Internal Model Industry Forum:

The Journey from Model Validation to Model Risk Management

February 2018

Internal Model *Industry Forum*

Supported by:

pwc

Milliman

Risk Dynamics

Institute and Faculty of Actuaries

LCP INSIGHT CLARITY ADVICE

EY Building a better working world

irm

Contents

Foreword

In order to gain approval for the use of an internal model, Solvency II, and indeed other regimes, requires insurers to perform independent validation to assess the appropriateness of the model for use and to help the Board understand the level of risk or uncertainty within the model.

As a result, the discipline of validation is becoming more established, but there is a growing feeling that it has been primarily focused on the regulatory capital models and the wider topic of "model risk management" has yet to be fully explored.

This paper recognizes a changing world and acknowledges that:

- **Models are essential**: The world is changing so fast, that statistical models based on long data series are not possible; in order to assess future risk amounts, we need much expert judgement, properly controlled.
- **Model risk is not (necessarily) the fault of models or modellers**: The fast changing risk environment means that models need strong governance.
- **Models are vitally important to the Board and senior management to inform a range of business decisions**: Models are necessary to assess the cost of future products, to assess the liabilities in the current balance sheet, and to assess the cost of risk and capital requirements, i.e. the biggest numbers in the company. Hence, strong model management is vital to the success of the company.

Model risk management as set out in this paper should be a valuable risk management tool. It should add value for insurers by helping them to understand and manage the risk within models used in key business decisions. While regulatory models have been a focus, we expect that to change. If this paper helps to broaden the discussion and debate around what is appropriate approach to model risk management, then we have met the objectives we set ourselves.

I would like to thank the members of our project team for their extensive work researching and developing the thinking in this booklet. Our IMIF Steering Committee provided overall project guidance and peer review.

We are grateful to representatives from the Prudential Regulation Authority (PRA) and the Central Bank of Ireland (CBI), who have enabled us to maintain a continuous and positive dialogue between industry and the regulators on our work.

I would also like to thank Risk Dynamics for their sponsorship of this paper. As a not-for-profit organisation IRM is reliant on enlightened industry support to help us publish documents like this. It is this kind of support that helps us maximise our investment in the development and delivery of world class risk management education and professional development.

Philip Whittingham BA (Hons) MBA ACII CFIRM
Chair, IMIF
Head of Model Validation and Risk Governance (including Operational Risk), XL Catlin.

Introduction

Model validation vs. Model Risk Management

Insurers have implemented internal model validation processes as part of their Solvency II IMAP, and this is now considered a "business as usual" activity in the industry. However, there is more uncertainty about what Model Risk Management (MRM) is and how it differs from the model validation process.

Fundamentally, **model risk management aims at ensuring that companies put in place the right level of controls for all material models supporting their business and decision-making processes**. In this context, MRM covers more ground than just model validation, although that would likely form part of the control environment. It considers model risk as a specific risk type, that should be managed similar to the other risks faced by insurers. This means that a thorough framework should be put in place to identify, assess, mitigate and monitor the evolution of model risk across the whole firm.

MRM addresses the entirety of a firm's model landscape, not just (regulatory) models requiring validation. For each model in scope, a sound MRM framework should define what is the right level of control required, which itself should depend on the impact the model could have on the business performance and reputation of the company.

A sound MRM framework is likely to include maintaining a model inventory that identifies who is accountable for each model and features each model's key characteristics. By clearly classifying models within the inventory, the efforts required to appropriately manage models can be determined in line with the model risk exposure and the risk appetite of the organisation. The inventory can also be used to capture risk mitigation actions taken in relation to models. As such, the MRM framework should improve the ability of an organisation to identify models that are not fit for purpose, allowing them to consider and prioritise the model developments required. Where this is not feasible due to time or resource constraints, further model controls or mitigating actions can be introduced to ensure no adverse outcome arises through use of the model. As a last resort, where significant uncertainty remains, insurers may consider the application of an uncertainty factor.

All three Lines-of-Defence have a role to play and the MRM policies should clearly delineate the responsibilities. These control activities will occur throughout the lifecycle of the model; from origination to retirement. A well-designed MRM framework should optimise the allocation of controls along the lines of defence and related functions, ensuring an efficient and effective control of model risk.

This paper recognises the latest developments around MRM regulation in the banking industry and forms a view on how these may be applied in a subtly different manner such that they remain appropriate, and maximise value, to the insurance industry.

Outcomes of poor MRM in practice – Tacoma Narrows

The Tacoma Narrows bridge was a suspension bridge that opened on the 1st of July 1940. During the lifetime of the bridge, it swayed violently in the wind. This was due to an effect known as "aerodynamic flutter" which was unknown at the time of its design. As a result of this, it hadn't been included in the engineering models of the bridge. A number of measures were taken to try to control the vibrations. However, due to a lack of understanding of the effect, they were unsuccessful. New models of the aerodynamics of bridges were developed, and a redesign of the bridge was proposed on the 2nd of November 1940. Unfortunately, this was too late, as the bridge collapsed on the 7th of November.

The bridge pushed the boundaries of design at the time, with a very slender deck. The failure to validate that the existing models still applied in these circumstances led directly to its failure.

Executive Summary

Given the growing risk posed by models, Model Risk Management (MRM) is becoming a key part of risk activities across financial services and is, an emerging discipline within insurers. MRM activities are expected to be of increasing importance to insurers in coming years.

This paper sets out an approach to the creation and application of MRM within a firm that encourages a risk based approach, specific to the individual firm's risks and culture with the intention of improving decisions. In particular, model validation functions and processes to date have been driven by regulatory requirements as opposed to a firm's own perception of model risk. This driver has created an inconsistency in the level of assurance undertaken for Solvency II Internal Models versus other models used to support key business decisions, that could be considered at least equal in materiality.

A wider model risk management approach aims to create consistency, supported by company defined materiality thresholds (based on company model profile and risk profile) and commensurate control principles for all models.

This includes classifying models so as to apply the appropriate level of discipline and testing to mitigating model risk. By integrating model risk firmly within a company's risk appetite, visibility is achieved and a proper level of attention can be applied to it.

Good MRM will allow firms to make the most efficient allocation of resources and maximise the benefit they achieve from their investment. A thorough approach to MRM will also allow insurance entities to refocus their effort across their business in a proportional manner, targeting key areas of risk which may have seen less focus in recent years due to the overemphasis that has been placed on the internal model by regulatory changes. In addition, careful consideration when setting a MRM policy should also ensure there is an enhanced level of efficiency around the model control framework employed across an organisation. Finally, a strong MRM process can lead to improved capital usage and more stable profits. As such, this can act as a competitive advantage for a firm. In addition, careful consideration when setting an MRM policy should ensure there is an enhanced level of efficiency and consistency around the model control framework employed across an organisation.

The recent consultation paper from the PRA on banks stress testing (CP26/17) puts a specific emphasis on model risk. Although the focus is currently on the banking side, it might soon extend to insurance as well.

Firms can take a lead on the practice of MRM within insurance through being proactive in developing MRM policies and reducing the impact of "bad" models which will ultimately lead to bad decisions.

Mercator Projection

The Mercator projection converts the surface of a sphere onto a flat map. It does this in a way such that straight lines maintain their bearing. This is important for sailors, so that they can tell what bearing they need to take to reach their destination. However, to achieve this feature, it stretches North-South distances at higher latitudes. As a result, this map is not appropriate for measuring distances or areas. This is an example of a model that is perfectly adapted for its original use, but is inappropriate for using outside of these limitations.

