is available, may be necessary. Such unsupported assumptions require greater attention to documentation, disclosure, sensitivity testing, and periodic review.

In the extreme case of a new product or risk, when the use of unsupported assumptions in an internal model would have a material impact on the total capital requirement produced by a model, it may be preferable to consider the temporary use of either standardized assumptions or even a standardized model. Such situations would usually be identified and addressed appropriately before they present a material exposure and where such standardized models or assumptions are not available, proactive steps would be taken to develop them.

### 5.1.5    Granularity of Model and Assumptions

A model may operate on a full seriatim level of detail of in force assets and policy liabilities, and have the ability to differentiate assumptions at a fine level of granularity. Alternatively, business being modelled may be assumed to be sufficiently homogeneous as to be modelled in groupings, cohorts, or using representative data rather than actual data, without material impact on the accuracy of the modelled results.

The granularity of assumptions would be chosen:

*   In light of the selected granularity of the business being modelled;

- In recognition of the increased difficulty in disclosing, managing, reviewing, validating and updating assumptions which are specific to a very fine level of granularity;

- In recognition of the granularity of current or planned experience studies that may be used to support or revise the assumption in the future; and

- Giving consideration to the impact on the accuracy of results and model run-time.

### 5.1.6   Validation of Assumptions

It is important to validate the model's application of assumptions from two perspectives:

- To confirm the reasonableness of the assumptions as selected; and

- To confirm those assumptions are implemented consistently in the actual model.

Approaches to confirming the reasonableness of assumptions include: independent review of the assumption development and supporting experience studies; industry benchmarking; and back testing. Approaches to validating the implementation include: independent review of coding; comparing results under simpler standard assumptions; and analyzing the difference; and backtesting.

Benchmarking is the comparison of the selected assumptions with those used by other institutions and the overall industry, to the extent that information is available. When there are significant differences with industry assumptions, there would normally be valid reasons that demonstrate that the risks are different and supported by different practices. For example, if the company's ratio of the mortgage loans to real estate values is generally lower than the industry (resulting in lower risk and better loan ratings used in the models), this would ideally be supported by specific company policies, operating guidelines, products and practices, and better underwriting of loan risks rather than by overvalued real estate appraisals. The same can be said about mortality experience that is better than average.

Backtesting is the process of comparing historical results to those produced by the current model. It validates both the reasonableness and the implementation of the assumptions. There are some variations on backtesting.

- The current model may either be run as at a historical valuation date using the corresponding in force data, or at the current valuation date using current inforce data. If using an historical valuation date, consideration may be given for new business issued since then. The current valuation date may be used if the model has the capability of projecting backwards in time.

- Some assumptions in the current model may be modified to improve the fit to historical experience. Any differences between the assumptions used to fit historical experience and those used to project forward would be justified, perhaps in terms of changes in practices, or that the forward assumptions reflect a more credible experience block than that reflected over the backtesting period.

Where backtesting is not practical, a review of projected results from the model versus reasonable proxies or benchmarks, such as recent history, adjusted for inflation, growth, etc. or business plans, is an alternative.

Further discussion of validation and calibration is provided in Section 6.

### 5.1.7   Use of Margins on Best Estimate Assumptions

Margins in assumptions are meant to reflect uncertainty around those assumptions. It is useful to consider the following sources of uncertainty which may exist around any assumption or risk.

- Volatility describes the random variation that most risks exhibit. Given the statistical distribution of a risk, a given observation may fall anywhere within that distribution.

- Catastrophe describes extreme events. Often, mathematical models describe the risk distribution well at most probability levels but not in the extreme tails. In these cases, specific adjustments or provisions may be required.

- Level uncertainty is the misestimation of the current mean of the underlying experience (perhaps due to lack of credible data, poor data quality, or that the experience is based on similar but not identical business).

- Trend uncertainty reflects that future experience may deviate from expected experience (perhaps due to secular trends).

Whether these sources of uncertainty are explicitly or implicitly reflected, it is important that each source is considered, an appropriate margin is applied for all sources in total, and that care is taken not to double count any margins.

Margins are applicable both over the risk horizon and in the terminal provision. Margins over the risk horizon would typically be at a much more extreme level than those in the terminal provision.

Margins can be applied in various ways. The following approaches may be used to model both uncertainty over the risk horizon, and in the terminal provision.

- Deterministic approaches involve choosing conservative scenarios (perhaps based on statistical analysis or via sensitivity testing and judgement), often implemented by applying a margin directly to the expected scenario. An example is to increase the realistically anticipated mortality rates in a deterministic cash flow projection model, by a specific adjustment such as x% or k deaths per thousand.

- Stochastic approaches generate multiple values of the assumption following a defined statistical distribution, and then select a conservative outcome based on a specified probability. An example would be the use of a CTE measure based on the average of the top y% of scenarios in a stochastic simulation of individual contract mortality experience.

To measure uncertainty in the terminal provision, the following additional approaches may be used:

- Risk Neutral approaches evaluate the market value of the security or liability at the end of the risk horizon, and by definition include an implicit market value margin; and

- The Cost of Capital approach estimates the margin required in the terminal provision, over and above best estimate liabilities, to provide an adequate return on capital that would have to be set aside to support those liabilities.

A combination of the above four approaches may be used to cover off different sources of uncertainty on any given risk, or one approach may be used to cover off all sources at once. A stochastic approach is preferable over a deterministic one where the risk is skewed, provided the underlying probability distribution can be reasonably estimated. Where different approaches are used for different sources of uncertainty or different risks, these differences would be justified and the use of the most aggressive or most conservative approach in each instance would normally be avoided.

Model risk, as defined in Section 4.2, encompasses both process error and general uncertainty elements.

- The process error element is an operational risk. Like other operational risks, it would be managed to a minimum, in this case via controls, validation and review. The remaining risk would be addressed as part of the operational risk assessment. No margin would normally be incorporated into the models for other risks to account for the process error component of model risk.

- The general uncertainty element includes the sources of uncertainty described above, and does warrant the inclusion of margins directly into the model. In particular, the use of a stochastic process to reflect and measure tail risk appropriately, may not eliminate the need to include additional margins when parameterizing and calibrating the stochastic process, if for example there is uncertainty in the specification of the probability distribution governing that process. This additional margin for parameter uncertainty may be implicit through conservative and/or standardized calibration, the selection of a higher CTE level than might otherwise be adopted, or the choice of a fat tailed distribution in the underlying assumption distribution.

The presence, level and reason for margins, both in the parameterization and explicitly applied to assumptions, would be clearly identified in documentation and properly disclosed, to avoid redundancy or duplication leading to an excessive level of margins.

The appropriate direction to vary an assumption (i.e., the appropriate sign of the margin) is not always obvious, nor is the quantified impact of the margin easy to predict, especially in combination with other margins, and as experience approaches the tail in experience overall. Due to interactions between assumptions, it is important to test the removal of margins one by one in isolation and in a consistent fashion, to verify that each one has had the expected impact and the expected relative significance of the impact of each margin to the others.  Such testing would be performed on various model points, and at various durations.

Dynamic elements in cash flow projection models which involve uncertainty could also reflect margins. These include dynamic lapses driven by market movements, the setting of non-guaranteed product features controlled by management, and mortality deterioration caused by anti-selective lapsation. Typically these margins will be set deterministically via the choice of conservative causal formulas.

### 5.1.8    Selecting Assumptions in Stress Level Scenarios

Most reported experience, whether for an individual company or from the industry, reflects normal market and experience results.  It is prudent to consider the relevance of this observed experience when predicting experience under unusual and adverse circumstances. Policyholder behaviour assumptions, in particular, may not reflect any previously observed patterns once experience in one or more relevant areas becomes significantly adverse. Unusual macroeconomic conditions such as sustained levels of low interest rates, or spikes in mortality such as may be experienced in a pandemic, or natural catastrophe situation, may well be accompanied by other aberrations to normal experience. While no exact science or logic may be useful in predicting these aberrations, the potential impact of them may be considered, and factored in as may be practical, or at a minimum disclosed in reporting results. Futurism techniques may be of help in assisting the actuary in developing an understanding of the potential impact.

In predicting changes in historic assumptions in stress level scenarios, the interdependence of assumptions in observed experience could be considered. Examples of this include:

- The impact of economic trends on recovery rates from disability;

- Declining lapse rates of guaranteed premium contracts under adverse population mortality scenarios;

- Anti-selective mortality arising from increasing lapse rates;

- The impact on lapse rates of products with embedded options or guarantees, as the key drivers of value to the policyholder evolve over time; and

- Policyholder disintermediation due to changes in the interest rate environment.

