



Model Risk Management

Survey Report



April 2022

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Foreword

» It seems there is no stability within the environment in which banks operate, run their businesses and from the perimeter of a risk manager in the area of estimation and forecasting of the bank's risks. Banks are constantly reviewing and testing their mathematical models, broadening their scope of use and adapting to new requirements.

Quite soon after banks implemented IFRS9 and related models became reasonably stable and reliable, the COVID-19 pandemic tested the flexibility of their frameworks to incorporate unprecedented shocks in their portfolios' behavior. Regulatory models have recently been finishing a transformation process imposed by the EBA guidelines; but before all the related changes are finally approved and implemented, a new set of complex statistical models aimed at incorporating ESG components needs to enter into the backlog of every risk manager.

With the increasing complexity and overall number of mathematical models in place, financial institutions across the globe are being challenged and need to adjust their approach to Model Risk Management (MRM) adequately.

With increasing costs of manpower, insufficient capacities of modelling specialists, institutions must push themselves towards automation and digitisation. A proper MRM framework and related technology solutions to empower it start to play an even greater role than in the past.

All of the above led us to perform a survey across financial institutions globally, specifically focussed on MRM and the relevant technology solutions in order to provide mainly answers to the following:

- how financial institutions see the importance of proper MRM,
- where are the main benefits which can be achieved by successfully implementing relevant frameworks,
- how far are organisations in terms of utilising of modern technology solutions and tools to support automation and digitisation in the MRM area.

We believe you will also find this report insightful and inspirational in terms of how you can possibly leverage MRM in your organisation, and we would like to thank all the participants in this survey for their time and valuable answers.



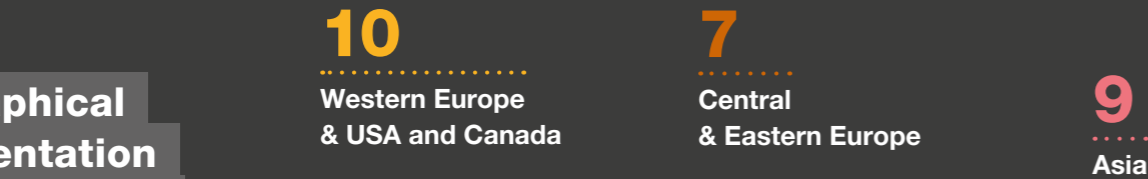
Rostislav Černý
Partner

About this survey

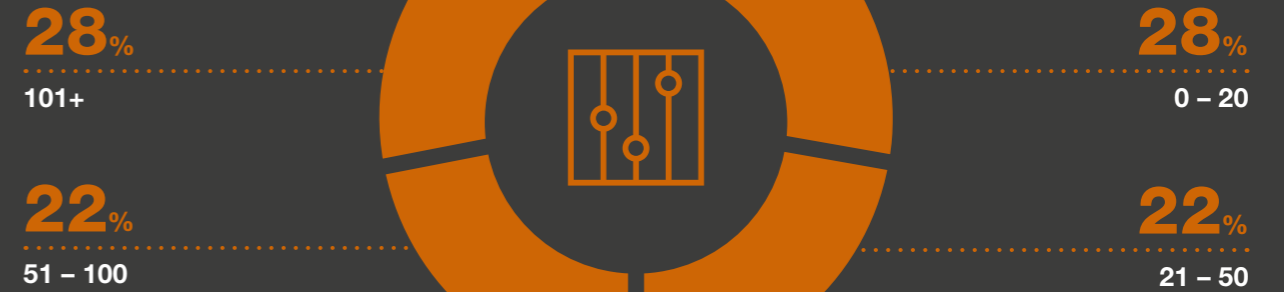
» PwC has conducted this global survey focussed on Model Risk Management (MRM) during January and February 2022. There were 32 respondents representing 32 financial institutions in total. Ten out of these were based in Western Europe and America, nine in Asia, seven in CEE and six in other regions. The survey has covered the range of financial institutions from small (with total assets below

USD 10 bln.) to large (with total assets above USD 100 bln.). Apart from total assets, we also categorised the financial institutions based on the number of risk-relevant models. The survey has covered financial institutions with a very low number of models (0–20), as well as financial institutions with more than 100 models and those in between.

Geographical representation of respondents



Number of models in the organisation



Respondents based on assets



Executive summary

The Survey provided the following key findings

- 
- **The overall readiness of the financial market:** The vast majority of risk managers (75%) tends to evaluate the MRM function in their institutions as strong and fit for the purpose.
 - **Technology not yet implemented:** As much as 56% of financial institutions do not utilise any technological solution to support their MRM function but more than two thirds of these institutions plan to implement such a solution in the near future.
 - **The size matters:** The number of models claimed by risk managers is highly correlated with the overall size of their financial institutions. The number of models also affects the need for technological solutions in the MRM area.
 - Institutions tend to improve their approach to MRM even when they feel confident with the current setup - out of all respondents who claim they do consider their current MRM function in the organisation to be strong and fit for the purpose, 38% plan to implement a suitable technological solution.
 - The most commonly expected benefit of model inventory is to reduce model risk, mentioned by 94% of respondents.

Introduction to Model Risk Management

» Models are an integral part of day-to-day business in financial institutions. Based on their outputs, senior management makes decisions, executes operations and reports the results. In addition, their numbers and complexity are increasing on a yearly basis. This generates additional risk that is commonly called model risk.

