



Model risk management

A guide for financial institutions in Saudi Arabia

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Foreword

Model risk represents the unfavorable consequences arising from inappropriate model usage, incorrect model outputs, or due to errors in model implementation resulting in operational, financial and/or reputational losses. Globally, an increase in the number and complexity of models adopted by the financial sector institutions across various aspects of their operations, including capital computation, credit risk, market risk, operational risk, liquidity, pricing, fraud detection, etc, have necessitated implementation of holistic Model Risk Management (MRM) frameworks to manage model risks.

High profile examples of model failures coupled with increasing global uncertainty and disruptive systemic events like the 2020-21 pandemic have called for a need for a structured approach to managing model risks and mitigating model losses. In addition, the use of MRM across the financial sector has also evolved driven by increasing regulatory oversight in this area. Leading regulators have provided guidance on the MRM process, covering identification, management, mitigation and reporting. In the region, the Central Bank of the United Arab Emirates (CBUAE) issued the Model Management Standards and Guidance (MMS&G) in December 2022 aimed at improving model quality, homogeneity and ensuring mitigation of model risks.

The Saudi Central Bank (SAMA) is also expected to roll out MRM guidelines soon given the increasing pace of growth, digitization, and complexity in the Kingdom's financial sector. Implementing a robust MRM framework is expected to result in improved decision making, enhanced efficiency, loss avoidance and capital optimization for the banking sector. Ensuring readiness to comply with upcoming SAMA MRM guidelines has thus become one of the key strategic and regulatory imperatives for the banking sector. This publication is presented to provide guidance for executives to implement MRM in their banks. We hope you find this insightful and look forward to feedback.



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The evolving landscape in Saudi Arabia

The MRM landscape is constantly evolving in Saudi Arabia through the last decade primarily driven by the large banks, with some of the most significant developments occurring in areas like model documentation, real-time monitoring, efficient model inventory tracking, integrated stress testing and scenario analysis, third-party outsourcing, and collaboration.

Given the technical resource constraints, banks in the Kingdom place high reliance on third parties for model development and validation which increases, the risks associated with model development that calls for robust documentation to verify the reliability and transparency of externally developed models. From a model governance perspective, this requires real-time monitoring of these third-party or inhouse models, giving users the ability to react and adapt to changing conditions or potential hazards before they escalate. These instances also underscore the need for collaborative approaches to model validation between institutions and external entities, including regulators and independent auditors, as standards continue to evolve.

Further, an uptick in new model types, such as climate risk and current expected credit loss (CECL) models, also introduces new complexities and risks due to the scarcity of historical data. These models often depend on external factors and data sources, driving a need to integrate qualitative methodologies and experienced judgment. The effectiveness of these models depends on strong scenario-building techniques and dependable data, so it is crucial that financial institutions have access to specialized

knowledge and skills in validating key risks. The Basel Committee on Banking Supervision's (BCBS) 239 standard: "Principles for effective risk data aggregation and risk reporting" provides fourteen basic principles around data management which are leveraged for MRM. The overall objective of the standard is to strengthen banks' risk data aggregation capabilities and internal risk reporting practices, in turn, enhancing the risk management and decision-making processes at banks.


The regulatory landscape

Under Vision 2030, the Financial Sector Development Program (FSDP) was launched, which aims to build a diversified and robust financial sector.

FSDP is playing crucial role in shaping the future of Saudi Arabia's financial sector, and through SAMA helping financial institutions in the Kingdom become stronger and more competitive.

In line with overall FSDP objectives, SAMA is also aiming to strengthen the financial ecosystem through adoption of initiatives like model governance and risk management in the next six to twelve months.

