



Note on the use of Internal Models for Risk and Capital Management Purposes by Insurers

November 2010



**Association Actuarielle Internationale
International Actuarial Association**

150 Metcalfe Street, Suite 800

Ottawa, Ontario

Canada K2P 1P1

www.actuaries.org

Tel: 1-613-236-0886 Fax: 1-613-236-1386

Email: secretariat@actuaries.org

Note on the Use of Internal Models for Risk and Capital Management Purposes by Insurers

This document has been produced by the Solvency Subcommittee of the IAA Insurance Regulation Committee and has been approved for distribution by the Insurance Regulation Committee.

Table of Contents

1. Introduction	1
1.1 The Purpose of this Note.....	1
1.2 Types of Model	2
1.3 Use of Models	2
1.4 Common framework within an insurer	4
1.5 Support for IAIS standards and guidance.....	5
2. Model Fundamentals.....	6
2.1 The Model - Introduction	6
2.2 Modeling Process	7
2.3 Proportionality & Simplification for Low Risk Products/ Companies.....	9
2.4 Risk Assessment Framework.....	11
2.4.1 Time Horizon.....	11
2.4.2 Risk Measure	12
2.4.3 Confidence Level.....	12
2.4.4 Terminal Provision.....	13
2.5 Real World versus Risk Neutral Probabilities and use of Market Consistent Valuation Techniques.....	14
2.6 Types of Model	17
2.7 Managing Models.....	18
3. Design Considerations.....	20
3.1 Results.....	20
3.2 Order of Calculation	21
3.3 Control over Assumptions	21
3.4 Reproducibility	22
3.5 Flexibility	22
4. Construction of Model	23
4.1 Granularity of Time Periods.....	23
4.2 Population of the Model	24
4.2.1 Product Descriptions	24
4.2.2 Product In-Force Data	25
4.3 Assets.....	28
4.4 Insurance Experience Assumptions	28
4.5 Insurance Assumptions for Projections	29
4.6 Calibration.....	31
4.6.1 General	31
4.6.2 Calibration – Stochastic Projections for External Environment.....	31
4.7 Assumptions Concerning the Insurer’s Future Actions	33
4.8 On the Use of Random Numbers	34
4.9 The Number of Simulations in a Stochastic Model	35
4.10 Extreme Values.....	36

5. Governance	36
5.1 Use Test	37
5.2 Sufficiency Testing	39
5.2.1 Conceptual Sufficiency	39
5.2.2 Implementation Sufficiency	40
5.2.3 Assumption Sufficiency.....	41
5.2.4 Business-data Validation	43
5.2.5 Calibration Test	44
5.2.6 Compliance with Insurer’s Strategy and Policies.....	45
5.3 Change Test	46
5.4 Controls	47
5.5 Accountability	48
5.6 Expertise and Tools	48
5.7 Documentation.....	49
5.8 Review.....	51
5.8.1 Internal Review.....	52
5.8.2 External Review.....	53
5.8.3 Audit	53
5.8.4 Regulatory / Supervisory Assessment	54
6. Communication	54

1. Introduction

1.1 The Purpose of this Note

This note provides educational material for those responsible for constructing, using and approving the use of models to assess and manage risk and capital within insurance enterprises (insurers). This material is also useful to those who rely upon the information derived from models, as an aid to understanding the derivation, uses and limitations of this information.

Internal models are primarily relied upon by boards of directors and senior management for strategic planning, regular monitoring of risk and managing an insurer's corporate capital. Internal models are also coming into use for determining regulatory required capital, usually subject to supervisory approval based upon satisfaction of specific conditions required by the supervisor. The International Association of Insurance Supervisors (IAIS) has a standard "On the Use of Internal Models for Regulatory Capital Purposes." A guidance paper on the same topic provides IAIS members with additional guidance.¹

This note first discusses the necessary grounding of internal models in the corporate risk management philosophy and governance of the organization, and then continues with a description of the design, construction, review and use of such models. This note is meant to be flexible enough to allow for future developments in this rapidly evolving field.

The use of models often brings the challenge of dealing with their being "black boxes." Lack of transparency can result in either an unjustified reliance on output from the model or complete scepticism of the model and rejection of valid results. Thus, this note will identify elements needed to discipline the design, construction, validation and use of internal models as well as the communication of results. The application of these elements will help to indicate the extent to which increased reliance can be placed on the model's results, its limits and its uses.

This note does not and should not be taken to set standards for practitioners. It describes some emerging practice, methodologies and concepts for the use of internal models. In practice models will likely reflect a blend of local professional and regulatory standards and other considerations including the nuances of required precision and the practical issues involved in all modeling approaches. As practice develops in the future, this note may become out-of-date and the reader should be aware of this.

Although the focus of this note is on models used for risk measurement and capital management, many of the issues discussed here apply also to models used by insurers for other business purposes. This note should therefore be useful in a wider context as well.

¹ The IAIS is also looking at Group issues. Therefore the IAA will start looking at several Group Issues related to internal models.

1.2 Types of Model

Fundamentally, an internal model is a mathematical representation of the insurer's business operations. It is often based on past empirical data and assumptions regarding the insurer's future experience with respect to a variety of factors including risk drivers, as well as management operating policies. This model will usually project cash flows and produce standard *pro forma* financial statements which can then be used to assess the possible effects of various risk elements on the overall risk position of the insurer. By varying the possible levels of future experience with respect to specific risk drivers, the model can also be used to quantify risks and determine the economic capital required to meet those risks. A definition of an internal model framed by the IAIS and contained in the CEA – Groupe Consultatif Glossary:

An internal model is a risk management system of an insurer for the analysis of the overall risk situation of the insurance undertaking, to quantify risks and/or to determine the capital requirement on the basis of the company specific risk profile.²

Internal models can take many forms and vary from simple, even standardized, calculations to extremely complex models. They may make use of sub-models that are devoted to the quantification of specific risks or to the quantification of risks in specific lines of business. Internal models can utilize component parts built either by the insurer itself or built by an outside vendor and selected by the insurer.

1.3 Use of Models

The use of internal models for insurer risk assessment and capital management is increasing due to the:

- emergence of comprehensive insurer risk management practices as a disciplined approach to improve the understanding and management of one's risk;
- widespread use of economic capital for risk and capital management;
- development of increasingly sophisticated risk-based insurance regulatory capital requirements;
- availability of inexpensive and fast computers, which makes modeling practical; and
- the increased availability of data.

Internal models are also being used for other purposes within insurers, including:

- valuation of insurance liabilities;
- financial condition analysis;
- stress and scenario testing;

² CEA-Groupe Consultatif Solvency II Glossary, Brussels, March 2007, p.35

- analysis of asset/liability mismatches and the refinement of investment policy;
- analysis of market risk in certain investment products with guaranteed values (such as segregated funds, participating products with maturity guarantees, and variable annuities);
- pricing of insurance products;
- evaluation of reinsurance programs;
- evaluation of various management and bonus strategies; and
- other uses.

In a stochastic approach, models may be run many times using different assumptions for a particular set of risk factors. These assumptions are often generated by a scenario generator, a sub-model, according to some probability structure (measure). In this case, the results of the multiple runs will form a distribution from which certain probability statements can be drawn.

It may also be useful and advisable to employ the same model in stress testing or scenario testing:

- Stress testing involves multiple runs of a model where the assumed experience for a particular risk factor is varied in a known deterministic fashion. In this way, one can understand the sensitivity of the insurer to increasingly unfavourable experience of a particular type and investigate the effect on the insurer of extreme or “tail” events, even if the probability of that event cannot be determined precisely.³
- Scenario testing involves single runs of a model where each run is based upon a complex set of interrelated assumptions that describe a comprehensive and often troublesome scenario. Scenario testing enables a risk manager to test the insurer’s resiliency under a situation that involves complex and possibly severe interactions that would not be tested using the usual correlation assumptions of stochastic testing. Scenario testing can also be a means of investigating the effect on the insurer of extreme or “tail” events.

Whenever one makes use of the results of a model, it is important to consider the limitations of models. Some of these limitations are described below but there may be many others that deserve consideration.

- Models are only approximations and cannot usually be expected to perfectly mirror all aspects of an insurer’s operations. Models can only be considered as a tool within the risk assessment framework of the enterprise;

³ At the date of the issuance of this note, the IAA Solvency Subcommittee of the Insurance Regulation Committee is preparing a companion note on stress and scenario testing.

- The results of models depend heavily on the initial data and the projection assumptions. If these are not appropriate to the situation, the results of the modeling exercise may be misleading;
- In stochastic modeling, projection assumptions are typically created by means of scenario generators which follow a particular probability structure or distribution. If the generator is faulty or its underlying probability structure is inappropriate to the situation, then the probability structure inherent in the modeling results may be misleading;
- In stochastic modeling, the interaction of various risk factors is often described by means of a statistical device such as correlation or a copula. While these devices may capture the general nature of such interaction, they cannot adequately describe the specific and sometimes compounding and severe interaction that can occur in particular situations. There is a need to model specific “extreme” cases through deterministic scenario testing.
- Use of only specific calibration points for yield curves and scenarios may limit the conclusions that can be drawn.

A detailed discussion of stochastic modeling can be found in the IAA publication, “Stochastic Modeling – Theory and reality from an actuarial perspective” (June 2010).

1.4 Common framework within an insurer

It is desirable that an insurer employs (to the greatest extent possible) a common model framework for all components of its internal model. This ensures that risk and capital management decisions throughout the insurer’s operations are aligned through the sharing of a common approach to the assessment of risk (e.g., through the use of a common risk metric). In this way, conflicting advice from models used in different areas of the insurer is minimized. A common framework enables the performance (both actual and expected) of various risks, products or businesses to be compared and appropriate risk management action taken.

The design, operation, maintenance and validation of internal models can be costly and require highly trained and experienced people whose costs are effectively deployed over several applications of a common internal model framework. Where risks or groups of risk are independent from other risks and require specialized expertise, these different risks will require different, specifically dedicated, resources. For example, modeling catastrophe risk may require expertise in weather phenomena and the related damage potential for a building structure. Modeling investment risk may require expertise in different investment categories, the options embedded in such investments and their impact on the liabilities they support.

To the extent that the risks across the insurer are relatively homogeneous, related to the same or similar risk variables and structures, there are significant benefits to the sharing of a common model framework and resources. Specific uses or applications will require tailoring of the model to suit those uses and applications. The structure of a particular sub-model may vary with the nature of the risk being modeled. For example, the structure of a model

dealing with spinal cord injury morbidity will probably be very different from that of one dealing with financial market risk from investment guarantees. Similarly, the specialized modeling for hurricane risk would be of minimal (if any) benefit in modeling equity risk. However, it is important for special sub-models to accept the same inputs as other model components when this is appropriate. One would also use a common risk metric, even if the frameworks are different, so as to allow the comparison and aggregation of risks across the insurer as a whole.

Since some risks are not (easily) quantifiable, not all risks can be included in a corporate measuring framework. Operational risk, reputation risk and the ability of management to execute its intended strategies are likely to be better mitigated through thoughtful planning based on stress testing results, strong cultural values and risk management oversight. Much thought in recent years has been given to the blend of corporate practices, regulatory oversight and required disclosures that are needed in addition to holding capital. Nonetheless, in determining an insurer's capital requirements, it would be prudent to add to the value determined by means of an internal model, an additional amount based upon judgment (or agreed upon methodology), to cover those risks which though non-quantifiable, can lead to significant financial costs for the insurer.

1.5 Support for IAIS standards and guidance

This Note is supportive of the Standards and Guidance materials developed by the IAIS for supervisors. It draws on industry experience, supervisors' supervisory practices, models and frameworks published by others and emphasizes practical considerations. It also seeks to help insurers assess internal model practices by reference to the characteristics associated with different stages of internal model development.

The IAIS Standard describes the requirements for:

- Initial validation and supervisory approval
 - Statistical quality test
 - Calibration test
 - Use test and governance
 - Documentation
- Ongoing validation and supervisory approval
- Supervisory reporting and public disclosure.

This Note includes each IAIS requirement as shown in the following table:

IAIS Requirement	IAA Note Concept
Use Test	Use Test – Section 5.1
Statistical Quality Test	Sufficiency Testing – Section 5.2 includes the concepts of, <ul style="list-style-type: none"> - Conceptual sufficiency - Implementation sufficiency - Assumption sufficiency - Business data validation - Calibration test - Change test - Controls - Accountability - Expertise & tools - Documentation - Review
Calibration Test	Calibration Test – Section 5.2.5 within the broader topic of Sufficiency Testing. Calibration described in Section 4.8.
Documentation	Documentation – Section 5.7
Ongoing fit for purpose	Same concept included throughout Note
Change control	Change Test – Section 5.3
Disclosure	Communication – Section 6

2. Model Fundamentals

2.1 The Model - Introduction

Fundamentally, an internal model is used to estimate a range of possible future financial states an insurer may find itself in as a result of the variety of risks to which it is exposed and the methods used by the insurer to manage those risks. While typically this projection only considers the runoff of existing contracts, some models include the impact of possible new business scenarios as well. The model output estimates the impact of the input assumptions as a resulting possible financial position (or distribution of positions) of the corporation. This output may be in the form of standard accounting reports (balance sheet, income statement, statement of cash flows, etc.) or in terms of capital ratios or other relevant financial measures. The risk manager will then concentrate on those states in which the insurer's financial condition is unfavourably impacted and seek to understand and possibly control or mitigate those factors which give rise to this unfavourable experience. For this purpose, it is not sufficient to determine only a single “best estimate” financial position; the internal model has to be able to quantify the financial position that would result from a wide range of possible future events.