There are various sources of model risk. It is associated with the use of models during their entire lifecycle. Risk can originate from the incorrect identification, erroneous model implementation in a system; unreliable or incomplete data; uncertainties about statistical and mathematical methods in place; inaccurate calibrations; model misuse; incorrect interpretation of model results; inappropriate assumptions stemming from the use of upstream and downstream models; incomplete or inaccurate model inventory and more additional sources.

To manage and remediate the associated risks, a financial institution needs to establish and implement the formal set of standards, policies, and processes broadly known as Model Risk Management (MRM). Hence, MRM is the control framework that supports the business and decision process around the use of all models in an institution.

The framework should be built on controls along the phases of the model lifecycle:

- Model development
- Model evaluation
- Model monitoring
- Model maintenance



Model risk means the potential loss an institution may incur, as a consequence of decisions that could be principally based on the output of internal models, due to errors in the development, implementation or use of such models.

(EU, CRD IV)

Formalised requirements on Model Risk Management are established by the industry practice as well as by regulations. Authorities such as the European Central Bank, Federal Reserve System, Bank of England or Canadian Office of the Superintendent of Financial Institutions require financial institutions to set up proper governance around Model risk.

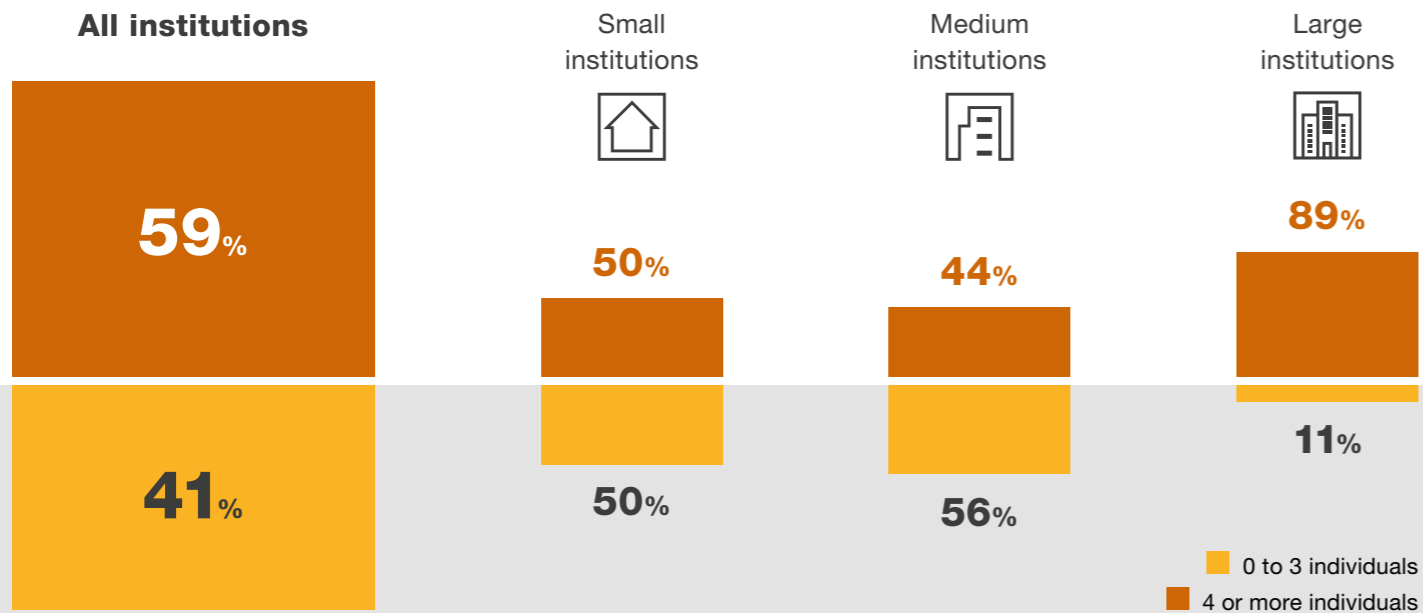
Financial institutions therefore employ dedicated persons or even teams for their MRM function. Our survey confirms this trend. More than one half of surveyed financial institutions (59%) employ 4 or more professionals in their MRM department.

” According to our expectations, the number of people in the MRM function becomes even more relevant for large institutions compared to small or medium-size institutions.

Adéla Mrázková
Senior Consultant,
MRM subject matter expert



How many people dedicated to model risk management activities are in your organisation?