Table 1: Global and regional trends in MRM

Region	Regulator	Regulation	Date
 Global	Bank for International Settlements (BIS)	Basel III Accord	December 2010
 UK	Prudential Regulation Authority (PRA)	Draft guidance on Model Risk Management	2022
 UK	Prudential Regulation Authority (PRA)	Final requirements for an effective MRM framework	May 2023
 Europe	European Central Bank (ECB)	A Guide for the Targeted Review of Internal Models (TRIM)	2017 (consultation), 2019 (final)
 Europe	European Central Bank (ECB)	Revised guide to internal models	September 2023 (consultation), February 2024 (final)
 US	Office of the Comptroller of the Currency (OCC)	Guidance on Model Risk Management	2011
 US	Office of the Comptroller of the Currency (OCC)	Guide on Model Risk Management	2021
 UAE	Central Bank of UAE	Model Management Guidance and Model Management Standards	2022
 Saudi Arabia	SAMA	MRM Guidelines (draft)	Expected soon

Notes to Table 1:

- The Basel III Accord is a global framework, while the other regulations are specific to individual countries or regions.
- The PRA's final requirements for an effective MRM framework are effective from May 2024.
- The ECB's revised guide to internal models covers general topics, credit risk, market risk, and counterparty credit risk.
- The OCC's latest Guide on Model Risk Management was released in 2021.
- The Central Bank of UAE's Model Management Guidance and Model Management Standards were issued in 2022.
- SAMA is expected to release a draft of its Model Risk Management Guidelines soon.

Model risk under high growth or stressed conditions

Several factors can significantly amplify model risk during periods of high growth or stressed conditions:

- **Increased data volatility and uncertainty**
High growth periods often involve rapid changes in market dynamics, customer behavior, and business operations. This can lead to increased data volatility and uncertainty, making it challenging for models to accurately capture the underlying relationships and predict future outcomes. Stressed conditions, such as economic downturns or market crashes, can also introduce significant volatility and uncertainty into the data. This can make it difficult for models to distinguish between normal fluctuations and true signals of distress.
- **Limited historical data**
During periods of high growth, companies may have limited historical data to train and validate their models. This can lead to models that are not robust enough to handle the increased complexity and variability of the data. Similarly, stressed conditions may be rare events with limited historical data available. This can make it difficult to develop models that can accurately predict the impact of such events.
- **Increased model complexity**
Companies may be tempted to use more complex models during periods of high growth or stress to capture the increased complexity of the environment. However, more complex models are also more prone to errors and biases. Additionally, the increased complexity can make it more difficult to understand and interpret the model's outputs, which can lead to poor decision-making.
- **Increased reliance on models**
During periods of high growth or stress, companies may become more reliant on models to make critical decisions. This can increase the potential impact of model errors or biases. Additionally, the increased pressure to make quick decisions can lead to shortcuts in the model development and validation process, further increasing the risk of model failure.
- **Changes in model inputs**
High growth or stressed conditions can lead to significant changes in the underlying assumptions and inputs used by models. This can invalidate the model's predictions and lead to inaccurate results. For example, a model that was developed based on assumptions of stable economic growth may not be accurate if the economy enters a recession.





Key considerations for implementing MRM

Governance and oversight

Developing and maintaining strong governance, policies, and controls over the MRM framework is fundamentally important to its effectiveness. Even if model development, implementation, use, and validation are satisfactory, a weak governance function will reduce the effectiveness of overall MRM. A strong governance framework provides explicit support and structure to risk management functions through policies defining relevant risk management activities, procedures that implement those policies, allocation of resources, and mechanisms for evaluating whether policies and procedures are being carried out as specified.

Model risk governance is provided at the highest level by the board of directors and senior management when they establish a bank-wide approach to MRM. As part of their overall responsibilities, a bank's board and senior management should establish a strong MRM framework that fits into the broader risk management of the bank. That framework should be grounded in an understanding of model risk—not just for individual models but also in the aggregate.

The framework should include standards for model development, implementation, use, and validation.

While the board is ultimately responsible, it generally delegates to senior management the responsibility for executing and maintaining an effective model risk management framework. Duties of senior management include establishing adequate policies and procedures and ensuring compliance, assigning competent staff, overseeing model development and implementation, evaluating model results, ensuring appropriate model inputs, assumptions and outputs, reviewing validation and internal audit findings, and taking prompt remedial action when necessary. In the same manner as for other major areas of risk, senior management, directly and through relevant committees, is responsible for regularly reporting to the board on significant model risk, from individual models and in the aggregate, and on compliance with policy. Board members should ensure that the level of model risk is within their tolerance and direct changes where appropriate. These actions will set the tone for the whole bank about the importance of model risk and the need for active MRM.