What is Model Risk and Model Risk Management?

Model Risk Management was originally developed within the banking industry. As a result, most of the definitions of model risk and model risk management come from this source. The most commonly used definition of model risk comes from the Federal Reserve's letter on Model Risk Management "SR11-7".

SR11-7 defines model risk as "the risk of adverse consequences (e.g. financial loss, poor business or strategic decisions, reputational damage) arising from decisions based on incorrect or misused model outputs".

Model risk management extends significantly beyond model validation. Model validation is just one control activity in the Model Risk Management process.

The following table highlights the main differences between Model Validation and Model Risk Management.

	Model Validation	Model Risk Management
Nature	**Control Activity**	**Control Process:** • Managing the model inventory • Setting overall model governance standards, e.g. development, testing and monitoring (including 1 LoD) • Ongoing monitoring of model risk • Reporting to the board on model risk • Managing committee authorizing exceptions for model use • Measuring model risk for capital purposes • Understanding model limitations • Appropriate responses to model limitations
Scope	**Regulated Models**	Material models
Responsibility	**2nd line of defence**	All 3 lines of defence
Testing	**Defined by Regulations**	Determined by Model Risk Appetite
When applied	**Mostly end of modelling process**	Throughout modelling process

The Benefits of Model Risk Management

Good model risk management can help **prevent losses arising from issues with models**. Such losses can be caused by problems in the model design, implementation or a lack of understanding of the model outcomes.

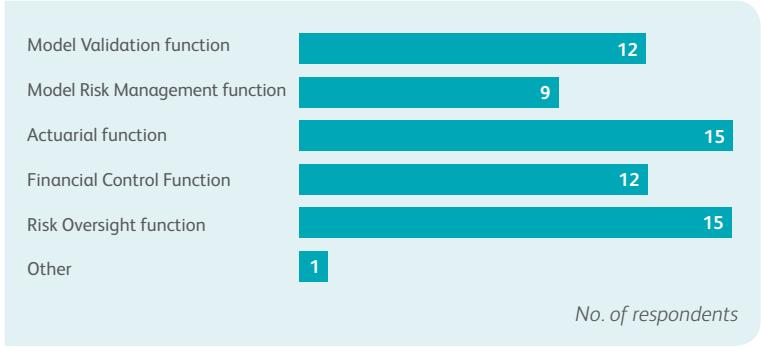
The following key benefits can be obtained through robust model risk management:

- **Reduced likelihood of poor decisions** – decisions based on the outcome of a model where the model is not fully understood may result in a misinformed decision being taken.
- **Holistic view of model risk, not solely confined to regulatory models** – widens the scope of consideration to models that are not subject to regulatory requirements but may still materially impact the business i.e. helps broaden the view of model risk beyond the capital model.
- **Maximise cost/benefit allocation of resources** – can identify areas where the most benefit will be obtained through model improvements or where the addition of a new model or control may be beneficial to an organisation which in turn will ensure resources are allocated to the areas yielding the greatest overall impact on the business.
- **Embedded understanding within the culture of an insurer that models are inherently risky** – will lead to better communication with stakeholders.
- **Improved control efficiency** – improved understanding of the model control framework will allow identification of potential duplications or inefficiencies (e.g. excessive use of manual procedures) across different regional offices, business unites or teams that can then be addressed. Ensuring that control levels are consistent between business units will also help to reduce risk.
- **Greater understanding of model assumptions, limitations and output** – will help ensure appropriate conclusions are drawn from the models and reduce the likelihood of models being used to influence decisions in situations where they are unsuitable.
- **Capital benefits** – better informed view of capital buffers, reduced capital requirement through lower likelihood of uncertainty loadings.
- **Increased confidence in the business planning process** – through reduced volatility in the capital calculations and greater confidence through better informed planning assumptions.
- **Portfolio optimisation** – due to a more accurate estimation of risks.
- **Prevent issues occurring, before they arise** – There is a natural human tendency to prioritise models which have recently caused problems. Strong MRM should improve the ability of an organisation to spot potential problems at an earlier stage, allowing remediation activities to take place, minimising the future impact on the bottom line.
- **Improved operation through better documentation** – a consistent approach can be taken across an organisation, ensuring documentation exists and is proportional to the models considered.
- **Enhanced reputation of the overall risk management function** – MRM feeds into the overall approach to managing risks within an organisation which can in turn influence credit ratings and the ability to retain and attract new business.

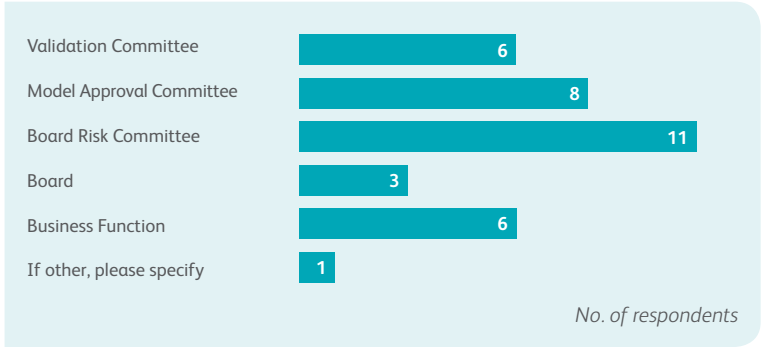
The Current State of Model Risk Management

As part of the preparation for this white-paper, we surveyed a range of insurers, with annual Gross Written Premiums ranging from less than £200M to more than £20B. Their operations spanned Life insurance, Property and Casualty, Pensions, Asset management and Banking. The companies span the globe between them, with every major market covered.

Which model control functions does your company have?



Who is responsible for approving models (initial and ongoing)?

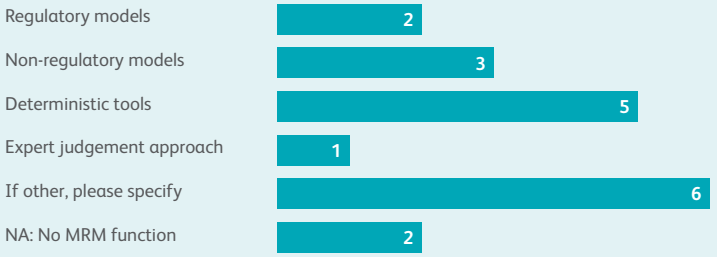


Almost all the respondents had actuarial and risk oversight functions involved in Model Risk Management activities, as well as the model validation and financial control functions. All companies had some form of oversight over MRM, but the seat of this varied considerably. In most companies, the Board Risk Committee is responsible for approving regulatory models and providing oversight. A model approval committee is also a common source of governance. In the case of non-regulatory models, the approval process may take place at a less senior level with sign-off from a change board, function head or equivalent.

A clear area of focus for some companies was expanding the scope of MRM to encapsulate more than current regulations (e.g. Solvency II) require. However, other companies where MRM was more established are looking more at the efficiency and effectiveness of the MRM process.

Several companies consider regulatory models to be outside of the scope of MRM. This may be due to the desire to maintain a separate framework for regulatory models such that the standard for MRM around non-regulatory models is one that suits the requirements and reflects the individual risks of the firm, rather than to pass a regulatory hurdle. Another instance where this may be the case, may be in relation to models such as the standard formula for Solvency II, where the model is predetermined. This makes perfect sense; however, we would expect to see some form of testing of the implementation of the model. For instance, a common control environment would reduce the risk that the data-sets or assumptions used were inconsistent. This is confirmed by the fact that nearly all companies apply model validation to regulatory models. There is a wide range of approaches to model validation, including companies which apply model validation to immaterial models.