An insurer's financial position is affected by many variables, such as:

- financial market performance (e.g., changes in interest rates, equity values, credit spreads, foreign exchange rates, etc.);
- insurance risk outcomes (e.g., claim frequencies, claim severities, change in policy interpretation, deterioration in pricing/underwriting, policyholder behaviour, trend uncertainty, level uncertainty, etc.);
- operational events (e.g., impact on financial states due to people or systems, changes in the legal, regulatory and taxation environments, changes to the insurer's reputation and consequent effects on its ability to continue with its business plan; other influencing factors that might be of relevance to the financial position include fraud within the insurer and the insurer's liquidity position; and
- management choices and strategies relating to investment options, marketing and new business, dividend and non-guaranteed element provisions in policies, and capital structure.

It should be noted that the financial effects of some of the variables indicated above, particularly (but not exclusively) those listed in the third point above ("operational events ..."), may be difficult to quantify except through stress and scenario testing. The range of possible future events to be considered can be specified through the identification of particular scenarios (e.g., a pandemic, a large earthquake, or a financial market crash, etc.) and combinations of these. Scenarios are an essential tool of risk management and allow for an intuitive assessment of the risk exposure of the insurer.

In addition, there can be significant dependencies between financial market performance, insurance risk, operational events and management options. The nature of these dependencies may change significantly in times of stress. Again, scenario testing using appropriately defined and implemented internal models should help the user to understand the implications of those dependencies in normal and in stressed environments.

2.2 Modeling Process

An effective modeling process is integral to the disciplined acceptance and management of risk. It is useful in providing for corporate accountability and enhances the insurer's ability to manage risk exposures.

Models should be as complex and sophisticated as needed to capture the nature of the risk to be modeled, but no more so.

The following processes are needed for effective modeling:

1. Identify the risks to be modeled

These will include not only all insurance risks assumed by the company but associated risks related to policyholder behaviour, asset related risks including credit

and market risks, environmental risks, as well as quantifiable risks inherent in the operation of an insurer. A model that ignores risks that are significant for an insurer can lead to misleading results and the drawing of improper and incorrect conclusions.

2. Set assumptions for insurance risk variables

Insurance risk parameters may be determined by random sampling from distributions. These distributions may themselves be the result of other associated models. An example is aggregate claims for a particular type of business: the distribution of such claims may be based upon frequency and severity distributions which are derived from the insurer's past experience (if this is credible), from industry-wide experience or from a credibility-weighted combination⁴.

In addition, some other approaches common for evaluating loss reserve risk for property/casualty commercial line writers are aggregate loss development-based approaches using either the bootstrapping or the Mack methods.

3. Generate assumptions for financial risk variables

Parameter values, (such as for interest rates or equity indices) may be obtained from scenario generators. These generators are usually referred to as stochastic generators although sometimes as Monte Carlo processes. They employ random numbers together with appropriate probability measures for the generation of future scenarios.

4. Set, if applicable, assumptions for policyholder behaviour risk

5. Set, as appropriate, assumptions on company management actions

such as asset/liability management (ALM), risk mitigation, pricing and re-pricing actions, expense management, etc.

6. Identify dependency relationships

This includes generally expected correlations in normal environments as well as dependencies in tail scenarios. It is important to understand the dependence structure among all the assumptions and other variables in the model since this will determine the structure of the model and the optimal order in which calculations are carried out. This may require projection forward of all variables together for a short period (maybe as short as a month) rather than projecting each of them forward separately for the full term of the projection.

7. Project and discount future cash flows

Frequently the model must determine the present value (as at a current date or future dates) of a stream of future cash flows. This is determined through some valuation process which involves rates of return to be used for discounting. The present value amounts result in financial quantities such as asset values and the value of projected claim and insurance obligations. A model should clearly document the algorithms or functions to compute these values based upon variables available within the model. There may be a variety of valuation methods in use within the

⁴ Even if a company is using wider market experience, there will be a need to review that the market assumptions are consistent with the company's experience and/or target market.

same insurer. For example, it may be useful to determine present values based upon regulatory, public or internal reporting bases. In these circumstances, the model will need to calculate values for each of the alternative sets of financial reporting rules. Many of these calculations make use of the same set of dependent variables calculated in the model, the raw elements that reflect the insurer's basic projected experience: volume of claims incurred, premiums received, expenses, taxes, investment income, business in-force, etc. These items constitute the transaction and event flows within the business.

8. Verify modeled cash flows of company against actual cash flows

The resulting projected cash flows need to reflect the underlying future experience. Securitized financial products require care to ensure that the true underlying risks are captured in the projection and are not temporarily obscured thus providing the insurer with only partial protection against the relevant risks. In addition, there often are corresponding "incurred but not paid or not received" items to be reflected in the future cash flows.

9. Assess estimates for model error.

Once these valuation variables have been calculated, a model will often go through a process to determine and project an insurer's modeled *pro forma* financial statements. It is only then that many other variables that the user is interested in, such as free surplus or capital ratios can be obtained and studied.

2.3 Proportionality & Simplification for Low Risk Products/ Companies

The preceding section is not meant to imply that all internal models need to be complex. The design of an internal model will likely be based upon the concept of proportionality: the structure of the model should reflect the nature, size and complexity of an insurer's risks.

At the highest level, the nature of risks might be described as being life, non-life, health etc risks. Alternatively the nature of risks might be described by the major product types or product lines offered by the insurer. The nature of risks might also be described by the major risk types such as credit, market, insurance, operational, etc. The nature of the insurer's risks depends not only on the business it has insured but also to the manner in which it operates. For example, if the insurer's investment policy leads to a close matching of its liabilities with conservative investments, it may not have significant credit or market risk.

The size of an insurer's risks refers to the size of their potential effect on the insurer. Any risks that have only a demonstrated marginal effect (with no other dependencies on other risks) on the finances of the insurer do not need to be modeled as accurately as the other risks.

The complexity of an insurer's risks refers to both the breadth and diversity of its risks as well as to the inherent volatility and uncertainty in cash flows stemming from each of them separately. For example, a multi-line insurer operating in more than one jurisdiction has more

complexity in its risks than a mono-line insurer operating in a single jurisdiction.⁵ Alternatively, a mono-line insurer which has assumed material risks with considerable inherent volatility and uncertainty has more complexity in its risks than another insurer whose assumed risks feature low volatility and are readily estimable. Interactions among risks, such as claim rates that may be influenced by economic factors, are a further source of complexity.

Important aspects of the concept of proportionality include the following:

- **Use of accepted and best practices**

Internal model designers will usually first examine accepted industry modeling practice (where such “accepted industry practice” standards exist) based on the nature of the risk(s) assumed and then decide whether or not there is need to choose a different approach. Note that the “accepted practice” is generally only reasonable for certain circumstances. For example, “accepted practice” for auto claim variability will not work for asbestos liabilities, or for high deductible or high excess workers’ compensation liabilities.

- **Size of risk**

The larger the size of an insurer’s risks, the greater the expectation that the insurer would use more detailed treatment to model those risks as well as employ the appropriate risk management practices.

Care should be taken to assess the size of the risk by the potential variability of cash flows or negative impact on capital. For example, assessing the size of risk by the amount of related revenue can understate risk if it is not properly priced. The smaller the size of an insurer’s risks, the greater the acceptance that the insurer may use simpler internal model designs while recognizing the cost/benefit trade-off of various internal model designs.

- **Breadth & diversity of risk**

The greater the breadth and diversity of an insurer’s risks, the greater the need for the insurer to use internal models for the majority of its risks and to capture risk interactions so that the aggregate risk and capital position of the insurance entity is appropriately modeled and managed. For insurers with limited breadth or diversity in their risks (e.g., a mono-line insurer operating in a single jurisdiction), the internal model may be based upon simpler, but still robust, designs for risk interactions that recognize the cost/benefit trade-offs of various internal model designs.

- **Inherent volatility and uncertainty of risk**

Inherent volatility refers to the random deviations around an expected mean. Uncertainty of risk is the randomness seen in results where even the mean is unknown and may itself have an unknown or random “reset level”. The greater the inherent volatility and uncertainty of an insurer’s risks, the greater the need for risk analysis, the greater the benefit from internal models and the more complex those models (and

⁵ It is not necessarily true that a mono-line insurer inherently has less risk than one that is multi-line. The multi-line firm may have risks that to some extent offset while a mono-line is subject to the vagaries of a single type of business with lesser ability to mitigate unfavourable experience.

associated risk management) generally need to be, keeping in mind that the greater complexity will require additional controls of the types listed in this paper.

Risks which feature low volatility and are readily estimated can be modeled using simpler, but still robust, internal model designs that recognize the cost/benefit trade-off of various internal model designs. For example, simpler models may be based upon deterministic scenarios without involving stochastic techniques.

- **Partial Models**

Insurers with risks that exhibit a wide variety in their nature, size and complexity would typically be expected to employ an internal model that includes components for various risks. These components may themselves be mathematical models. When risk or capital assessment is carried out with some, but not all, components being mathematical models, the internal model is referred to as a “partial internal model”.

While the concept of proportionality allows for a variety of model designs, it is to be stressed that the use of simpler models in appropriate situations should be carried out in a manner that respects the overall goal and principles of a solvency framework.

2.4 Risk Assessment Framework

As stated previously, an internal model can only be considered as a tool within the risk assessment framework of the enterprise. That framework will likely include the following elements which form a necessary foundation for the internal model design. These elements will each be described in more detail below:

1. Time Horizon
2. Risk Measure
3. Confidence Level
4. Terminal Provision.

2.4.1 Time Horizon

The selection of an appropriate time horizon may vary with the specific use made of the internal model. Frequently for risk and capital management, the time horizon over which extremely adverse experience is assumed to occur is set by regulatory or accepted reporting practice, and reflects some reasonable time frame during which management and/or supervisory action is expected. For example, in formulating a capital requirement, a supervisor will take into account the time horizon between the date when the insurer’s financial statements are prepared and the expected date by which a supervisor could take effective action if this was deemed to be necessary. Since this time horizon depends upon local business practices, the supervisor’s resources, legislation and the legal system, this horizon may vary from one jurisdiction to another. For example, European supervisors have chosen a time horizon of one year for Solvency II.

In some cases the time horizon is set to longer periods or even the entire lifetime of the risks. A time horizon longer than one year may be useful when assessing the impact of risks which may take some years to fully emerge (e.g., a full economic or underwriting cycle) or for management's response to changing circumstances to have a material effect on the insurer's financial position. For example, some supervisors require insurers to conduct a multi-year future financial analysis involving adverse scenarios. Regardless of the length of the time horizon, the remaining risks beyond the time horizon according to the stressed assumptions (i.e., assessed in the light of the projected experience in the time horizon) will often be provided for through a present value amount or terminal provision.

2.4.2 Risk Measure

A risk measure is a numeric evaluator⁶ that can be used to help determine the solvency capital requirement for an insurer. The most useful risk measures for solvency assessment will exhibit a variety of desirable properties (e.g., consistency). Of course, one risk measure cannot adequately convey all the information necessary for the management of a particular risk. A risk measure that exhibits several desirable properties for various (but not all) risks is Tail Value at Risk (also called TVaR, TailVar, Conditional Tail Expectation, CTE or even Policyholders' Expected Shortfall). In many situations, this risk measure is better suited to insurance risks than Value at Risk (VaR), a risk measure commonly used in banking, since it is common for insurance risk distributions to be skewed with lumpy or fat tails. An advantage of using TVaR as a risk measure is that, given an appropriately represented risk distribution, it provides an indication of the potential size of catastrophic losses above a certain confidence level.