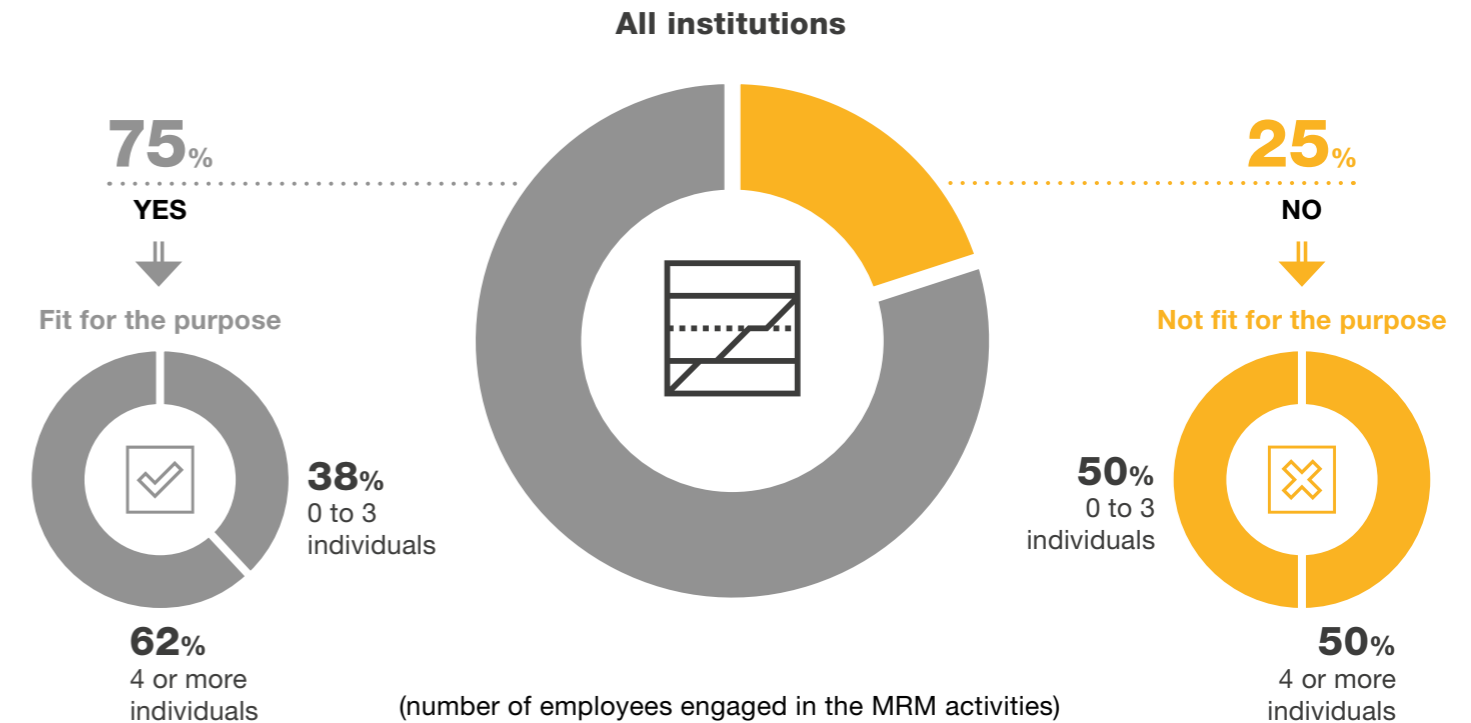
Current Shape of MRM

As the reliance on models within financial institutions continues to grow and regulatory scrutiny increases, the expectation is that Model Risk Management will become a regular part of internal risk processes. In fact, the vast majority of risk managers (75%) tends to evaluate the MRM function in their institutions as strong and fit for the purpose. However, there is still a significant number of managers (25%) that found their

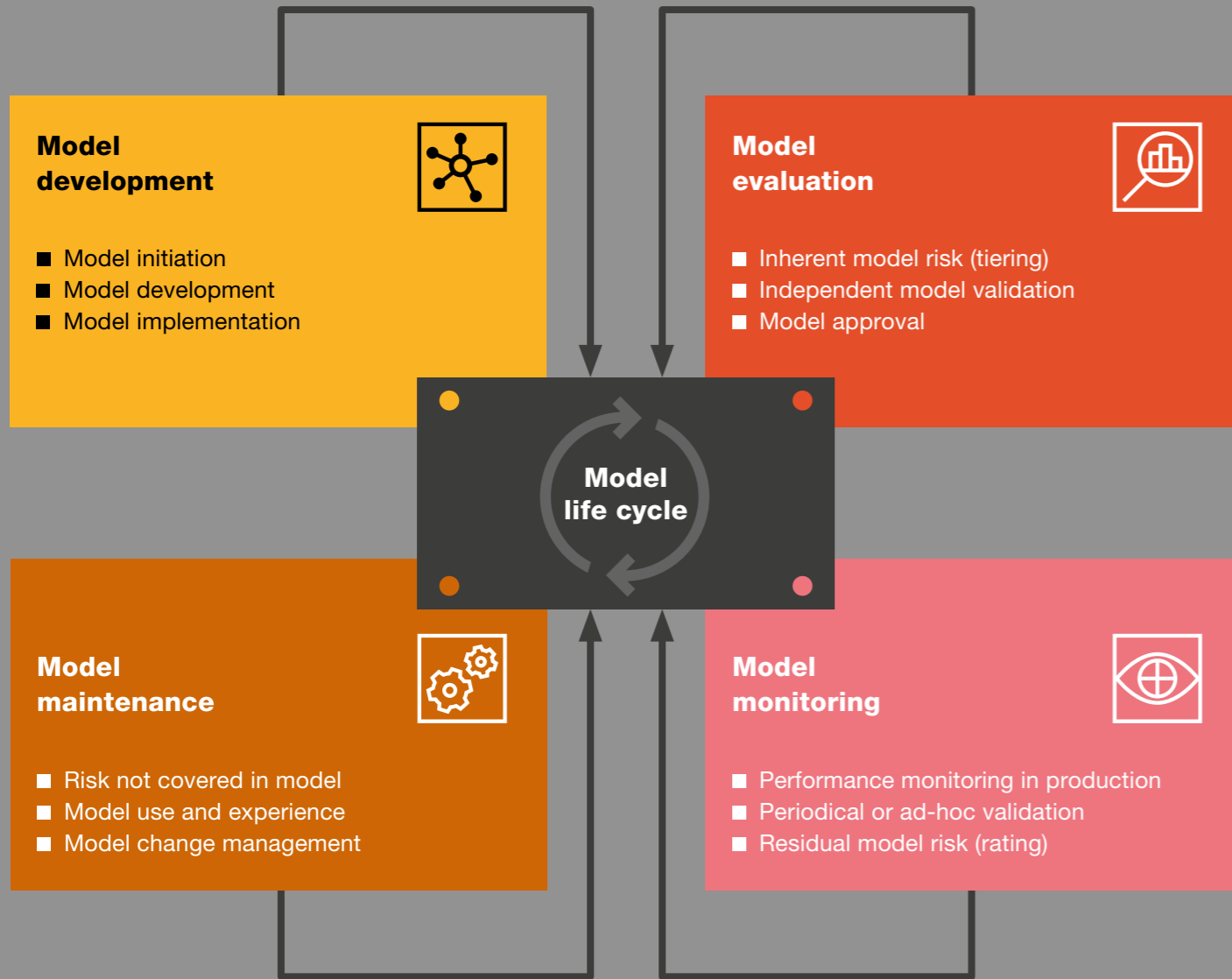
MRM function insufficient. Those institutions that have the MRM function strong and fit for the purpose also tend to have more individuals employed in this function.