- **The increasing reliance on models in today's digital and automated environment calls for a robust MRM framework. Governance and standards form a crucial part of the MRM infrastructure. Two levels of governance need to be set up: one for oversight at the board and senior management level and the other covering the steps of the model lifecycle.**
- **Having a positive and all-inclusive model risk culture in place is a fundamental step toward successfully embedding robust MRM practices.**

Model development and validation

Effective MRM starts with a comprehensive governance and oversight framework supported by effective model lifecycle management.

The model lifecycle broadly comprises three main processes:

- **Core modelling process** – model development, implementation, and use;
- **Model validation** – the set of activities intended to verify that models perform as expected, through:
 - A review of the suitability and conceptual soundness of the model (independent review);
 - Verification of the integrity of implementation (process verification);
 - Ongoing testing to confirm that the model continues to perform as intended (model performance monitoring); and
- **Model risk controls** – the processes and procedures other than model validation activities to help manage, control, or mitigate model risk.

Modelling process

An effective development process begins with a clear statement of purpose to ensure that model development is aligned with the intended use. The design, theory, and logic underlying the model should be well documented and generally supported by published research and sound industry practice. Comparison with alternative theories and approaches is a fundamental component of a sound modeling process.

The data and other information used to develop a model are of critical importance; there should be rigorous assessment of data quality and relevance, and appropriate documentation. Developers should be able to demonstrate that such data and information are suitable for the model and that they are consistent with the theory behind the approach and with the chosen methodology.

An integral part of model development is testing, in which the various components of a model and its overall functioning are evaluated to determine whether the model is performing as intended. Model testing includes checking the model's accuracy, demonstrating that the model is robust