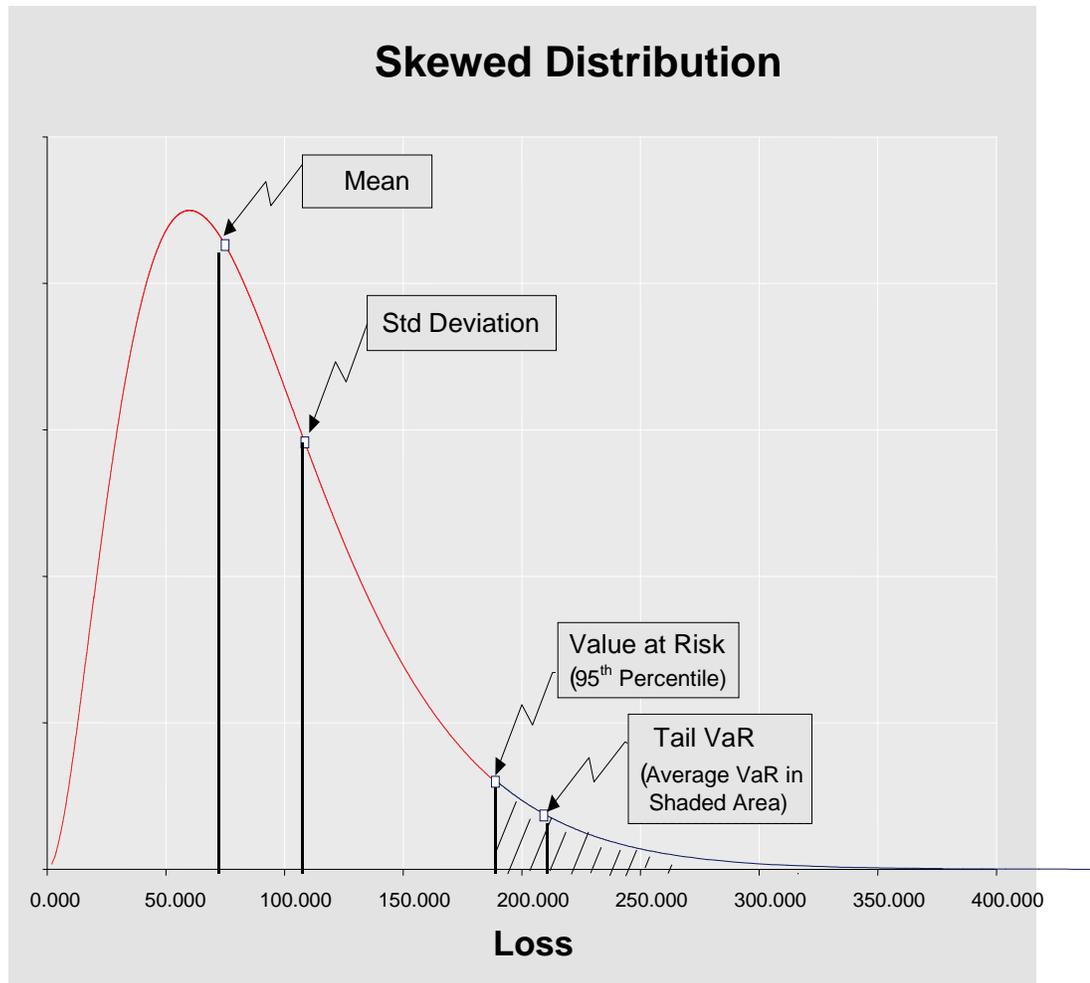
While the insurance regulator will specify the risk measure(s) to be used for assessing regulatory capital requirements, the company may well set up its own measures to fit its risk management objectives.

2.4.3 Confidence Level

The selection of an appropriate confidence level for an insurer to use in an internal model will depend on the specific use of the model, its time horizon and choice of risk measure. In the design of an economic capital model the insurer may be guided by the work of rating agencies in assessing insurers and the substantial volume of credit rating and default data available from these agencies. In the case of internal models used for regulatory capital requirements, the insurance regulator will generally specify a minimum confidence level for the industry to use. For internal models for internal use, the company may choose to set their own confidence levels.

It is important to note that the degree of protection afforded by a given confidence level needs to also consider the length of the time horizon over which it is to be applied. For example, a 99% confidence level measured over a one year time horizon with what would

⁶ The equivalent of a key descriptive adjective in a sentence.



be a current estimate terminal provision after one year (in the hypothetical circumstances relating then to that confidence level) may be a weaker requirement than 95% confidence level measured over the entire lifetime of the remaining risks. However, it is generally accepted that the confidence level required will decrease as the time horizon lengthens.⁷

2.4.4 Terminal Provision

A terminal provision must be calculated whenever the time horizon is shorter than the full lifetime of the insurer's obligations. It can represent a very material portion of the total balance sheet requirement, particularly when the time horizon is short compared to the ultimate runoff (e.g., as in one year for most life insurance products). The considerations involved in determining the terminal provision at the end of the time horizon may vary by the specific use of the internal model, but typically include the following:

⁷ One additional consideration is whether the level is measuring insolvency or becoming non-viable as a going concern.

- **Conservatism**
Depending on the use to which the measurement framework is being put (e.g., for capital requirements), it should include an appropriate level of conservatism (in excess of the then current estimate at the end of the time horizon) to allow directly or indirectly (e.g., by calculating a cost of capital) for the uncertainty or volatility of the current estimate. The method and amount of the conservatism may differ depending on whether the model is being used for regulatory or economic capital purposes.
- **Reflecting the position at the end of the time horizon**
The risks allowed for in each terminal provision should be assessed in the light of the relevant (potentially stressed) assumed conditions at the end of the time horizon as well as including provision for subsequent future risk.
- **Risks that do not fully develop within the time horizon**
Insurance risks can take years to develop (e.g., a deteriorating mortality trend or a progression of adverse court rulings), or develop quickly but take years to have a significant impact (e.g., product guarantees). The terminal provision should make appropriate allowance for risks that could develop or otherwise have an impact after the time horizon. There is a need to consider any correlation of adverse outcomes within the time horizon to adverse outcomes beyond the time horizon. Such a material correlation is common for claim liability estimates for property/casualty business.

2.5 Real World versus Risk Neutral Probabilities and use of Market Consistent Valuation Techniques

The generation of economic scenarios is an important component of modeling risks over time horizons where the funding of the risk over time is material to being able to provide the promised benefit. These scenarios are produced by an economic scenario generator (ESG) which is (usually) stochastic (see section 2.2) in nature. If the values were produced via stochastic simulations economic scenario generator's can produce a suitable economic related stochastically input.

Two types of probability measures are often used in this context:

- real world
- risk neutral.

The distinction between risk-neutral and real-world probabilities is an important one. Depending on the modeling purpose, either risk neutral or real world probabilities have to be used.

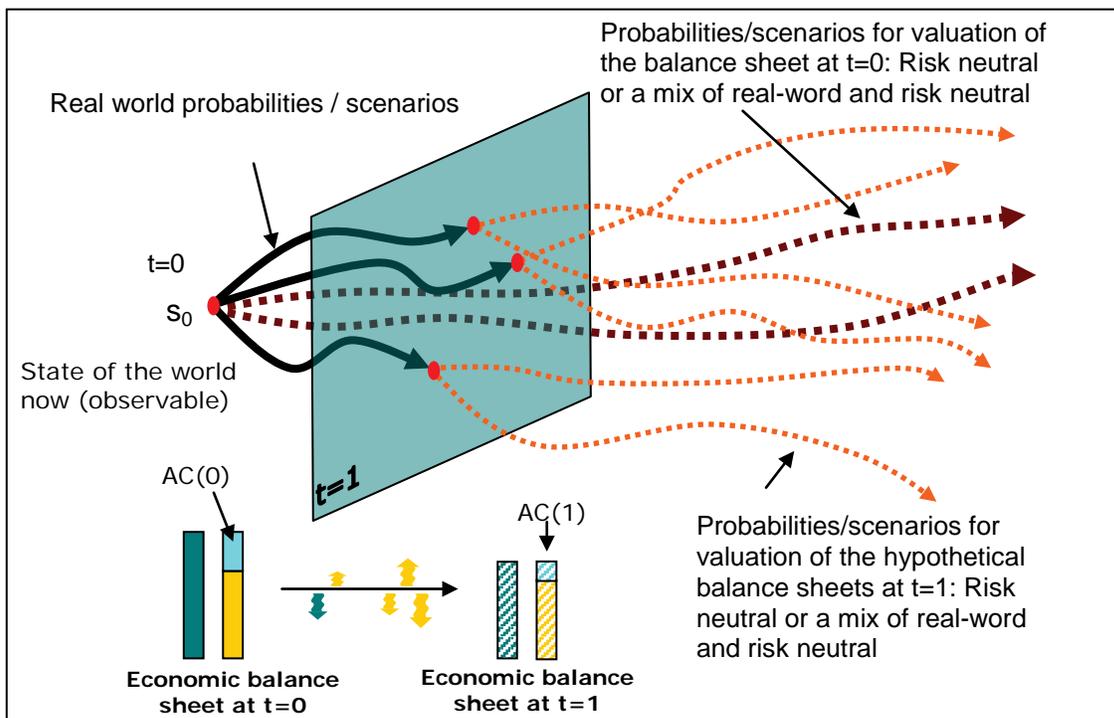
Risk neutral valuation is a mathematical tool to arrive at a market consistent valuation that reflects the markets view and expectations of risk.⁸ Risk neutral valuation assumes that the

⁸ Assume that an otherwise risk-free security has a 10% chance of a loss of X. The market value is consistent with a, say, 20% chance of a loss of X, reflecting the market's risk aversion. The 10% probability is the real-life probability, while the 20% probability is the risk-neutral probability.

stochastic cash flows of a financial instrument (be it an asset or a liability) can be replicated perfectly with assets which are traded in a deep and liquid market. The price of the financial instrument is then given by the cost of the replicating portfolio. Rather than explicitly having to define the replicating portfolio, risk neutral probabilities allow for a direct calculation of the value of the financial instruments. If the instrument can be replicated, the valuation using real-world probabilities would be wrong since then the prices obtained would allow for arbitrage opportunities. If however a perfect replication is not possible – and this is the case for most insurance liabilities – then a pure risk-neutral approach might also not be suitable. In this case further assumptions have to be made, e.g., by enlarging the set of replicating instruments or by having to make assumptions on the utility function and risk aversion of investors. For further reference, see the IAA’s Measurement of Liabilities for Insurance Contracts: Current Estimates and Risk Margins (April 2009).

Real-world probabilities have to be used to arrive at a future, observable state of the world. In the context of economic capital models, the necessary economic capital is defined as the risk measure applied on the change of available capital over a given year time horizon. To determine the available capital at the end of the time horizon (often after one year), the observable future state of the world has to be used. To determine the available capital, the portfolio of assets and liabilities has to be valued given the future state of the world. This valuation then has to be done using risk-neutral probabilities, conditional on this future state.

The figure below tries to depict the distinction for the use of real-world and risk-neutral probabilities or scenarios.



There are several – in theory equivalent – ways on how to arrive at market-consistent, economic values for assets and liabilities, for example:

- Risk-neutral valuation
- The replicating portfolio approach
- Economic scenario generators
- Analytic, closed form solutions.

Risk-neutral valuation is a technical tool in which – very loosely speaking – the physical, observable probabilities are replaced with risk-neutral ones. The underlying theory is based on the fact that the valuation should not allow for arbitrage opportunities. This then implies that for the valuation, options are replicated and hedged with financial instruments. In this sense there is a close link to the replicating portfolio approach.

The risk neutral measure captures, via its calibration to market prices, market participants' risk aversion to extreme events. Risk aversion means that failure is much more significant to a market participant than is success. Therefore the risk neutral measure adjusts the probabilities to give greater weighting to “bad” events than actually occurs in the real world in order to capture this empirically observed influence on market prices.

In the **replicating portfolio approach**, the cash flows of financial instruments (assets or liabilities) are replicated with a set of financial instruments which are traded in a deep and liquid market. If the replication is perfect, i.e., if the cash flows of the liabilities are identical to the cash flows of the replicating portfolio under all possible states of the world, the market consistent value of the liabilities is equal to the market value of the replicating portfolio. In most cases, the replication will not be perfect and the cash flows of the liabilities will deviate from those of the replicating portfolio in certain states of the world. In that case the remaining risk (basis-risk) gives rise to an additional risk premium.

Economic scenario generators supply scenarios which describe the evolution of financial market parameters (e.g., yield curves, spreads, share prices etc.). The scenarios are chosen such as to not allow for arbitrage opportunities. If used for valuation, the probability of the scenarios are assigned in such a way that observable prices of traded financial instruments (bonds, options, etc.) are obtained by averaging the value of the financial instruments over the different economic scenarios. In this way, risk-neutral probabilities are obtained naturally from the observed market prices of financial instruments.

Economic scenario generators can also be used with real-world scenarios. This then allows generating hypothetical, observable future states of the financial market. These future states can then be used to arrive at the necessary economic capital of an insurer.

Analytical solutions are possible for the valuation of financial instruments. If the prices so obtained are to be arbitrage-free, the underlying model for the analytical solution has – as above – to be based on an approach where the instruments are replicated with traded financial instruments. In that case, analytical solutions will then lead – up to numerical

inaccuracies – to the same values as when using the methodologies described above. Analytical solutions have the advantage that they allow for an efficient numerical evaluation and easy analysis.

When valuing embedded options, it is important to be very clear on the key assumptions underlying the valuation framework, for example:

- the ability to replicate the liabilities (i.e., the existence of a deep, liquid market);
- the ability to replicate continuously and the cost for such a hedging strategy; and
- completeness or incompleteness of the market model.

It might not be necessary that all preconditions of the model are met; however the actuary has to be clear as to the effects of the deviations of the real world to the idealized model assumptions.

2.6 Types of Model

Internal models may take many forms. This section considers many of the more common ones. As stated in the introduction to this note, a model that is used to determine required capital (regulatory or economic) should be able to determine all material elements of a corporate balance sheet so that capital may be quantified. A model which does this, however, may be structured so as to use results from a variety of specialized sub-models, each of which deals with one portion of the insurer's business or one particular risk. These sub-models may be very sophisticated and are what some would consider as the true internal models. This note includes these sub-models in its discussion of "models".

The type of models used by a particular insurer will, of course, depend greatly upon the nature of its business. For life insurers the long term nature of the business and the importance of investments and asset/liability mismatches will normally lead to an emphasis on modeling the interaction between insurance products and their supporting investments. The models used to study the risks in this business are to a considerable extent financial in nature and usually depend heavily upon external economic factors. In stochastic versions, they usually make use of economic scenario generators. They are most commonly structured as cash-flow projection models.

Models used in non-life or general insurance are often structured so that the greatest sophistication is found in sub-models dealing with claim distributions. The tails of these distributions are particularly important when considering capital requirements and are the subject of catastrophe models. This is not to say that general insurers can safely ignore asset/liability mismatch risks; these risks are present in all lines of insurance and while they may be relatively less important in shorter-term business, they should still be taken into consideration.

