North American CRO Council

Model Validation Principles Applied to Risk and Capital Models in the Insurance Industry

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Section 1: Executive Summary

With the progression of computer technology, model development and use has increased. While models themselves have become more complex, the purpose of a model has remained the same: to estimate reality in order to provide insight into posed questions. For example, in the context of insurance companies, models are often used to estimate potential financial outcomes under alternative assumptions of the risks inherent in the business profile.

Relying on models to inform decision-making exposes a company to model risk. Model risk refers to the risk that a model is not providing accurate output, that a model is being used inappropriately, or that the implementation of an appropriate model is flawed. During and after the financial crisis of 2008, models were perceived to be ineffective in producing sufficiently severe outcomes, which has put increased scrutiny on model risk management.

While model risk management includes elements of model development and governance, model validation is a key area of research that can help mitigate model risk, and its important role in model risk management is the focus of this paper. Robust model validation can help provide internal and external stakeholders a level of confidence that a model framework is sound and that results, at some level, can be relied upon to inform decisions. The primary purpose of model validation is ultimately to help address the management of model risk. By mitigating model risk, the perspectives provided by models should play a larger and more credible role in helping to shape company strategies to achieve established objectives.

The North American CRO Council is a professional association of Chief Risk Officers (CROs) of leading insurers that seeks to promote key risk management principles, including that of model validation. Through the perspective gained from reviewing industry practices and the engagement of model validation practitioners both in North America and abroad, this paper strives to promote sound model validation practices. While the Council's intention is that these established principles can be applied to any model, the discussion that follows will be focused on risk and capital models in the insurance industry. Such models are a core component in an enterprise risk management framework and are critical for enabling CROs and others to perform their duties. This paper is intended to be a useful guide in applying validation efforts to a particular model as well as in helping with the development of an overall company validation process.

Key model validation principles laid out and addressed in this paper are as follows:

1. Model design and build need to be consistent with the model's intended purpose

2. Ensure that model validation is an independent process

3. Establish an owner of model validation

4. Ensure appropriateness of established model governance

5. Make model validation efforts proportional to evidenced areas of materiality and complexity

6. Validate the model components

    a. Input components

    b. Calculation components

    c. Output components

7. Address limitations of model validation

8. Document the model validation

In summary, the primary focus of this paper is model validation. In addition to initial validation of a new model, ongoing testing of model performance and revalidation are important aspects of model maintenance. Model governance-related issues are also touched upon, in particular through Principle 4, which addresses an effective framework with defined roles and responsibilities as well as the authority to restrict model use (i.e. policy and control-related activities). In general, distinct parties are responsible for these activities.

Typically, comprehensive model risk management adopted in the market includes the following elements: (i) model development, (ii) model validation, (iii) model governance and (iv) model use. A comprehensive approach to model risk management requires an effective approach to address each of these four elements. Again, the focus of this paper is limited to element (ii), model validation.

Section 2: Introduction

By addressing aspects of model validation, the objective of this publication is to provide guidelines to interested stakeholders (i.e. internal management, rating agencies, and regulators) on how to approach model validation and to gauge the credibility that can be assigned to a risk or capital model framework.

The general principles that follow are intended to be applicable to insurance company models and could help guide a company's internal procedures, policies and processes around model validation. It is important to keep in mind that resources used to address validation should be kept proportional to the materiality and reliance placed on the models used by the business. In the context of the principles, a "model" can be seen as a tool that uses pre-defined logic to arrive at potential financial assessments at various levels of the organization depending on inputted assumptions. With regards to the components of a model, these principles address inputs, the calculation engines, and outputs.

While these principles can be applied to any model, this paper applies the principles with practical discussion and examples to risk and capital models. These models are used to assess risk and the related capital needs for both individual risks types as well as their aggregation (e.g. an enterprise economic capital model). For example, categories of models that can be applied to the principles include:

- Catastrophe Risk Models
- Credit Risk Models
- Insurance Risk Models (i.e. underwriting, reserving, policyholder behavior, etc.)
- Market Risk Models
- Capital Models (i.e. aggregate risk models)

The principles are generally listed in sequential order such that a particular principle should be contemplated prior to addressing a subsequent one. In general, the more robustly these principles are applied, the greater the credibility that can be assigned to a model's output. Given capital models in practice are typically aggregate risk models, unless otherwise stated, the applications of the principles discussed will refer generally to risk models. The applications of the principles to specific types of risk models are thematically similar, except for Principle #6 which demonstrates how validation of the core model components can vary depending on the model type.

Section 3: Core Validation Principles

A high level summary and reference chart of the core validation principles can be found below. However, the reader is highly encouraged to read the accompanying background and detail that follow under each principle. The detail includes useful background context, explanations, examples, and applications that will enable the interested reader to apply the principles to a specific model or a company model validation process.

