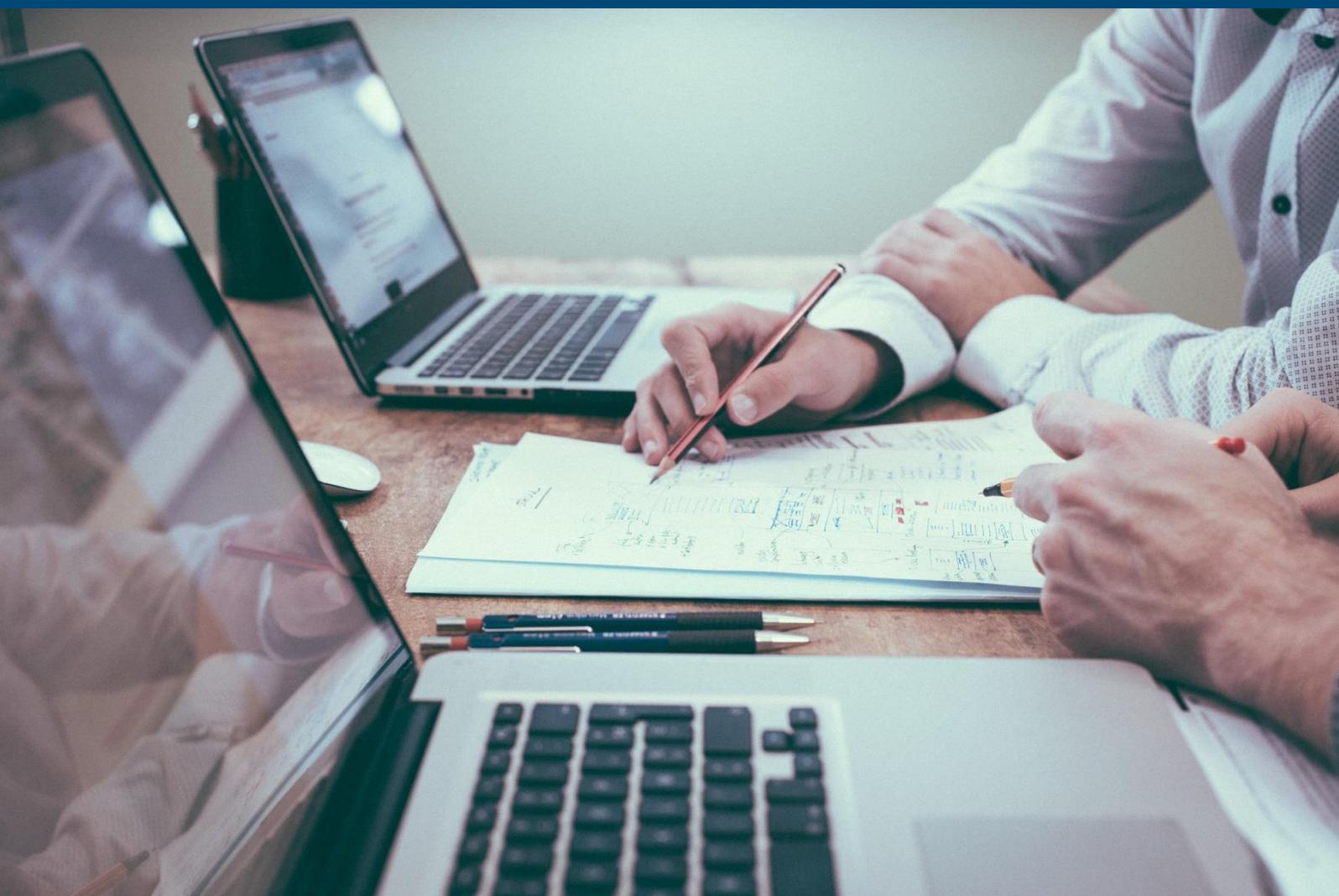




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Model Risk Management

Fundamental concepts



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1 Executive Summary

Models are used across the whole financial sector. Practically anything we use to assist in decision-making, from a simplest excel file to the complex AI algorithm, is a model. In more formal terms, a *model is an algorithm which is based on mathematical, statistical, or economic assumptions, is being used for business purposes and is implemented in an appropriate IT tooling*¹.

Nowadays, financial institutions rely on models more than ever before, using them from pricing of new financial products, calculating capital, to marketing analytics using AI models. Most of the financial institution's decisions are based on a models' output.