Figure 1: Modelling process

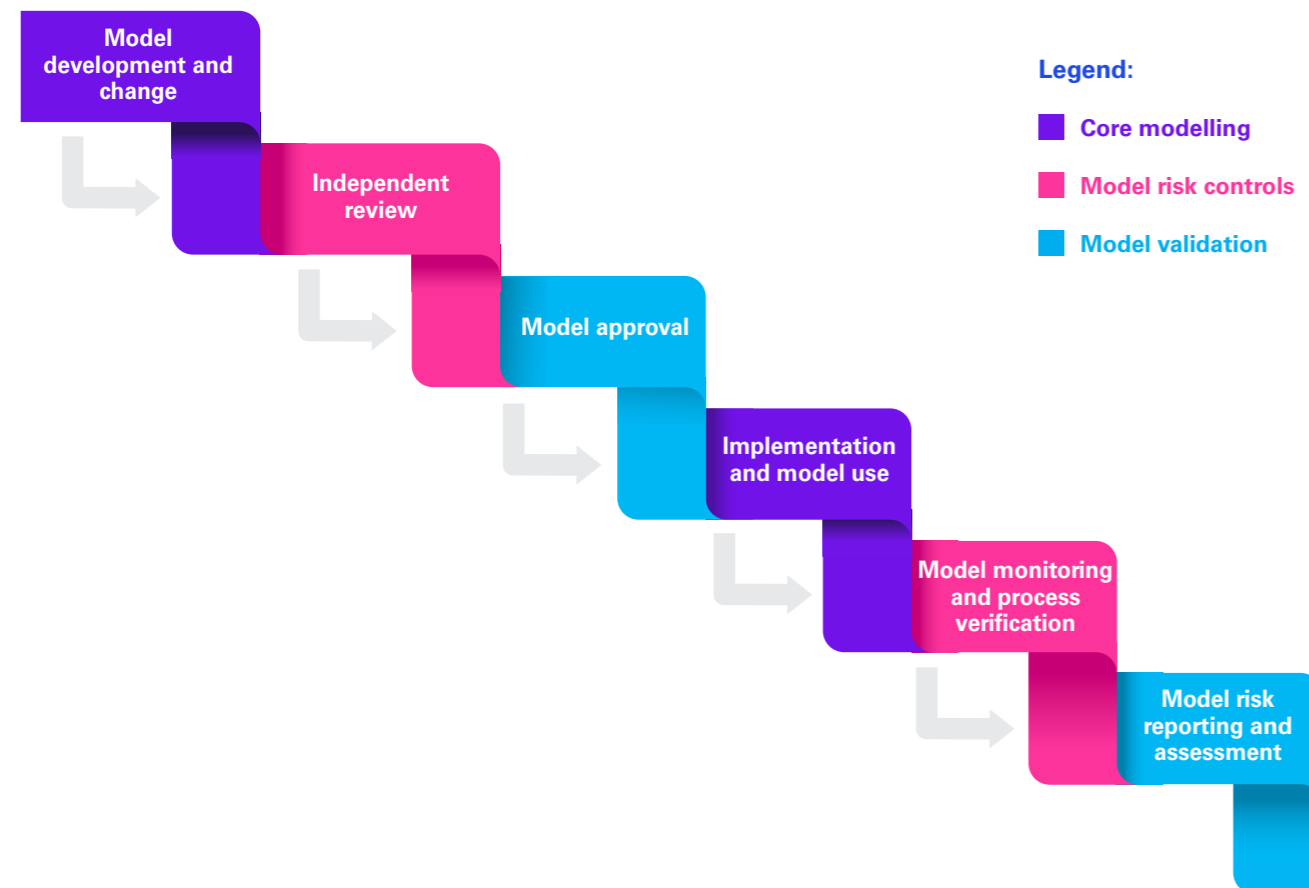
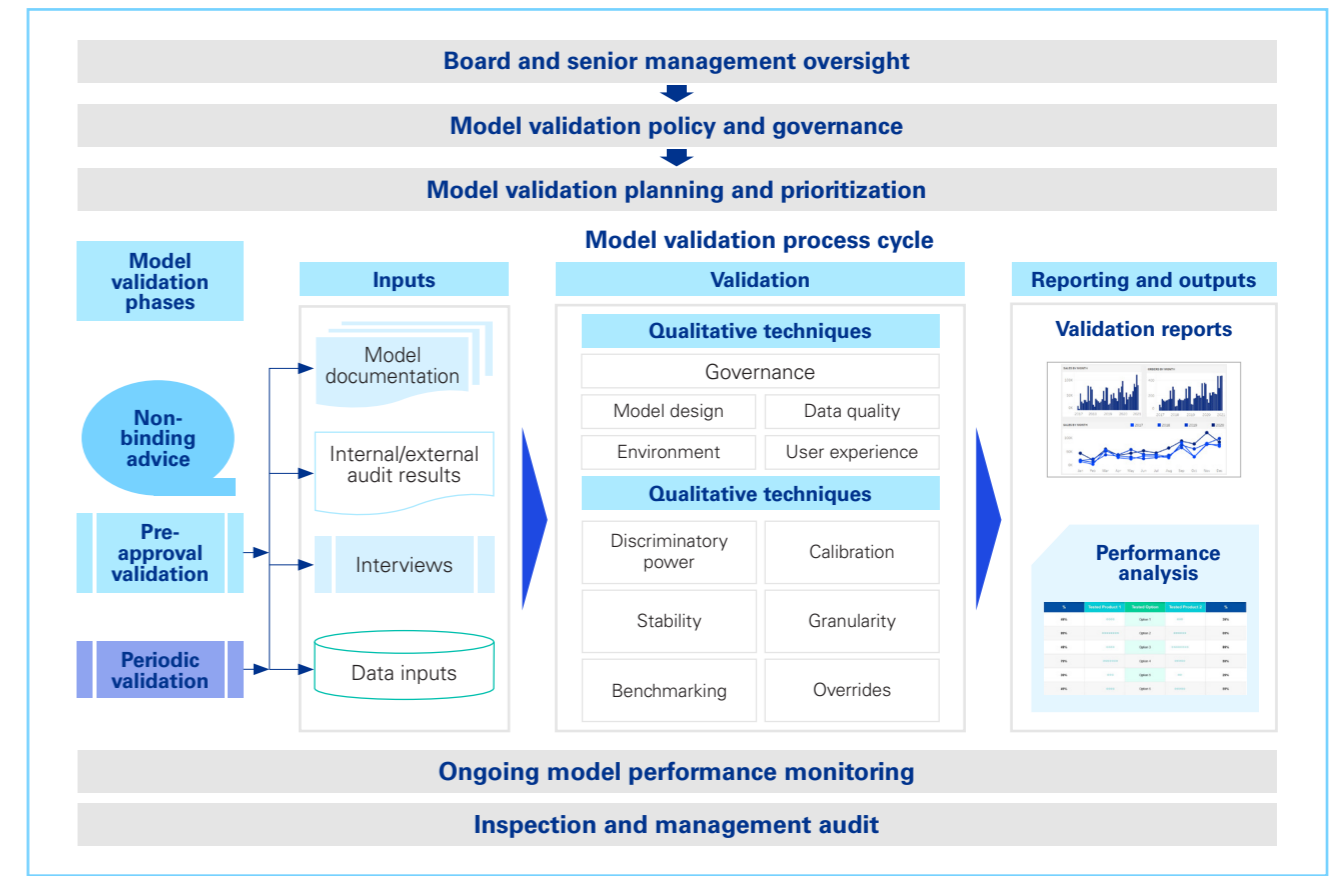