What type of models are considered out-of-scope for the Model Risk Management or Validation function?

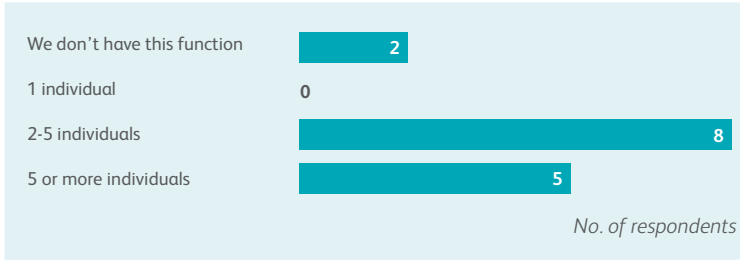


In terms of priorities for MRM, validation of new models and process efficiencies were frequently mentioned. A number of companies are still looking at regulatory approval as a priority.

Most companies reported group MRM functions (where they existed) of 2-5 people. The companies employing the most people in MRM across the company are also the most likely to be considering a decrease in headcount. This contrasts with the general trend, which is one of status-quo or an increase.

The most common skills required for MRM were Actuarial and modelling, with communication skills another strong requirement. Relatively few companies saw the ability to challenge or to have a holistic understanding of the business as important.

What is the size of your group model risk management function?

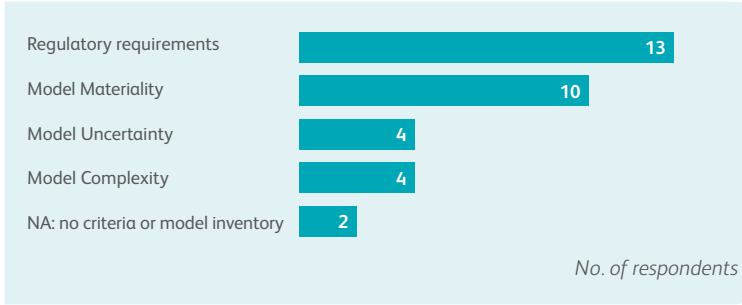


All companies use internal, on-shore staff for model control activities, with about half using external staff in addition.

In terms of whether a model is included in the scope of MRM, regulatory requirements and materiality are the most frequent model determinants, with other considerations being significantly less common. Model materiality is typically determined by its exposure, application and use.

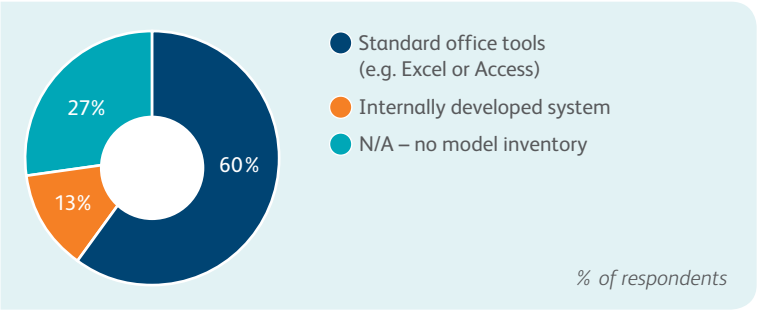
The activities performed as part of a model review naturally varies with the intensity of the model review. For a high-intensity review, back-testing, reviewing model governance and documentation are the most frequent activities.

Which criteria are used to determine the most relevant models (to be included in the MRM scope)?



Where a model inventory is kept, this is typically in standard office tools, with a limited number of companies having their own, internally developed systems. The use of vendor systems, whilst available, is not widespread.

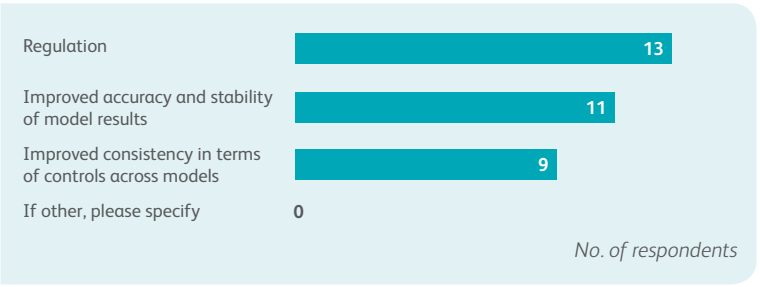
What system(s) do you use to maintain the model inventory?



Only a quarter of the companies in the sample have model risk metrics linked to their statement of model risk appetite, with the others not reporting on model risk, or only doing so qualitatively.

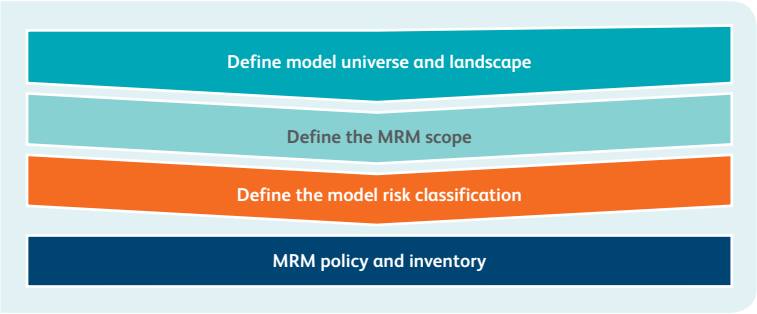
A large number of respondents considered improved accuracy, stability and consistency of results as being a driving force behind MRM. It is good to see that most companies do not just see MRM as a regulatory requirement and expect to gain business benefit from it.

What is the driving force behind Model Risk Management for your company?



Developing the Model Risk Management Framework

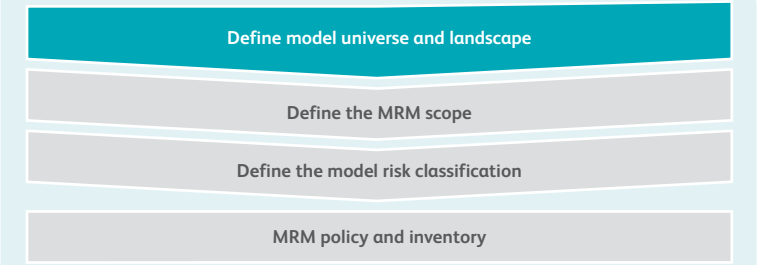
Developing the MRM Framework



Each firm will want to develop a Model Risk Management (MRM) framework that is in-line with its general risk management and governance processes. Despite specificities in implementation due to a company's culture, there are however significant commonalities between the approaches taken by different firms.

Define model universe and landscape

Developing the MRM Framework



What is a model?

Many insurance companies use informal definitions of models, and rely on judgement as to what is or is not a model. Despite this, it is helpful to have a more formal definition of a model, as this helps prevent disagreements about whether a tool is a model or not, and therefore whether it requires a full governance process. A commonly used definition is that provided by the Federal Reserve's SR11-07:

"The term model refers to a quantitative method, system or approach that applies statistical, economic, financial or mathematical theories, techniques and assumptions to process input data into quantitative estimates. A model consists of three components: an information input component, which delivers assumptions and data to the model; a processing component, which transforms inputs into estimates; and a reporting component, which translates the estimates into useful business information."