Cash flow projection models project the operations of an insurer or part thereof over a specific time period. Projection output usually include all financial activities such as receipt of premiums and investment income, payment of expenses, insurance claims and other

policyholder benefits, taxes and shareholder dividends as well as purchase and sale of investment assets. This output is based on a number of specifically projected future economic paths called *simulations*, each of which consists of a series of consecutive possible situations, each situation being influenced by its predecessor. Such models may be run many times generating different results for each simulation. If the situations are themselves derived stochastically from probability distributions, the projection models will produce distributions of financial results. However, situations may also be chosen deterministically; this is particularly useful when “extreme” scenarios are chosen for purposes of stress or scenario testing.

Models of claim distributions may be constructed using frequency–severity models.⁹ In this case, distributions of claim frequency (probability of a claim) and claim severity (loss amount given a claim has occurred) are constructed. The resulting distributions are then frequently combined using well-known recursion methods to obtain the distribution of aggregate claims. These methods are described in standard actuarial text books. Since the tail of the aggregate claims distribution is particularly important for purposes of capital requirements, it is important to ensure that the tail adequately captures extreme events. These events may be the result of a great number of claims, each caused by the same event (e.g., an earthquake or a hurricane) or relatively few claims of extreme severity such as medical coverage for the care of premature infants.

2.7 Managing Models

In all but the simplest of insurers, it can be difficult to construct a single model to capture all elements of the insurer’s business. Insurers may employ specialized models for particular aspects of their operations or to capture the financial effects of particular types of risk. In addition, it may be more convenient to model different segments of the insurer separately, either due to the nature of the insurer’s organizational structure or to the geographical distribution of its operations.

Nonetheless, an overall assessment of the entire insurer is often needed. In this situation it is important to plan the modeling exercise to ensure that:

- each of the component models is constructed and run in a manner that is consistent with the insurer’s possible actions to manage its underlying risks as well as consistent with the other models;
- assumptions used in the various component models are consistent within the insurer;
- the topmost corporate model is able to accept as inputs the results of the various component models and to produce from them an accurate representation of the total firm.

⁹ Other methods common to general insurance product lines are the Mack and bootstrap methods.

One approach to achieve consistency is to employ the same modeling software for all the component models. This will usually facilitate the compilation of results from all component models into the topmost model. It provides uniformity of treatment. However, it is quite possible that the software used for the topmost corporate models may be unable to adequately capture features of local products and/or assets. Thus it may be necessary to employ different software in particular cases. Should this be necessary, it is vital to ensure the various quantities output by the local component model have the same basic definition as similar quantities determined using the more standard software and that these results can safely be combined with those from other component models.

It is important to coordinate the choice of scenarios being modeled within the various component models in order to ensure that their combination gives an appropriate picture of the entire firm. Similarly, most basic assumptions within the component models require coordination when they are correlated. This occurs frequently in life insurer risks. However, whenever the risks and processes being modeled are generally independent, such coordination is not needed. This may frequently be true for non-life insurer risk.

Insurers generally differ among each other as to the degree of central control of operations maintained by the corporate centre. Nonetheless, it is advisable to consider implementing some centralized controls on the modeling process in order to obtain an accurate corporate-wide picture.

Multinational insurance groups are faced with particular issues in modeling. One of the first questions that must be considered is whether all local models are to be based upon the same software or whether various local operations may use local software. The argument for the software throughout the insurer's operations rests on uniformity of calculations, better control of input and results. The argument for the use of local software is that it may better capture the features and peculiarities of local products and markets. There is no clear-cut choice of one approach over the other. Whichever approach is taken, the group modellers must ensure that adequate controls are in place so that the results of all the local sub-models, when put together, give a fair picture of the entire group.

Economic assumptions will often vary by geography and currency. However, economic assumptions for various regions, while not identical, should not be considered to be mutually independent. It is important to employ a family of economic scenario generators which collectively model the partial correlations between various economies.

When results of various component models are combined, it may be necessary to convert quantities expressed in one unit of currency into units of another. Since currency conversion (FX) rates are often variable, the overall model may recognize and provide for currency risk.

Since many jurisdictions place minimum limits on capital and surplus that must be held locally for local insurance operations, capital is not completely (fungible) free to flow from a local subsidiary or branch to the parent group. Therefore, when combining local modeling results to portray the parent group, it is important to design the aggregating model so that

restrictions on the movement of capital between component parts of the insurance group are appropriately reflected. Similar considerations apply with respect to the effects on the insurer of taxation.

3. Design Considerations

Design considerations are important for anyone actively constructing a model. For those who are basing their models on software produced by others, they serve as a checklist to help in evaluating commercial modeling packages. The fundamental idea is to first consider how the model will be used, what objects and actions are to be modeled, how they interact and what results they produce or affect. Early consideration of what results are expected to be obtained from the model will be quite valuable later on.

3.1 Results

The desired results will depend on the specific purpose of the model (e.g., financial condition projections, product pricing, capital determination, in-force management of policy dividends (bonuses) or other non-guaranteed elements, etc.). The model can then be constructed to produce the desired results. For example, these might include the figures needed to construct *pro forma* financial statements. Therefore, before constructing a model one should consider the insurer's financial reporting cycle and the detailed results required from the model for this purpose. A model would follow these financial requirements as closely as possible.

Internal models are likely to produce a very large number of results. Often, it will be current and projected balance sheets across a range of future scenarios. Many corporate models will contain sufficient results to produce complete *pro forma* financial statements for each simulation (run) and for each interim period included in the overall time period covered by the projections that produced the simulation's results. In many models, such statements will be made available for major divisions of the insurer.

In the case of stochastic models involving a very large number of simulations, particularly if each simulation is a multi-period simulation, storage of all the sets of results may be beyond available storage capacity. It is therefore often necessary to decide which subset of all results is to be saved and to build into the program a routine for saving the desired results.

If only a subset of all results is to be saved, there should nevertheless be a way of reproducing all results for audit purposes and for checking on and correcting errors. Therefore it is important to implement a model so as to leave an audit trail. In a stochastic model, it may be simpler to save all the random numbers used, or their seeds, on the assumption that these will provide for the reproduction of results which are not saved. However, if this procedure is adopted, the strategy should be checked and reproducibility verified.

Consideration should also be given at an early stage in model design to the need to calculate and store interim results which will facilitate the validation of the model itself.

Once the results are available, various reports can be constructed from them. Many of these reports will be part of the financial statements that are the ultimate output of the modeling process. However, it is important to also include reports that can be used to check the internal consistency of the computed results. For example, a non-exhaustive list could include:

1. trace the development of the volume of business in force (in the case of life insurance, by number of policies, premiums and volume of insurance. For general insurance it might be by number of policies and premium);
2. unit testing of a single cell;
3. the use of defined reports from a change control process to verify that the same values are produced by different versions of the software.

3.2 Order of Calculation

The order in which calculations are carried out can significantly affect the model's ability to reflect specific interactions between modeled components. In particular, if one is modeling insurance products whose performance or value is linked to the values of a portfolio of supporting assets, it is imperative that the model allow for the interaction of liability cash flows and asset cash flows.

For example, for some products, policyholder behaviour can strongly influence the amount of cash that would be invested or disinvested in any particular time period. For these products, variations in policyholder behaviour are an important consideration that should be reflected in the model. If the results for assets are calculated without reflecting the variation in cash flows induced by policyholders' behaviour, the model will produce misleading information.

3.3 Control over Assumptions

Centralized coordination and/or control over common assumptions is essential. Since the same assumption may be used in many different places within a complex model, it is important to be able to control and/or coordinate changes in common assumptions centrally in order to ensure that any change is properly reflected wherever the particular assumption is used. This is particularly important for stochastic models since each scenario involves a change, or a series of changes, from period to period in assumptions. Moreover, since many assumptions interact, it is convenient and good practice to maintain important common assumptions in one location within the model so the interactions can be properly specified and controlled. It is therefore desirable for a model to contain a system of internal references

between its various components if contained within one system or have a central process to ensure coordinated changes occur over sets of models.

3.4 Reproducibility

It is important to be able to run a model several times with the same data and assumptions and verify that the same results are obtained each time. Such testing is certainly part of standard model development. It is also an important factor in validating changes made to a model.

Models should be subject to a regular audit process. This process is likely to involve repeat runs of the model.

As discussed in section 3.1 above, reproducibility is essential, yet it may be impractical to store all output from each run. In this case the insurer should be able to recover all results including those that have not been saved to be able to fully explain the results of a particular run. This means when a stochastic scenario is rerun it should be verified that the initial and repeat runs make use of the same random numbers. This is particularly important when models contain stochastic-on-stochastic calculations.

3.5 Flexibility

Insurers, like most commercial bodies, are dynamic organizations that often change. Change may involve the introduction of new products, changes in internal policies that directly affect operations, such as the introduction of designated asset segments, internal structural reorganization or external reorganization through merger. Anticipating that change is likely to occur in the future, modellers should construct their models to be flexible and facilitate the reflection of changes.

At the individual product and asset level, this flexibility is usually facilitated by including into the model templates, each of which describes the properties of an insurance product or asset. Each such property or feature is usually linked to a sub-program that incorporates that property or feature in the calculations. These various templates usually provide a very large number of specific properties or features, many of which will not be needed to describe any particular product or asset: this is particularly likely to be the case for commercial (as opposed to in-house) modeling software.

A programmer who is describing a particular product or asset within the model is required to make a significant number of choices among these properties or features. It is essential to verify that the product or asset has been accurately described by those choices. This requires extensive documentation so that all aspects of the templates are well understood by the programmer as well as providing a rigorous audit program. Both documentation and the need for audits of models are discussed elsewhere in this note.

The model should allow for changes in the reporting hierarchy within the insurer. It should also provide for incorporation within the overall corporate model of separately modeled

results from sub-units of the insurer, such as particular divisions or lines of business or branches or subsidiaries operating in various jurisdictions. This required flexibility can be accomplished through a hierarchy structure within the model that allows for change.

Most commercial modeling software used within the industry provides this flexibility. However, it is important that the relevant documentation should be clear and well-understood by programmers who use such software. For those who plan to construct the whole or part of a model in-house instead of using commercial software, it is important to incorporate facilities that will provide the required flexibility.

4. Construction of Model

This section discusses the considerations that enter into the construction of a specific model once the basic design has been decided.

4.1 Granularity of Time Periods

Time granularity is concerned with the length of the interim periods that usually make up the overall period during which modeled events are assumed to occur. For example, the model may use annual interim periods, or quarterly, monthly, weekly or even daily periods. Cash flows, as opposed to events such as the distribution of dividends or bonuses to policies, can generally be treated as taking place at the central date within each interim period (though attention to this needs to be given when considering the validation procedures and the integration of actual to expected results). Since a model will normally cycle through all events that occur within an interim period before moving on to the next interim period, the number of calculations necessary to portray a full year's activity will increase rapidly as the length of the interim period decreases and the number of such periods in a year increases. Therefore, the choice of interim period length will be strongly influenced by run-time of the model and the availability of sufficiently fast computing resources. However, the time granularity of the model needs to fit to the required reporting dates for model results and furthermore needs to take into account how volatile model variables usually appear in the time periods between the reporting dates.

Granularity of time periods is also related to the length of the overall projection period. It may be acceptable for some insurers (depending on the nature of their business) to use annual or semi-annual periods when the overall projection runs over several years; on the other hand, short-term overall projection periods will usually require the use of shorter interim periods (i.e., of finer granularity).

Granularity implies the use of approximations in models. The use of longer interim periods (i.e., coarser granularity of time periods) is equivalent to making greater approximations.

Therefore, in choosing an appropriate granularity the modeller should balance accuracy against materiality, computing power and run time.

4.2 Population of the Model

Once the basic structure of a model has been decided, one that reflects the insurer's hierarchy and reporting structure, the next step is to populate the model with descriptions of the insurer's products, in-force business and existing liabilities or obligations (such as claim liabilities), current assets, assumptions regarding future developments, future management actions and policyholder behaviour. Each of these aspects can be quite complex, and is discussed separately below.

4.2.1 Product Descriptions

One of the most important elements of any insurer's internal models(s) is the description of the products it sells to its customers.

When commercial modeling software is used to construct a model, it is important to remember that such software is designed to be extremely flexible and handle almost all insurance products. Such software usually offers a wide variety of options that can be used to describe product features and behaviour. The modeller should have a thorough understanding of the differences between these features in order to make proper choices and be confident that he or she can judge whether these sufficiently accurately describe each product.

The importance of an accurate description of the insurer's products cannot be exaggerated. The results of the model are those of the insurer *as described in the model*. Reliability of the results requires that audit of a model should commence at its construction. In particular, once a product's description has been inserted into a model, this description should be reviewed by an independent person who is familiar with both the product and the modeling software. The review should include comparing the product as modeled with the product's features, including any options, as described in a policy contract.

Products should be modeled so as to generate projected future cash flows that are sufficiently close to those that would be generated by the actual products under a wide variety of scenarios covering the insurer's possible experience.

An insurer with a large number of different types of contracts in force may often choose to represent a number of "similar" policy types by a single product description in the model. Often it is possible, for example when non-life or re-insurance business is modeled, to aggregate types of products to insurance portfolio segments which show the same characteristics regarding cash flows from premium inflow and claim payment and cost related outflows. As with any grouping, such procedures are acceptable if the error introduced in this approximation is not material to the results of the model. In choosing such groupings, the modeller should take into account whether the group of products would

exhibit similar financial results under *all* possible future scenarios. When models are being used to determine capital requirements, it should be borne in mind that the “tail” scenarios are particularly important and that differences that only arise under these scenarios may invalidate certain product groupings.