No.	Principle	Brief Description
1	*Model design and build need to be consistent with the model's intended purpose*	• Have clear understanding of problem statement model is trying to answer • Understand model limitations • Review and ensure connection with model logic and flow
2	*Ensure that model validation is an independent process*	• Understand model validation is separate from model build • An independent person or group should be responsible for validation
3	*Establish an owner of model validation*	• Single individual held accountable • Owner empowered to escalate related concerns and issues • Owner responsible for attesting, resolving, and reporting on model validation aspects
4	*Ensure appropriateness of established model governance*	• Validation focuses on relevant application of model governance policy • Ensure access rights are updated and refreshed • Consider alignment with internal audit
5	*Make model validation efforts proportional to evidenced areas of materiality and complexity*	• Define materiality and complexity • Align validation with time and resources needed • Incorporate balance between precision and timelines of results
6	*Validate the model components*	• Validate model input components • Validate model calculation components • Validate model output components
7	*Address limitations of model validation*	• Validation limitations should be recognized and made clear • Validation should connect with model limitations • Set priority for enhancements in the future for both model design and validation
8	*Document the model validation*	• Encompass aspects of preceding model validation principles • Ensure documentation is aligned with its usefulness to business • Validation is primarily about accountability, not documentation

1. Model design and build need to be consistent with the model's intended purpose

Fundamentally, models are constructed to make estimations of reality. In the context of insurance companies, models are critical for estimating potential financial outcomes at various levels of the organization under alternative assumptions. Useful models provide insight into what could potentially happen by answering hypothetical questions and providing meaningful information to a user.

Before beginning the process of validating a model, having a clear understanding of the business problem statement (or problem statements in the case of a model with multiple intended uses) that a model is trying to answer is important. For example, valuation models produce required regulatory-based reserves based on the specific characteristics of products owned by policyholders. By comparison, pricing models are fundamentally designed to assess adequate prices to charge based on the design characteristics of a product, the requirements of various stakeholders (e.g. regulatory requirements, shareholder profit objectives), and future expectations. Risk models are used to provide information about the potential change to a base level of expectations at a variety of levels within a company. CROs are tasked with understanding the risks that affect a company's success and, as such, often rely on these models to provide perspectives across the entire enterprise. These models try to determine for a particular cause or causes (e.g., interest rate movement, mortality event, weather phenomenon) the effect on baseline conditions. Particular baseline conditions can be defined in a multitude of ways, such as best estimate company derived expectations or based on the expectations required by a particular accounting convention. Unlike other models, risk models are primarily focused on determining measures of loss and profitability in a distribution of potential outcomes. The focus, especially in assessing capital needs, is often on the tail of the distribution which is driven by a particularly adverse event or series of events.

Risk models are designed to assess performance relative to an expectation at a certain level of the organization. Thus, the validation effort should review the connection of model logic and flow aligned with that purpose. These efforts should not be concerned with authenticating a risk model for an alternative purpose, such as performing reserve calculations for specific policyholders. Instead, the validation effort should be concerned with critical assumptions that could have significant implications for that model. In risk models, these critical assumptions will likely be more concerned with relative impacts to large groups of policyholders (or even product lines) than with granular or policyholder level accuracy. Risk models are inherently limited in their precision at a granular level because this is at odds with their intended purpose. Validation of risk models should be concerned with results across a wide spectrum of possibilities while other models may be focused on the output at a very specific and prescribed set of circumstances. While the level of precision may be relatively high when modeling tail exposures for single risks, aggregate capital models that combine risks may be less concerned with precision around a single risk and instead focus on the relative rankings of risk exposures.

Validation of a model also needs to be consistent and current with updates that are performed on a model. After updates are made, the validation exercise should be repeated prior to updated model results being relied upon.

2. Ensure that model validation is an independent process

The team that designed and built the model will often be heavily invested in the model being "correct." A model designer who is heavily engaged with specific calculation logic, parameters, or input to output logic flow may have a more limited perspective than one who is removed from the process. As a result, an independent model validation team should be established that is separate and distinct from the team responsible for the model design and build process. This independence can be accomplished through a single or combination of approaches, for example:

- When a model is both developed and validated internally, validators can be employees of the same company as the model builders, but should be drawn from a separate department or area of the company
- An external party could be hired to validate a model that was built by internal company resources (however, model validation is still ultimately the responsibility of the company even if it relies on a third party to perform the independent validation)
- An externally developed model could be validated by the internal company team that plans to use the model

While other approaches and combinations to achieve independence are possible, what is most critical is that an independent person or group is responsible for validation. However, model owners/builders are often closest to the intricacies of a model and should have their own validation processes. Therefore, in a sense, the independent valuation can be seen as a "second line of defense". The independent validation team needs to be qualified to do the work and sufficiently informed as to the model intent and rationale behind decisions related to the model design and logic. This will often mean the model's designers, builders, and validators will have similar backgrounds and will interact heavily prior to and during the validation process. These interactions should not be confused with the overall priority of maintaining independence in the model validation process.

When complete independence between the model validation team and the model build team is not feasible, at a minimum, the person to be held accountable for model validation should be independent from the model design and build processes.