Figure 1: Model validation components



and stable, assessing potential limitations, and evaluating the model's behavior over a range of input values. Testing activities should be appropriately documented.

Model use provides additional opportunity to test whether a model is functioning effectively and to assess its performance over time as conditions and model applications change. It can serve as a source of productive feedback and insights from a knowledgeable internal constituency with strong interest in having models that function well and reflect economic and business realities.

While conservative use of models is prudent in general, banks should be careful in applying conservatism broadly or claiming to make conservative adjustments or add-ons to address model risk, because the impact of such conservatism in complex models may not be obvious or intuitive.

In summary, robust model development, implementation, and use is important to MRM. But it is not enough for model developers and users to understand and accept the model. Because model risk is ultimately borne by the institution, the institution should objectively assess model risk and the associated costs and benefits using a sound model-validation process.

Model validation process

Model validation is the set of processes and activities intended to verify that models are performing as expected, in line with their design objectives and business uses. Effective validation helps ensure that models are sound. It also identifies potential limitations and assumptions and assesses their possible impact.

Validation involves a degree of independence from model development and use. Staff doing validation should have the requisite knowledge, skills, and expertise. Staff conducting validation work should have explicit authority to challenge developers and users and to elevate their findings, including issues and deficiencies.

Validation activities are expected to continue an ongoing basis after a model goes into use, to track known model limitations and to identify any new ones. Ongoing validation activities help to ensure that changes in markets, products, exposures, activities, clients, or business practices do not create new model limitations. For example, if credit risk models do not incorporate underwriting changes in a timely manner, flawed and costly business decisions could be made before deterioration in model performance becomes apparent.

Building on the above, an effective validation framework should include three core elements,

- Evaluation of conceptual soundness, including developmental evidence.
- Ongoing monitoring, including process verification and benchmarking.
- Outcomes analysis, including back-testing.

Evaluation of conceptual soundness

This element involves assessing the quality of the model design and construction. It entails review of documentation and empirical evidence supporting the methods used and variables selected for the model. Documentation and testing should convey an understanding of model limitations and assumptions. Developmental evidence should be reviewed before a model goes into use and as part of the ongoing validation process, whenever there is a material change in the model.

A sound development process will produce documented evidence in support of all model choices, including the overall theoretical construction, key assumptions, data, and specific mathematical calculations. As part of model validation, those model aspects should be subjected to critical analysis by both evaluating

the quality and extent of developmental evidence and conducting additional analysis and testing as necessary. Comparison to alternative theories and approaches should be included. Key assumptions and the choice of variables should be assessed, with analysis of their impact on model outputs and particular focus on any potential limitations. The relevance of the data used to build the model should be evaluated to ensure that it is reasonably representative of the financial institution's portfolio or market conditions, depending on the type of model.

Qualitative information and judgment used in model development should be evaluated, including the logic, judgment, and types of information used, to establish the conceptual soundness of the model and set appropriate conditions for its use. The validation process should ensure that qualitative, judgmental assessments are conducted in an appropriate and systematic manner, are well supported, and are documented.