How is the model universe identified?

Key to being able to apply a model risk management framework is the ability to identify the models being used in the company. The first approach is a bottom-up approach, which looks at each of a firm's quantitative tools being used in all its processes, and then decides whether they are models, and progressively builds this inventory. The second approach is a top-down approach, which starts from the measures being used by management in their key decision making and identifies all the models that are used to produce these measures. By drilling down through the chain of models (as there are dependencies between models), an inventory of the most material models can be built.

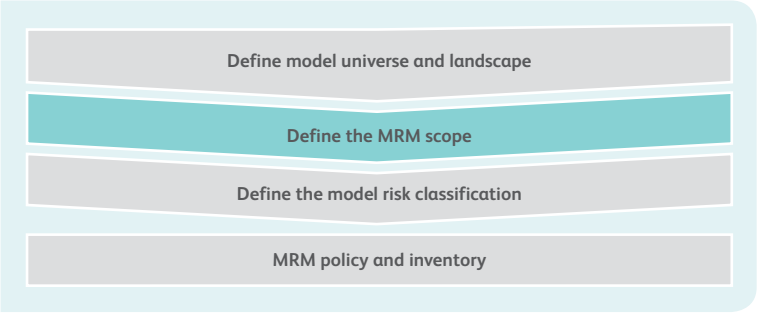
The top-down approach has a number of advantages. The first is that it is much more efficient to quickly obtain a good understanding of the most material models for the company, including their relationships. It is also not prescriptive in terms of categories of models to scope, as it is based on actual use in key decision processes.

The bottom-up approach in theory provides a comprehensive coverage of all models, but may be more onerous to deploy. This approach is mandated for large institutions within the U.S. banking industry to structure their model inventory, and has resulted in significant volumes of work. One important factor to note is that even when applying a bottom-up approach, some models may still be missed perhaps as a result of new models not being added to the inventory at the point at which they are deployed or models simply not being adequately identified during the discovery phase.

In conclusion, a bottom-up approach requires more work than a top-down one, but a top-down approach is possibly more focussed. When selecting the approach to follow, organisations should ensure that all activities are helping to improve the overall risk management approach while maintaining the most appropriate cost/benefit ratio. In addition, it is vitally important that the inventory is kept under regular review to ensure it remains up to date and the full benefits of MRM can be achieved.

Define model risk management scope

Developing the MRM Framework



This paper proposes that all of a firm's models should be within the scope of MRM. This avoids disagreements about whether the policy applies to a particular model or not. The policy should be set by firms in a manner that allows them to effectively apply and manage their controls framework through a principle based approach with specific reference to their own view of risk and materiality. The policy should ensure that the level of controls applied to each model remains proportional to the risk it presents. By classifying models within the framework, the effort required to implement MRM can be fitted to the need for it. By having non-onerous requirements for the lowest risk or materiality level model, there can be little disagreement about the inclusion of any particular model.

In order to best fit within the firm's governance framework, it is likely that the MRM policy will cover the responsibilities of each of the three lines of defence.

The MRM policy should cover all stages of a model's lifecycle, from origination through development, validation, deployment, monitoring and replacement. The Risk or CRO function will own, monitor and report on the overall MRM policy. The implementation of the policy including the creation of more detailed policies and development standards will be with the various model owners.

The policy should also define core principles guiding the governance of models, typically along the following dimensions:

- **Responsibility** – each model should have a single owner, ideally this accountability should reside with the final users of the model (and not necessarily the developers).
- **Explainability** – the model outcomes, including their dynamics and limitations, should be understandable by the model users.
- **Accuracy** – the accuracy of the model outputs should be tested, in proportion to its materiality.
- **Auditability** – interested third parties should be able to probe, understand, and review the behaviour of the model through disclosure of information, including through provision of detailed documentation and/or permissive terms of use.

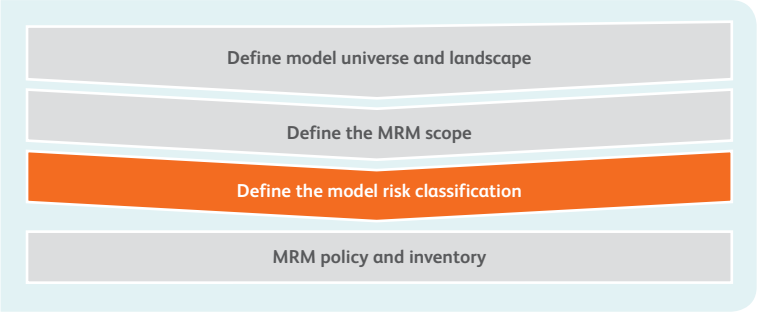
The use of models and their results should be controlled by the MRM policies. Ideally, each model should have a list of approved and non-approved uses. However, it is understood that this in itself can become a time-consuming exercise and as such, over-arching policies may be useful to define the uses of groups of models.

It is expected that all the above principles should be implemented with proportionality, which should itself depend on the relative importance of the model considered, represented by its classification.

To govern the operational aspects of MRM, insurers may wish to rely upon the overarching principles laid out in the MRM policy itself or alternatively put in place sub-policies that will provide further guidance at a more granular level for specific groups of models. The ultimate decision as to whether sub-policies are required will reflect the individual culture of each organisation.

Define model risk classification

Developing the MRM Framework



The classification of models within the model inventory should enable models to be subject to a level of control appropriate to the level of model risk arising from them. This could involve defining a formal risk score or a more 'high level' model risk ranking. The ranking should be linked to the risk of losses arising from deficiencies in model development, implementation or misuse. Mitigating factors for model risk such as model development, model controls or uncertainty factors should be deployed relative to this classification. This will ensure that resources allocated to model controls and development will be deployed in an efficient and effective manner.

Outcomes of good MRM in practice – Delta Works

A study done by the Dutch Rijkwaterstaad in 1937 showed that the flood defences of the South-West River Delta were inadequate to withstand a major storm-surge. Instead of building protection sufficient to deal with past floods, the Delta works commission developed a new conceptual framework. Acceptable limits were placed on the probability of flooding in different areas.

Following the devastating floods of 1953, the plans were revived and a comprehensive system of defences was developed.

Although building of the system was completed in 1997, regular reviews are conducted to allow for changing circumstances, such as climate change induced sea-level rise.

Due to the comprehensive model development and sound model risk management, there have been no breaches of the system to date.

Often, models are classified according to their materiality, complexity and/or regulatory scrutiny.

The model materiality is typically assessed through a combination of business exposure (the relative size of activities that are covered by the model) and of its use (whether the business processes are more or less reliant on the model outcomes).

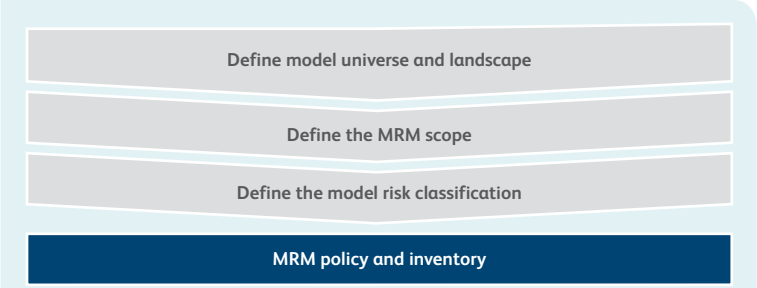
The complexity relates to the nature of the model design (e.g. sophistication of the techniques and/or number of assumptions) and/or of the overall environment (e.g. data/process flows) in which the model operates.