One of the key findings shows the overall readiness of the financial market to face the challenges associated with the Model risk. The worrying sign might be that half of the respondents evaluating their MRM function as insufficient comes from the developed financial markets.

Do you consider the current MRM function in your organisation to be strong and fit for the purpose



Model life cycle in detail



On the way to digitised Model Risk Management

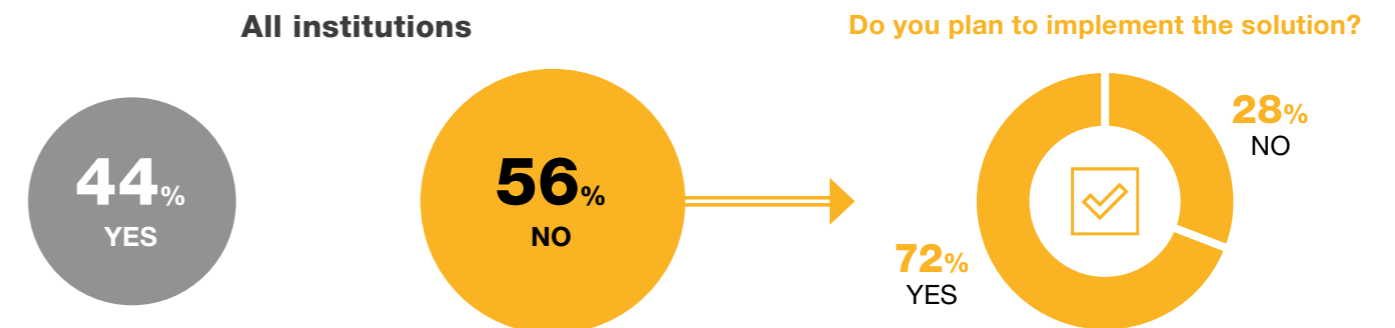
» The use of proper technology and automation plays an essential role in Model risk. The digitalisation of the MRM function can help risk managers to identify, evaluate and address risk throughout the entire Model life cycle early enough to be able to tackle it before associated harm can be realised.

Our survey shows that 56% of financial institutions that responded do not utilise any technological solution to support their MRM, but more than two

thirds of them plan to implement such a solution in the near future. This leaves only 44% of financial institutions having a technological solution in place.

This finding indicates space for improving the modernisation of the risk management function, which is to a great extent already acknowledged by risk managers.

Do you have a technological solution supporting the model risk management function in your organisation, or do you plan to implement such a solution in the near future?



The “First step”

The first step towards the digitalisation of model risk is to collect all available information about existing models in the institution and build up an inventory of models. The Model Inventory is a central database of all relevant models in the organisation. It is a prerequisite for a robust MRM framework.

” Prior to populating a model inventory, a financial institution needs to establish its own definition of a model in order to populate the inventory. Such a definition needs to provide clear rules for model identification and to be applicable across the institution. Even though the definition of a model is organisation-specific, it shall follow minimal regulatory requirements. Banks are also frequently working with so-called “non-models” within their inventory. This also helps them to monitor risk associated with certain calculation or decision engines that may or may not turn into a real model later during their lifecycle within the institution.

David Dolejší
Manager,
MRM subject matter expert



” 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.

(FED, SR Letter 11-7)

A model definition outlines the scope of an inventory in terms of the number of models in it. Model inventory shall not contain only models but also all relevant information associated with them. It shall cover at least basic model characteristics such as the model use, restrictions, model owners, model risk tier, key model weaknesses or change versioning. The full list of key information shall be a part of the MRM function and in line with the market practice and regulator’s expectations.

” Banks should maintain a comprehensive set of information on models ‘implemented for use’, ‘under development’, or ‘recently retired’. The information should clearly identify model owners and users, and should also include all model uses and direct or material dependencies, i.e. models that depend or use the output of other models.