3. Establish an owner of model validation

Model validators should be accountable for verifying the soundness of the model. As opposed to model builders and owners who have significant accountability for designing and applying a model that is aligned with its intended purpose, the model validator takes ownership of the model review process. In essence, the party or parties responsible for validation are signing off that the model does what it is intended to do and does so reasonably. As a best practice, a single individual should be held accountable for model validation. For example, this person could be the head of the validation team, a single validator (when one person performing validation is deemed sufficient), or a person from an independent third party (e.g., a consultant) who is assigned validation responsibility. While the assigned individual ultimately held accountable may or may not be directly involved in actually performing the validation work, he or she should have relevant and proper qualifications and possess sufficient authority to drive important validation decisions.

The individual accountable for validation should be empowered to escalate related concerns and issues to the appropriate parties who oversee or rely on the models. If the validation process is producing unacceptable results, draws negative attention to some aspect of the model (or the entire model), or is leading to disputes between model builders and validators, the validation team needs to be able to communicate this effectively to the appropriate parties, such as senior management. Whether internal or external to the firm, this need for escalation requires that the validation team and the individual accountable for validation are relatively independent of the model designers and builders as examined in the preceding principle. If significant rework or a rebuild of the model is required, that decision should be made by the appropriate senior level parties after receiving effective and unbiased input from the validation team. This process of escalating invalid results as a result of the validation effort is an important responsibility of the individual responsible for model validation.

Another key responsibility of the validation owner concerns the process of resolving issues arising through the validation process. Unreasonable model output can be the result of an inappropriate model design, invalid parameters, or unreasonable logic linking inputs to the model calculation engine that ultimately influences the output. At times, these deficiencies might be easily resolved by the model design or model building teams if raised directly with those teams. The ability to distinguish between a minor issue capable of easy resolution and a major issue requiring escalation to management is a required skill of the individual responsible for model validation. As issues arise through the validation process, the individual accountable for validation should be prepared to resolve these issues and make the critical decisions that drive the effectiveness of the validation process. Thus, the person in charge of the validation team will often be the logical choice for the individual owner accountable for model validation.

Ultimately, this person will not only be responsible for resolving and reporting on model validation aspects, but will be required to attest that the model has been properly validated. This attestation should be included in the model validation documentation discussed in one of the following principles.

4. Ensure appropriateness of established model governance

Reviewing the appropriateness of a model governance framework and ensuring it is properly established are important aspects of the overall model validation effort. While a comprehensive discussion of model governance is beyond the scope of this paper, a model governance policy should define the segregation of duties required as well as designate the group of individuals (either by name or by position) responsible for model usage, model maintenance, information technology (IT) support and other key model functions. Additionally, proper model governance should also include elements of senior management's involvement (e.g. capacity to take relevant actions, support commitment) as it relates to model implementation. Access to the model should correspond to particular roles within the model governance structure. For example, a complex hedging model may be subject to a relatively involved governance structure that defines owners, users, developers, testers, and IT support. Each involved party may have different access that corresponds to his or her function. In contrast, a simple model may not require a segregation of duties between, for example, developers and users.

This step of the model validation process should focus on the relevant application of the model governance policy and verify that model governance is aligned with the complexity and importance of the model as part of the decision making process. For example, in some circumstances, a single person tasked to develop, test and use a simple model may be appropriate whereas in other circumstances (e.g., where complex models produce enterprise risk calculations), this level of access applied to one individual may not be appropriate. Model validation should ensure access rights are updated and refreshed as people's roles evolve and confirm that any model life cycle considerations (e.g. version control, update cycle, change control) described in the governance policy is applied correctly. Validation should also consider that the segregation of duties and corresponding access rights as part of model governance are appropriately aligned within the life cycle stage of the model (e.g. creation, development, usage, decommission phases).

Ensuring the appropriateness of model governance is a similar task to those performed by internal audit departments or, where appropriate, Sarbanes-Oxley Act (SOX) control teams. Alignment between teams, frameworks and processes should be reviewed to ensure the correct personnel are assigned to the correct tasks and access levels. The exact nature of this alignment will depend on the scope and mandate of the various teams.

5. Make model validation efforts proportional to evidenced areas of materiality and complexity

The more the model build can balance complexity with pragmatism, the more useful the model can be in terms of informing decision-making. When applied to risk models or capital models that combine risks, this balanced approach to model building requires careful consideration as to the nature and complexity of the risks being modeled. For example, little is served if an insurer expends extensive resources modeling default and credit exposure in great detail when a majority of its assets are held in short-term liquid government securities. Given that the complexity of a risk is usually consistent with its intrinsic uncertainty, assessing the degree of risk complexity requires a review of related variables, such as a firm's operating in multiple jurisdictions, a risk's exposure being influenced by multiple drivers, and historical volatility characteristics.

Similar to the resource considerations given to the build of a risk model, resources devoted to the model validation effort should be prudently considered. Model validation should be targeted towards achieving a model that is useful and of high quality. Validating a simpler model will naturally be less resource intensive that validating a complex model. If the sophistication of a risk model build is aligned with the materiality and complexity of a risk, then the validation effort should be consistent with this established level of model sophistication. However, if a simpler model is built for a material and complex risk, then the validation effort should exceed the proportional sophistication level of the model. Complex models or those that model risks material to the company should require more effort to validate. Thus, the validation effort needs to consider both the complexity and materiality of the risks in question when deciding on how to allocate validation resources.