### 5.2    IT Implementation

IT is an important part and enabler of any risk assessment model and framework. The model used to perform assessments of capital required for solvency or internal risk assessment is the sum of the underlying theoretical framework, the IT implementation that attempts to effect that framework, plus the data and assumptions entered into that IT implementation. It is important to consider the IT implementation as an integral part of the model, and understand the potential impact of various IT strategies and decisions separately from the other components. At the same time, the IT implementation would ideally be separated sufficiently from the way in which the model is built so that technology upgrades do not require a complete re-implementation of the model. This independence is not always easy to achieve.

### 5.2.1   Goals of IT

The primary goal of the IT implementation is to remain faithful to the model methodology being implemented, so that any calculated results will be precisely as may be predicted by an independent knowledgeable observer or reviewer, and so that attention can be focused on assumptions and data when using the model and not on unwanted distortions caused by the implementation.

A second goal is to achieve an economically appropriate solution, in terms of implementation, maintenance and future upgrade, keeping in mind the various anticipated applications of the model, while also achieving acceptable set-up, maintenance and processing runtime performance.

In certain model frameworks, such as those that might imply stochastic simulation at a seriatim level, trade-offs may become inevitable in terms of approximations or simplifications to data or assumptions chosen to meet runtime constraints. Usually, the IT implementation would:

- Be transparent as to the use of each such approximation; and

- Support the alternative of running without those approximations, where feasible, in order to study and assess their impact.

Technology is constantly advancing in power and in innovation, and it is advisable that the implementation anticipate the eventual ability to run without scenario or data limitations, as opposed to building in permanent restrictions.

### 5.2.2   Transparency of Methodology, Assumptions, and Parameters

End-users of information place considerable reliance on persons who run the models as well as on those who vet the information along the way. A computer model often attracts the label of being a "black box" because the inner workings are not easily visible or understandable to the user of the model, let alone the intended audience of the results. The internal logic of most models is usually very abstract and limiting to the end-users of the information from such models, often more so as the complexity and flexibility of the software grows or the operational efficiency of the implementation increases. Formulas may be implemented in code using shared functions to represent recurring complex operations, and fundamental calculations which are repeatedly executed may be rearranged in unfamiliar patterns for reasons of pure speed.

For reasons of confidence, validation, ease of review, and maintenance, it is important that there be some transparency as to the methodology implemented as well as the assumptions and parameters selected and applied. This transparency need not allow the user to verify the exact details of formulas implemented as such detailed verification requires the same technological expertise and familiarity with the model as the original coding does. Transparency may be achieved by providing sufficient flexibility in obtaining detailed calculation results including the results of interim steps in a complex calculation, and in easily testing the impact of alternative settings and assumptions for the model, and confirming what assumptions have been applied in a given model test.

To achieve acceptable performance at reasonable cost, developers would choose the most effective, efficient, and maintainable ways to translate assumptions entered into assumptions used, and perform repetitive calculations in a consistent way. However, this ideally would not sacrifice the transparency and maintainability of the assumptions entered in the model. It is therefore important to place sufficient priority on the design of the user interface and its usability and transparency.

The application of approximations may be necessary to enable optimal run-time performance but increase the need for transparency, especially with respect to the application and impact of the approximations. It is advisable that all approximations inherent in the model design and implementation be clearly documented. Approximations arising from discretionary data compression, assumption simplification, or alternative calculation approaches would generally be separable and identifiable, so that their use is more easily controlled and verified, and the impact quantifiable.

### 5.2.3 Separation of Data from Assumptions

Model input can be considered to include both source data for liabilities and assets, as well as assumptions governing the future experience as predicted by the model. Where those assumptions have a low level of granularity, the IT implementation may allow assumptions to be embedded in the data. This approach would be used with caution, as it is important to be able to monitor, document, and test the choice of assumptions used in any model processing. Embedding assumptions in data can complicate these processes, and reduce the transparency of the assumptions applied.

The embedding of assumptions in the data would only be performed as part of a clearly documented and controlled process, with convenient options to adjust and redefine such embedded assumptions.

### 5.2.4 Change Control

Change control approaches and techniques for all components of the model would be planned in advance as part of the IT implementation. Model calculations are an important component in reporting of financial results and risk measures that drive operational decisions critical to the strength and integrity of the company. Adequate knowledge and control is therefore required over changes in the IT implementation of both the model calculation processes and the assumptions being implemented while still allowing an acceptable level of flexibility and productivity in testing and updating these aspects of the model. This is often facilitated through the use of "test" and "production" environments, each with appropriate levels of access controls.

### 5.2.5 Review, Replication and Business Continuation

Design of the IT implementation of a model would ideally allow for important processes such as review, replication and business continuation in addition to the maintenance and operation of the model. It is important that the review of model assumptions and set-up, and replication of any given model run be supported. For example, in the case of models employing stochastic processes that may require random number generators, it is important

to achieve appropriate randomness, yet also to be able to replicate any given run if required.

The need for the application of powerful and advanced technology in order to achieve acceptable runtimes can make the IT implementation of risk assessment models expensive and somewhat unique within a company's IT infrastructure. Disaster recovery and business continuity planning would contemplate the resumption of a consistent and verifiable modelling capability in a reasonable timeframe following the sudden loss of the primary site under various scenarios. The timeframe for recovery would anticipate the expectation that the model is used for management and operational purposes and not just the annual calculation of required capital. However, it is likely that the immediate recovery of risk assessment processes will have less urgency than other critical operational functions.

### 5.2.6  Design for Future Technology Upgrades

Whether or not the initial IT implementation achieves anticipated performance and capacity targets, the inevitability of useful advancements in technology becoming available could be anticipated. Planning for the implementation of such advances within a model framework without total rebuilding of the model is preferable because:

- It will facilitate the implementation and use of new technology on a timely and more cost effective basis; and

- It will reduce the resource costs in validating and retesting the implementation to the degree that elements of the implementation such as the coding and application of assumptions have not changed.

### 5.2.7  Considerations of In-House versus Third-Party Software

The IT implementation of a model can be wholly or partly achieved using third-party software. Concerns regarding the selection, maintenance, control and validation of third-party software are often just as applicable to software developed by in-house professionals, to meet user specifications.

It is important for both internally designed and purchased software to be:

- Flexible and readily enhanced to meet changing needs, performance expectations, and to implement or exploit advances in technology;

- Well tested, robust, and suitable under the proposed operating conditions; and

- Well controlled in terms of the implementation of updates in code, operating systems and hardware platforms.

When software is purchased or licensed, it is important to consider the reputation and permanence of the vendor should it be vendor maintained, and the potential risk and impact of a vendor withdrawing from the marketplace or being unable to provide required support.

### 5.3 Business Data

### 5.3.1 Actual Business Data versus Business Model

Wherever possible, the business data reflecting the actual insurance contracts and actual invested assets held at the date for which a capital assessment or risk analysis is to be performed would be used in entirety and without adjustment as input to the working model. Especially when stochastic analysis is required, run-time considerations in combination with assessments of materiality of result may lead to the application of various data reduction techniques, which are generally referred to as model compression.

Model compression techniques include:

- Grouping of similar contracts by characteristics such as policy form, risk class, issue age and issue date;

- Substitution of an assumed group of identical policies reflecting on average the characteristics of the group; or

- Elimination of minor blocks of contracts or miscellaneous benefits, possibly with offsetting increase in volumes of more significant contract forms.

The above examples describe compression of the liability data. Similar techniques can be used to compress the asset data.

Model compression is by nature an approximation technique and as such requires careful monitoring and control over the materiality of the impact of the approximation. This in turn implies, wherever feasible, that the comparison of risk analysis calculations be performed both before and after compression to quantify the impact. Comparative tests designed to quantify impact may, however, be usefully performed on representative portions of the entire portfolio, or on a sampling basis. Accordingly, it is important to design and implement model compression techniques that are flexible, both in aggregate and on a block specific basis, as to the choice of specific compression rules, including the number of model points used for each block of business.

Optimally, compression technique implementation would include options to remove all compression, and to control the level of compression on a product line or plan specific basis. This will facilitate testing of the impact of compression and the adjustment of the level of compression over time as the significance of the block changes in relation to the business in total, and the evolving capabilities of the IT implementation produce shorter run-times.

For similar reasons, it is appropriate that compression processes be transparent and identifiable within the control parameters and assumptions defining the business data preparation process.