(BoE, Model risk management principles for stress testing)

Inventory Requirements from Regulation to Best Practice

- 1 Model description**
 - Model inputs such as data inputs
 - Key information about the model and scope
 - Model approval specification
 - Model limitations
 - Purchased from vendors
 - Model versioning
- 2 Responsibilities**
 - Model owner identification
 - Model users
 - Model developer
 - Model validator
 - Model approver (for use)
- 3 Risk tiering**
 - Materiality of models
 - Risk ranking of models based on specific categories such as model use, materiality, complexity
- 4 Life cycle**
 - Date of inception / production
 - Model changes history
 - Validation date
 - Approval date and notification date
 - Time frame during which the model is expected to remain valid
- 5 Documentation**
 - **Inventory of documentation:**
 - Validation report
 - Development documents
 - Implementation documents
 - Approvals
- 6 Findings**
 - References to outcomes analysis (e.g. back-testing results)
 - References to internal audit or validation findings as they pertain to the model

Functional aspects of Model Inventory



The inventory should describe the purpose and products for which the model is designed, actual or expected usage, and any restrictions on use.

(FED, SR Letter 11-7)



In order to build a comprehensive inventory with all required information, financial institutions may resort to technological tools. Indeed, almost half of the financial institutions that responded (**44%**) already have a technological solution for MRM. These 14 institutions in total within our sample consist of four that deployed a large complex solution such as SAS, three that utilise self-developed solutions and five that adjusted an existing management software. There were 2 institutions which could not disclose what solution they use. Out of those who have a technological solution in place, **79%** claim they consider their current MRM function in

the organisation to be strong and fit for the purpose. The remaining **21%** do not feel confident with the current MRM function. Therefore, we conclude that there is still room for improvement even in the set of institutions who have already deployed some technological solutions.

At the same time, out of all the respondents who claimed they do consider the current MRM function in the organisation to be strong and fit for the purpose, only **46%** already have a technological solution in place and **38%** plan to implement a suitable solution. This indicates that institutions still tend to improve their approach to MRM by implementing a proper MRM tool even if they feel confident with the current setup.

44% of the financial institutions have a technological solution

Combination of technological solution in place and satisfaction with the MRM function

9%

Technological solution **in place**, MRM function not strong and fit for the purpose

13%

Technological solution **not in place**, not planned to be implemented, MRM function strong and fit for the purpose

34%

Technological solution **in place**, MRM function strong and fit for the purpose

3%

Technological solution **not in place**, not planned to be implemented, MRM function not strong and not fit for the purpose

13%

Technological solution **not in place**, planned to be implemented, MRM function not strong and fit for the purpose

28%

Technological solution **not in place**, planned to be implemented, MRM function strong and fit for the purpose