An insurer needs to define clearly and succinctly what is meant by materiality (e.g. via a materiality policy) and complexity when making decisions on how to approach the validation of a model. Furthermore, when designing and validating a model, evidence should be provided to support the degree of materiality and complexity that is in scope. Evidence that a risk is material and complex can be demonstrated when certain measurement criteria fall within company defined parameters or guidelines. While it may seem circular in nature to build and validate a model that is intended to assess risk based on preconceived notions of materiality and complexity, an insurer should see guidelines as evolving. For instance, expert judgment and historical experience may suggest that a risk that has demonstrated low cash flow variability or minimal adverse capital impacts and so has low materiality. While careful attention must be given to the current market conditions, defining materiality and complexity could initially be established based on company-specific and industry-wide experience to a risk. This criterion could then be used to define which risks are material and complex which ultimately can guide model design. Validation of the models could then be aligned and proportional to these evidenced areas of materiality and complexity.

6. Validate the model components

Validating the model components provides credibility to the model output as a representation of conditions that could occur given a set of inputs. A model that has been appropriately validated will position it to be useful for informing decisions. After all, a thoroughly and appropriately validated model provides credibility that a model is performing as intended and is able to meet its objectives. Before discussing how a model can be validated, care must be given when defining the components that make up a model. Before a model is validated, it can be helpful to distinguish between and specify separately the different components that make up a model. Further, it is important to understand those risks that are not addressed by the model, for example through the absence of critical data, and the potential impact on the model's intended business purpose.

This principle discusses the core components of a model, generalizes the validation considerations for each of these components as they relate to risk models or capital models that combine risks, discusses special considerations needed for vendor models, and finally, provides further detail relating to specific model types. When considering model validation, there should be a sign-off process (or validation process) for all material judgment, assumption, parameters and input scenarios used by a model. While peer review can be useful, there are occasions where this review can be subjective and may not be sufficient for rigorous model validation. Some models use input that is calculated from other models (i.e., upstream models). Since reliance upon non-validated input obviously poses risks, all upstream models must also be validated.

A model can be broken down into an input component, a calculation component, and an output component. The following sections address each of these components in turn. It is important to note that this paper is not intending to comprehensively cover all aspects and demonstrate all practical validation tests that can be performed as they relate to models. Instead, this paper seeks to provide insight into some specific aspects of model validation and their application to risk and capital models.

Input component

The input component is comprised of the data and assumptions that are brought into the calculation processes. In the context of risk models, the inputs will normally be comprised of policy data as well as the assumptions and parameters to be applied to that data. For example, to portray the exposures of a life insurance product to interest rate movements, the core inputs to that model could include both the policy data (e.g. face amounts, account values, riders) as well as algorithms that define the types and degree of term structure movements. In the cases where model inputs come from the outputs of other models, validation of those outputs should be performed (see discussion on model output components). A variety of validation aspects need to be considered when assigning credibility to model inputs.

For any risk model, the robustness of data relied upon will significantly influence the credibility of the assumptions that are ultimately derived. When dealing with data, definitions should be succinct and unambiguous to promote consistency and to enable proper trend analysis. When data is available, internal data underlying experience studies should be supplemented and compared to external data available in industry studies. While relying on internal data that is driven by underwriting standards is optimal, some reconciliation with external data can help limit any data anomalies. Similarly, as data is used to form estimations on probability distributions, these calibrations should be compared to relevant industry developed calibrations with explanations provided for material differences. There should be established basic data quality standards that address, for example, how missing values and data outliers are handled. Some acceptance will be required that at best, data will only be available to support the body of a distribution and not the extreme tails.

Another key aspect of input validation involves performing a static validation. Static validation of a model usually refers to reconciling the appropriateness of the policy or population data (e.g. in-force positions) to administrative systems. Any particular policyholder or asset groupings should not distort the actual and intended underlying population.

When applied to risk models, expert judgment must often be employed. With data limitations, careful consideration must be given to thoughtful plausible disaster scenarios that will ultimately drive the inputted risk driver assumptions into a model. In addition to looking at history, attention should be given as to how emerging conditions in the current marketplace can challenge historical observations. Peer review to the judgment provided by subject matter experts should also be conducted.

In summary, when applied to model inputs, certain types of practical validation tests should be performed, including (but not limited to):

- Static validation – policy or population data reconciliation with other administrative type systems
- Back-test established distributions – validate scenarios that drive the body of the distribution; more extreme tails with limited historical observations could consider how short-term shocks (i.e. 1 year) compare to less severe long-term movements (i.e. over 5-10 years)
- Reconcile risk driver distribution with other prevailing assumptions – for example, the distribution mean should compare to established best estimate assumptions; established adverse scenarios driving strategic planning should be compared to scenarios implied by distributions
- Benchmarking – compare inputs to appropriate benchmarks in the industry
- Expert judgment – applied and justified judiciously to challenge history, consider emerging developments, especially when dealing with limited data; as is practical independent experts should review opinions brought forth by other experts

Calculation component

The calculation component of a model involves the processing of the inputs into financial assessments. This component applies the model logic to the given inputs. This is distinct from the output component (to be further discussed) which focuses on transforming the calculations into relevant and useful reported output. As with the input component, in the context of risk models, there are a variety of validation aspects that need to be applied to the calculation component.