### 5.3.2 Using Common Data Sources

Business data that has already been validated and perhaps transformed by another process, such as a valuation system, may be a convenient and cost effective source of business data

for risk assessment purposes, provided that the value and accuracy of the original data has not been impaired by any transformations or compressions in that other process.

The extraction of business data from administration systems, the validation of that data as being suitable for its purpose, and testing that the extraction represents a complete and accurate representation of the assets and liabilities of the insurance entity are important processes that require regular review and testing by internal and external auditors. Accordingly, it is preferable that the same data prepared, validated and used for valuation processes be used if possible as the starting point for risk analysis and capital assessments, even if additional data compression is needed to meet runtime constraints applicable to these risk assessment models. This helps assure consistency and quality comparable to that attained for financial reporting.

### 5.3.3   Control Total Validation Techniques

Risk model output, similar to production financial reporting systems, could include key statistical totals such as number of contracts, volumes of benefit, and amounts of premiums. These types of checks and balances help enable confirmation of continuity and completeness of the business data entering the model, and consistency with administration systems and other applications. The control totals would be available both before and after any compression techniques are applied, and after calculations of required capital are performed. Where compression has been applied, some judgment may be required to assess whether changes in control totals are reasonable and consistent with the compression technique, and typically these would be clearly explained in supporting documentation, and periodically validated.

### 5.3.4   Use of Data Files Generated Prior to Reporting Date

Risk assessment models may involve very long run times in order to perform a comprehensive risk analysis on a full portfolio of business on a stochastic basis. It is possible that such models may not practically be used in critical financial reporting processes with tight timeframes unless they are run on business data generated at a date prior to the reporting date and possibly even prior to data used for other reporting purposes. This is an approximation technique, and would normally require some suitable adjustment to the results otherwise produced, such as:

- Generalization of the risk analysis results into factors that can be applied to the actual reporting date business data; or

- Projection of the business data to the reporting date, prior to running the model.

When the use of prior date business data is used in a model, it is important to consider the following:

- Is the business date of the data on which the model is actually run transparent to all users, and clearly disclosed in model results?

- Does the model assume a specific time period difference between data extraction and reporting or is it able to react to or compensate for the actual period of delay in

each usage to facilitate reduction or elimination of such an approximation technique?

## 5.4    Processes

### 5.4.1    Flexibility of Use

While models are primarily developed with their intended usage in mind including the specific solvency framework and calculation methodology, it is preferable that the model and its results can be used to support multiple processes. If practical within the required cost and performance expectations, they could also be designed with the general purpose of accurately reflecting all material cash flows arising from the liabilities and assets anticipated to be modelled, and realistically reproducing the corresponding material financial statement impact, for the following reasons:

- Using the results of an internal model regularly for multiple business management purposes, including pricing or operational risk management, demonstrates the company's commitment to and reliance on the model's validity and usefulness for regulatory capital assessment;

- The capability of running multiple processes and extracting various calculation results from a model, increases the transparency of the model, and provides more ways in which the validity of the model can be tested and confirmed, thus improving the confidence in the model; and

- Multiple uses of a risk assessment model will increase the company's experience with and understanding of the model and of the impact of various assumptions, increasing its ability to detect any operational concerns or theoretical errors in the model's construction, or problems with data and assumptions being applied using the model, and motivating additional improvements in the detail and usefulness of the results available from the model.

General purpose models may be impractical or unsuitable for capital assessment to the extent that they are too detailed in operation or in reported results to perform the specific risk analysis requiring thousands of scenario iterations in a timely fashion, especially considering today's technology and risk analysis techniques. Additionally, the risk assessment framework may be inconsistent with other purposes which will necessitate material differences. For example, a risk assessment framework that uses a one year risk horizon and/or defines the terminal provision on a market consistent basis may require significant changes from a CALM valuation model.

When an internal model is initially developed specifically for capital and risk assessment purposes, opportunities may be sought to broaden the application of the model to additional applications through ongoing enhancements and improvements, as the modelling techniques and technology implementations evolve over time. For example, it may be possible to share components of general purpose models and risk assessment models to the extent those components can be practically shared without compromising the methodology and runtime performance of the risk assessment models.

### 5.4.2   Backtesting

Backtesting refers to the process of validating a model by using actual historic assumptions applied to an in force file and comparing the model's projected cash flows and financial results, as may be available from the model, to known results. While this process provides some confirmation of the basic operation of the model under normal operational circumstances and assumptions, it cannot be used to validate the model's operation under stressed conditions that are unlikely to have happened in the past.

Other forms of testing on historic data, in which some assumptions are set to neutral or artificial values for the purpose of easily confirming the impact of the remaining assumptions on results, in comparison with the experienced results, may also be useful.

### 5.4.3   Sensitivity Testing

Sensitivity testing is an important process both for validating the operation of a model, and for providing useful information to management. Sensitivity testing refers to the determination of the incremental impact of predefined changes in single assumptions, or in combinations of assumptions, on calculated model results. Validity of a model can be tested by rationalizing the observed results of sensitivity testing based on limited changes in single assumptions.

Sensitivity testing is facilitated if the IT implementation of the model permits the base assumptions and parameters to be easily modified. Ideally these modifications would be flexible so as to allow for additive and multiplicative changes over any limited period.

Additional management information can be obtained by comparing the relative sensitivity of different blocks of business to the same incremental changes in basic assumptions, or by comparing the relative sensitivity of the same blocks of business to those changes at different points in time. Regulators and company management may benefit if they are able to compare standardized sensitivity test results among companies or over time.

### 5.4.4   Model Calibration

Calibration of the parameters used in these models to recent, market specific experience is an important and regularly repeated process, especially when mathematical models are used to represent the probability distribution of certain assumptions such as the movement of asset values or of yield curves over time.

Calibration of such models could be supported by features that facilitate the testing of changes to the model parameters in a methodical manner which allows the selection of the appropriate combination of parameter values producing the best fit to the experience, and the verification that minor changes to those parameters do not, in fact, produce a better fit.

### 5.4.5   Application of Calculation Processes to Specified Blocks or Policies

While the model's purpose is to quickly and efficiently process large volumes of possibly seriatim business under possible multiple scenarios, it is also important for transparency and validation purposes to be able to view and reproduce the model calculations on single

policies or specified subsets of business, and to allow the variation of specified assumptions to observe the impact at those levels.

### 5.4.6 Archiving and Model Replication

The use of an internal model is a critical financial application that would generally be expected to be reproducible and auditable. Accordingly, it is essential to be able to reproduce the results obtained from an earlier operation of the model at a specific reporting date, and to support the detailed investigation of the model calculations at various levels of detail or granularity. This implies that an archiving process be developed that readily produces a back-up copy of all model components (historic business data, model code or executables, complete details of all assumptions and parameters, and the definitions of all processes or calculation routines necessary to produce the key results) such that, if necessary, the model could be reconstructed, perhaps on a different physical machine at a remote location, and used to produce identical results.

### 5.4.7 Model Output

Both for purposes of audit and for internal review, it is useful to be able to extract reports from a model which document the assumptions actually applied by blocks of business, or even individual policies. Comparison of assumption details can isolate inconsistencies and thus contribute to management confidence that the assumptions were implemented as intended. Assumption documentation is also useful for purposes of external review of assumption reasonableness that is independent of the model implementation.

Flexibility in the generation of other reports that provide by-products of a calculation such as detailed cash flows, or elements of the reserve calculation, can also contribute to understanding of a model's operations, and to audit reviews. For both these purposes, flexibility in reporting would include the ability to control the periodicity of the financial values output (monthly, quarterly, annual) within the granularity available in the model implementation.

## 5.5 Results and Analysis

### 5.5.1 Reporting Flexibility

Ideally reports would be available at various levels of granularity and periodicity for usefulness to management as well as for model testing and validation purposes. Attribution analysis, or the analysis and explanation of changes in results from period to period, may require detailed components sufficient to decompose and to understand, the model's operation or even reproduce the changes independently, at least at a single model point level. Hands-on testing may require reports to be immediately available in visual format, or to be saved in, or exportable to, common formats, such as databases or spreadsheets.

### 5.5.2 Validation of Customized Reports

Validation processes will normally focus on the calculation results produced by the model and reported as standard or default model reports. For flexibility of use, it is valuable to build in the capability of defining customized reporting tools, provided the additional risks

and challenges of using such reports is addressed within validation and control processes. Such risks are increased in proportion to the amounts of customization permitted, the options for building in formula based report lines, and the number of user-defined line titles.