4.2.2 Product In-Force Data

Product in-force data are derived from an insurer's internal records. They describe the policies in force, including amount and type of insurance, age and gender of the insured, rating class, any guaranteed values or options, etc. They also include outstanding claims, together with an estimate of their value and time of payment. For certain claims, particularly those that are incurred but not reported, estimates are necessary. These are usually based upon past experience patterns and are similar to the quantities used in the insurer's financial reporting.

When considering insurance products in the financial management and reporting the practice of insurers usually differs in life and general insurance (non-life) business. While in life insurance consideration starts on contract level non-life insurers tend to work on a higher level of aggregation. This is due to the fact that any statement about profitability needs to reflect claim provisions adequacy. Incurred but not reported claim provisions for non-life insurance business have to be derived by application of statistical estimation procedures which need to be based on homogeneous groups of policies.

Therefore the modeling practice for insurance products differs as well.

Life Product In-Force Data

While the greatest accuracy in life product modeling would be obtained from use of a seriatim listing of all an insurer's policies, in order to avoid excessively complicating a model and to keep computer programming and run-times within reasonable limits, it is often appropriate to represent each group of broadly similar policies by a group consisting of an equal number of identical hypothetical policies. The specification of such a hypothetical policy is often referred to as a “*model point*”. Then, when the model is run, the assumed rates of claim, discontinuance, etc., will reduce the number (non-integer numbers being the norm) of hypothetical policies relating to each model point. Additional model points will be needed to represent any future new business to be modeled.

Choosing the model points involves a balance between speed and accuracy. The closer the model points fit the actual policies that they are representing, the more accurate is the result but the greater is the number of model points as well.

In effect, the use of model points means the grouping of policies. The grouping criteria may be quite complex. For instance, for life insurance policies they might be a combination of the following, resulting in anything up to a few tens of thousands of model points being needed to represent the most complicated portfolios of policies:

- class of policy
- whether future premiums are payable
- duration in force
- outstanding term of coverage
- current age and age at maturity
- types of options (e.g., guaranteed annuity rate) in the policy
- how close guarantees in the policy are to being 'in the money' (if duration in force is not an adequate proxy for this).

Where investigations show that the results of the modeling will not be very sensitive to a particular factor, the range of values of that factor that is covered by one model point can be relatively wide. For instance, it will usually be found that one model point for an endowment assurance can represent actual policies with quite a wide range of ages of lives assured but may be restricted to policies maturing in one calendar year, and for some types of with-profits policies to policies started in one calendar year.

One common way to assess the acceptability of model points is to compare the results of deterministic valuations of the modeled policies with equivalent valuations of the actual policies that they represent. This should be done not only against the background of current financial conditions but also in a range of alternative financial scenarios. The time values (derived from the two sets of data) of policyholder options should also be compared. The results from the actual data and the data based on model points will not be identical, but they should not be materially different.

General Insurance Product In-Force Data

Product in-force data from general and reinsurance business are not restricted to information about the products which are included in the insurers portfolio but also include information about related claims experience.

Insurance business model segments

The determination of the segment structure to be used in the internal model is one of the most important conceptual steps of model design for non-life business. Some of the segmentation criteria to be considered are of statistical nature, like homogeneity and statistical mass. Nevertheless the most important segmentation criteria are either given externally or are due to the intended purpose of the model. Therefore model segments are mostly fixed up-front without detailed statistical analyses which are quite common in pricing of general insurance products.

External requirements

- If the model is intended to be used for supervisory reporting and related capital assessment one needs to consider requirements by the respective supervisor, e.g., related to the minimum granularity of business reporting.

- Non-life insurance business shows cyclic behaviour, which usually varies by market, product and customer segments. Multi-period models need to reflect the different cycles properly.

Company specific requirements

- If the model is intended to be used for company internal management purposes one needs to consider related internal requirements, e.g., related to the structure of lines of businesses and business entities used in internal financial reporting and management or the business segments in which the portfolio is managed and responsibilities are assigned.
- The segmentation used in the model needs to be fine enough to reflect the current and expected future reinsurance programs properly which potentially adds further complexity. For example, if the reinsurance is organised around cause of losses like hailstorms one needs to have separate consideration by claims causes.

Technical requirements

- The emergence of claims and claims run off behaviour may be different even if the products appear to be quite similar at first glance. Often a refined portfolio segmentation is used for reserving (e.g., different run-off behaviour of private vs. commercial liability resulting in different reserving classes used), which could be a starting point for modeling purposes as well.
- In non-life insurance often cumulative claims have to be observed e.g., windstorms, which affect various lines of business. In this case losses by event may be modeled first and then loss amounts distributed to model segments.
- Another technical requirement is simply data availability.

As mentioned above in non-life insurance one usually starts on a higher level of aggregation than policy level when considering the product model segmentation. A common starting point is the business segmentation used for internal reporting purposes. Considering all the aspects mentioned further above one would come up with pretty many segments. However the resulting segments need not to be too small to retain necessary statistical mass.

Model variables

Having fixed the model segments one would consider at least the following variables for each segment:

- Number of contracts
- Premiums (gross and net of reinsurance)
- Reinsurance contract details like layers, retentions, reinstatement premiums
- Losses (attritional, large, extreme)
- Expenses (administration, distribution)
- Loss development patterns, tails, estimation errors.

4.3 Assets

Depending on the purpose of the internal model it will include a projection of the cash flows resulting from the assets currently held (or expected to be purchased) by the insurer in support of its insurance business.

Mapping of the insurer's assets to proxy asset classes or indices should be plausible, intuitive and conceptually sound. Documentation, including both theoretical and empirical evidence, should be maintained to demonstrate that the mappings are representative of the risk of the underlying holdings. The relationships of the mapped assets to the proxy asset classes should be reviewed regularly.

In the case of hedging or other risk mitigation techniques where risk mitigation is imperfect, procedures should be in place to determine basis risk due to mismatches of:

- financial instrument features versus underlying asset;
- term to maturity;
- specification of payments;
- credit ratings;
- unavailability of appropriate instruments.

The basis risk should be allowed for, either within the model or in some other way.

4.4 Insurance Experience Assumptions

Assumptions about future experience for insurance risks are among the most difficult issues in constructing an internal model and some issues will be unique to the type of insurance risk that is being modeled such as general versus life insurance. This section needs to be read in conjunction with the next section, which includes discussion of establishing assumptions about probability distributions for many risks.

For many risks a starting point in the process of deciding assumptions for projections into the future would be studies of the insurer's experience in the recent past. Recent past experience might sometimes be taken as a reasonable estimate of the insurer's expected (best estimate or mean) future experience. However, this might be inappropriate for several reasons, such as the following:

- The experience upon which a study is based may be insufficient for the study to yield sufficiently credible information. The natural response to this situation would be to make use of industry data, either in whole or in part through a blending with the results of the insurer's own data through credibility theory. In using industry data, the modeller would compare the composition of the insurer's own business to the business of the firms contributing to industry experience studies. Allowance should

be made in the values selected for significant differences in these portfolios in order to better approximate the insurer's expected future experience.

- There may be reasons to expect future experience to differ from that in the past. If there are sufficiently strong doubts concerning the applicability of past experience to the future, and they are considered to be sound, this would usually lead to a new set of expectations. If the reasoning is considered to be sound, it may be appropriate to use these new assumptions. Alternatively it may be appropriate to take an intermediate course of blending these new expectations with experience rates of the immediate past.
- The insurer may have new products under which experience is expected to differ from that of its older products. Unless there are similar products with available experience, either within the insurer or external to it, best estimate assumptions for future experience will have to be based largely upon sound judgment. This may be the only available approach.

When there is significant uncertainty in the assumptions to be used, the modeller, in choosing assumptions for projections of future experience, may be required to reflect that uncertainty by including margins in the assumptions. Since those who are given model results may not know the details of the model, disclosure of the margins can be an estimate of the uncertainty of the models results when used as a basis for making business decisions.¹⁰ If, in the presence of considerable uncertainty about projection assumptions, the modeller has concerns about the reliability of the results, the situation needs to be disclosed to those who use the model's results, preferably with some sensitivities also disclosed. Of course, materiality should also be taken into consideration.

4.5 Insurance Assumptions for Projections

The form in which assumptions about future experience appear within a model may be different for different risks. For any given risk this depends first of all upon whether the model is based for that risk upon stochastic approaches or is based upon discretely chosen scenarios.

The current stochastic simulation models of life insurers, while including stochastic economic scenario generators, tend not to model life insurance variables stochastically. For example, for reasons of statistical data credibility, most mortality or morbidity studies focus on the derivation of expected rates with, in the more modern studies, analysis of past mortality variation from year to year and longer-term improvement by age. However, actuarial (and other) literature presently contains little information with respect to probability distributions for rates of improvement over future years suitable for use in the projection of

¹⁰ It is a challenging, and important, consideration that while in theory the use of margins represents an estimate of the degree of uncertainty, in practice, (if not done in a thoughtful and transparent manner) the use of margins can introduce even further bias.

mortality or morbidity rates.¹¹ The situation is likely to improve in the near future as the use of stochastic models becomes more widespread and the need for this work becomes more apparent.

On the contrary the current models of general insurance business usually use stochastic simulation techniques to model insurance business variables and often use simpler approaches to model economic variables.

In general less is known about probability distributions with respect to surrender or lapse rates which are important in life and general insurance as well. In many jurisdictions, these have hitherto not entered into the regulatory valuation of life insurance liabilities and little consideration has been given to variability and its effects in this context. Moreover, these rates vary by product type and marketing method and are significantly driven by policyholder behaviour which in turn is influenced by external factors, often economic ones. Experience has shown that the effects of variability in these rates can be complex and not necessarily intuitive. This experience indicates that a stochastic approach (coupled with dynamic dependencies where appropriate for policyholder and management behaviour) is to be preferred in principle; unfortunately, very little is known at the time of writing concerning the stochastic properties of these rates due to a lack of historical data for lapses in a rising interest rate environment.

When probability distributions for specific assumptions are not available, one alternative, in cases where it is desired to use a stochastic approach, could be to use a central estimate plus an appropriately scaled random variable selected from an appropriate statistical distribution with mean zero. Given the public's and the profession's increased awareness of the shortcomings of assumed normality, though, other distributions (for example, skewed) may be better representations which use a multiplicative factor or a regime switching construction. The chosen distribution should be aware of the emerging industry practice and regulatory expectations for the risk being considered.

In many cases, assumptions for the projection of any one risk will depend upon external variables or projected scenarios. This is often the case with respect to policyholder lapse or surrender rates, although this dependence varies with product design, distribution methods, and other factors. Claim experience may depend upon economic variables or other external factors such as weather or court decisions. In all of these cases, these dynamic relationships will usually be reflected within a model by means of algorithms that are used to express the experience assumptions.

¹¹ One exception to this is in the UK, where the Continuous Mortality Investigation Bureau (CMIB) has published a range of projections incorporating distributions using P-splines, Lee-Carter, etc.

4.6 Calibration

4.6.1 General

Calibration refers to the process of validating estimated parameters and assumptions used in the model to their real life values as relevant to the particular modeled circumstance at hand.

The calibration process consists of adjusting inputs (e.g., assumptions about lapse rates, investment performance), and product features so they reflect the circumstances at hand. The changes in model outputs that result from each change in inputs should be explainable (e.g., if assumed investment volatility has increased, the tails of the results should have become fatter but the central points should be about the same).

The process of calibration will generally involve variation of each parameter value in a structured (or perhaps in a randomly fashioned way) with a calculation of the likelihood that each set of tested parameters could have produced the observed historical data (unless market-consistent assumptions are involved or the assumptions for the future deliberately do not reflect the past). The parameter values with the maximum likelihood should probably be used. Caution should be taken with this process since the likelihood functions may have several local maxima. Professional and regulatory guidance specific for each model type, where available, should be observed with respect to calibration.

The parameters used in the internal models should be periodically re-calibrated to the extent appropriate to allow for recent, relevant and credible experience (as well as relevant older historical experience) as part of a regularly repeated process.

For some life models, (when margins are required) it may need to be demonstrated that the direction of any margin added to an input parameter produces changes in the results that are in the appropriate directions (e.g., an increase to a parameter margin produces an increase in the case of required capital).

Calibration can be aided by features in the model that facilitate the methodical testing of changes made to the parameters. Methodical testing allows the selection of a combination of parameter values producing a good fit to the experience, and the verification that minor changes to those parameters would not improve the fit.¹²

Insurers should document and be prepared to demonstrate their calibration procedures and results.

4.6.2 Calibration – Stochastic Projections for External Environment

Although this section discusses economic scenario generators, many of the issues discussed apply to scenario generators used to produce possible future outcomes for other types of risk such as mortality or other risk factors as well.

¹² This is distinguished from comparing actual to expected results on the back end. Here the purpose is to set reliable best fit parameters.

Calibration has a special significance in the case of a model employing stochastic projections of economic scenarios. Since each ESG is governed by parameters, those parameters should be calibrated so that the specific implementation of the economic model produces results consistent with historical experience or current market data (according to whether the model reflects a real world or market consistent valuation) relevant to the insurer, its business, and the circumstances applicable at the date of the analysis.