Validating that data is being transferred properly between the input and the calculation component is critical. Checks should be undertaken to ensure that particular input assumptions are driving the intended impacts to the policy or population data. Models that aggregate all risks should carefully take into consideration relevant cash flow interactions, such as those between asset and liability cash flows that can influence reinvestments. Similarly, calculations of risk exposures should consider, for the appropriate products, the ability to pass-through investment performance to the crediting rates of liability account values. Material or complex calculation and methodologies should be clearly documented to allow the appropriate validation.

Understanding the stability of a model necessitates determining how sensitive a model is to changes in key inputs, including the assumptions, population groupings, and methodology choices. Sensitivity testing seeks to determine how the calculation component assesses the impact from changing inputs. Even if the probability of an event cannot be determined precisely, understanding the degree of sensitivity the calculations have to the inputs provides insight that can be compared to expert judgment.

Dynamic validation should be performed to check the consistency between input assumptions and those derived from output across key scenarios. Dynamic validation is the process of analyzing how projected cash flows roll forward across a spectrum of scenarios and comparing that analysis to the originally inputted assumptions. Validating calculations through this process can provide confidence that the proper application of scenario parameters within the calculation module.

In summary, when applied to model calculations, there are certain types of practical validation tests that should be performed, including (but not limited to):

- Sensitivity testing parameters – test the accuracy of calculations to increases and decreases of parameters of key stress scenarios; validate alternative inforce groupings
- Dynamic validation – validate derived assumptions across spectrum of scenarios to the inputted scenario parameters for those scenarios
- Validate appropriateness of modeled behavioral (e.g. management, policyholder) actions associated with stressed scenarios produced by risk models
- Dependencies between lines of business – Ensure the model properly calculates the aggregation between product lines, taking into account risk exposure offsets or concentration effects

Output component

The final component of a model that requires validation is the output component. This component converts the calculations into meaningful analysis to ultimately be used in decision-making. Model output needs to be understood and relevant from the perspective of end users, especially if the results of the output could significantly influence strategic decisions. In the context of risk models, model output often estimates the financial impacts from a possible distribution of model inputs. As with the other model components, there are a variety of validation aspects that need to be considered when assigning credibility to the model outputs.

When validating model output, it is important to confirm consistency and alignment with other internal or external reports or reporting processes. Insurance companies, in practice, report financial conditions for purposes of determining reserve adequacy, deferred acquisition costs recoverability testing, operational cash flow analysis, and so forth. While it is beyond the scope of this paper to delve into the range of financial reporting in existence, reasonable reconciliation and comparison of the output from risk and models to reporting output for other purposes should be accomplished. A sound output validation process can explain differences between model outputs that are used for different projection purposes.

The exposure profiles generated from risk models should be compared to historical past experience. Validation would consider how loss exposures experienced in specific scenarios compare to those suggested by the model. Of course, this exercise would require employing proper adjustments for model population differences. Recent history provides a number of candidates (e.g. 2008 Financial Crisis, Hurricane Katrina, September 11th Terrorist Attacks, DotCom Bubble) that could be tested for the modeled and actual financial statement impacts. In addition to specific scenarios, back-testing should also include how the volatility of model output from distributions and over time compare with the volatility of actual historical reported financial performance. In addition to back-testing against one's own company, where possible and as deemed appropriate, analyzing the historical performance of peer groups can cast a wider net on comparing historical observations to model output.

Detailed scenario analysis should be performed on key scenarios driving exposures. A robust risk model allows a user to trace the losses to the scenarios or combination of risk driver movements that resulted in the defined losses. These scenarios should be reviewed for reasonableness by subject matter experts to determine if the scenario indeed represents a plausible scenario that could expose the firm to financial volatility. When dealing with the interaction of risk drivers, compounding or offsetting effects should be reviewed. When reviewing output under particular scenarios, the robustness of the validation effort will be enhanced if results can be demonstrated and reproduced using alternative means, such as with a high level Excel model.