Separate classifications can be set aside to meet regulatory requirements, for instance, there could be a specific classification for the Internal Model and those that feed results into it.

Where models have been classified within the MRM framework, there should be regular reviews of the classification, so that the classification remains relevant. These reviews should take into account changes in the business environment and use of models, as well as any coding or data changes.

Model risk management policy and inventory

Model risk management policy and inventory



As previously mentioned, a robust MRM framework requires establishing an inventory of models. Aside from listing each material model, and its classification, what additional information is useful in the inventory?

Any data which has been used to classify each model is useful, and should this information change, will likely drive a reassessment of the model classification.

The model owner and developer is also valuable, as are links to the relevant documentation. With these included, the inventory can be a living document that has clear business uses beyond the need to comply with the MRM policy.

Any processes that the model is used for, and whether these are regulatory or not is required for the classification of the models.

Part of the model risk management framework will be a regular review and revalidation of the models. The frequency and dates of these reviews and revalidations should also be noted in the model inventory. Likewise, the inventory could contain a view on all the past findings issued on the model (coming from the internal validation, the audit or supervisors).

The capture of dependencies between models is a clear ancillary benefit of inventories. For instance, if a capital model uses the results of a reserving model, then the model risk for the latter is clearly dependent on the former. Having a clear view on these dependencies is an important mitigant of model risk.

In complement to the models' inventory, a centralised assumptions process could enable appropriate controls around the assumptions of a firm's models. This would help to ensure that the firm's models are consistent and robust. Another advantage of this approach is that it will simplify the review and approval process.

Finally, a robust MRM framework should define clear risk appetite statements and derive them into manageable indicators. This can help reporting on model risk exposure, how this risk is being mitigated and facilitate the integration within the reporting of the firm's other risks. Such indicators could be produced based on statistics derived from the inventory (e.g. number of models having been reviewed, number and type of findings opened, frequency of reviews, timeliness of remediation, etc.). Whilst each organisation should create a risk appetite statement unique to their own view of risk and materiality, this paper recognises that this is not straight forward and will require careful consideration. The following example provides an illustration of what a group MRM risk appetite statement may look like.

"We have very limited tolerance for model risk where inaccuracies would result in poor decision making, material financial misstatement, disruption or delay to disclosure of results, widespread customer detriment, or impact the reputation of the Group. However, we accept that we cannot completely eliminate the risk and are prepared to tolerate a degree of model uncertainty, provided it remains within pre-set operating ranges.

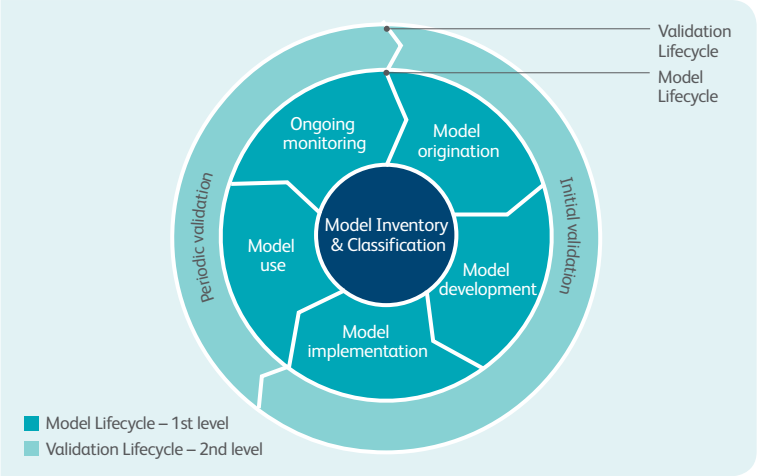
We will set minimum standards for the documentation and operation of financial models, which must be followed to mitigate higher than acceptable exposure."

Regarding a clear example of a model risk appetite we also refer to the Delta works example discussed previously. Following the 1953 flooding the Dutch government had a low risk appetite for future large scale flooding and hence the Delta works commission developed a new conceptual framework reflecting this risk appetite. Acceptable limits were placed on the probability of flooding in different areas. As mentioned previously no significant flooding has occurred since this framework was put in place.

The ongoing Model Risk Management Cycle

Once the framework has been established it is important to develop a robust cycle for MRM. This cycle should ensure that each model adheres to the MRM policy in the sense of when the reassessment of risk takes place as well as how, when and to where the results are ultimately reported.

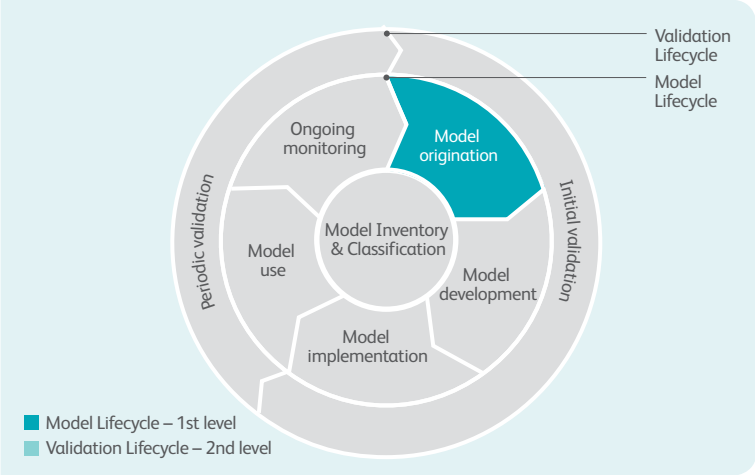
The Ongoing MRM cycle



The diagram above provides an illustration of how the ongoing MRM cycle may look with a possible distinction between lines 1 and 2.

Model origination

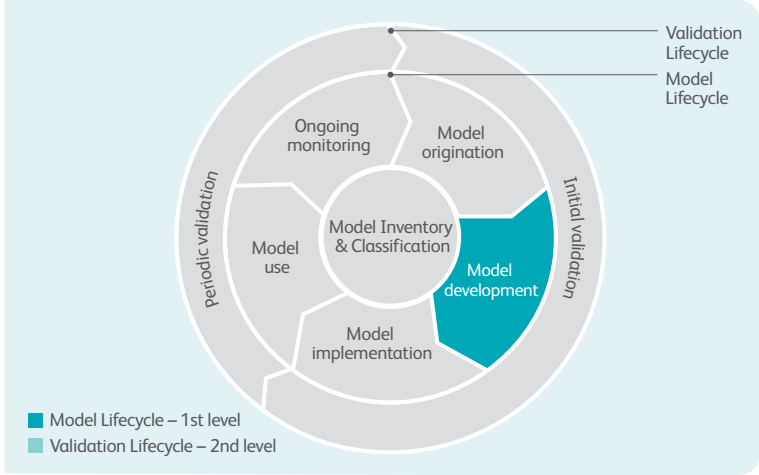
The Ongoing MRM cycle



Each model should have a (business) owner and a clearly defined purpose. As such, this should be determined as part of the model origination. The model requirements derive from this purpose and should be drafted under the responsibility of the model owner. When determining these requirements, the mitigation of model risk should be considered. In certain circumstances or organisations the validation may issue a non-binding opinion regarding the proposed model. However, this opinion should not influence the validation to be performed at a later stage.