In order for an ESG to be used over time, it should be updated frequently to reflect the changing observable physical and, where relevant, risk neutral dynamics. This requires a strict ESG management regime to ensure that it is always up to date.

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 should be conducted by automated inspection and analysis tools and not just by visual inspection.

Before basing any decisions on the parameterized ESG, a useful reality check is to analyze the relevant output of the ESG as fed to the cash flow model.

For a real world ESG, a detailed statistical analysis should ideally be performed comparing the economic scenarios output with the historical record. Although history provides only a single scenario, extensive testing of the ESG model should be carried out 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 with the historical record. The analysis should include examinations of such characteristics as skewness, kurtosis, and quantiles in the tails. It should also include carrying out testing of characteristics specific to certain economic variables. For example, for interest rates, some key questions to address might be the following:

- Does the model produce negative interest rates and, if so, is that acceptable for the model's purpose and application?
- Can the model allow for very long term cycles of high and low interest rates?
- If an interest rate model is mean-reverting, is the strength and nature of the reversion appropriate?

When equity returns from a real-world ESG 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) should be measured, along with the mean returns and their volatility.

When used in a real world framework, the distributions in the output by the ESG for various asset classes need to closely match the distributions derived from by historical records, particularly in the tails of the distribution which represent outcomes that are adverse to the insurer.

A market-consistent ESG, on the other hand, should be calibrated to current market prices of securities and derivatives as well as yield curves and related derivatives.

The ESG should reproduce sufficiently accurate market prices for a representative selection of relevant and widely traded derivatives.

For *non-financial-market risks* that are modeled stochastically and influenced by the output of the ESG, calibration should take place only once the ESG has been tested and validated.

4.7 Assumptions Concerning the Insurer's Future Actions

Apart from assumptions with respect to variables reflecting insurance risks and economic risks, internal models for insurers often need to incorporate assumptions about the insurer's future policies and practices in its on-going operations.

The primary assumptions to be considered include the insurer's investment policy (including asset and liability matching, investment type and quality, etc.), its policy and plans with respect to new business, its own expense management levels, renewal rates and its policies with respect to the payment of dividends to shareholders, bonuses or dividends to participating policyholders and charges and excess interest credits to policyholders. For general insurers the future reserving policy needs to be considered.

These policies will usually be implemented within a model as algorithms that are responsive to or a function of other model variables or results. For example, the level of policyholder bonuses or dividends is likely to depend upon recent (within the model) financial results and trends in experience. Similarly, the insurer's investment policy may evolve in response to changing economic conditions as well as projected cash flow requirements arising from the insurer's business. Finally, assumptions regarding new business will depend upon external economic and insurance factors as well as upon the insurer's business plan.

Algorithms may be based upon past experience, upon management plans, and possible future management behaviour. The modeller should have a good understanding of all of these.

One important difficulty is that past experience can be thought of as representing a single (evolving) scenario. Even if the past contains various periods of differing experience, it may not be sufficient to assume the management actions of these periods are an accurate reflection of what management would do if similar circumstances develop in the future. For instance, there may be (or have been) changes in management personnel, sophistication or philosophy, or changes in market and regulatory effects.

An additional difficulty is that an insurer may express its operating policies in terms that go forward from the present situation but that may not be expressed in terms that are contingent upon developments in external factors, such as economic factors. Since the purpose of the models discussed in this note is to test the insurer's financial resilience under

a wide variety of scenarios of future experience, it is necessary to develop algorithms that express these contingent relationships.

The design of appropriate algorithms is usually not a simple matter. Before designing such an algorithm, the modeller should discuss the underlying plans and policies with those in the insurer who are responsible for their design and implementation. These discussions could well lead to the development of new or broader policies within the insurer that incorporate contingent and dynamic reactions. Here, communication is essential.

The modeller should be cautious in how the relevant algorithms would allow for the insurer's reaction to developing future experience. Changes in action or behaviour by management, the sales force or policyholders may often lag changes in the fundamental (e.g., economic) variables and only emerge after strong trends emerge in the fundamental variables. If these delays or lags are not reflected in the model, the results could prove to be highly unreliable.

Due to all of these considerations, all algorithms should be subject to detailed and varied testing. Results of these algorithms should be studied under a variety of discrete scenarios and attention should be paid to their reasonableness. This is particularly the case with respect to extreme or "tail" scenarios: the modeller or the insurer may never have encountered such experience in practice and it can be both difficult and important to assess whether an algorithm is acceptable or requires modification.

Relationships that are expressed through algorithms are often, in practice, not fully deterministic in nature. In designing appropriate algorithms, the modeller could consider whether to include a random or stochastic component or to just test several discrete sets of alternative values.

4.8 On the Use of Random Numbers

Stochastic simulation models depend upon random numbers. There are a variety of random number generators available, both in computing literature and commercially. Leading software packages used for modeling and computational purposes often contain embedded random number generators. It is tempting to make use of these without further thought. However, some caution is necessary in this regard.

Random number generators do not in fact generate purely random numbers. These generators are algorithms and produce pseudo random numbers which at one hand pass statistical tests on randomness but on the other hand are generated by a deterministic procedure. The algorithms require an initial number as a "seed" in order to produce the next number. A large collection of numbers produced sequentially in this way will appear to be distributed in proportion to the probability distribution upon which the generator is based. In this sense, these are "pseudo-random" numbers.

In choosing a generator, the modeller should first be sure that the distribution upon which the generator is based is appropriate for the situation in which it is being used. Note that

most common generators are based upon the Uniform distribution over the unit interval [0, 1]. Generators for other distributions can typically be obtained by applying a specific transformation to the values produced by a Uniform generator.

Generators, being algorithms, normally are cyclic or have a fixed period; after sufficiently many values have been drawn from them, the values will repeat. In large scale simulations such as are being considered in this note, if the number of random numbers required exceeds the period of the generator, the numbers can no longer be considered to be random and the simulation would be greatly flawed. Therefore, it is essential that the modeller understands the structure of the random number generator, and is assured that the generator's periodicity exceeds by a considerable margin the number of random numbers that will be needed in any simulation.

In order to de-bug models and for audit purposes, one can re-run models to verify their results. In stochastic models, this requires the ability to reproduce the random numbers that are used in a particular simulation. Therefore, in designing and operating a stochastic model it is essential to retain the value of the initial random number generator seed used in each simulation and to store this with the results of the simulation. If a model involves internal branches which may require different numbers of random numbers to be used under different scenarios, it will not be sufficient to save only the initial seed; a more complex strategy will be required, usually tailored to the nature of the possible branching.

4.9 The Number of Simulations in a Stochastic Model

Internal models of an insurance enterprise are usually large and complex. Calculation of results under even a single simulation (which is likely to involve the model stepping forward over a number of sub-periods) can require considerable computing resources and extended run-time. It is therefore tempting to make use of a minimal number of simulations. The difficulty lies in the determination of how many simulations are sufficient.

Statistical literature contains numerous discussions on the number of simulations necessary to obtain a result with a desired degree of confidence. However, due to the complexity of insurers' models, the formulae suggested in such literature may not be applicable for such models. This point can be illustrated by considering stochastic models used in banking to price financial derivatives or to determine the Value at Risk for a book of assets held for trading. Simulations under these models can use in excess of one hundred thousand simulations and run in a very short time. This is possible due to the relatively simple nature of the model and the short projection period. Insurers' models, by contrast, often simulate an entire block of business together with the management of the asset portfolio supporting that business, and each simulation often covers a future period of several or many years. In practice, simulations for life insurance purposes often number in the thousands and in some cases a few tens of thousands, but not in the hundreds of thousands due to the significant computing resources and run-time required. For non-life insurance the number is more variable: there are at least some examples of over a million simulations being used.

The modeller needs to establish how many simulations will be required to produce a distribution of results that is sufficiently stable and reliable. In many cases, this will only be determined through empirical testing. For example, a rather unsophisticated method would be to run five separate sets of one thousand simulations each and then compare the results from each set with the others, and with the results obtained by combining all five sets in a single distribution.

Since an internal model developed for risk and capital management purposes will be used for studying the impact of extreme scenarios in the tails of the probability distributions, it will be necessary to ensure that a sufficient number of simulations are run to be able to place sufficient reliance on the results. For example, 1,000 simulations would not be sufficient if it were desired to estimate capital requirements at the 99.9% level, and might also be deemed inadequate for a 99.5% confidence level.

A number of applications are available for either reducing the variability of estimates derived using stochastic simulations (variance reduction techniques), or for concentrating on the tails of distributions by increasing the frequency with which tail simulations are selected.

4.10 Extreme Values

It may be advisable to supplement stochastic modeling by the testing of deterministically selected extreme scenarios (effectively a form of stress or scenario testing). The use of expert opinion should be considered in this regard. In this case it is advisable to review the events of a long enough time period such that some extreme events are included in the history, if possible. Additionally one should try to consider a long as possible period for the external economic components of the scenarios as well as for any needed catastrophe modeling. Examination of history will reveal that many “extreme” events occur with a greater frequency than is often inferred from casual observation.

5. Governance

As stated earlier in this paper, an internal model is fundamentally a mathematical model. However, when such a model is an integral part of a cohesive governance structure for the corporate risk management function then the internal model can also be viewed as integral to the company’s risk management system.

This section describes the governance elements important to the design and operation of internal models as risk management systems. These elements include:

- use test
- sufficiency testing
- change test
- expertise

- controls
- documentation
- review.

5.1 Use Test

The internal model itself can be a key governance tool to evaluate the risk and capital management of the insurer. Risk management practices are the primary defence in protecting an insurer against losses but capital is there to deal with the cases when losses do occur. For the use of internal models within a sound governance framework to be considered as a primary defence, regulators will likely require that the internal model satisfy a “use test” and be an integral part of a cohesive governance structure that includes internal models as well as other risk management functions.

Formula based requirements for capital tend to be conservative, in that they are intended to apply more generically, to a wide range of products and insurers. They can be considered to be derived from a simpler, standardized model of a typical insurer. Since internal models are normally expected to produce a more customized capital requirement than regulatory formula-based requirements, the overall level of capital produced, for the same underlying level of safety, is likely to be lower, due to the better precision of the customized risk calculation, than an industry derived formula. Consequently greater oversight will be needed of the quality of the actuarial control cycle, risk management and governance processes of the insurer. While the description of enterprise risk management (ERM) and its underlying governance structure for insurers is beyond the scope of this note, some aspects pertinent to internal models are noted below in this Governance section.

The reliability of an internal model is strengthened when used actively and pervasively as a basis for management decisions in areas such as:

- the monitoring and controlling of the insurer’s risk profile
- setting desired required capital, and capital management in general
- planning
- pricing of products
- performance measurement and hence management compensation
- management of policyholder dividends, rates and policyholder charges and credits
- evaluating the impact of possible corporate strategies.

While the specific assumptions used and the outputs produced may vary with the specific use of the model (e.g., risk assessment, asset liability management, capital determination etc.), having a core underlying model that ensures consistent use of assumptions strengthens the reliability of the model’s results.

Satisfying a use test is frequently required by a regulator before it will approve a model for use in the calculation of regulatory capital requirements. If an insurer is not confident to use, and is not actively using, the model to make decisions in managing its own business, regulators will not usually be prepared to base regulatory capital on the model outputs.

Depending on the regulatory requirements, it may be the responsibility of each insurer to determine which key risk factors the insurer is exposed to. In these cases, senior management will likely need to ensure that aggregate exposure limits exist and are approved by the Board. Senior management will also need to ensure that the limit-allocation architecture and reporting systems are such that the insurer is capable of ensuring that its aggregate exposure does not exceed established limits. This may include a formalized process by which proposed risk metrics are reviewed and, as appropriate, integrated into the risk management system and process. This may even lead to the allocation of limits to each part of the business to which the limits apply¹³.

The insurer's Board and/or senior management may be expected to have overall control of and responsibility for the construction and use of the internal model for risk and capital management purposes. They may also be expected to ensure that they have sufficient understanding of the model's construction, outputs and limitations as they are relevant for their impact on risk and capital management decisions.

Although the key methodologies and results of the internal model may be expected to be used pervasively in the risk and capital management of the insurer, this does not necessarily mean using the model in exactly the same form for each area of the insurer. Specific applications of the internal model may require some modification, in assumptions or methodology, appropriate to the application. Nevertheless, consistency should be maintained among the assumptions linked to similar phenomena.

While a full application of the model will likely be performed at least once a year, it is likely that a complex insurer would reassess its risks regularly during the year using the model as necessary. A reassessment of the risk position, possibly including a full recalculation, would almost always be expected to be performed when the insurer's risk profile changes substantially, which could happen in the event of a:

- merger or acquisition;
- discontinuation of a part of the business;
- change in business or investment strategy;
- successful introduction of a new product-line;
- significant increase or decrease in premium income; or
- significant increase or decrease in the value of assets.

¹³ An interesting implication of this risk limit process for regulatory review of internal models is when a company's risk limits are defined in terms of "the amount of loss that could lower the corporate credit rating. This is a stronger standard than the usual regulator standard to ensure that all policy obligations be met because it targets a higher safety level. This has led to the regulatory exploration of being able to leverage off a company's Own Risk Solvency Assessment (ORSA).

5.2 Sufficiency Testing

An insurer needs to be able to demonstrate through a range of “sufficiency tests”, both initially and during its on-going operation, that its internal model appropriately captures and assesses the risks of the insurer and the manner in which they are managed.