Quantitative validation can be broadly classified into benchmarking and back-testing. While the following section provides required details for each of them, the following pictorial representation shows the different statistical tests carried out to conclude upon model suitability.

Table 2: Back testing and benchmarking

Back testing					Benchmarking
Discrimination	Accuracy	Stability	Granularity	Overrides	
Graphical <ul style="list-style-type: none"> • Cumulative accuracy profile • Receiver operating characteristic 	Graphical <ul style="list-style-type: none"> • Observed versus predicted outcome 	Graphical <ul style="list-style-type: none"> • Migration matrix 	Graphical <ul style="list-style-type: none"> • Model output distributions (PD, LGD and EAD) 	Graphical <ul style="list-style-type: none"> • Override rates over time • Impact of overrides on rating profile 	<ul style="list-style-type: none"> • External rating agency comparisons • Methodology benchmark • Market data • External model comparisons • Related portfolio comparisons - quantitative and qualitative assessment
Tests to tests <ul style="list-style-type: none"> • Accuracy ratio • Gini Coefficient • K-S test 	Tests to tests <ul style="list-style-type: none"> • Binomial test • Chi-square Test • Normal test 	Tests to tests <ul style="list-style-type: none"> • Population stability • Characteristic stability 	Tests to tests <ul style="list-style-type: none"> • Herfindahl index 		
Correlations <ul style="list-style-type: none"> • Pairwise correlation • Kendall's tau • R-squared 				Qualitative <ul style="list-style-type: none"> • Override reasons 	

Ongoing monitoring

The second core element of the validation process is ongoing monitoring. Such monitoring confirms that the model is appropriately implemented and is being used and is performing as intended.

Ongoing monitoring is essential to evaluate whether changes in products, exposures, activities, clients, or market conditions necessitate adjustment, redevelopment, or replacement of the model and to verify that any extension of the model beyond its original scope is valid. Monitoring begins when a model is first implemented in production systems for actual business use. This monitoring should continue periodically over time, with a frequency appropriate to the nature of the model, the availability of new data or modeling approaches, and the magnitude of the risk involved.

Process verification checks that all model components are functioning as designed. It includes verifying that internal and external data inputs continue to be accurate, complete, consistent with model purpose and design, and of the highest quality available. System integration can be a challenge and deserves special attention because the model processing component often draws from various sources of data, processes large amounts of data, and then feeds into multiple data repositories and reporting systems. Reports derived from model outputs should be reviewed as part of validation to verify that they are accurate, complete, and informative, and that they contain appropriate indicators of model performance and limitations.

Sensitivity analysis and other checks for robustness and stability should likewise be repeated periodically. If models only work well for certain ranges of input values, market conditions, or other factors, they should be monitored to identify situations where these constraints are approached or exceeded.

Ongoing monitoring should include the analysis of overrides with appropriate documentation. In the use of virtually any model, there will be cases where model output is ignored, altered, or reversed based on the expert judgment of model users. If the rate of overrides is high, or if the override process consistently improves model performance, it is often a sign that the underlying model needs revision or redevelopment.

Benchmarking is the comparison of a given model's inputs and outputs to estimates from alternative internal or external data or models. It can be incorporated in model development as well as in ongoing monitoring. For credit risk models, examples of benchmarks include models from vendor firms or industry consortia and data from retail credit bureaus.

Discrepancies between the model output and benchmarks should trigger investigation into the sources and degree of the differences, and examination of whether they are within an expected or appropriate range given the nature of the comparison. The results of that analysis may suggest revisions to the model.

Outcomes analysis

The third core element of the validation process is outcomes analysis, a comparison of model outputs to corresponding actual outcomes. The precise nature of the comparison depends on the objectives of a model and might include an assessment of the accuracy of estimates or forecasts, an evaluation of rank-ordering ability, or other appropriate tests. Such comparisons help to evaluate model performance, by establishing expected ranges for those actual outcomes in relation to the intended objectives and assessing the reasons for observed variation between the two. Outcomes analysis should be conducted on an ongoing basis to test whether the model continues to perform in line with design objectives and business uses.