As any widely used tool, models are error-prone and require management. Famous errors like J.P. Morgan's unnoticed 2 billion trading loss [1], or Apple's delay of entering into financial services due to gender biases in the AI algorithm for credit approvals [2] are only two examples. Naturally, institutions aim to minimize such errors. In this paper, by using the term "institution", we also refer to non-financial firms which are using models for their operations. For the purpose of this paper, we would like to cover both financial institutions such as banks and companies in a broader sense of the term, for example technology firms.

In this whitepaper, we describe the model risk management cycle and crucial elements which are needed for successful model management. After reading this whitepaper, you will develop an understanding of the key model development steps and key model risks for these steps, as well as possible practical solutions to address the risks.

To effectively manage models and model risk, we propose that institutions establish clear roles, accountability, and responsibility, as well as process around model management. A Model life-cycle, which we explore in this whitepaper, can be a helpful tool for institutions to implement successful model risk management.

Through the text we use some terms. The process of managing model(s) is called simply – "*model management*". The process of managing risks which models pose also has a straight-forward name: "*model risk management*".

¹ IT tooling is used in a broad sense of the word here, and includes both IT systems and end-user developed applications ("EUDAs").

2 Introduction

Models are used everywhere in the financial industry: from pricing complex financial products to credit decisions and from HR to marketing. Nowadays, financial institutions heavily rely on models for their decision-making and meeting capital requirements. Model applications are constantly becoming more complex, and their potential appears boundless.

Model risk is possibility of losses or reputational damage due to errors in model development, implementation, or use. Ignoring model risk inadvertently leads to substantial financial losses and reputational damage. Even large and established companies like JP Morgan or Apple suffer from the consequences of poorly managed model risks.

A successful *Model (Risk) Management framework* relies on a set of key concepts. Financial institutions which adopted MRM elements are likely to prevent model losses, effectively manage model risks, and have substantially added value through Model validation and Model risk management departments. In this paper, we outline some key concepts that need to be recognized to implement successful MRM culture in financial institution.

In the first part of this paper, we discuss key MRM components (such as model owner, model life-cycle, inventory, and many others). In the second part, we elaborate on a few trends and practical challenges which can arise when implementing the MRM framework. Throughout the paper, we outline some practical recommendations and best industry standards which can be used to minimize model risk.

3 Model: definition

'What is a model?' – seems to be a simple question, especially for anyone involved with the model development process. However, there are cases when it is hard to distinguish mathematical models from other IT functionality or reports used by financial institutions. A typical model definition example is: "*A model is an algorithm based on mathematical, statistical, or economic assumptions, which is implemented in the financial institution's IT tooling and transforms input data into the output used for decision making or regulatory reporting*". Notice critical elements of the model definition: assumptions, data, implementation, use for decision making. This definition allows to effectively distinguish models from the other IT functionality, such as reports.

A model is an algorithm based on mathematical, statistical, or economic assumptions, which is implemented in the financial institution's IT tooling and transforms input data into the output used for decision making or regulatory reporting.

The best practice for financial institutions is to develop and document model definitions in the corresponding policies. Moreover, financial institutions could develop a standardized checklist or a questionnaire, which would allow model users to easily identify (and possibly to classify) models.

4 Model development life cycle and key model risks

The *Model development life cycle* is one of the best ways to describe a model's evolution. A typical model life cycle involves model users ("the business"), model developers ("the quants"), validators ("the independent check") and the IT implementation team ("programmers").

- I. Model Development life cycle starts with the *model initiation*. Usually, model users (business owners) ask the quantitative analysts to create a new model for their internal (e.g., new product) or external (e.g., new regulation) needs.
- II. The model is *developed* based on academic literature and industry best practices. This stage usually includes data analysis, model prototyping, and estimation of the regulatory- or business impact of the new model. Model documentation and prototypes are the main output of the model development process.