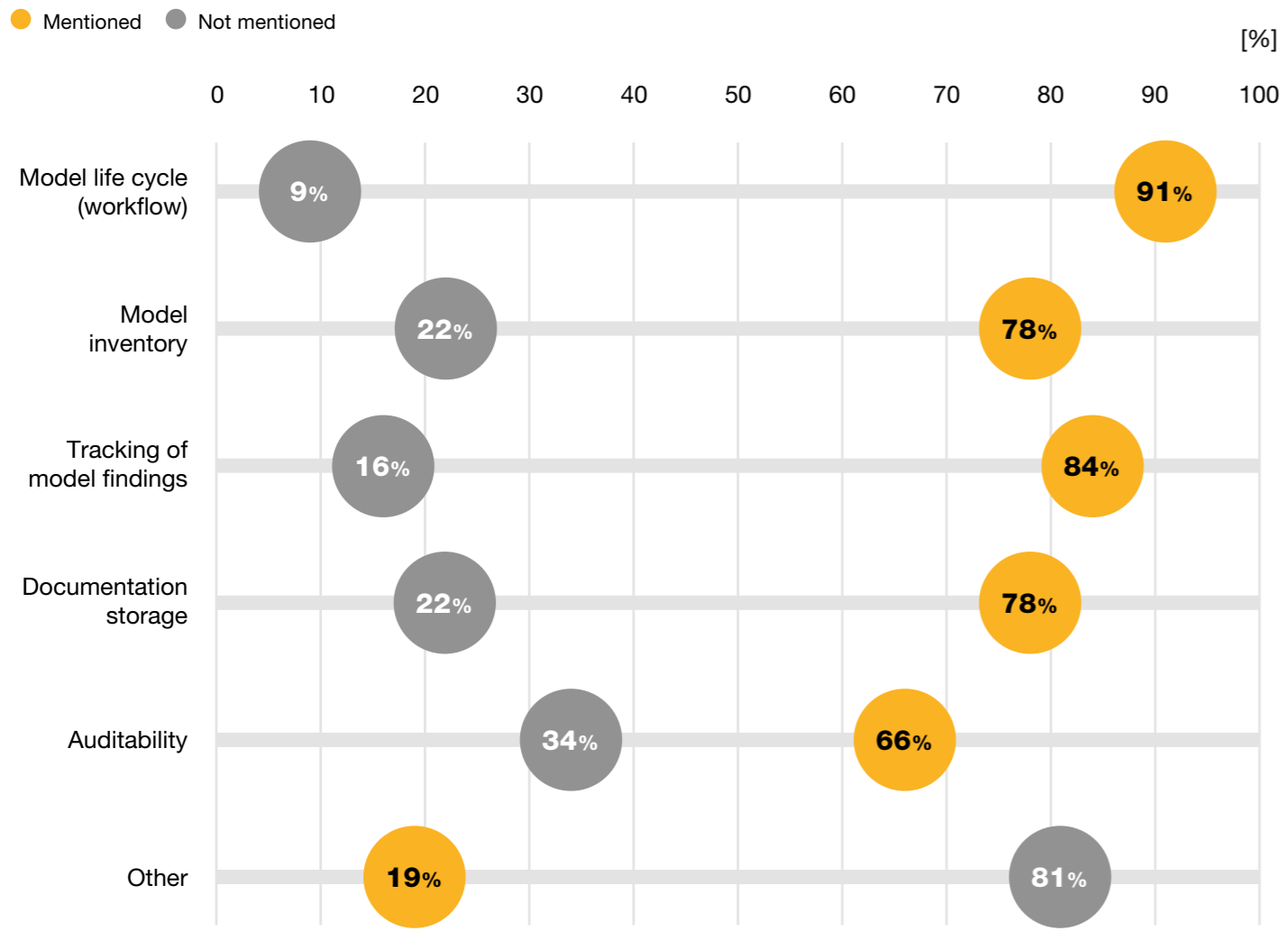


The technological solution should cover the various components of the Model Risk Management. We typically propose to our clients that the following functions are essential:

- Model life cycle
- Tracking of model findings
- Model inventory
- Documentation storage
- Auditability

The most important component according to the answers in our Survey is Model life cycle (**29 respondents**). The respondents also mentioned Tracking of model findings (**27 respondents**), Model Inventory (**25 respondents**), Documentation storage (**25 respondents**), Auditability (**21 respondents**) and Other components (**6 respondents**).

Which components of a Model Risk Management technology solution do you see as essential?



Technological Aspects

PwC Approach



Generally, there are many possibilities of MRM technological solution complexity – it can be a very simple model register implemented in a spread-sheet like software, a database automated inventory, or a complex MRM platform. Each of these has its pros and cons and should always be tailored to the specific needs of the organisation. While the simple solutions are easy to implement without the need to involve any third party, the more complex solutions are auditable, customisable and the efficiency gain is more significant.



David Dolejší
Manager, MRM subject matter expert

Approach	Description	Easy to implement	Auditability	Independence	Customization	Efficiency gains
Manual Input Inventory	A simple model register implemented in a spread-sheet like software.	●●●	●●●	●●●	●●●	●●●
Database Automated Inventory	An application over-seeing inventory and connecting all model lifecycle components & the related functionalities	●●●	●●●	●●●	●●●	●●●
Complex MRM Platform	Model governance platform serving your institutions as a control framework across all modeling aspects	●●●	●●●	●●●	●●●	●●●

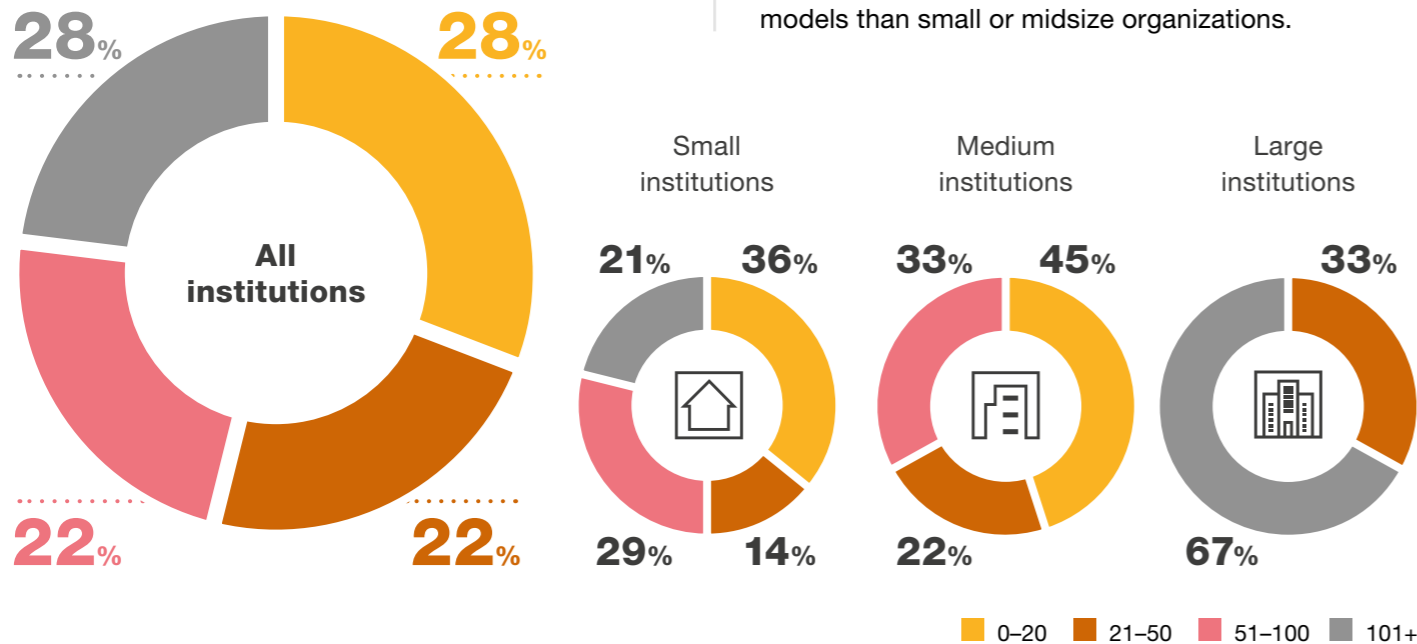
The current model landscape



How many risk-relevant models do you have in your organization?