Model development and initial validation

The Ongoing MRM cycle



When considering the development of a new model, the model developer should define acceptance criteria with the model owner (i.e. "how good" the model should be). The criteria should be defined with reference to the overall MRM policy and specifically, the risk appetite statement and materiality set by the risk function. The model risk function will then review these criteria with the developers and model owner, acknowledging that "over-engineering" and "gold-plating" a new model to meet the perceived requirements of the risk function add costs to the business without necessarily reducing model risk. Equally, a model design which is incapable of meeting the requirements of the MRM process will waste development effort. Compliance with the criteria should be confirmed by either Validation or, in the case that the model is not subject to direct validation, the Risk function. The MRM framework should set out when the Model Risk function is involved in the modelling process and hence, this also does not necessarily mean that they will be involved in the review of all models. This is likely to be done on the basis of the materiality and complexity of the business decisions that the model supports.

By reaching early agreement, the development and validation efforts can be optimised to the requirements of MRM.

A robust MRM framework, which considers model risk from the start of the process, and making sure that testing is appropriate, expensive failures can be avoided. It can be too expensive, or too late to rectify errors later in the process.

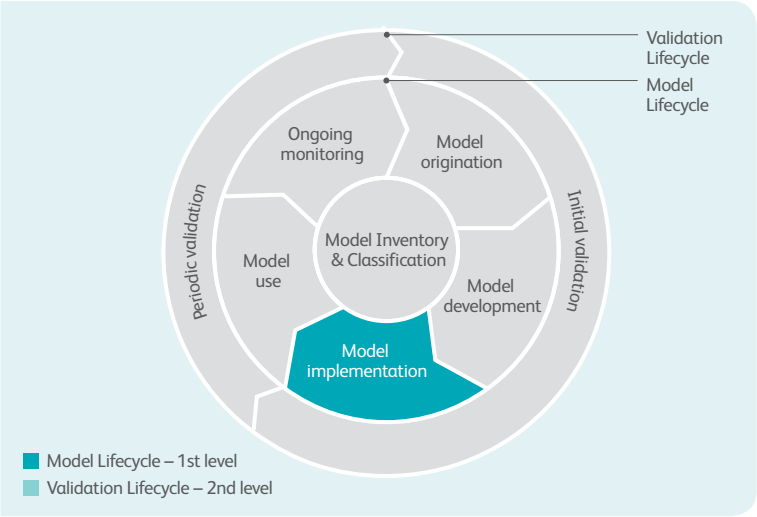
Clear coding standards should be applied across all model developments. This should ensure easier comparisons between models and faster development and testing times in future.

This also mitigates model risk, in that the coding standards should make the model more understandable in the event that a new modeller needs to work on it.

As part of the model development, rigorous validation and testing should be applied. This should reflect all parts of the model specification and requirements.

Model implementation

The Ongoing MRM cycle



Models should be implemented in a secure, "production" environment, where sufficient controls are available to ensure that the results are reliable.

Versioning should be applied to each implementation of a model's code, data and assumptions. This ensures the replicability of model results from historic periods and helps to meet regulatory requirements. For general purposes, the model should be run on the latest, most relevant versions.

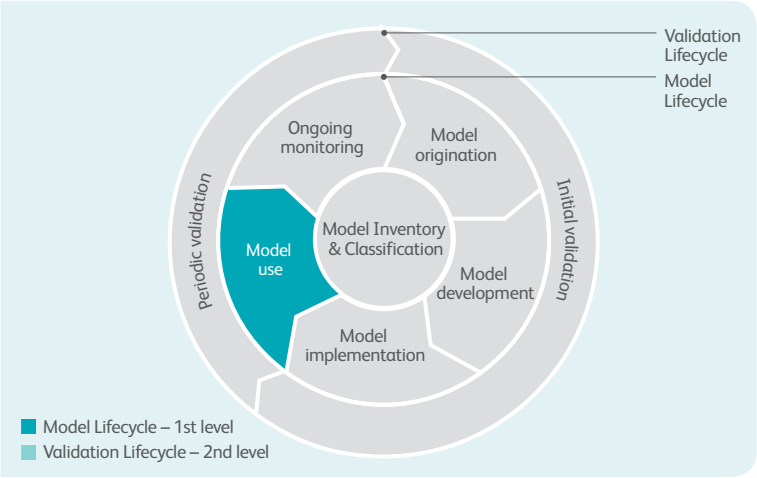
The model should be backed-up and protected from accidental or malicious damage. For instance, in the production environment, the model code should be read-only.

The users responsible for each change of the model and each run should be recorded. These users then have primary responsibility for ensuring that the model controls are appropriately applied.

Models should also be tested and validated (generally by an IT control function) at the point at which they are implemented. This ensures that the model as implemented meets its requirements.

Model use

The Ongoing MRM cycle



Controls should be applied to both the running of the model and the use of the results. The provenance and sign-off of data and assumptions should be traceable through the model from input to output. This way, trust in the results of the model can be maintained.

It should be noted that MRM does not seek to harmonise the controls applied to all models across an organisation but rather to ensure appropriate controls are in place to minimise the probability that models will produce misleading outcomes or outcomes that are misinterpreted, leading to poor decisions being taken. The following simplified example compares differing controls that may be applied to three separate models within a non-life insurer:

Control	Capital Model	Pricing Model	Reserving Model
Regulatory body approval	✔	✘	✘
Board-level sign-off	✔	✘	✔
Head of business unit sign-off	✔	✔	✔
Independent validation	✔	✘	✘
Internal audit	✔	✔	✔
External audit	✘	✘	✔
Peer review	✔	✔	✔

The differing level of controls would be defined by the MRM policy with reference to the key metrics identified by the insurer that best reflect the risk profile.

Outcomes of poor MRM in practice – Shell Reserves Overstatement

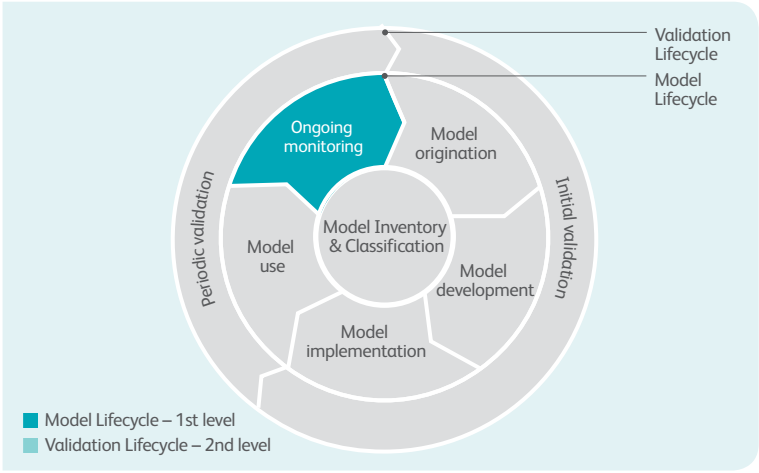
Shell announced false or misleading proven reserves and reserves replacement ratios to the market throughout the period 1998 to 2003 inclusive. The FSA imposed a fine of £17 million. There was a $450 million settlement with European and American shareholders due to the overstatement. The FSA ruled that Shell had: "...failed to put in place or maintain adequate systems or controls over its reserves estimation and reporting processes".

This was due to a set of assumptions which were not in-line with the regulatory requirement (Securities and Exchange Commission Rule 4-10). Assumptions and production forecasts were "reverse-engineered" to produce replacement ratios that would support the reserve figures. By failing to put in place adequate systems and controls, and by failing to act on indications and warning that its proved reserves were wrong, the FSA concluded that Shell had committed market abuse.