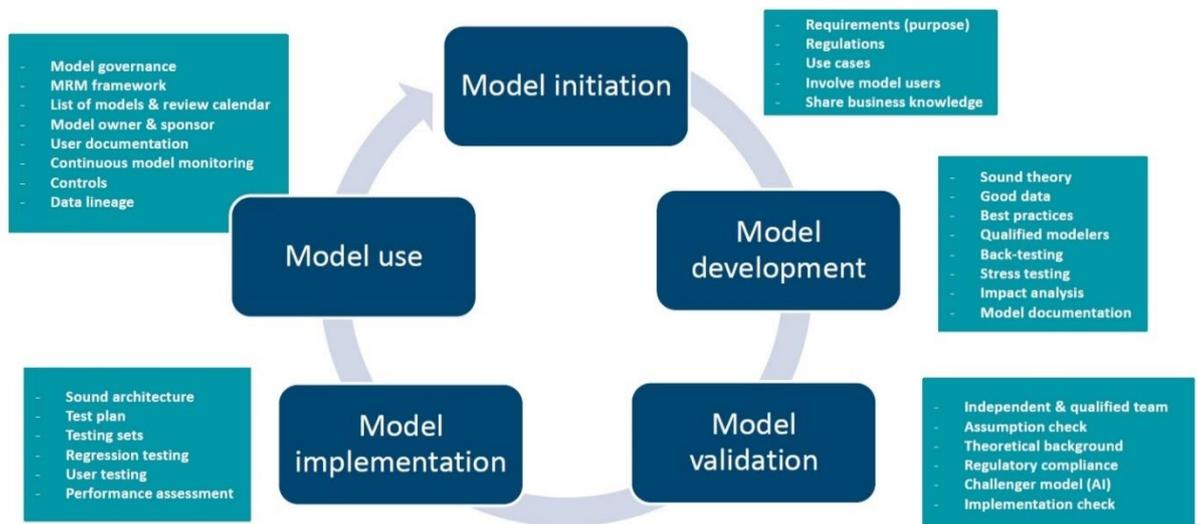


Figure 1: Example of the model life cycle. Lifecycles that financial institutions adopt may contain additional steps, such as regulatory approval of the model.

- III. Once the model is created, it is handed to the *model validation team* (MV) to assess the model's quality. MV checks qualitative and quantitative aspects of the model and identifies any model issues. Based on MV's advice, management can take a decision whether to go forward with model implementation.
- IV. After the model approval, the model can go for *IT implementation*, which is either done by a separate IT team for larger models, or by the modelling team for simpler ones. It can happen that model validation is useful after the model is implemented in the test environment but not yet released into production use.
- V. Finally, after the user acceptance tests, the model is released into production and the model use phase of the life-cycle starts. Here we see Model Use phase not only as pure usage of a given model, but also its management, assessment of its performance and whether it is still relevant for a given business purpose. For example, a model may be used differently than originally intended, or key assumptions in the model become invalid due to market or legal changes. It is important to periodically re-validate used models, for example annually or every three years.

5 Key roles

Successful implementation of MRM depends mostly on the people in critical positions. *Model owner* is responsible for supervising the entire development process, including stakeholder management, and therefore has a vital role in the process. A *model sponsor* is ultimately responsible for the model performance and resolving the model's (regulatory) issues. They have a high-level understanding of the model, focusing on the people and processes around the model.

Ideally, the financial institution establishes a *model committee*, dedicated to model-related decisions, where both model owner and model sponsor are present.

Please consider that the roles which we propose below can be combined in one department or function for smaller institutions, or can be broader for larger institutions.

A detailed and up to date model inventory and classification, covering all the financial institution's models is key for model risk management.

5.1 Model owner

Model owner is one of the critical roles in model risk management. This person is responsible for a model; he or she oversees model development, collaborates closely with the stakeholders, promotes the model inside and outside (if appropriate) of the organization. Key skills for this role include strong quantitative, data, IT knowledge, in addition to understanding business processes and relevant regulations. There can be many rationales on how to select a model owner. In some companies, the model owner does not combine model ownership with other roles, such as developer or user. However, in smaller institutions it can occur that the model owner performs an additional role, or that this role is placed on Board level and combined with the role of model sponsor.

ORGANIZATIONAL CHALLENGE

In large multinational financial institutions, a particular model can be developed in the corporate office and used in the business units which are frequently scattered across different countries. This practice may result in ignored wishes of model users.

In this set-up, should there be a single global model owner or a local one within each country?

One way to resolve this challenge is to appoint both global and local model owners. The global model owner can ensure resources are allocated while the local model owners provide links with an actual model use.

It is an industry best practice to have a model owner clearly defined for each model and to make sure that the person in this role has the appropriate resources to execute this role.

5.2 Model sponsor

A model sponsor is typically a senior manager who oversees the model development domain or a domain where the model is used. The model sponsor should have a high-level understanding of the model and focus

on the people and processes around the model. The model sponsor is ultimately accountable for model performance and resolution of the regulatory issues with the model.