» The institutions in the industry have dozens or even hundreds of risk models in place.

It is notable that around a quarter of our respondents (28%) have reported that they have less than 20 models and the same number of respondents have reported having over 100 models. According to our expectation large organizations claimed to have more models than small or midsize organizations.



” It is our observation that a manual, non-automated Model life-cycle management is becoming a challenge with more than 50 models and it becomes almost impossible with more than 100 models. To face this challenge, our clients often utilize technological solutions.

Adéla Mrázková
Senior Consultant,
MRM subject matter expert



Respondents in the Survey indicate that all but one institution with more than **50 risk models** have already implemented or are planning to implement a technological solution for managing their models. When investigating a subgroup of institutions with more than **100 risk models**, this became an universal rule. Three institutions are planning to implement such a solution and the rest has already implemented some.

This result is in line with our expectation that the number of models dramatically increases with the size of an institution. In turn the number of models affects the need for automation in the MRM area.



Model Taxonomy

PwC Approach

➤ Having all your models in the database is however often not enough. It is difficult and even impossible with hundreds of models to properly identify risks, their sources and to meet regulatory expectations without proper model diversification. Hence the taxonomy of models is a key aspect of their governance. In fact, unclear taxonomies may lead to an improper use of models and ultimately to financial losses to the institution.

The key functionality of model taxonomy is therefore to facilitate the proper use of models. There are business uses (performance and management reporting), risk management uses (credit risk, market risk), applied uses (mortgages), functional uses (Loss Given Default), geographical uses and others. The challenge for taxonomy is to capture all essential model uses.

MRM taxonomy example

Model ID	Model name	Risk	POSSIBLE MODEL DIMENSIONS			
			Scope	Functional use		Business use
				Level 1	Level 2	
101	Masterscale Retail Score	Credit Risk	Mortgage loans Consumer loans Credit cards	Scorecard	Scoring	Pricing/Scoring
205	Regulatory PD Mortgages	Credit Risk	Mortgage loans	A-IRB	Probability of default	Regulatory rep.
208	Regulatory EAD Secured	Credit Risk	Mortgage loans Consumer loans	A-IRB	Exposure at Default	Management rep.

Single choice dimensions

Most dimensions shall allow only single value selection.

Multiple choice dimensions

Some dimensions may support selection of one or more values.

Hierarchal dimensions

Some dimensions may set values in a hierarchical structure, where the first level decides the options for the second level, and the second level decides options for the third level and so on.

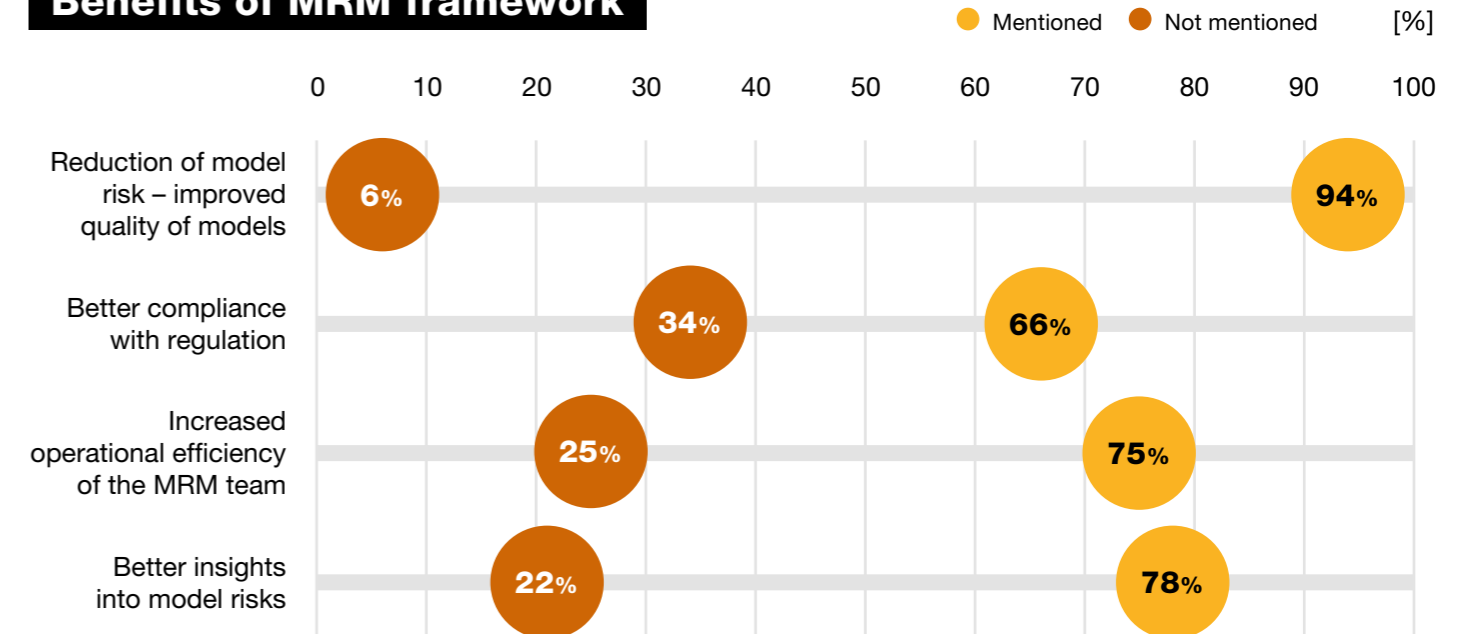
Benefits of MRM framework (why it matters)

➤ In PwC's view, the most important benefits of having a suitable MRM framework in place are:

- Better insights into model risks
- Increased operational efficiency, reduced necessity of human resources
- Better compliance with regulation, better auditability

The most commonly expected benefit in our survey is the reduction in model risk (**30 answers**). The other mentioned benefits were better insights into model risks (**25 answers**), increased operational efficiency of the MRM team (**24 answers**) and better compliance with regulations (**21 answers**).