### 5.5.3 Standard Terminology and Format

The use of standard terminology and format can significantly reduce model and operational risk. Model implementations can provide clear and detailed identification or prompting for the input of assumptions, and clear and complete labelling of calculated results that conform to standard usage of business or technical terms, such as financial statement elements. This will help avoid confusion or misinterpretation of input prompts and model results, both within the company, and by external reviewers.

It is advisable that user manuals or help screens also adopt standard terminology and be consistent with its usage in the system itself.

Formats of input and output items (for example, definition of units of financial values, the use of proportions versus percentages, the format of date values) would consistently conform to standard usage, and would be clearly documented in the interface and in reports, as appropriate.

### 5.6 Stochastic Model Implementation

A stochastic model is an imitation of reality: it is a technique that provides statistical estimates and not necessarily exact results. Stochastic modelling serves as an important tool in a company's risk measurement toolkit. It is important to keep in mind that stochastic modelling is part art, part science, part judgment, and part common sense.

Stochastic models by nature are complex and run-time intensive, especially when used for solvency assessment. For example, a tail measure of high confidence (99% and over) will require thousands of scenarios to be tested to measure the tail risk with any reasonable level of stability in the results.

The results produced by stochastic modelling are not always intuitive. It is important to fully understand the strengths and limitations of any model as well as continually perform reasonability checks. Such modelling often requires a different way of looking at problems, issues, results, and potential solutions. It is also important to be cognizant of the greater exposure to model risk and operational risk inherent in the added complexity of stochastic modelling.

Under certain circumstances, it may be appropriate to apply adjustments to the modelling methodology in order to reduce runtime. To cope with practical limitations of available hardware resources on total runtime, a variety of approximations have been designed for stochastic modelling. Two examples are:

- Selecting representative scenarios: This technique attempts to replace a larger set of scenarios by a much smaller number of scenarios with weights assigned so that each tested scenario represents a subset of similar original scenarios; and

- Predictive scenario processing: Analysis of the full set of scenarios applied to the business model enables selection of specific indicators in results, or in the scenario, which are reliable predictors of whether that scenario falls in the x% worst. Then, when actual model runs are required, scenarios of the full set are pre-screened based upon criteria employing these predictors to be either skipped entirely or cut short, if interim results predict they will not be among the worst scenarios, nor have material impact on the answer. As the prediction algorithm will not be entirely accurate, the number of scenarios run would normally meet a predictive threshold proportion higher than the tail risk measure eventually used. For example, to end up with a 95% CTE measure, it may be prudent to run the scenarios predicted to result in the worst 10% of results and use the 50% CTE measure on that 10% set.

The algorithms used to effect these methods may well have differing effectiveness according to the current economic market, the specific set of scenarios generated and the business and asset models on which they are run. Accordingly, it may be appropriate to use these techniques with caution. In addition, such techniques being comparable to approximations require a significant amount of effort with respect to the validation of their effectiveness and confirmation of their impact. Since thorough validation requires running the full set of scenarios as well as the reduced set, the total runtime for this type of approach may well exceed the run time without employing the method, with the advantage gained only for the run constrained by a short reporting window.

A potential drawback introduced by some scenario reduction techniques is that the results will be limited to a certain point in the distribution. It is often useful for understanding a risk, and for reflecting diversification benefits between risks, to estimate the entire risk distribution.

## 6.     MODEL VALIDATION AND CALIBRATION

Model validation and model calibration are terms that are sometimes used interchangeably; both are related to the process of assuring that a model works both in general and in the particular circumstance at hand.

In this paper, *validation* will mean the process of proving a working model is valid in the sense that it reasonably reproduces some known or independently generated results, or that model software faithfully implements the technical and theoretical concepts in its design. *Calibration* refers to the process of setting parameters and assumptions that are relevant to the particular circumstance at hand.

For example, a newly developed model would be *validated* that it works at all. It would then be *calibrated* to the specific situation at hand, and then, typically be *re-calibrated periodically* to reflect new interest rates, stock returns, etc., depending on the nature of the situation.

Calibration has a special significance in the case of a model employing stochastic analysis based on economic scenarios. Since each economic scenario generator is governed by parameters, those parameters would be calibrated so that the specific implementation of the economic model produces results consistent with historical experience or with current market data (according to whether the model reflects a real world or market consistent

valuation). The parameterization ideally would also be relevant to the company, its business, and the circumstances applicable at the date of the analysis.

## 6.1　Conceptual Validation

Conceptual validation confirms that the model adequately covers the risks and circumstances that should be covered according to the selected framework. Each different risk characteristic (misestimation, deterioration, volatility and catastrophe) would either be covered implicitly by the model, or by explicit adjustments external to the model.

Any model would start with a conceptually valid framework – that framework can be validated by external research papers or internal research. For example, while abundant published research supports an assumption that stock market returns behave more or less lognormally most of the time, other published research supports an assumption that distributions produced by regime switching lognormal models are more appropriate when the tails of the distribution are of interest. It would not necessarily be wrong to use some materially different distribution than either of these, if such an assumption was supported by strong evidence about why that assumption was valid for the task at hand.

Likewise, there are numerous publications available describing reasonable approaches to modelling interest rate and claims volatility. Use of models other than those would require some evidence as to why the chosen method is more (or equally) appropriate as one of the conventional approaches.

Even when conventional or published approaches are being used, in a different environment or in a different application, the conventional model may not necessarily be appropriate. It is important for the actuary to recognize that the model selection process will always require some form of judgment to be exercised by the actuary.

## 6.2　Implementation Validation

Implementation validation is the process of proving that implementation of the model (e.g., an actual computer program) works in a manner consistent with the conceptual validation and the actual data and parameters at hand.

There are several approaches to implementation validation, none of which is perfect and some of which may be easier than others in different situations. Typically, some combination of the approaches is used. Some of these approaches include the following:

- Validate Component Calculations: To allow validation, models may be constructed to allow interim calculations and values to be analyzed. For example:

  - Models usually generate various policy-level values such as cash values and death benefits. These values can be reconciled to policy illustrations systems for consistency;

  - Interest rates or stock market returns can be viewed on their own to confirm their reasonableness and the range of results generated; and

  - Cash flows can be output and validated against other, possibly deterministic, models.

- Test Simple Cases: Experience and investment scenarios can be generated that are simple enough to check manually and/or with spreadsheets. For instance, interest rates are assumed to be flat and lapses are assumed to be zero until the $n^{th}$ year, then 100%. Failing this test means that a model is not valid. However, passing this test with simple situations is not complete proof that the model is valid in more complex cases.

- Add Complexity Incrementally: Items of complexity can be added one at a time either separately or in combination. For instance, a model could be run with no decrements, then decrements could be added one at a time. Each such change can be reviewed to see if it produces a justifiable change in model outputs. Unexpected results are not necessarily wrong. They might in fact be proof that the model is doing what it is supposed to by highlighting those unexpected results. However, it is important that the results be confirmed.

- Test Selected Scenarios: A model may be built to allow running deterministic scenarios. Results can be viewed for reasonableness, or compared to other models that can only run deterministic scenarios. While the results of a model integrating many different assumptions can be difficult to validate directly, validating the incremental results of selected sensitivity tests (i.e., changing one assumption by a small defined amount) may be more practical to validate for reasonableness, if not reconciled exactly.

- Check Individual or Extreme Cases: Once a model is running, individual scenarios can be viewed for reasonableness. For instance, how does the scenario that produces the $99^{th}$ percentile compare to the scenario that produces the $95^{th}$ percentile? How does the $99^{th}$ percentile scenario look compared to any specific worst possible scenario? When extreme values are used for various assumptions, does the model still behave rationally and produce meaningful results consistent with the assumption used? By artificially forcing an assumption to an extreme case, sometimes faults in the internal working of the model or the way in which assumptions interact, can be revealed since part of the model results may not be consistent with expectations under that scenario. This is particularly important for dynamic elements (e.g., interest crediting rate, lapses that vary with market returns, reinvestment strategies, etc.) where formulas that work well within a normal operating range may not capture management and policyholder behaviour in extreme situations.

- Compare to Other Models: If an independently produced model is available, or a previous version of the current model is available, then results can be reconciled to those models with similar inputs. Differences are not necessarily a sign of error but it is important that the differences be explainable. For example, the model accurately reflects a change that was intended to be made and removing that change, in fact, reproduces the earlier result. The test includes confirmation that the elements of the model that were not expected to change, did not change.

- Compare to Published Factor Models: Many factor-based capital formulas, such as the current Segregated Fund OSFI factors, were developed using a model approach. The product features and other assumptions on which those models were based are available from published sources. To the extent those features and assumptions can be

reflected in a new model, that model should reasonably reproduce the published factor-based results.