Back-testing is one form of outcomes analysis; specifically, it involves the comparison of actual outcomes with model forecasts during a sample time-period not used in model development and at an observation frequency that matches the forecast horizon or performance window of the model. Models with long forecast horizons should be back-tested but given the amount of time it would take to accumulate the necessary data, that testing should be supplemented by evaluation over shorter periods.

— Banks should have a robust model development process with standards for model design and implementation, model selection and model performance measurement. Testing of data, model construct, assumptions and model outcomes should be performed regularly to identify, monitor, record and remediate model limitations and weaknesses.

Model usage and controls

Model usage is an integral part of model management. Model usage must be defined, documented, monitored, and managed as per set standards.

Usage definition and control

As part of the definition of model strategy and objectives, institutions must articulate and document upfront the expected usage of each model. Model usage must cover, at a minimum, the following components:

- i. The users identified either as individuals or teams.
- ii. The expected frequency of model utilization.
- iii. The specific source and nature of the inputs in the production environment.
- iv. The destination of the outputs in terms of IT system and operational processes.
- v. The interpretation of the outputs, i.e., how the outputs should be used, their meaning and the decisions that they can support.
- vi. The limits of the outputs, associated uncertainty and the decisions that can be supported by the model versus those that should be supported.
- vii. The governance of output overrides.

Any deviation between the real usage of a model and the expected usage of a model must be documented in the monitoring and validation phases and remedied promptly, by reverting to the intended usage of the model.

Roles and responsibilities

The management of model usage is shared between several parties. The model owner is responsible to define the usage of his/her models. The usage of each model should then be approved by the Model Oversight Committee, a committee responsible for approving model usage and monitoring adherence. If the model owner and model user are different parties, the owner is responsible to provide documentation and training to the user. The model user must therefore follow appropriately the guidance provided by the owner.

The monitoring of model usage can be performed by the model owner, by the validator, or both, depending on the bank's circumstances. Irrespective of the party performing the monitoring process, the validator must conduct an independent assessment of the appropriate usage of models as part of the validation process. For this purpose, the validator should refer to the monitoring reports, when available.

Input and output overrides

Manual overrides of model inputs and outputs are possible and permitted but within limits. For this purpose, institutions must put in place robust governance to manage these overrides. Such governance must be reviewed by the internal audit function. Institutions must implement limits and controls on the frequency and magnitude of overrides. Models whose input or outputs that are frequently and materially overridden must not be considered fit for purpose and must be recalibrated or replaced.

The development and validation teams must analyse and understand the reasons for input and/or output overrides and assess whether they are caused by model weaknesses. Overrides must be tracked and reported to the Model Oversight Committee, Senior Management, and the Board as part of the monitoring and validation processes.

User feedback

Institutions must have a process in place to ensure that model functionalities are working as expected during ongoing utilization to ensure that models have been designed, calibrated, and implemented successfully.

The user feedback must cover the model functionalities, stability, and consistency of output against economic and business expectations. The user feedback must be documented and reported during the monitoring and validation steps.

— **Model usage and associated controls are an integral part of model management. Banks use models to inform business decisions as well for regulatory purposes, and a robust MRM framework would lead to better models, which in turn, could lead to improved business decisions, better pricing, and customer management.**



Model risk reporting and communication

The model validation exercise must be rigorously documented in a validation report. Validation reports must be practical, action orientated, focused on findings, and avoid unnecessary theoretical digressions. A validation report should include, at a minimum, the following components:

- The model reference number, nomenclature, materiality, and classification.
- The implementation date, the monitoring dates, and the last validation date, if any.
- A clear list of findings with their associated severity.
- Suggestions for remediation, when appropriate.
- The value of each performance indicator with its associated limit.
- The results of the qualitative review.
- The results of the quantitative review.
- The model risk rating.
- A conclusion regarding the overall performance.

The model validation report must refer to the steps of the model lifecycle. Its conclusion should be one of the following possible outcomes:

- Leave the model unchanged.
- Use a temporary adjustment while establishing a remediation plan.
- Recalibrate the model.
- Redevelop a new model, or withdraw the model without further redevelopment.