Ensuring that models and key assumptions are sufficiently transparent, tested and subject to challenge and sign-off from all three lines of defence as well as having oversight from control bodies and the Board of Directors, failures of controls, such as occurred at Shell can be avoided or managed appropriately. It is well known that some insurers have struggled with similar problems in the past and hence, the insurance industry has control frameworks in place to manage and mitigate these risks. An appropriate MRM framework consisting of a robust control framework could allow to reduce and manage appropriately these risks.

Ongoing monitoring

The Ongoing MRM cycle



Models should be monitored on an ongoing basis to ensure they remain relevant and appropriate for use.

As part of ongoing monitoring, it is useful to report regularly to the board on the state of the company's exposure to model risk. Examples of appropriate metrics might include the proportion of the company's models that are compliant with the policy, and the number of risk events involving models.

A robust MRM framework with sound ongoing monitoring that the models were being appropriately used and they were still relevant to the fund's business practices would have helped to mitigate the risks of collapse at LTCM. Ongoing monitoring activities which could have helped in this respect include stress testing of assumptions, back testing and monitoring of model performance.

Outcomes of poor MRM in practice
Long-Term Capital Management (LTCM)

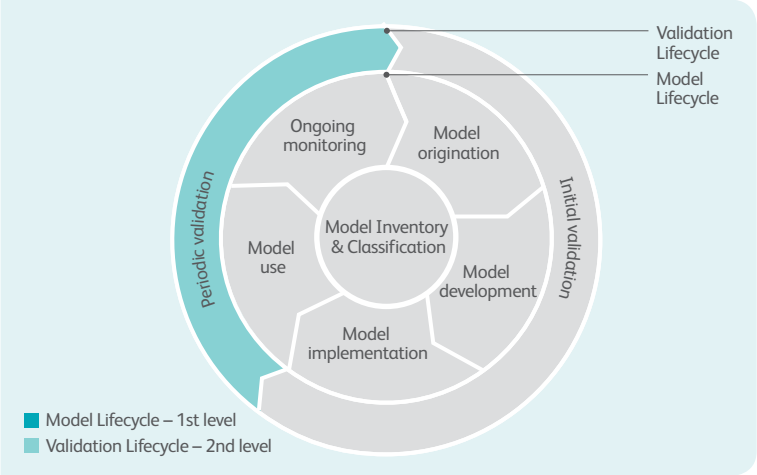
LTCM was a hedge-fund which operated between 1994 and 2000. It was based on the theories of Directors Merton Black and Robert Scholes, who won the 1997 Nobel Prize for economics for their work on the valuation of derivatives.

The fund's strategy relied on using quantitative models to find arbitrage opportunities between liquid securities, combined with high financial leverage. Over time, the fund grew with its successes and was unable to find sufficient arbitrage opportunities to invest in. As a result, it expanded into other strategies. In 1997 and 1998, as a result of the Asian and Russian financial crises, the markets moved unfavourably for the positions held by LTCM. This caused significant losses over a period of months and redemption requests by its capital providers.

Overall, LTCM lost $4.6 billion as a result of very high leverage combined with a reliance on mathematical models that did not capture the potential market movements accurately.

Periodic validation

The Ongoing MRM cycle



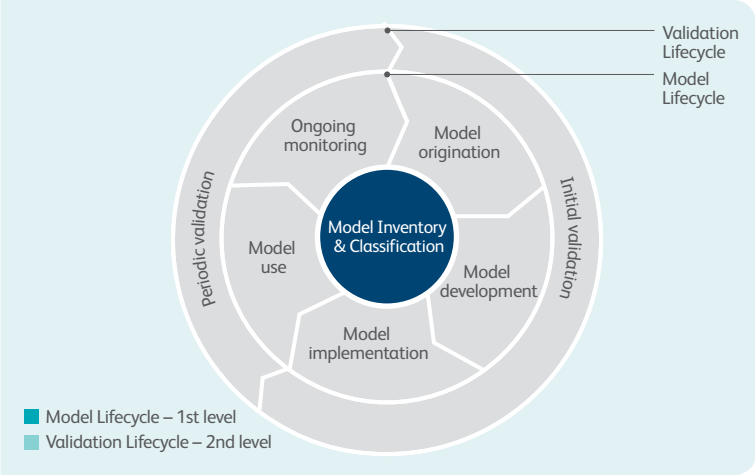
Models should undergo a periodic validation process to ensure that they remain relevant for their use within decision making. This monitoring should consider the business environment, any model changes or changes in use, any legal or regulatory changes, as well as any changes in model requirements.

Regular validation of the model is required, where the frequency and depth of the validation will depend on the model risk. Knowing the critical drivers of model validity will also determine the frequency of review. For instance, a model dependent on the asset returns is likely to require more frequent review than one dependent on mortality rates. The frequency of model review will also depend on regulatory requirements.

The testing and validation applied during the periodic validation is likely to have a lighter touch than that applied during model development. More in-depth testing can be used, where required, to investigate deviations from expected model performance.

Model inventory & classification

The Ongoing MRM cycle



As mentioned earlier in this paper, the model inventory and classification is an important element and will remain within the ongoing MRM cycle. The illustration below provides a simplified example of the types of fields a model inventory may include.

Dimension	Capital Model	Reserving Model
Model characteristics	**Item description**	ID, name, version, category, champion/challenger, in-house/ vendor, data source(s), methodology, output, platform/system
	Model use	Use category, detailed use, use frequency, underlying
	Model dependency	Upstream models, downstream models, associated challenger/ champion models
Governance	**Key stakeholders**	Vendor (if applicable), legal entity, geography, business unit/LoB, owners, developers, validators, users, implementer, business sponsor
	Key dates	Submission date, approval date, deployment date, last validation date, next scheduled validation date
Classification	**Key dimensions**	Materiality, model usage, external impact, classification result
Risk & Control	**Validation**	Validation status, last validation type, model risk assessment results, validation frequency
	Risk	Issues from validation (notices), regulatory/audit issues, limitations, ongoing monitoring status
	Mitigation	Compensating controls, remediation action plans, use restrictions

Example model risk classification

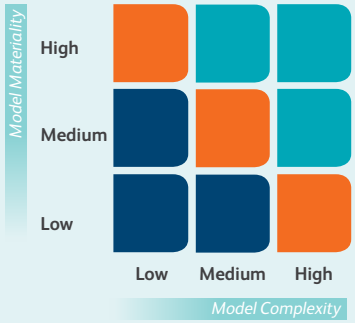
The application of risk classifications to a company's models is still an emerging practice. As such, the best practice is still developing. Typically, a risk classification would consider a model's materiality and complexity. The use of the model is also usually considered, for instance, a model for regulatory reporting will typically have specific requirements. The diagram below shows an example Model Risk Classification methodology.