The “sufficiency tests” cover:

- conceptual sufficiency
- implementation sufficiency
- assumption sufficiency
- business data validation
- calibration
- strategy and policy compliance.

5.2.1 Conceptual Sufficiency

Conceptual sufficiency confirms that the model adequately covers the risks, risk management and other circumstances it is intended to cover. Each different risk and each risk characteristic (whether insurance, financial, or behaviour related, as well as mis-estimation, deterioration, volatility and catastrophe) should be covered explicitly or implicitly by the model, by explicit adjustments external to the model, or by other measures such as stress and scenario testing.

A useful model needs to start with a conceptually valid framework – that framework can be validated by external research notes or internal research. For example, while some published research supports an assumption that stock market returns behave more or less lognormal most of the time; other published research supports an assumption that distributions produced by other models such as regime-switching lognormal models are more appropriate when the tails of the distribution are of interest. And more recent research is showing how distorted results can be if the lognormal results valid “most of the time” are assumed to occur “all of the time.” This kind of decision on how to model the distribution of returns needs to be supported by strong evidence about why the adopted distribution was valid for the task at hand.

Likewise, there are numerous publications available describing reasonable approaches to modeling interest rate and claims volatility. Use of approaches other than those may be required to show some evidence as to why the chosen method is more appropriate than (or just as appropriate as) one of the conventional approaches.

Even when conventional or published approaches are being used, in a particular environment or in a particular application, a conventional approach may not necessarily be appropriate and the selection of approach will require some form of judgment to be exercised.

5.2.2 Implementation Sufficiency

This is the process of verifying how well the 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 are dealt with below:

Validate component calculations. To allow validation, models should be constructed to allow interim values, and the calculations that produced them, to be identified and analyzed. For example:

- Interest rates or stock market returns can be viewed on their own to confirm their reasonableness and the range of results generated.
- Cash flows can be output and validated against other, possibly deterministic models.
- Life insurance models usually generate various policy-level values such as cash values and death benefits. These values should be checked for consistency with other intermediate values at the same stage of the relevant simulation. Verifying against policy illustration systems is also a useful procedure.

Test simple case. Insurance experience under certain investment scenarios can be generated that are simple enough for the results to be checked manually or with spreadsheets. For instance, it could be assumed that interest rates will be flat and that lapses of life policies will be zero until the n^{th} year and then 100%. Failing such a 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. Features can be added to, or activated in, the model one at a time either separately or in combination. For instance, a model could be run with no decrements (policy terminations) and then decrements could be added one at a time. Each such change should produce 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, such results should be confirmed.

Test selected scenarios. A model should be built to allow the running of 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 stress tests (i.e., changing one assumption by a small defined amount) may still be a practical way to validate for reasonableness even if the various results cannot be reconciled exactly.

Check individual or extreme cases. Individual scenarios can be viewed for reasonableness. For instance, how do the simulation or scenarios near the 99th percentile compare to those near the 95th percentile? How do those near the 99th percentile 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 formulae that work well within a normal operating range may not capture management and policyholder behaviour in extreme situations.

Compare against 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 the differences should be explainable. For example, such a test might be to check that the model accurately reflects a change that was intended to be made and that by removing that change the model in fact reproduces the earlier result. The test includes confirmation that the elements of the model that shouldn't have changed did not change.

Compare to published factor models. Many regulatory factor-based capital formulae 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 that 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. For instance, aggregating product lines subject to different risks should normally show diversification benefits. On the other hand, where a key risk is economic, aggregating product lines that are exposed to the similar risks should not produce significant diversification benefits: if it does, the model may need to be investigated and the result explained.

5.2.3 Assumption Sufficiency

Assumption sufficiency is the process of confirming:

- the reasonableness of the assumptions selected; and
- the consistent implementation of those assumptions in the model.

Some approaches used to confirm the reasonableness of assumptions include:

- independent review of the assumption development and supporting experience studies;

- industry benchmarking; and
- backtesting.

Some approaches used to validate the consistency of assumption implementation include:

- independent review of coding;
- analyzing the difference between the calculation results with those arising from the use of a simpler (but similar) set of assumptions; and
- backtesting.

Industry benchmarking involves the comparison of selected assumptions with those used by other insurers and, where appropriate, the overall industry, to the extent that information is available. When there are significant differences from industry assumptions, there should be valid reasons that demonstrate that the risks are different or supported by different practices. For example, if the insurer's ratio of the mortgage loans to real estate values is generally lower than the industry average (resulting in lower risk and better loans ratings used in the models), this should be supported by specific insurer policies, operating guidelines, products and practices, and should represent better underwriting of loan risks rather than being the result of 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 back testing.

- The current model may either be run as at a historical valuation date using the corresponding in force data, or as at the current valuation date using current in-force data. If using a historical valuation date, allowance should be made for new business issued since then. If using the current valuation date, a life insurance model should usually have 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 should be justified, perhaps in terms of changes in practices, or that the future assumptions reflect a more credible representation than that reflected over the back testing period.
- Backtesting can also be used to validate that an internal hedging model can replicate observed market prices of options and futures.
- 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.

5.2.4 Business-data Validation

Data validation is the process of confirming the accuracy of the data used to populate the models. This section should be read in conjunction with section 4.4, which deals with the subject of “model points”.

Business data that have 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 usefulness and accuracy of the original data have not been impaired by any transformations or compressions in that other process.

The extraction of business data from administration systems, the validation of the data as being suitable for its purpose, and testing that the extracted data represent a complete and accurate¹⁴ 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 helpful if the same data extracts be used as the starting point for the model as those used for other purposes such as financial reporting and risk analysis, even if additional data compression is needed to meet runtime constraints applicable to the model. This helps assure consistency and quality, and can minimize effort needed to explain differences due only to different data extracts.

Control-total validation helps to confirm the continuity and completeness of the business data entering the model, as well as consistency with administration systems and other applications.

A model’s output should include key statistical totals (as they are material for model construction) such as number of contracts, volumes of benefit, and amounts of premiums, etc. These control totals should be available both before and after any compression techniques are applied, and as part of the outputs 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, which should be clearly explained in supporting documentation, and periodically validated.

Stochastic risk-assessment models may involve very long run times in order to perform a comprehensive risk analysis on a full portfolio of business. 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

¹⁴ This assumes that “complete and accurate” reflects the level of materiality needed to get reliable results.

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

When prior-date business data are used in a model, it is important that the prior date, and the method of adjustment of the results or data to the reporting date, be transparent to all users, and clearly disclosed in model results. The model should not be limited to a specific time period difference between data extraction and reporting but should be 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, when this is a material issue for the model purpose.

5.2.5 Calibration Test

As mentioned in section 4, calibration refers to the process of validating estimated parameters and assumptions used in the model to their real life values as relevant to the particular modeled circumstances at hand. To demonstrate that an internal model is fit for its purpose it is important that various calibration tests be carried out. For example, when using an internal model for regulatory capital purposes it will frequently be necessary to demonstrate that the parameters used are representative of relevant industry or market experience. In addition, such a model may need to demonstrate that it produces results consistent with the confidence level required by the regulator.

The sections Calibration-General and Calibration-Stochastic Projections in section 4 contain many criteria on which to base a calibration test.

Where a stochastic simulation model includes an ESG (whether as a separate module or built into the working model), when testing the calibration of the ESG it is important to test the ESG both separately and as part of the entire working model.

Deterministic scenarios can be used as an integrity check for an internal model by providing an assessment of the reasonableness of the outcomes of the model. In particular, scenarios leading to extreme losses can be used to assess whether the tail of the distribution generated by the internal model based upon stochastically generated scenarios is of an acceptable shape and density

In this type of test, one would choose a scenario that is thought to be particularly extreme. While it is usually not possible to assign probabilities to scenarios, one can make a judgment that a particular scenario is likely to represent, for example, a one in one hundred year event. Assuming for the moment that this judgment is correct, one would expect the loss resulting from this scenario to be at approximately the 99th percentile of the distribution of losses generated from the internal model. A comparison of this expectation with the actual position of the result in the distribution can provide confirmation of one's the model's integrity or cause one to re-examine either one's judgment as to the scenario's likelihood or the model and /or the stochastic scenario generator.

If one is confident as to the likelihood of each a set of deterministic scenarios, the results of these scenarios generated by the internal model can be used to construct or fill out the tail of the distribution of calculated results. This is, for instance, done in the standard model of the Swiss Solvency Test.

Reverse scenarios are an excellent means to assess the reasonableness of an economic capital models and its limits of applicability. In this approach, one could examine various percentiles of the distribution of results produced by the model, e.g., for the 80th, 95th, 99.5th and 99.9th percentiles. For each percentile, the capital required to buffer risk is then calculated. The risk manager could then formulate for each result a reverse scenario that describes a potential event that would have led to a comparable loss. One could then subjectively appraise the likelihood of these reverse scenarios and thereby come to a conclusion on whether the internal model delivers reasonable numbers. For example, if a rather mild and likely scenario corresponded in magnitude to the required capital calculated on the 99.9th percentile level, it would provide a clear indication that the model is not applicable.

Such integrity checks are important since in many cases, the methodologies and mathematical approaches used in internal models break down in extreme cases. Models are often calibrated (implicitly or explicitly) to normal situations (e.g., parameters based on past experiences without catastrophes, assuming unlimited capital mobility in consolidated models for insurance groups, etc.). Often these assumptions are not sufficiently clear to the users and scenarios can help find the limits of models.

5.2.6 Compliance with Insurer's Strategy and Policies

Model and Processes

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

The Board will likely want assurance 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 person. The mandate could cover assurances that:

- risk management models are being used in accordance with documented policies;
- the responsibility to ensure proper use of the models rests with a senior manager of the insurer;
- risk management models are reviewed, by individuals not engaged in the development or regular use of the models, for soundness and appropriateness, and that 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 modeled results from one period to the next;
- models are in compliance with the disciplined methodology appropriate for advanced models;
- models are consistent with the user manual for the modeling; and
- models reflect the insurer's actual operating practices and product features (for example, they reflect the hedging practices of the insurer).

Models are of most value when they reflect the insurer's actual operating practices and product features. For example, if the insurer is using dynamic hedging, then the modeling of the hedging program may well want to reflect the insurer's actual practices. In addition the tracking of the model over time may well want to evaluate residual risks arising from hedging strategies.

Results

The internal model is intended to provide appropriate information to facilitate the management of the insurer's risk positions within the aggregate risk exposure limits approved by the Board. The allocation of risk exposure limits and their relationship to the internal model will need to be clearly understood and documented by each business unit to which the limits apply.

The results from stress and scenario testing will likely be reviewed regularly by both senior management and the Board, and considered when establishing policies and limits. For scenarios that exhibit vulnerabilities, a discussion of appropriate management strategies to reduce or manage them will likely occur along with the model then being used to quantify the effects of potential strategies over the range of possible strategies.

Results from internal models can also be compared to financial targets and realized cash flows so any material divergence can be investigated.

5.3 Change Test

The change test is the process by which the insurer reconciles and explains the differences in results of the internal model from one run to the next. The change test is an important element of the entire control process.

If applied to a model producing an income statement, such a test might be described as a "sources of earnings" analysis. Such sources might include gains/losses (relative to prior model assumptions) from investments, claims, expenses, new business etc. If applied to a model producing an economic capital, such an analysis would seek to explain the components of change in economic capital.

If the model itself is changed in any way (e.g., model usage, algorithms, key assumptions etc.), or the surrounding organizational structure or risk management process is changed, then change management controls need to be in place to ensure the changes are approved, validated, and reconciled.

Selected validation tests should be performed on a periodic basis even in the absence of changes, to confirm that the results from the model are identical to those from prior tests.

5.4 Controls

Adoption of a model based methodology, specifically for capital management and measurement needs (as well as for regulatory/supervisory purposes), may well need to be approved by the insurer's Board after the recommendation of senior management and a review and/or sign off from an actuarial and/or risk officer designee/specialist?¹⁵ The approval would be made in the light of a good understanding of the application of the model and its implications in relation to the types of risk, level of exposure and risk management framework of the insurer, as well as of the regulatory/supervisory requirements for ensuring that appropriate capital management strategies are in place. The Board would then want to make sure that the relevant organizational structures and policies, together with adequate resources, are in place.¹⁶ This includes addressing the issue of the moral hazard if bonuses are based on the results of an internal model. This will likely warrant stronger governance around the model's design, parameter setting and usage (e.g., an element of model result sign off could involve a senior executive whose bonus is not based on results of the model).

For capital purposes, the model's development may be the responsibility of the CRO or a chief or lead actuary in charge of ERM issues and internal models for the company Actuary. However, in any case, were one exists, this chief or lead role would be responsible for the sign-off of an opinion on the application and results of the model. This role could then be responsible for the application of the model to insurance risks and for the aggregation of risks. However, the application of the model to asset risks and other business risks may also be shared between this role and the CRO, CEO or Chief Financial Officer (CFO) or delegated to others in the organization. All in all, the work of this internal model oversight role, the CRO and the CFO needs to be coordinated for the application of models in general.

The following items are important elements for ensuring security of the model:

1. Systems developed, changed and maintained in a controlled environment with limited user access.
2. A documented change control process.

¹⁵ For example, perhaps from both the head of the insurer's actuarial function (HA) and the Chief Risk Officer of the insurer.