In summary, when applied to model output, there are certain types of practical validation tests that should be performed, including (but not limited to):

- Historical back-testing – test the consistency of the volatility and stresses of historical financial performance to the volatility and stresses suggested by the model output
- Reconciliation with other reports – compare model output with output from an alternative projection system already in use to produce financial reports
- Prudent deterministic scenario analysis – validate the reasonableness of the movement in the risk driver(s) leading to key exposures in the model
- Contribution analysis – as applicable for the risk model or capital model that aggregates risks, analyze the reasonableness of the contribution to the total risk profile by lines of business, geographies, or any other key segments
- Parallel testing/version control – for particular versions of the model, ensure select output from models can be demonstrated and reproduced using an alternative model or high level tool

Application to vendor models

Certain risks, such catastrophe or economic scenarios, are often modeled using vendor-supplied algorithms or self-contained vendor models. While reliance on vendor parameters, algorithms, and models may shift some accountability from the principal users (i.e., the company relying on the vendor information or models) to the vendor itself, validation by the principal users is still required so as to assess whether the model is appropriate for the intended use and to check that model implementation is appropriate. Model validation aspects include inputs and outputs, and to the extent possible, the vendor-supplied calculation components. Vendor models are generally well documented and a thorough understanding of the logic contained in the model should be gained prior to putting any vendor models to use. At a minimum, some reasonability check is required to verify the output of the model makes sense given the inputs. Where possible, benchmarking of the model results to company experience should be employed. Investigation of any results deemed unreasonable and, if necessary, bringing these results to the vendor's attention for resolution, is a best practice. Under a consistent model validation framework, there should not be a different standard for vendor model valuation. Vendor models may be "black-box" models and rigorous validation is required to assess 1) that the model is appropriate for the intended use as proposed by business lines and 2) whether the implementation of the model in the vendor system is accurate.

In some cases, adjustments to vendor model output may be appropriate. Expert judgment regarding reasonable results, especially when those results are significantly different than unadjusted vendor model output, should be applied to bring vendor model output in line with appropriate use and purposes. Where applicable judgment and adjustments are applied, a thorough understanding of the reasons for differences between judgment-oriented results and those of the vendor model should be gained prior to applying any modifications. Furthermore, the basis for the adjustments and/or expert judgment should be clearly documented.

Specific considerations to specific model types

In addition to the above generalized considerations, specific considerations also apply which typically vary by the category of the risk model. The examples provided below are not intended to be exhaustive but rather to provide some insight as to the considerations required for a robust validation process.

	Input Component	Calculation Component	Output Component
Catastrophe Risk Models	• Geographical considerations on data granularity • Limitations in tail frequency (i.e. pandemic, terrorism) • Apply scenario frequency to emerging trends	• Reliance on vendor models • Risks specific to insurer • Testing impacts of multiple cat events	• Compare exposures to vendor models • Examine reasonableness by concentration exposures or multiple simultaneous cat events • Include non-modeled risks (e.g. inland flood) • Deterministic scenario analysis (historical & hypothetical)
Market Risk Models	• Derivation of ESGs (i.e. vendor or in-house) • Granularity of assets and funds • Testing of risk driver correlations • Influence of cross-risk drivers • Incorporation of emerging events	• Demonstrate appropriate pass-through of asset performance to liabilities • Assumptions on asset holding periods • Implied calculated Greeks compared to reported Greeks • Testing bias from grouping	• Back-testing • Deterministic scenario analysis (historical & hypothetical)Reconciliation to alternative regulatory reports

	• Market cycle consideration	assumptions • Impact of risk mitigation strategies	
Insurance Risk Models	• Reconciliation of different data sources (i.e. varying underwriting standards, internal vs external sources) • Reserving assumptions • Emerging trends • Address finite sampling • Use of predictive modeling for policyholder behavior assumptions • Interaction of behavior with market and other risks • Coordination with industry stress studies and data	• Sensitivity testing of long-tailed parameter uncertainty • Sensitivity testing of trends • Influence of underwriting changes or claim paying process • Reasonability of hand-picked scenario	• Impact analysis of reinsurance • Comparison of impact relative to other risks • Special back-testing review of policyholder behavior with exercising embedded options • Compare with prices underlying insurance linked securities for reasonableness • Deterministic scenario analysis (historical & hypothetical)
Capital Models	• Where relevant, reconciliation of output from risk models as inputs to capital model • ESGs that combine interdependent events • Historical basis for correlation assumptions • Reconciliation of correlations with industry research	• Fungibility constraints • Sensitivity testing between key risk categories • Reconciliation to risk model inputs at key sensitivities • Stress testing correlation assumptions • Testing impacts of multiple risk events • Management actions • Checks for potential double counting • Tax consideration	• Ability to explain drivers of capital at various key return periodsReconciliation with alternative capital frameworks (i.e. RBC, rating agency) • Where relevant, reconciliation of mean distribution results with baseline expectations • Deterministic scenario analysis (historical & hypothetical)

7. Address limitations of model validation

The validation process is a review process. Its objective is to limit the risk of improper use of the model and provide stakeholders a level of comfort as to the credibility of the model results. Validation operates under time and resource constraints while focusing on preventing material misstatement or misuse. As it may be costly to perform deep and thorough model validations on a frequent basis, some companies may need to supplement less frequently performed deep-dive model validations with more regular high level reviews. Companies can further address resource constraints by targeting detailed validation reviews in specific areas. For example, while model results and movement analysis could be reviewed on a regular basis, other aspects, such as data quality, expert judgment and parallel calculations, could be reviewed on a less frequent and rotational basis.