In the example methodology, 2 factors are considered:

Factor	Group vs. LE
Model Materiality	The model materiality is determined based on **Model Category** and by type of Model **Category A** • External Solvency models • IFRS Accounting models **Category B** • Product Development/ Pricing Models • Reinsurance models • Regulatory reporting (not public disclosure) • EV models • ALM models • Risk Dashboards • Other management models **Category C** (other)
Model Complexity	**Nature** of the business (e.g. volatile vs. non-volatile covered by the model and an assessment of the model environment

Materiality increases from Legal Entity to Group

Model Risk Classification Methodology
Example Methodology



Classification of models for Model Risk Management

- High Risk
- Medium Risk
- Low Risk

The **model materiality** should be linked with **modelling** and **validation efforts**. The expectations for the Model Control Framework is set by the 2nd LoD and mostly implemented by the 1st LoD

Example Model Risk Management Policy

The starting point for an effective Model Risk Management process, is a Model Risk Management Policy which has the support of the Board. The diagram below shows the typical documents that would comprise such a policy:

Focus on the set of MRM-related documents

1 Model Inventory Procedure
2 Model Tiering Procedure
3 Model Risk Scoring Procedure
4 Model Management Governance Policy
5 Model Approval & Escalation Procedure
6 Model Change Procedure
7 Model Risk Mitigation Policy

Model Risk Policy

1. **Definitions**
2. **MRM function mandate**
   - Organizational structure (global vs. local)
   - Roles and Responsibilities
   - Reporting lines
   - Etc.
3. **MRM committee**
   - Organizational structure (global vs. local)
   - Roles and Responsibilities
   - Reporting lines
   - Etc.
4. **Model risk management**
   - Definition model risk
   - Model identification process and model inventory
   - Reference to model tiering and model risk scoring
5. **Model portfolio Management**
   - Model lifecycle standards
   - Reference to Roles and Responsibilities
   - Model approval process
   - Model change
6. **Model validation and model controls**
   - Roles and Responsibilities
   - Validation methodology
   - Validation process
7. **Model risk mitigation**
   - Reference to model mitigation techniques

8 Model Development & Implementation Procedure
9 Testing Procedure
10 Data control Procedure
11 Reporting & use procedure
12 Model monitoring & review Procedure
13 Model monitoring & review – Test plan template
14 Documentation Standards (inc. all the Model Lifecycle templates)
15 Validation Policy
16 Model Validation Procedure
17 Model Validation Plan

Our project team

We would like to thank those listed below for their work on this document. It should be noted that contributions have been made in a personal capacity and any views expressed are those of the individuals concerned and not their employers.

Workstream leader:

Philip Whittingham, Head of Model Validation and Risk Governance (including Operational Risk), XL Catlin

Consultancy support:

Marc Taymans, Managing Partner, Risk Dynamics, part of McKinsey & Company
mtaymans@riskdynamicsgroup.com

Roel Van den Heuvel, Associate Partner, Risk Dynamics, part of McKinsey & Company
rvandenheuvel@riskdynamicsgroup.com

Robert Mumford, Senior Manager, Risk Dynamics, part of McKinsey & Company
rmumford@riskdynamicsgroup.com

Alistair Esson, Manager, Risk Dynamics, part of McKinsey & Company
aesson@riskdynamicsgroup.com

Workstream members:

Andrew Hitchcox, Tokio Marine Kiln

Bianca Hanscombe, Aviva

David Innes, RSA Group

Elizabeth Cabrera, Talbot Underwriting

Michael Hosking, Faraday

Peter Telford, Legal & General

Roger Dix, Wesleyan

Our steering committee

The IMIF steering committee comprises:

Phil Whittingham, IMIF Chairman, XL Catlin

Kieran Barnes, Bank of England (PRA)

Raphael Borrel, LV=

Sebastien Delfaud, Bank of England (PRA)

Vishal Desai, Bank of England (PRA)

Steven Graham, Institute and Faculty of Actuaries

Joe Reid, Standard Life

Michael Hosking, Faraday

Eamon McGinnity, KPMG

Matthew Pearlman, LCP

David Skinner, PwC

Grace Sweeney, Central Bank of Ireland

Russell Ward, Milliman

Carolyn Williams, IRM

Neal Writer, EY

Additional MRM reference material

Alongside the contributions of those listed above, this paper has also considered the following publications in the area of, or relating to, model risk management:

Model Risk – illuminating the black box by the Model Risk Working Party of the Institute and Faculty of Actuaries, 29 June 2017.

Leading practices in model management by the CRO Forum, March 2017.

The evolution of model risk management by McKinsey & Company, 2 January 2017.

Model Risk Management – Practices and Principles by the North American CRO Council, August 2016.

Model Risk – Daring to open up the black box by the Model Risk Working Party of the Institute and Faculty of Actuaries, 23 March 2015.

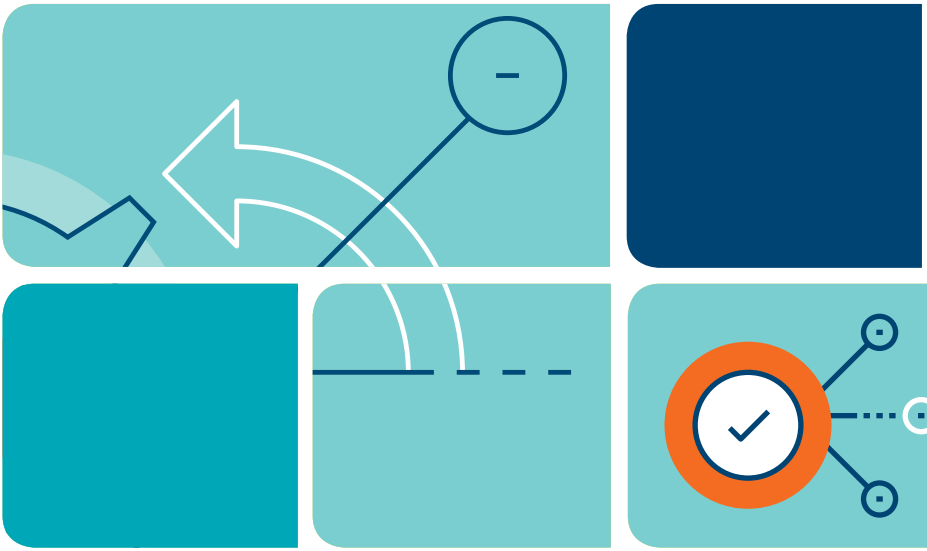
SR Letter 11-7: Supervisory Guidance on Model Risk Management. Board of Governors of the Federal Reserve System Office of the Comptroller of the Currency.

Long-Term Capital Management
https://en.wikipedia.org/wiki/Long-Term Capital Management

Shell
https://www.fca.org.uk/publication/final-notices/shell_24aug04.pdf

https://www.theguardian.com/business/2009/may/31/royal-dutch-shell-compensation-shareholders

PRA CP26/17
https://www.bankofengland.co.uk/prudential-regulation/publication/2017/model-risk-management-principles-for-stress-testing



IRM
T: +44(0) 20 7709 9808
E: enquries@theirm.org
www.theirm.org

Institute of Risk Management
2nd Floor, Sackville House
143-149 Fenchurch Street
London
EC3M 6BN
United Kingdom

Our supporters

As a not-for-profit organisation, IRM is reliant on industry support to publish guidance like this. We would like particularly to thank the following organisations who have made this publication possible:

PricewaterhouseCoopers LLP

David Skinner
david.w.skinner@uk.pwc.com

Bill Gasson
bill.gasson@uk.pwc.com
www.pwc.co.uk/

Russell Ward
russell.ward@milliman.com
uk.milliman.com/

Marc Taymans
MTaymans@
riskdynamicsgroup.com
www.riskdynamicsgroup.com

Building a better working world

Neal Writer
nwriter@uk.ey.com
www.ey.com

Matthew Pearlman
matthew.pearlman@lcp.uk.com
www.lcp.uk.com