¹⁶ For an excellent summary of this background, we recommend Section 2 of the IAA Note on Enterprise Risk Management for Capital and Solvency Purposes in the Insurance Industry

3. Access to inputting data, running the model and producing reports is restricted to a limited number of qualified personnel, but there is still sufficient separation of duties between these qualified personnel.
4. All data systems have adequate security and back-up capabilities.
5. Business recovery plans are developed, properly documented and tested prior to the use of the models for capital purposes.
6. Both short and long-term contingency plans are in place to address the potential inability to operate the models with a tested procedure for disaster recovery.
7. Qualified systems support is available at short notice to deal with technical failures.
8. A stored, "lock down" version of prior used models.

5.5 Accountability

Companies with formal ERM disciplines and/or strong risk management standards will likely gain value by clearly organizing the use of internal models to support and link the internal accountability to:

1. Identify and document the risks it has assumed, both on a gross and net basis.
2. Define the reports and measurements it will use to assess and manage its risk limits/tolerances.
3. Determine the frequency of the needed reports to ensure effective actions can be taken when needed.
4. Create the written responsibilities and accountabilities for each position in the risk management system and ensure they are clearly understood by all incumbents. For the internal models, this would include documented policies, controls and procedures covering, for example, measurement of capital, stochastic modeling, validation, and sign-off.
5. Document risk limit breaches, who was notified and which actions were taken.

5.6 Expertise and Tools

The capability and experience of senior management and other levels as well as approval bodies to assess and interpret risks should be commensurate with the complexity of the identified and measured risks. A model needs to be sufficiently understood at the various hierarchical levels, as do the limits of the model and the model's applicability within the insurer. While the use of the actuarial control cycle process¹⁷ by an internal model does enhance the specific risk knowledge, the insurer's general risk management will still benefit

¹⁷ Australian material on the Control Cycle can be found at:
http://www.actuaries.asn.au/Libraries/Education_ProfessionalDevelopment/FinalPartII_Syllabus.sflb.ashx

from being updated and renewed by continuous education and training of the personnel responsible for risk modeling.

The personnel responsible for a model would generally be expected to have:

- the ability to work in interdisciplinary fashion in the area of risk identification and assessment;
- the ability to adapt models and risk management systems to the most recent developments; and
- adequate resources and tools, including appropriate software.

The model and its implementation as an IT solution are intrinsically linked and often cannot be separated.

External resources may be used for any aspect of a model. However, they should satisfy the governance principles and practices within the insurer as well as any external professional and regulatory/supervisory requirements.

5.7 Documentation

Internal models require strict documentation of their structure, their contents, and their changes. Since results of these models may often form the basis for corporate decisions such as capital allocation, dividends, product design and pricing, the company will likely want to, at all times, be able to determine the state of the model and form a sound judgment as to its reliability and “fitness for purpose.”

Similarly, all algorithms relating components and assumptions in the model should be thoroughly documented. The documentation should also cover the testing of these algorithms. Changes to the model should also be thoroughly documented.

If a commercial software package is used as the basis of the model, the manufacturer’s manuals will form an important part of the documentation. When all or part of a model is constructed totally in-house, documentation of each step in the design and construction should be integrated into the construction process. Personnel who construct an insurer’s model will not always be available to explain its workings or make appropriate changes. It is therefore important to have complete documentation available so that others may carry out these tasks correctly.

Documentation enables the model user, the insurer’s senior management and control bodies as well as the supervisor to review the model and assess its conformity to any required criteria. Documentation may consist of:

- user manual for those maintaining the model
- log of all changes to the model for those doing audits and control checks

- Executive Summary of items relevant to the Board's and/or senior management's responsibility to oversee the management of the business. In particular, documentation has to be such that the Board, senior management and the personnel responsible for the model clearly understand the framework of the model, the methodology used, the underlying assumptions, and the limits of applicability of the model. These documented items could include:
 - the principles on which the models are built;
 - the general theoretical framework, (for example, what the models are attempting to capture, mis-estimation, deterioration, volatility, catastrophe, etc.);
 - the risks captured and those which are not;
 - the limitations and known weaknesses of the model;
 - the lines of business captured and those which are not;
 - the key assumptions (economic, policyholder behaviour, management action, risk mitigation, possible lack of liquidity in financial, etc.), how were they set and whether they reflect the insurer's actual risk;
 - the theory and mathematical basis for the model;
 - the techniques used by the insurer to meet the more difficult modeling requirements;
 - the approximations used;
 - define the validation, update, sufficiency testing and change processes;
 - the decisions that are made based upon the model;
 - the tracking error and/or actual to expected results and reports of the investigation of those results.

Different levels of documentation should be available for users, the Board, senior management, and for the personnel responsible for the model.¹⁸

The quality and depth of the documentation should be such that it would be possible for independent professionals to comprehend the major design decisions and, in principle at least, to reproduce the model's outputs with reasonable accuracy if all parameters and exposure data were available. In this context the independent professionals would be persons who have experience in building and assessing models for insurance or reinsurance companies and knowledge in the modeling of the relevant risks the insurer is exposed to.

As part of each internal and external review, the area of review, type of report and periodicity should be documented. Audit trails from internal and external reviews should be retained. The results of testing should also be adequately documented. For scenarios that exhibit vulnerabilities, a discussion of possible management actions is warranted.

¹⁸For a comparison, bank documentation includes the following requirements:

1. Name of report;
2. Who prepares it and how often;
3. Who receives it;
4. Exception reporting process;
5. List of actions taken based on exception reports

Documentation of the technology used should be complete and set out in a manner that supports the review and approval processes, whether the model uses “in-house” solutions or whether they are provided externally. It should include both contingency plans (what to do when problems occur with IT) and business recovery plans (how to resume use of the model after problems occur with IT).

Documentation is needed for all substantial model changes.

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 may need to be available for on-site audit or supervisory reviews.

Documentation also includes continuity planning for all material aspects of the model process including the inability of the software vendor to continue software support.

5.8 Review

The review process provides an effective independent challenge to those who build, maintain and use an internal model. It is an important part of ensuring the strength and integrity of the internal model, including the infrastructure of controls that are related to the model. In general, there are four types of reviews:

- internal review;
- external review;
- audit; and
- regulatory or supervisory review where a model is to be used for regulatory capital purposes.

Both internal and external reviews encompass all material aspects of internal models. The type and scope of reviews employed can, within limits, be insurer specific. For example, for an insurer 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 an insurer undergoes a thorough external review of the model, internal audit requirements could be reduced. In all cases, a minimum level of transparency is needed with respect to both types of review.

Review of both these types may need to be undertaken when a model is implemented. In the event 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 would then be documented and the effects on the output of the model disclosed. An audit trail would then be maintained for model and assumption modifications, including the rationale supporting the changes.

A review of substantial model changes could include, but is 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 any other reviews of some parts of the model.

5.8.1 Internal Review

Internal review involves the use of internal experts in an effective challenge role to provide an independent (of the model builders) assessment of one or more aspects of the internal model.

It can be used in conjunction with internal audit and its work be supplemented by any external review conducted. The mandate for internal review is typically clearly specified. Internal review is usually best targeted at the on-going review of data integrity and completeness.

The extent and frequency (normally no less frequently than external review) of the internal review conducted by the insurer will often be organized by internal audit and in exceptional circumstances by senior management itself. Internal reviews are typically triggered by a material change to the model, assumptions and processes.

Findings of the internal review are generally available for consideration by all users of the internal model including senior management and internal audit.

Internal review, at a minimum, will typically document the findings with respect to the following:

- the adequacy of the documentation of those parts of the risk management system and process that apply to internal models;
- the organization of the risk control unit as it relates to the internal models;
- the integration of risk measures produced by the internal model into regular risk management;
- 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 by the model; and

- the scope of risks captured by the risk measurement model;¹⁹
- the completeness of the process to update assumptions used in the model.

5.8.2 External Review

External review involves the use of independent external consultants in an effective challenge role to assess one or more aspects of the internal model.

It is used in conjunction with internal review and its mandate should be clearly specified. External review can be useful with respect to complex or sensitive aspects of the model to benchmark the insurer's internal model to industry best practices, and to vet major model changes. An independent external review of data integrity and completeness is generally conducted every few years by knowledgeable and experienced professionals.

The external reviewers are expected to be knowledgeable and experienced in the aspects of the model they are to review.

The extent and frequency of external review may be influenced by guidance from professional associations or the supervisor/regulator, but in the absence of self verification procedures, major aspects of the internal model would likely benefit from a review on a rotating basis at least every few (three, for example) years.

External reviews are frequently organized by the business unit responsible for the model. They can also be organized by internal audit and in exceptional circumstances by senior management itself.

Findings of the external review are typically available for consideration by all users of the internal model including senior management and internal audit.

5.8.3 Audit

This is a rapidly evolving topic and specific practices will be impacted by future regulatory requirements and expectations. However, the builders of an internal model will, most likely, need to consider that the inputs, formulas and outputs of the model must be testable (auditable) on a regular basis. For example, consider: a model in which there is a particular location where all the fundamental assumptions and scenario generators can be found is easier to audit than one in which these elements are scattered throughout the structure.

A model should be constructed so as to provide an audit trail. In particular, it is important that random numbers, or random number seeds, used in model calculations are tracked and saved with the results of the calculations in order that the calculations may be reproduced and verified.

¹⁹ An effective maxim here would be "follow the risk" to parallel the audit guidance to "follow the money". Risk cannot "disappear", it just gets transferred, as the participants in the subprime market have discovered.

5.8.4 Regulatory/Supervisory Assessment

In some instances, the regulator/supervisor may require approval of models as a condition of their use to meet regulatory requirements, or may rely on the approval of the insurer's Board. The supervisor will likely want to be satisfied that all aspects of the model are appropriate, satisfy regulatory/supervisory requirements, and are reviewed regularly. The regulator/supervisor has a number of options for doing their assessment:

- it can undertake part or all of the review;
- it can delegate part of the review process to external consultants; and
- it can decide that prior internal and external reviews along with continuing control standards are sufficient.

The choice of the type of review or reviews will depend on the specific situation of an insurer and the supervisor's discretion. Whichever type is chosen, there will likely be qualitative, quantitative and organisational requirements to be met that are defined by the supervisor before the model will be accepted and approved for use.²⁰ Beyond just being allowed for use, the feedback from the regulator to the modellers will be a useful way for the regulator to help accelerate the advancement of improved practice.

6. Communication

The development of internal models for an insurer's capital requirements is a complex task requiring a variety of technical skills. The key results from these internal models are very important to a variety of the insurer's internal and external stakeholders, helping them to assess the insurer's exposure to risk and its financial soundness (to name but two). These stakeholders will have a wide range of needs for information about the internal models, depending on their different perspectives and range of technical skills. It is crucial for the communication to focus on what the model results mean and how they can be used to make better strategic and operational decisions. The communication must inform stakeholders on their ability to rely on the model and its results. The numbers being produced by the model should not be the focus, as this is likely to engender over confidence in the model results and lead to blinkered vision about possible outcomes and options.

Good communication practices are essential in any work or business process. In the building and operation of internal models they help to ensure that:

- the models are constructed using sound economic principles;
- the models reflect the insurer's operating practices;
- the models use sufficiently accurate and relevant source data;

²⁰ This does not mean that the model is "correct" just because it has been accepted by the supervisor.

- each of the key stakeholders receives sufficient and appropriate information to meet their needs as stakeholders; and
- the reporting requirements of various stakeholders are met.

Failure to communicate effectively throughout the development and on-going operation of internal models can pose serious risks to the insurer. In the absence of good communication practices, internal models can easily be viewed by stakeholders as a “black box” or perhaps worse as being unreliable and not useful. For example, failure to communicate between the business unit whose risks are being modeled and the risk modellers will result in models which do not properly reflect the risks and risk management of the insurer. Failure to properly communicate the key assumptions, issues, and results to senior management and through public disclosure will result in lost credibility for the models and in the latter case perhaps even affect outside perception as to the value to be placed on the insurer’s shares.

Good communication practices are therefore essential for the sound and effective use of internal models for risk and capital management.

Some examples of poor communication:

- An insurer built a sophisticated internal model to manage its risks. One use of this model is to annually conduct a future financial condition report which is presented to the insurer’s Board. The purpose of the report is to identify significant risks to which the insurer is exposed and the potential impact on the insurer’s future financial condition. The report recently identified that market risk had the potential to breach regulatory capital targets. Unfortunately, in recent years this report had become viewed as a compliance exercise. As a result, when equity markets declined significantly, the resulting sharp drop in capital ratios caught the CEO by surprise.
- An insurer built a stochastic model for its variable annuity business with guarantees. The guarantees provided by these products provide a valuable option to policyholders in the event that equity markets decline. Lack of disclosure within the insurer regarding the severe sensitivity of capital to the impact of market declines on the value of the guarantees in these products caught the insurer off-guard. The subsequent adjustment of several model assumptions dramatically improved the model results but severely weakened the credibility of the model in the eyes of the regulator.

Some examples of good communication:

- An insurer with a sophisticated economic capital model recognized that an effective manner of presenting the results of its model to its Board was to provide the model results along with the results from certain specific economic scenarios with which the Board could readily identify. This enabled the Board to better position the insurer’s own economic capital position in comparison with recognizable scenarios.
- An insurer which had just completed the building of an internal model for its most significant risks recognized that the risk limits for its insurance products needed to be revised. The model results were used within a Board package successfully seeking changes to the risk limits.