- Examine the Results of Various Levels of Aggregation: Insights can be gained by looking at whether aggregation at various levels is or is not producing diversification benefits. Where a key risk is economic, aggregating product lines that are exposed to the same economic risk would usually not produce diversification benefits. If it does, the model would be investigated and the result explained. Non-economic risks, such as the number of deaths, would show diversification benefits when different lives are involved.

Having validated a model in general, the calibration process consists of adjusting inputs (e.g., lapse rates, investment performance, etc.), and product features to reflect the circumstances at hand. As with the validation exercise, it is important that the change in model outputs be explainable relative to the validation cases, for example investment volatility has changed and therefore the tails of the results have gotten fatter but the central points are about the same.

Any margins added to input parameters are subject to the same considerations as valuation margins in other actuarial work. For example, it would be demonstrated that the direction of margins produces an increase in the result or capital: larger margins are appropriate when data is less reliable.

### 6.3   Data and Change Control

Any risk assessment model could be subjected to the same checks and balances that would normally be applied to any other actuarial work. Data inputs, such as files of policies or assets in force would typically be validated. Input screens would be checked to ensure that the intended assumptions were actually input.

If the model is changed in any way, change management controls ensure that the changes are approved, validated, and reconciled. Selected validation tests could be performed again after any changes are made, or on a periodic basis, to confirm the identical results are achieved as in prior tests.

### 6.4   Validating and Calibrating an Economic Scenario Generator

A stochastic simulation model may include an Economic Scenario Generator (ESG[3]) as a separate module or built into the working model. Testing, validation and calibration of the ESG as a separate component and as part of the entire working model are important.

The object of the ESG is to provide many scenarios of possible future outcomes of all variables in the model economy. For solvency assessment, it is important that such scenarios include sufficiently extreme values or events, which are still plausible. Due to the large numbers of values found in generated scenarios, testing and validation of generated values would normally be conducted by automated inspection and analysis tools and not by visual inspection.

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[3] ESG is used here to include a stochastic scenario generator for any risk including, but not limited to, interest rates, stock market returns, mortality rates, etc.

Before basing any decisions on the parameterized ESG, one would analyze the relevant output of the ESG as fed to the cash flow model. Ideally, a detailed statistical analysis would be performed comparing the economic scenarios with the historical record. Although history provides only a single scenario, it is necessary to carry out extensive testing of the ESG model to ensure that key features of historical data can actually arise in the scenarios generated by the ESG with probabilities that are reasonable when compared to the historical record. The analysis would include examinations of such characteristics as skewness, kurtosis, and quantiles in the tails. One would also carry out testing of characteristics specific to certain economic variables.

For example, for interest rates, some key questions to address might be:

- Does the model produce negative interest rates?

- Can the model allow for very long term cycles of high and low interest rates?

- Is the model mean-reverting, and if so, is the strength of the reversion appropriate?

When equity returns are being generated, the maximum positive and negative annual returns and the number of shifts between low and high volatility regimes (if applicable to the model) could be measured, along with the mean returns and their volatility.

Calibration is particularly important to a model employing stochastic analysis based on economic scenarios, and would take place only once the ESG has been tested and validated. When used as an input to a market value-based valuation tool, the ESG is calibrated to current market prices of securities and derivatives as well as yield curves and related derivatives. When used in a real world framework, asset yields produced by the ESG for this purpose would generally closely match the distributions determined by historical records, particularly in the tails of the distribution which represent outcomes that are adverse to the insurer. In order for the ESG to be used over time, it would usually be updated frequently to reflect the changing observable physical and risk neutral dynamics. This requires a strict ESG management regime to ensure that it is always up to date.

The process of calibration will generally involve iteration of each parameter value in a structured or perhaps random way, with a calculation of the likelihood that the observed historical data were based on each set of tested parameters. The parameter values with the maximum likelihood would probably be used. Caution with this process is advisable since the likelihood functions may have several local maxima. Professional and/or regulatory/supervisory guidance specific for each model type, where available, would be observed with respect to calibration. Finally, the testing, validation and calibration procedures and their results would normally be well documented and auditable.

## 7.    GOVERNANCE

This section outlines governance practices for the use of risk assessment models. In particular, internal models for capital purposes are appropriate only when the risk management processes of an institution are adequate. While risk management practices are the primary defence in protecting an institution against losses, capital is also available in case losses occur.

Formula based requirements for capital tend to be conservative, as they are intended to more generically apply to a wide range of products. Since internal models are normally expected to produce a more customized capital requirement, the overall level of conservatism is very likely to be lower. The consequence is greater reliance being placed on the quality of the risk management and governance processes.

In summary, it is important that capital models be formally approved and controlled at all management levels and be consistent with all risk management and measurement practices.

## 7.1     Roles, Responsibilities, Resources

### 7.1.1   Approvals, Sign-Off, Reviews, Opinions, Reliance

Adoption of a model based methodology, specifically for capital measurement needs and regulatory/supervisory purposes, would be approved by the Board of Directors after the recommendation of Senior Management and both the Appointed Actuary (AA) and the Chief Risk Officer (CRO) of the company. The approval would be made after a good understanding of the application of the model and its implications in relation to the types of risks, level of exposure and risk management framework of the company, as well as of the regulatory/supervisory requirements for ensuring that appropriate capital management strategies are in place. It is advisable that the Board make sure that the relevant organizational structures, policies and adequate resources are in place.

The Chief Executive Officer (CEO) and Senior Management would usually be responsible for ensuring the establishment of a risk management process that operates in accordance with the authorities delegated by the Board. Specifically, they would ensure that a risk management culture exists within the company and the risk management function is comprehensive and global in scope, with underlying risks and models being incorporated into the overall risk management systems of the company.

For capital purposes, the model development may be the responsibility of both the CRO and the AA. It is expected that the AA is responsible for the sign-off of the opinion on the application and results of models. The AA would also typically be responsible for the application of the models to insurance risks and for the aggregation of risks. However, the application of the models to asset risks and other business risks may be shared between the AA and the CRO or Chief Financial Officer (CFO). All in all, there is an exceptional need for the work of the AA and CRO or CFO to be coordinated for the application of models in general.

### 7.1.2   Appropriate Policies

It is advisable that written responsibilities and accountabilities for each position in the risk management system be in place and clearly understood by all incumbents. This would include documented policies, controls and procedures integral to the risk management process or function. Examples include valuation or measurement of capital, stochastic modelling, validation, and sign-off. A routine, such as a formal review process by internal audit, would be in place for ensuring compliance with risk management policies, controls and procedures. The risk measurement system would be well documented, clearly

articulating the basic principles of the risk management system and providing an explanation of the quantitative techniques used to measure risk.

### 7.1.3    Appropriate Expertise and Tools

The capability and experience of Senior Management and other levels, as well as approval bodies to assess and interpret risks would normally be commensurate with the complexity of the identified and measured risks. The insurer's knowledge would also normally be updated and renewed by continuous education and training of the personnel responsible for risk modelling. The models would be sufficiently understood at the various hierarchical levels including the limits of the models and their applicability.

It is important that the personnel responsible for the models have:

- The ability to work in interdisciplinary fashion in the area of risk identification and assessment; and

- The ability to adapt models and risk management systems to the most recent developments.

The model and the implementation as an IT solution are intrinsically linked and can often not be separated. There is no restriction in the type of IT solutions or software required.

### 7.1.4    Reliance on External Resources

External resources may be used for any aspect of the model application; however, they would usually satisfy the governance principles and practices within the company as well as any external professional and regulatory/supervisory requirements.

### 7.2      Risk Management Policy and Practices Characteristics

### 7.2.1    Pervasive Use of the Capital Model

The output from internal capital models would typically be an integral part of the process of planning, monitoring and controlling the company's risk profile. While a full application of the model would be performed at least once a year, it is expected that a complex company would reassess its risks regularly during the year using the model as necessary. Reassessments of risk position, possibly including a full recalculation, would have to be performed when the insurer's risk profile changes substantially, which could happen, in case of:

- Mergers or acquisitions;

- Discontinuation of parts of business;

- Change in business or investment strategy;

- New product-lines;

- Significant increase/decrease of premium income; or

- Significant increase/decrease of the value of assets.

It is important that capital models be actively used for decision-making, including risk/capital management, capital allocation and planning, and may also be an input into performance measurement, and consequently management compensation. The models used for determining required capital would also be closely coordinated with, if not integrated into, the pricing and valuation processes of the company.