Benefits of MRM framework



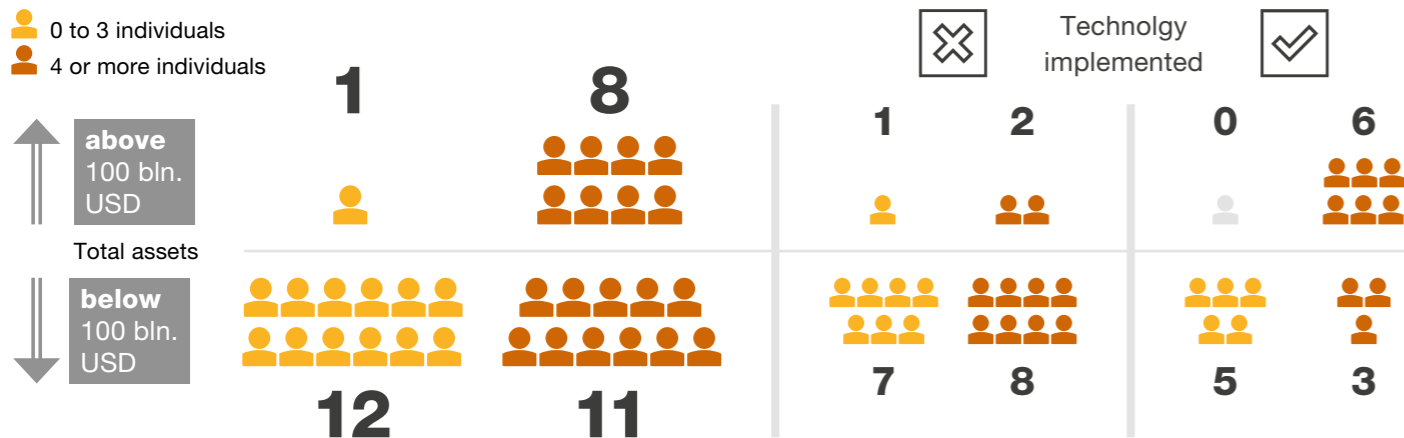
When we think about the dependency of the number of individuals dedicated to MRM activities on the size of the bank measured by total assets, we would expect that in larger institutions there would be more individuals needed. The survey results show however that this does not necessarily hold - while for large banks with total assets above USD 100 bln. there are typically (in **89%** of cases) 4 or more individuals dedicated to MRM activities, in smaller institutions (with total assets below USD 100 bln.) the number of individuals range significantly from zero to more than 11 individuals. Around half of the smaller institutions have 0 to 3 individuals dedicated to MRM activities but the remaining have even more than four individuals dedicated to MRM.

When we look at the same dependency in the context of having an MRM tool in place, the first thing we notice is that large institutions (with total assets above USD 100 bln.) mostly have some (**67%** of respondents).

The number of individuals is distributed more or less evenly for smaller institutions (with total assets below USD 100 bln.) that do not have a technological solution in place covering the range from zero to more than 11 individuals – **47%** have 0 to 3 individuals and **53%** have 4 or more individuals). The ratio changes in favor of saving human resources when we look at smaller institutions with technological solutions in place – **63%** have 0 to 3 individuals and **37%** have 4 or more individuals dedicated to the MRM activities.

For larger institutions, the savings of human work coming from having a technological MRM solution in place seems to be less significant, as most of them have 4 or more individuals dedicated to MRM activities even though they have technological solutions in place. There can however be other effects, for instance, larger complexity of the model landscape leading to both implementing the solution and hiring more dedicated personnel.

Number of individuals dedicated to MRM activities in relation to the institution size



Conclusion

With the overall number of models in financial institutions rising, accompanied by the greater complexity and variability of the models, financial institutions are searching for effective ways on how to automate and digitise relevant processes and ensure proper governance of the models.

The survey performed by PwC confirmed the overall good position of the financial market within their MRM function maturity, since the majority of risk managers tends to evaluate the Model Risk Management function in their institutions as strong and fit for the purpose. However, at the same time, the survey revealed that more than half of financial institutions still do not utilise any technological solution to support their Model Risk Management. Many organisations (even those who see their MRM function as strong and fit for the purpose) plan to deploy a suitable MRM tool in the upcoming years.

The key steps on the successful journey to having an effective Model Risk Management for those organisations who aim at being more effective and competitive are the implementation of a suitable Model Risk Management framework and its automation through a relevant Model Inventory Solution.

We at PwC have the right experience, solid knowledge and relevant solutions in place that can raise your Model Risk Management function to another level. We will be glad to guide you on this journey.

Yours sincerely,



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