It is worth noting how insurers' financial statements are already subject to various validation processes, such as those involving the Sarbanes-Oxley Act (SOX) controls as well as independent audit reviews. Arguably, validation could be enhanced by leveraging SOX-type certifications. These established validation processes attempt to limit as much as possible the risk of reporting misstatements while recognizing that complete elimination of reporting errors is not feasible. Model validation is also limited in nature and will not completely remove model risk.

Establishing pass-fail criteria may be relatively easy in some aspects while being more difficult in others, especially when considering quantitative or qualitative criteria. For example, setting quantitative tolerance error and significance threshold is standard practice for extract-transform-load (ETL) processes where data is transferred from one system to another. In contrast, methodology choices are more judgmental in nature and are more difficult to quantify and validate.

Modeling is a representation of reality and inherently includes judgment. For instance, the translation of an experience study into a forward looking assumption relies on both actuarial and financial judgment with respect to the availability, credibility and relevance of underlying data. The calibration of risks that rely on a historical context (e.g. the 17th century Dutch tulip-mania, the Great Depression, the 2008 financial crisis) requires the application of both art and science as data limitations and methodology interpretations present challenges. The validation process needs to take these limitations into account when any model review is performed and make these limitations transparent to stakeholders using model results. Furthermore, the validation effort should review the appropriateness and effectiveness of the communication process that addresses these limitations. Reasonably ensuring a model is used to answer questions that it was built to answer is an objective of model validation. In addition, the scope of the model validation should be recognized and made clear to the model result users.

The validation process will undoubtedly discover areas where model improvement and robustness is needed. These findings should be included in the model development life cycle that seeks to implement future model enhancements which, in turn, will impact the future validation process. For instance, a validation finding may uncover that a model is being used outside of an appropriate applicability window (e.g., an interest rate model structure that is not compatible with prevailing low interest rates as seen in the current environment). These validation findings should prioritize model enhancements that modify the model design and address the deficiencies (e.g., build a regime switching model that can accommodate interest rates at both low and high levels). In turn, the validation process would require that new features would be tested and validation documentation be refreshed.

8. Document the model validation

Building and keeping up-to-date extensive documentation on every aspect of a model presents a challenge and may be misaligned with a model's usefulness to the business. Similarly, voluminous documentation of model output to support model validation may be at odds with validation's primary purpose. While model validation needs to be documented (including any aspects of sign-off procedures) in order to provide assurance it was adequately performed and that there exists an accountable validation owner, prudence should govern when determining documentation standards.

In essence, a sound validation document will encompass the aspects discussed in the preceding model validation principles.

Documentation of the assurance of model validation and other processes could look to other similar existing auditing processes in the financial industry. For example, an external auditor's letter to shareholders included in published financial statement for stock companies indicates that a review has taken place and that an audit team is accountable. In the US, the audit of financial statements follows the Generally Accepted Auditing Standards (GAAS) while international standards are set via the International Standards on Auditing. Similar to these processes, model validators should focus the documentation on articulating the model validation process, the findings, and the accountability considerations. Furthermore, as previously noted, validation has inherent limitations that should be documented and communicated. Proper and effective documentation enables model users to apply judgment with regards to the credibility and application of model results.

The documentation should address aspects of change management with respect to the extent validation testing is performed when underlying models change. Models are apt to change from both modifications in primary functionality as well in methodology. To the extent changes to models are tested to ensure they meet the principles outlined in this paper, the validation documentation should reflect these efforts. The documentation should clarify the change triggers that would cause the reexamination of a model. Furthermore, the model should be subject to periodic review to assess the intended usage against business requirements or market conditions, which could change from the time of original validation.

Model validation is the review of certain aspects of a model and applies judgment regarding appropriateness in the context of a model's objectives. In terms of an analogy, validation is akin to a legal case where supporting evidence is used to argue a point in a given context. Model validation documentation is primarily concerned with the recording of the model validation findings and its placement in perspective within the model validation process. It is akin to the court record of the lawyer presenting its case with evidence.

Section 4: Conclusion

Both internal and external stakeholders have struggled as to how much credibility they should assign to model output. As history has shown, overreliance on models to drive decisions can have devastating consequences. No model is infallible, and those who rely on models need to recognize those models' limitations. However, proper model validation can increase the credibility assigned to model output and the use of the model by the business.

This paper has attempted to establish standardized principles to be applied to model validation efforts that will be useful to relevant stakeholders. By gauging how a model validation process compares to the established principles in this paper, the credibility of a model can be more objectively assessed.

With increased global uncertainty, risk models that can correctly portray risks on the horizon and the capital required to withstand those risks are more essential than ever. Risk professionals are under increased pressure to establish robust risk frameworks with quantitative expressions of exposure being at the forefront. This paper has demonstrated the application of validation principles to risk models and capital models that combine risks, including some practical tests that can be performed, in the hopes that they help risk professionals achieve their goals. After all, models and their output should only be used and relied upon once stakeholders are convinced that reasonable measures to maximize their credibility are in place. Proper validation is such a measure, and its application should help increase the credibility assigned to the models we use.