It is expected that the same or at least consistent assumptions and models would be used in all areas of the company. There may be applications that require different assumptions or models, or situations where such differences are pragmatic. Nevertheless, it seems reasonable to keep consistency among the assumptions linked to similar phenomena.

### 7.2.2   Level of Risk Exposure

It is the responsibility of each insurer to determine which key risk factors the company is exposed to. Senior Management is responsible for ensuring that aggregate exposure limits exist and are approved by the Board. Senior Management would also ensure that the limit allocation architecture and reporting systems are such that the company is capable of ensuring that aggregate exposure does not exceed established limits. There would be a formalized process by which proposed risk metrics are reviewed and, as appropriate, integrated into the risk management system and process. The allocation of limits and their relationship to the risk management model would be clearly articulated and documented and well understood by each part of the business to which the limits apply.

### 7.3   Review Process

The review process is an important part of ensuring the strength and integrity of a risk assessment model, including the infrastructure of controls that are integral to the model and framework. In general, there are three types of reviews:

- Internal review;
- External review; and
- Regulator/Supervisory review.

The total review process using the three types of reviews above would typically encompass all aspects of risk assessment models. The type and scope of reviews employed can, within limits, be company specific. For example, for a company with a strong internal audit function and robust risk-based compliance program, an external review might be de-emphasized (subject to professional and regulatory/supervisory requirements) whereas if a company undergoes a thorough external review of the model, internal audit requirements could be reduced. In all cases, there would be a certain minimum level of transparency with respect to the engagement of the three different types of review.

Assumptions review covers parameters as well as assumptions. Data review includes data process and data integrity.

A full model review is normally undertaken when a model is implemented. Particular care is required when a model and its implementation are first to be approved by the regulator/supervisor. In the case of substantial changes, additional reviews might become necessary. Substantial model changes would include a change of methodology, a change of

data quality, a recalibration of parameters leading to substantial changes in target capital, etc. Changes in assumptions are normally documented and the effects on the output of the model disclosed. An audit trail would be maintained for model and assumption modifications, including the rationale supporting the changes.

It is advisable that all substantial model changes be subject to review, including but not limited to:

- Changes in representation or compression of business or investment data;

- Selection of assumptions or parameters;

- Implementation or application of assumptions;

- Removal or introduction of approximations;

- Changes in IT implementation; and

- Correction of errors.

The extent of the model review could take into consideration other reviews of some parts of the model. For example, a capital model built from a reserve valuation model would usually require less review since the valuation system controls would have already been reviewed and vetted.

### 7.3.1   Internal Review

It is important that the internal review unit (typically internal audit) be independent from the model builders and have sufficient resources and expertise to fulfil its mandate. This mandate would usually be clearly specified. If the internal review unit checks the model methodology and assumptions then it would typically be staffed with specialists in these areas. Models would be reviewed at least every three years. Models for more volatile risks would be reviewed more frequently (e.g., it may be appropriate to review segregated fund guarantee models every two years) and material changes would be reviewed as part of the implementation process. The review, at a minimum, would document the findings with respect to the following issues:

- The adequacy of the documentation of the risk management system and process with respect to internal models;

- The organization of the risk control unit as it relates to internal models;

- The integration of risk measures produced by internal models into regular risk management;

- The scope of risks captured by the risk measurement model;

- The integrity of the management information system;

- The accuracy and completeness of insurance and market data;

- The verification of the consistency, timeliness and reliability of data sources used to run internal models; and

- The accuracy and appropriateness of the assumptions used.

### 7.3.2   External Review

External review would be used in conjunction with internal review and can be used for all aspects of the model. The mandate would be clearly specified. If the external review encompasses an assessment of the methodology and assumptions, then it is important to ensure that the external consultants are knowledgeable and experienced professionals. An independent external review of data integrity and completeness would be done at least every three years. The frequency of the review would be based on the extent of the review. The work done by the internal auditor would also be reviewed. Exposure (position) data is normally reviewed by an external auditor within the scope of the yearly company audit.

### 7.3.3   Regulatory/Supervisory Review

The regulator/supervisor may require approving models before they are put in place or may rely on Board approval. The supervisor will want to be satisfied that all aspects of the model are appropriate, satisfy regulatory/supervisory requirements, and are reviewed regularly. The regulator/supervisor has different options for the review:

- The regulator/supervisor can undertake part or all of the review;

- The regulator/supervisor can delegate part of the review process to external consultants; or

- The regulator/supervisor can ascertain that internal or external review is adequate.

The choice of the review depends on the specific situation of a company and is at the supervisor's discretion. If the qualitative, quantitative and organisational requirements defined by the supervisor are satisfied, the model will be accepted and approved for use. In no case does that mean that a company can communicate externally that the model is "correct" due to the acceptance by the supervisor.

### 7.4   Documentation

In order that the insurer's Senior Management and control bodies as well as the supervisor can review the model and control the conformity to the required criteria, the model has to be documented accordingly. In particular, model documentation has to exist such that the Board of Directors and Senior Management and the responsible personnel for the model clearly understand the framework of the model, the methodology used, the underlying assumptions as well as the limits of applicability of the model. It is advisable that the following items be documented:

- The principles on which the models are built;

- The general theoretical framework, (for example, what the models are attempting to capture, misestimation, deterioration, volatility, catastrophe, etc.);

- The risks captured and those which are not;

- The lines of business captured and those which are not;

- The key assumptions (economic, policyholder behaviour, management action, risk mitigation, etc.) and how they were set and whether these assumptions reflect the company's actual risk;

- Elaboration on the techniques used by the company to meet the more difficult modelling requirements; and

- The approximations used.

Documentation would typically confirm that model standards have been met and that global standardized assumptions or tests (if any) have been used.

Different levels of documentation will have to be used for the Board of Directors and Senior Management and personnel responsible for the model.

The quality and depth of the documentation has to satisfy the criterion that it would be possible for independent professionals to comprehend the major design decisions and, in principle, to reproduce the model's outputs within reasonable range, if all parameters and exposure data were available. Independent professionals would require experience in building and assessing models for insurance or reinsurance companies and knowledge in the modelling of the relevant risks the company is exposed to.

With respect to internal and external reviews, it is advisable that the area of review, type of reports, and periodicity be documented. Audit trails from internal and external reviews would be retained and the results of testing be adequately documented. For scenarios that exhibit vulnerabilities, a discussion of appropriate management actions is warranted.

Documentation of technology used would typically be complete, in a manner that supports the review and approval process, whether they are "in-house" solutions or whether they are provided externally. It would include both contingency plans (what to do when problems occur with IT) and business recovery plans (how to resume business after problems occur with IT).

Documentation is appropriate for all substantial model changes (as discussed in Section 7.3) from the previous valuation.

The type of documentation could range from a concise memo to full documentation, depending on the importance of the information. Files, working paper, programs, and data sets would normally be available for on-site audit or supervisor reviews.

## 7.5    Compliance

### 7.5.1  Model and Processes

The Chief Risk Officer (CRO) or other designated Officer would typically be responsible for ensuring that the use of the models is in line with the company's risk management strategy and policies, and with regulatory/supervisory requirements. The CRO or other designated Officer would report any non-compliance issues to the Board or the Board's delegated committee.

It is important that the Board be assured that models comply with all requirements such as regulatory/supervisory rules (model standards or standard models) including conditions

required subsequent to approval, internal policies, and professional guidance. This assurance could be the responsibility of the CRO or other designated officer. The mandate would cover the following:

- Risk management models are used in accordance with documented policies;

- The responsibility to ensure proper use of the models rests with a senior officer of the institution;

- Risk management models are reviewed by individuals not engaged in the development or regular use of the models for soundness and appropriateness, and the results of such reviews are documented;

- Suitable controls are in place to ensure that model changes are identified, documented and audited;

- There is a process for ongoing analysis of changes in modelled results from one period to the next;

- Models are in compliance with standardized elements of advanced models;

- Models are consistent with the user manual for the modelling; and

- Models reflect the institution's actual operating practices and product features (for example, reflect the hedging practices of the company).

### 7.5.2 Results

The internal models are intended to provide appropriate data to facilitate the management of the insurer's risk positions within the aggregate risk exposure limits approved by the Board of Directors. Usually there would be a formalized process for reviewing risk metrics and all modifications to the internal models. The allocation of limits and their relationship to the internal model would be clearly understood and documented by each business unit to which the limits apply. The result of sensitivity testing would usually be reviewed regularly by both Senior Management and the Board, and be considered when establishing policies and limits. For scenarios that exhibit vulnerabilities, a discussion of appropriate management actions is warranted. Such strategies would focus on risk reduction and capital preservation. If possible, the strategies would also be modelled to quantify their effects.