It is typical for either a CRO or a CFO to be model sponsors for the models within their domain, even though it may be different depending on institution type and complexity. With the advance of AI and ML models, a CTO can be a model sponsor for some applications. The person for this role should have enough authority and influence in the organization to ensure that the processes around the model's development, implementation, and use are running smoothly.

It is an industry best practice to have a model sponsor identified for each model within the financial institution and ensure that model validation activities are independent of this role. Depending on the organizational size and complexity, the role of the model sponsor can be combined with the role of the model owner.

5.3 Model developer

The model is developed based on academic literature and industry best practices. This usually includes data analysis, model prototyping, and estimating the new model's impact on the business and on the regulatory capital. Model documentation and prototypes are the main output of the model development process.

Model developers align with model users to ensure the model is fit for purpose, IT department to ensure the model is implemented as required and Model Validation team to support validation and ensure regulatory compliance.

5.4 Model user

Model user is a role which can be allocated to multiple teams on multiple organizational levels. In short: model users are those people in the institution who use the model or its outcomes for their daily activities and decision making. Model users should generally have an understanding about the model and have an opinion about model performance, as well as provide feedback and input to model validation and model development teams.

As with the other roles, it is considered a best practice to have formally defined users for each model. In case there are multiple users, one user can represent all others as senior user in communicating with other roles.

5.5 Model approval committee

The model (approval) committee is a part of the financial institution's governance structure that is dedicated to model decisions. This committee would usually have business representatives, model owner, model sponsor, and representatives from the model validation department. A right mixture of senior management and experts ensures most effective discussions. The model committee typically approves all models used by a financial institution with support of periodic validations and expert opinions.

For large financial institutions, multiple model committees might be set up (i.e., for market risk, for credit risk, etc.). For a smaller organization, a single model committee delegated from the risk committee might be sufficient. Although there are hardly any regulatory requirements for the committee structure, setting up

It is an industry best practice to set up a separate model committee and establish strong governance around its work.

a dedicated model committee is the most efficient way for financial institutions to ensure that the senior management is aware of the model landscape, recent developments, and model issues.

5.6 Model validation department

A Model Validation (MV) team is responsible for validating models. Model Validation team usually consists of people who in addition to a technical PhD or MSc, have a good understanding of the organization's business processes, knowledge of the relevant regulatory requirements, and possess strong communication skills.

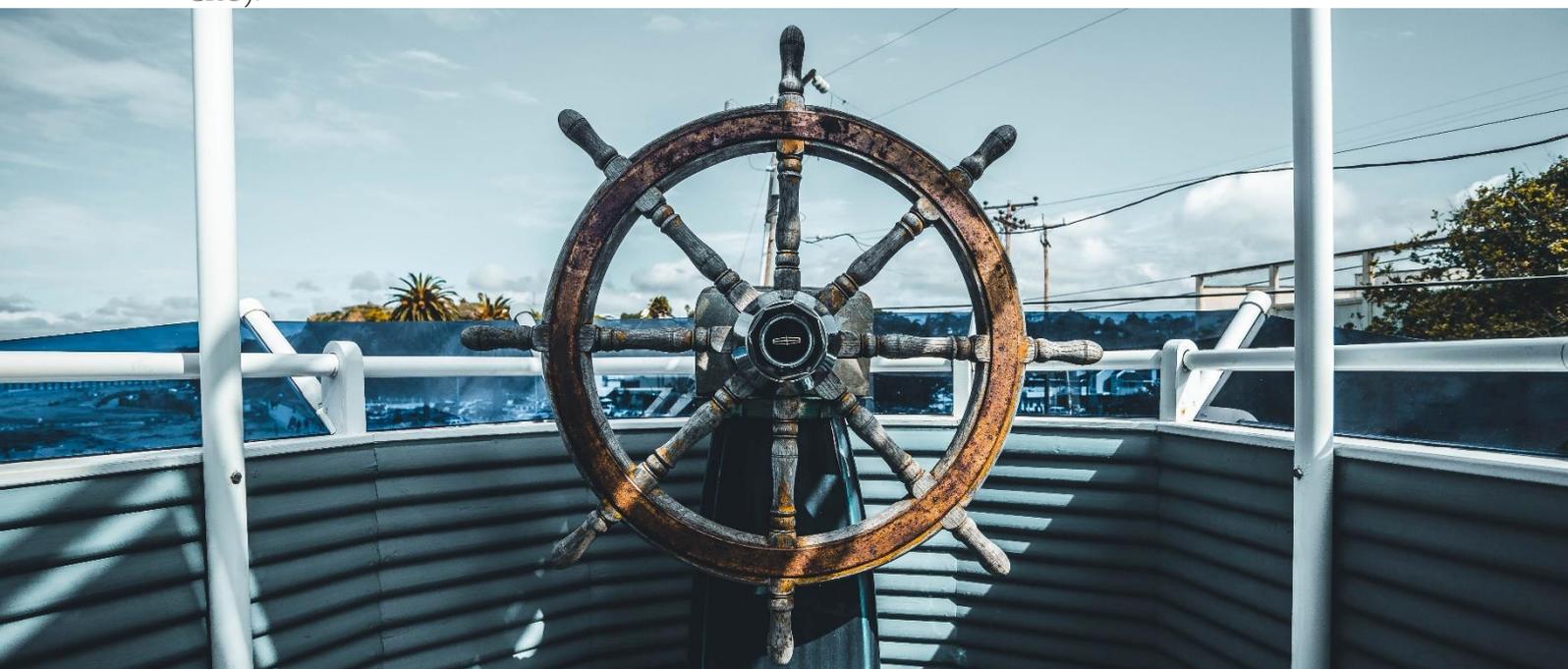
Typically, the MV team performs the model risk management activities. However, recently, large organizations have started setting up dedicated model risk management (MRM) teams for these tasks.