Section 5: Literature Review and References

The topic of model validation is not new and has been discussed in a variety of published papers. While not intending to be an exhaustive review, research was performed in the area of model risk and model validation, but was limited to discussion on models that relate to the financial industry. The model validation principles established in this paper considered relevant discussed aspects in the reviewed literature. Overall, our CRO Council's perspectives of model validation principles are consistent with the external literature. The literature reviewed assisted in both framing the model validation principles expressed in this paper as well as providing reasonable assurance that the principles were complete in capturing the various aspects of model validation prevalent in the insurance industry. Specific references are noted at the end of this section.

Publications that were reviewed from insurance regulatory bodies include those from the Bermuda Monetary Authority (BMA), the Financial Services Authority (FSA), and European Insurance and Occupational Pensions Authority (EIOPA), the advising body to Solvency II. Companies subject to Solvency II regulation are permitted, with proper approval, to compute regulatory capital requirements using internal models. This approval centers on properly and thoroughly evidencing model robustness and validation. In the areas specific to model validation, Solvency II literature expresses the need to demonstrate validation with an independent reviewer, including addressing the frequency, depth, and scope of the model review as well as a follow-up process to close issues. Validation tests are expected to show that results are based on sound actuarial and statistical principles and, under Solvency II criteria, the ultimate output of the model calibrates to an equivalent 99.5% one-year value-at-risk (VaR) confidence level. While the BMA's published guidance on internal model approval is very similar to that relating to Solvency II, the BMA is not as prescriptive when relating to specific capital setting calibration criteria.

The literature review related to validation practices and expectations was also conducted in the banking industry, including publications related to Basel II and the Federal Reserve. As Solvency II borrows heavily from the principles expressed in Basel II, the model validation criteria of Basel II concerning data quality, documented internal validation processes, and so forth were found to be largely consistent with those of Solvency II. The Federal Reserve has also issued guidance on model risk management including specific discussion on model validation. The Federal Reserve's validation framework is articulated around the evaluation of conceptual soundness, ongoing verification monitoring, and outcome analysis. Unlike the insurance regulatory bodies which express required minimum criteria, the Federal Reserve's publications promote guidance in its discussions on model use and communication.

Rating agencies also publish writings on model validation principles and expectations. The literature review focused primarily on Standard & Poor's (S&P) model review criteria as it relates to their enterprise risk management review process. While the review criteria is evolving, the most recent publications discuss a specific "Testing and Validation" criterion that examines the extent capital model output is reconciled to company accounting valuations, is validated to the output used for different projection functions, and is analyzed for changes over time.

A final area of literature that should be reviewed for insight on model validation includes those from industry associations that frequently provide educational material for model practitioners. One notable paper reviewed was from the International Actuarial Association. This paper discusses model validation components, including testing selected scenarios, checking extreme cases, comparing a model against other models (both internally and any published factor models), and examining results at various levels of aggregation. Model validation efforts should also recognize the need for independent reviews and performing tests to understand alignment with any industry benchmarks.

Core publications reviewed:

Publisher	Description	Paper title	Internet Link
CEIOPS (now EIOPA)	European Authority: steps around model outputs	CEIOPS' Advice for Level 2 Implementing Measures on Solvency II: CP56, Articles 120 to 126, Tests and Standards for Internal Model Approval, 2009	https://eiopa.europa.eu/consultations/consultation-papers/2010-2009-closed-consultations/july-2009/consultation-paper-no-56/index.html
Financial Services Authority	UK Regulator: criteria when reviewing models	FSA Solvency II: Internal Model Approval Process Thematic review findings, 2011	http://www.fsa.gov.uk/pubs/international/imap_final.pdf
Financial Services Authority	UK Regulator: template of documentation	FSA Internal Model: Self-Assessment Template	http://www.fsa.gov.uk/static/pubs/international/sol-ii-self-assessment-template.xls
Bermuda Monetary Authority	Bermuda Regulator: steps around model outputs	BMA Standards and application framework for the use of internal capital models for regulatory purposes	http://www.bma.bm/SitePages/Home.aspx-tp-h_lmXYg
Bank of International Settlements	Central Bank Organization: Modeling best practices	Implementation and validation of Basel II advance approaches in Spain, 2006	http://www.bde.es/webbde/en/supervision/funciones/Documento_Supervision_Web_ingles_completo.pdf
Office of the Comptroller of the Currency	Federal Reserve - guidance on models to banks, supervised by the OCC	Supervisory Guidance on Model Risk Management, 2011	http://www.federalreserve.gov/bankinforeg/srletters/sr1107.htm
Standard & Poor	Rating agency – capital model review criteria	A New Level Of Enterprise Risk Management Analysis: Methodology For Assessing Insurers' Economic Capital Models	http://www.standardandpoors.com/prot/ratings/articles/en/us/?articleType=HTML&assetID=1245291726312
International Actuarial Association	Professional Association: modeling best practices	Note on the use of Internal Models for Risk and Capital Management Purposes by Insurers, 2010	http://www.actuaries.org/CTTEES_SOLV/Documents/Internal_Models_EN.pdf