Typically, results from internal models would be compared to financial targets. Any material divergence would be investigated and explained.

## 8. REPORTING

### 8.1 Objectives of Reporting

It is important that the results of a risk assessment model be reported in a manner and with a level of detail appropriate for the purpose and intent of the report in concert with the stakeholder in question.

For some stakeholders, it may be sufficient and appropriate to report only a final few numbers and a statement confirming that the report was prepared in accordance with relevant professional and regulatory/supervisory standards. For other stakeholders, it may be appropriate to report more detail about methods, validation and calibration of the model. The purpose of the report is not only to convey the result, but also to provide sufficient level of documentation and details to persuade the stakeholder that the result is appropriate.

Depending on the stakeholder, it may also be appropriate to explain the context in which model results should be viewed and the degree of rigor behind the model. This would be based on the purpose of the risk assessment model, which could include pricing, embedded value, enterprise risk management, stress testing, economic capital, regulatory capital, DCAT, valuation of liabilities, or any other relevant purpose.

Transparency and comparability of internal models across the industry is best facilitated by the public disclosure of methodology. Appropriate reporting, in particular in the context of public disclosure, would also promote to some extent better models and model standards in the industry.

## 8.2    Type of Reporting and Frequency

Formal official results reporting is generally required annually, but some formal quarterly reports might also be required on a simplified basis. More frequent internal informal reports on different aspects and tests, during the implementation process by example, may be prepared. Reporting is necessary to communicate the model final results, but may be also used in the building and operation of internal models to document (or verify) that the models:

- Are constructed using sound economic principles;
- Reflect the company's operating practices; and
- Use accurate and useful source data.

Internal reports exchanged between the business units and the corporate actuarial sector of the insurer will more likely result in models that properly reflect the risks and risk management of the insurer.

The general result report would probably follow an annual cycle and meet prescribed formats for regulators/supervisors in particular, but perhaps including more information for other audiences. This could include both required numbers filings and stress test analysis.

## 8.3    Regular Result Reporting to Stakeholders

Reporting may be customized for the needs of each stakeholder. However, there are common elements that would normally be included in reporting provided to all stakeholders. For example, reporting on capital would include, regardless of stakeholder, the following:

- Available versus required capital;
- A split of required capital by risk type;

- Identification of diversification benefits;

- Sensitivity of results, including confidence intervals; and

- Comparison to prior periods.

### 8.3.1   Internal Management

**Senior Management and Board**

Senior Management and Board Members will generally be concerned that appropriate checks, controls and validations are in place. They would not normally be interested in the actual workings of the model except to the extent it improves their understanding of the strengths and limitations of the model and its results.

The focus of the report to these stakeholders would be to promote a clear understanding of the nature and magnitude of the company's risks, and provide assurance that they are being managed and priced for appropriately. The report would usually discuss how the models are used in risk management.

The major strengths and limitations of the models and their application would also be described generally with discussion of any planned or recommended corrective actions by management. The report would also state that the models used conform to the company's policies and procedures, industry practices, professional requirements, and regulatory requirements.

**Business Units and Risk Managers**

These stakeholders will need a description of the models, the assumptions used, the source of data, and the results for each line of business. Changes since the previous report would be highlighted.

Model results would be analysed by lines of business, and by major risks, including comparisons both to results of prior years and with other tests (DCAT, simplified approaches, pricing, etc.) to help the understanding and management of the risks and capital. A section with recommendations would be useful to improve the use of the models and thus benefit risk management practices.

### 8.3.2   Examiners

Examiners include regulators/supervisors, internal & external auditors, peer reviewers, and rating agencies. Examiners are generally privy to any and all details about a model they consider to be relevant to their assessment of whether the model is reliable and appropriate. Any concerns about confidential or proprietary information would be addressed in the engagement terms agreed with the examiner.

The focus of the report to these stakeholders will be the degree of rigor of the application of the models, and any changes or updates to the models, describing the validations performed and the controls in place. If the models are not subject to a formal pre-approval, all the information that is to be submitted with the approval report (see Section 8.6) would also be included in the examiners' reports. If the models are subject to a formal pre-approval, the report to examiners could refer to the approval report for specific details. The

report would also describe the current numerical results with analysis of the results based on comparisons with other approaches and other tests performed.

Any report written for the purpose of obtaining regulatory/supervisory approval for the use of the internal models for capital requirement calculation purposes, would generally need to be detail oriented. The report could follow each section and element of this paper as well as any other regulatory/supervisory requirements.

### 8.3.3   Public

Public stakeholders include shareholders and policyholders, market analyst and investors. This group generally will receive only the final numbers and a statement confirming that the result was obtained by applying relevant professional standards. Of note, generally this group is not privy to commercially sensitive or confidential information about rates, reinsurance structures, or proprietary processing techniques. However, the reports to the public stakeholders could be a good opportunity to educate them about different aspects of models and their applications.

The focus of reporting to public stakeholders is on the comparability of the models within the industry and their consistency with prior periods so these stakeholders can make informed decisions. The report would also state that the models used are in compliance with the company's policies, industry practices and regulatory requirements. Any significant changes in the results would be well explained.

Any information about scenarios, assumptions and techniques that are not confidential would be useful to market analysts for their review. For example, the report could include a risk analysis summary, as often provided to market analysts.

### 8.4     Other Risk Analysis Reports

A risk assessment model could conceivably be used for regular internal reporting on the company's current risk profile and the adequacy of capital, but also on an ad-hoc basis to address the potential impact of:

- A proposed transaction (acquisition, divestiture, new venture);

- A change in policy (pricing approach or assumptions);

- Risk mitigation strategies (reinsurance transaction, or hedging activity); or

- Some significant environmental event (catastrophe, economic change, tax law).

This report would focus on the particular and specific purpose of the analysis and include the information related to that. Any special adjustment to existing general or specific models used for this specific purpose would be described with any test to measure the impact of them. There could exist prescribed guidelines for this specific report or particular information that need to be considered before doing the report.

## 8.5     Model Development, Change, and Implementation Reporting

Regular project status reports, both for line management/risk managers and senior management, prior to the actual implementation of an internal risk assessment model, will facilitate the model's acceptance and adoption.

Model development, change, or implementation could be done by a corporate office, a business unit, or a third party. In the model development process, there is a need to inform and communicate to all participants to facilitate implementation in an effective and efficient manner.

The purpose of this type of report would be to inform participants on model development progress and to seek their feedback. This could be a specific report on a few issues or a general update on current status and planned next steps. Reporting of this type would be concise and frequent to keep interested people up to date and make sure there is a good coordination at the company level. This type of report would normally include details about the data, assumptions and parameters used in the models, as well as model results and applications. The format could be flexible.

It is appropriate that these types of reports be kept simple and understandable to a wide audience.

## 8.6     Approval Reporting

This report would justify the planned use of an internal model for Regulatory Capital, or justify significant changes to an Approved Internal Model. This type of report would likely follow prescribed content guidelines.

The application for approval would document, by section, how the institution is complying with different criteria, with specific emphasis on the management of risk exposures and the use of internal models in the measurement of such risks. The application would include, as appropriate, information on the frequency of audits and model reviews, documentation and sample reporting.

The elements listed below are intended to highlight areas that will be of greatest importance when preparing an application to use internal models for calculating required capital.

Reporting Elements:

1.     Role of the Board of Directors and Senior Management;

2.     Risk management infrastructure;

3.     Corporate and operational limits;

4.     Model integration;

5.     Stress testing, validation and calibration;

6.     Documented policies;

7.     Internal audit;

8.      Quantitative model standards;

9.      Information technology; and

10.     Capital requirements.

The regulator/supervisor may specify particular requirements for any application. This type of reporting would be very formal and official and will put responsibility on the author, the company and the Board.