To ensure that the MV team would provide an adequate challenge for the model development team, it needs to be independent from model development. The independence should be enforced not only by splitting the work into separate departments (or outsourcing one of the activities to the external organization) but also by ensuring segregated reporting lines to senior management (e.g., directly to the CRO).

ORGANIZATIONAL CHALLENGE

On one hand, it is typical for MV to perform the technical implementation check of the newly developed model functionalities. On the other hand, model users also test typical model applications. This can sometimes lead to a disagreement between the two functions.

In our opinion, both MV implementation check, and users' testing are important. While the MV team checks the model for consistency and correctness, the model users can assess if the requested model changes meet their expectation and what the model's limitations are.



6 Model risk management governance: key concepts and trends

6.1 Model landscape

Typically, models are implemented in different IT systems within financial organizations. Moreover, one model could be implemented across different IT systems, with each performing only a part of calculations. Alternatively, one model can be fully implemented in a legacy system and next to the legacy system - in a new shiny target architecture. All these situations exist in practice and add to complexity.

One way to disentangle the complexity is setting up *model* and *IT landscapes*. A *model landscape* is a visualization of the organization's models. A model landscape, combined with the IT landscape, data flows, and human processes, makes a powerful tool which can show strong points and gaps of the organizational set up, and visualize required architectural changes.

6.2 Model repository

Model repository (or *model inventory*) is a database which contains all the required information about models, and allows the model owner and sponsor to have a holistic view on the models. Typical information stored in the model repository could be the name of the model, ID of the model, owner, sponsor, application area, type of the model (e.g., Monte Carlo Simulation, Formula, numerical approximation, etc.), IT system where the model is implemented, dates of IT releases, minutes of the committee meeting where the model was approved, list of model issues, impact, quality, and much, much more.

It is an industry best practice to have a detailed and up to date model inventory that covers all the models used by the financial institution.

Recently there is a trend for maintaining model repositories in more advanced IT tools. There is a shift from simple Excel spreadsheets and Access databases towards dedicated IT solutions. Examples of more modern tools are SAS Model Risk Management [3], Refinitive MRM [4], Miratech [5], and Tableau [6]. Additionally, Tableau can be used for building interactive reports or dashboard with the model inventory information.

6.3 Model classification

Financial institutions use a significant number of models to support day to day business and regulatory compliance. A large multinational institution can easily have more than 1000 different models of different complexity, materiality, and areas of application.

Thanks to ever-advancing data collection and calculation speed, we see a trend towards an increasing number of models. One way to overcome complexities associated with a significant number of models is to classify them. The model classification is typically maintained within the model repository and aims at helping to effectively allocate model development and validation resources to the most important models.

Strong governance goes further than knowing what the models are. Mapping of data processes, having controls over the full model development lifecycle, setting up appropriate guidelines are other key elements which we aim to explore in our future whitepapers.

In practice, models can be classified on:

- Monetary exposure.
- Model quality (as assessed by MV).
- Model type (market risk models, credit risk, marketing models, etc.).
- Regulatory use vs business use.
- Level of maturity.
- Potential reputational impact, and much more.

6.4 Model validation and agile model development

Many financial institutions adopt some form of agile work, aiming at incremental improvements of final product (financial model) during a short period of time (one- or two-weeks sprints). This concept however clashes with the idea that each change of the model should be validated, partly because validations typically take from one to six months.

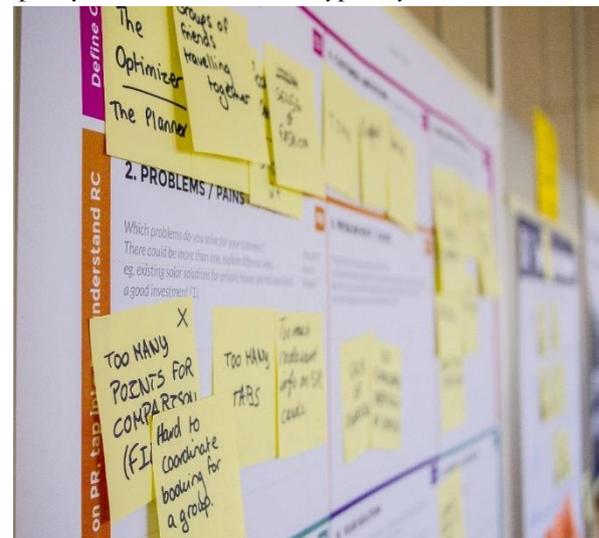
The challenge lays in making a choice: go for full scope, lengthy validations, or establish some way to do “mini” validations to accommodate agile working style. There is no simple answer, and we see the need to account for existing governance and model complexity when developing a solution.

6.5 Continuous model performance monitoring

Continuous model performance monitoring is an upcoming trend in a model risk management. The idea is that the performance of the financial models can be monitored and continuously reported to model users, senior management and other stakeholders. Such approach depends on a higher degree of automation and on improved data quality, compared to traditional yearly or quarterly reporting. Continuous performance monitoring can raise early red flags, for a number of violations of Value-at-Risk model, or the quality of fit of interest rate curve.

However, the approach also raises questions on who should perform model monitoring? Should it be modellers, model validators or perhaps, model users?

Model owner is in principle accountable for monitoring of the model performance. Organizations need to establish an independent monitoring function, to ensure independence and objectivity of the monitoring.



6.6 Artificial Intelligence and Machine Learning

Artificial Learning (AI) and Machine Learning (ML) models are a natural result of the massive amounts of data generated and consumed in the financial services industry. These models frequently use concepts and implementation mechanisms that do not allow for easy validation.

As technology develops, we can expect to see more comprehensive, seamless ways of understanding model risk and eliminating potential pitfalls. Look out for innovative advancements in model risk management throughout 2021 and beyond, as model risk evolves in line with new technology and innovation.

These are only some of the challenges and trends in the field of model (risk) management. We will be exploring these and more in our upcoming whitepapers.

7 Conclusion

The reliance on models, the amount and the complexity of models are increasing. Now and in the near future, it is more important than ever for the businesses to know and manage model risks. Therefore, model risk management is of paramount importance now and will continue to be going forward.

Understanding several fundamental concepts is essential for financial organizations which need effectively implemented model risk management. The model life-cycle is a convenient representation of the key roles including model users, model developers and validators. Model owner and model sponsor are two crucial senior roles ultimately responsible for the models. Furthermore, to ensure proper segregation of duties and effective challenge, the financial institution needs to separate the model validation activities from the model development activities.

Implementation of model risk management heavily depends on the particular organization and the model landscape at hand. Many issues do not have a clear answer and are subject to expert judgement. Such topics include, but are not limited to, segregation of model testing activities between model users and model validators, local vs global model owner, organization of model risk management from a perspective of 3LoD and many others.



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About Probability & Partners

Probability & Partners is a risk consultancy firm that provides comprehensive services in model risk management and model validation. Probability & Partners has tremendous experience in model development and validation for major model types and across all asset classes, including derivatives pricing, market, credit, counterparty, and operational risk models. Our team has a unique blend of practical and academic expertise when it comes to model development, model risk management and model validation.

Probability & Partners can help your organization with the technical side of model validation and implementation of the broader model risk management framework. Our offering includes, but not limited to: model audit, setting-up model governance, writing policies and procedures, creating model development guidelines and standards, creating or reviewing model inventory, including model categorization. We can assess and improve modelling processes in your organization by developing minimum requirements for model validation per asset class or model type.

For more information, please check: <https://probability.nl/en/model-validation/>

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