**APPENDIX A**

**GLOSSARY**

| Term | Definition |
|---|---|
| **Advanced Model** | An approach that calculates the impact of risks by directly determining the volatility of the result. This model typically includes forecasts of cash flows or benefit payments.<br><br>By contrast, see Standardized Approach. |
| **Back-Testing** | From Solvency II glossary: The process of comparing actual experience with statistical predictions. For example, it is used as a formal statistical framework to verify if actual losses are in line with projected losses in VaR models. |
| **Closed Form Model** | A model that determines the impact of risks by formulas that are based on probability curves. A simple example would be to assume claims costs followed a Normal Distribution with a determined mean and standard deviation, and then determine the amount to cover risks to be a certain percentile from that curve.<br><br>By contrast, see Monte Carlo Simulation. |
| **Deterministic Model** | A model that reflects deterministic scenarios (i.e., scenarios individually designed or selected based on past experience or judgement). These scenarios may be based on best estimate assumptions with or without additional margins, or more extreme adverse stress tests.<br><br>By contrast, see Probabilistic Model. |
| **Extreme Value Model** | From Solvency II glossary: Mathematical and probabilistic models that provide methods to assign probabilities to the tails of the distribution curve of a particular kind of risk factor.<br><br>Extreme value theory covers the following two main types of models:<br><br>• The distribution of the maximum value of a sequence of random observations, as a reference distribution for more general cases; and<br><br>• The distribution of the excesses over a high threshold. |
| **Fair value** | From Solvency II glossary: The amount for which an asset could be exchanged or a liability settled, between knowledgeable, willing parties in an arm's length transaction.<br><br>Related terms: Arm's length transaction, Market value, Market-consistent valuation<br><br>This is a similar concept to market value, but the fair value may be a mark-to-model price if no actual market price for asset/liability exists.<br><br>Note that that there exist different concepts on what a market price is, especially considering prices observed in markets which are not deep, active or liquid, or where different markets exist. |

| Term | Definition |
|---|---|
| **Internal Model** | A model that differs from the Standardized Approach to reflect aspects that are specific to the company situation. Usually, this is an Advanced Model, meaning there has been some work which directly assesses the cash flows or benefit payments.<br><br>Also, from Solvency II glossary: Risk management system for the analysis by an insurer to analyse the overall risk situation of an insurance undertaking, to quantify risks and/or to determine the capital requirement on the basis of the company specific risk profile. |
| **Market-Consistent Valuation** | From Solvency II glossary: The practise of valuing assets and liabilities on market values where observable with a given quality (mark-to-market), and where not, on market-consistent valuation techniques (mark-to-model).<br><br>Related terms: Market Value, Mark-to-market Valuation, Mark-to-model Valuation. |
| **Model Risk** | From Solvency II glossary: The risk that a model is not giving correct output due to a misspecification or a misuse of the model.<br><br>Related term: Parameter Uncertainty Risk<br><br>Possible sources of model risk include, but are not restricted to:<br><br>• The use of an inappropriate model;<br><br>• The inappropriate use and implementation of models;<br><br>• The selection of inappropriate models;<br><br>• Errors within the models or the estimated parameters;<br><br>• Insufficient or incorrect data; and<br><br>• Correct model choice given the information available, but a deviation of reality from the model at a later stage. |
| **Monte Carlo Simulation** | An approach that determines the impact of risks by generating individual scenarios on a stochastic basis, then looking at the range of results. By contrast, see Closed Form Model. |
| **Operational Risk** | From Solvency II glossary: Risk of a change in value caused by the fact that actual losses, incurred for inadequate or failed internal processes, people and systems or from external events (including legal risk), differ from the expected losses. Operational risks relate to operational loss events caused by internal or external reasons, excluding all 'financial' risks that a company has taken on in the expectation of a financial return.<br><br>Related terms: Business Risk, Compliance Risk, Expense Risk, Legal Risk, Management Risk, Model Risk, Reputation Risk, Strategic Risk. |

| Term | Definition |
|---|---|
| **Parameter Uncertainty Risk** | From Solvency II glossary: A change of value caused by the uncertainty in the estimation of the parameter values applied in a model.<br><br>Related terms: Model Risk, Operational Risk<br><br>Possible sources of Parameter Uncertainty Risk include, but are not restricted to:<br><br>• The number of observations on which best estimates are based is limited because the observation period is too short;<br><br>• The volatility of the observations makes estimation less certain;<br><br>• The period over which the observations were made may not include certain calamitous events that, in fact, should be reflected in the parameters of the distribution;<br><br>• The observed population differs from the one being underwritten;<br><br>• The observations contain contaminated data; and<br><br>• There is an uncertainty for long-term insurance in projection of the parameters (diagnosis versus forecasting). |
| **Probabilistic Model** | A model that directly reflects the volatility of a risk in its calculations – this could be accomplished by either a Closed Form Model or a Monte Carlo Model.<br><br>By contrast, see Deterministic Model. |
| **Required Economic Capital** | From Solvency II glossary: The total of assets measured at market-consistent value internally required by an insurer above the market-consistent value of obligations in order to reduce the risk of not meeting the obligations to a defined risk measure (e.g., VaR, TVaR, EPD) and within a defined time period (e.g., one year).<br><br>Related term: Available economic capital. |
| **Scenario Analysis** | From Solvency II glossary: Simulation of an alternative set of parameters within a model in order to establish the impact on the outcome.<br><br>The following types of scenarios analysis can be distinguished:<br><br>• Historical scenarios;<br><br>• Hypothetical scenarios; and<br><br>• One-off events (e.g., simulation of strategic decisions).<br><br>Synonym: Scenario Testing<br><br>Related terms: Sensitivity Test, Stress Test. |
| **Sensitivity Test** | From Solvency II glossary: A simulation designed to test the robustness of a relationship or projection, given various changes in the underlying assumptions.<br><br>Related terms: Scenario Analysis, Stress Test<br><br>A sensitivity test estimates the impact of one or more small moves in a particular risk factor, or a small number of closely linked risk factors. |

| Term | Definition |
|------|------------|
| **Standardized Approach** | An approach that makes use of published factors to determine capital levels. These factors might be applied to simple measures such as fund value or volumes of insurance. They might be applied to more advanced metrics such as a standard deviation or a Macaulay duration. By contrast, see Advanced Model. The Standardized Approach is typically developed by working with an Advanced Model on some type of standardized products, and translating those results into a factor-based formula. Standardized Approach includes situations where a complex calculation, such as a policy liability, is recalculated using a defined change or increase in margin of one of the inputs. |
| **Stochastic Model** | A model that directly reflects risks using stochastic scenarios (i.e., multiple scenarios generated by a random process reflecting a selected underlying statistical distribution), and a statistical analysis of the model results over all scenarios. |
| **Tail-Value-at-Risk (TVaR, TailVaR, CTE)** | From Solvency II glossary: A coherent risk measure. For a given confidence level 1- $\alpha$ it measures the average losses over the defined threshold (typically set as the VaR for a given quantile), i.e., the conditioned mean value, given that the loss exceeds the 1- $\alpha$ percentile. <br><br>Abbreviations: TVaR, TailVaR <br><br>Synonym: Expected shortfall <br><br>Related term: Value-at-Risk |
| **Total Balance Sheet (TBS) Approach** | From Solvency II glossary: Principle which states that the determination of an insurer's capital that is available and needed for solvency purposes should be based upon all assets and liabilities, as measured in the regulatory balance sheet of the insurer and the way they interact. <br><br>A Canadian perspective on TBS approach might not require the use of the regulatory balance sheet values. |
| **Total (or Target) Asset Requirement (TAR)** | A capital requirement using the TBS approach, in which the requirements are based on the level of assets required to cover the global margins and risks traditionally covered separately in the liabilities and required capital. |
| **Value-at-Risk (VaR)** | From Solvency II glossary: Value-at-risk is a quantile of a distribution and used as a (non-coherent) risk measure. <br><br>Abbreviation: VaR <br><br>Related term: Tail-Value-at-Risk <br><br>For example, if the twelve month value-at-risk with a 95% confidence level ($\alpha$= 0,05) represents the amount of one million Euro, this means that an insurer would only expect to lose more than one million Euro once in 20 years (1/ $\alpha$). |

## APPENDIX B

## CANADIAN SOLVENCY FRAMEWORK REFERENCES

Office of the Superintendent of Financial Institutions (OSFI) website:

http://www.osfi-bsif.gc.ca/app/DocRepository/1/eng/guidelines/capital/guidelines/MCCSR_cmt_e.pdf

Autorité des marchés financiers (AMF) website:
http://www.lautorite.qc.ca/projets-speciaux/comite-consultation-solvabilite.en.html

Canadian Institute of Actuaries (CIA) website:
http://www.actuaries.ca/members/organization/PC/RISK/PC_RISK-SF_e.cfm?CODE=RISK-SF

- Draft: Economic Capital: Calculation of Terminal Provision

- Preliminary Priorities and Timeline for Solvency Framework Development

- Draft: Risk Based Economic Capital - Time horizon

- Selection of Appropriate Risk Measures for Economic Capital

Solvency II Glossary : Comité Européen des Assurances – Groupe Consultatif Actuariel Européen website.

http://www.abi.org.uk/Display/File/Child/659/CEA_Solvency_II_Glossary.pdf