Model validation reports must aim to be practical, action-oriented, contain both qualitative and quantitative elements and have specific findings related to model usage. ”

Upon completion, the validation report is required to be discussed between the validator and the development team, with the objective to reach a common understanding of the model weaknesses and their associated remediation. Both parties are expected to reach a conclusion on the validation exercise, its outcomes, and its remediation plan.

Typical areas identified for enhancement of MRM framework to ensure appropriate readiness with upcoming regulatory guidelines are listed below.

Establish model identification process

Institutions need to establish a consistent firm-wide process for application of post-model adjustments (PMAs) which should be documented in the policies and procedures and include a governance and control framework. Documentation of PMAs also need to be enhanced and their use should be

properly justified and linked to model limitations. Moreover, PMAs should be subject to independent review, including root cause analysis, to ensure that they are not applied due to significant model deficiencies. Institutions should have escalation matrix in place so that the key stakeholders (model owners, users, validation function and senior management) are promptly made aware of any model exceptions.

Revise model governance process

Different regulators expect banks and financial institutions to have a robust model governance process with increased accountability of senior management and board of directors on MRM. Banks need to identify personnel who have the right expertise. Moreover, banks need to familiarize the board with the material and complex models. They also need to understand the underlying risks and limitations on models. Although, the board of directors is expected to delegate this responsibility to senior management, it is necessary to apprise them of model risks on a regular and timely basis.

Data quality governance framework

Banks need to ensure a proper and effective data quality framework which covers assessment of data quality dimensions, full data life cycle from data entry to reporting, and have both current and historical application databases. Banks also need to set up an independent data quality function as a second line of defense which ensures that quality data is used between hosts and databases.

Expansion of model validation expertise

Banks will need to add the capacity and expertise to validate new models which come under the MRM framework. Dealing with a much broader scope of models, they will need to apply a standard that consistently manages the risks across very different model types and their uses – for e.g., anti-money laundering (AML) and financial crime compliance (FCC) models are traditionally built using expert-driven rules which are not considered as models. However, banks are increasingly using ML techniques for AML/FCC models, which will require these systems to be brought under the MRM framework. Similarly, the use of ML is also increasing in IRB models. ML models can produce parameter estimates that are not easily understood, especially when the model's structure is complex and hard to interpret. As the use of AI/ML models increases across functions, banks will need to upskill their resources so that they are able to challenge these models. Since these models require highly specialized skills, banks may need to establish new teams with more focus on AI/ML model validation.

The Covid-19 pandemic has highlighted the value of MRM and raised the function's significance as a strategic risk partner. MRM maturity varies by region, in part due to different regulatory guidelines. Nonetheless, improving validation effectiveness and operational efficiency are universal priorities. Within financial institutions in every region, MRM functions are evolving faster than ever, primarily because models are proliferating in number and scope. The future looks bright for MRM – but it will evolve over time.

Challenges and opportunities in Saudi Arabia

The challenges for implementation

Market structural changes, increasing business complexities, machine-learning techniques and climate risk management initiatives will present some of the most interesting MRM obstacles and opportunities for banks.

Modeling teams and risk managers must adapt their tools to unfamiliar economic conditions, and one ongoing challenge will be to strengthen linkages between evolving macro economic and structural factors with outcomes.

Opportunities to improve financial risk models in this new economic environment will arise from leveraging analytical insights that may discern risk outcomes in data patterns from earlier periods that are reflective of higher inflation and interest rates.

The financial institutions may leverage the opportunity to enhance their modelling and model risk capabilities across all aspects of the model lifecycle in a comprehensive and sustainable manner. They shall adopt a strategic mindset to this transformation to achieve futuristic MRM practices and create a scalable solution capable of accommodating new model and risk types as they emerge.

Opportunities for leveraging technology and collaboration to enhance the MRM practice

Models can help increase automation, transparency, and consistency of bank activities. The number, scope, and complexity of models have continued to increase over time. Examples of model uses include all kinds of models for credit risk, market risk, liquidity risk, AML and forensics, and compliance review frameworks. The expanded use of models combined with their increasing complexity and value in decision making undermines the importance of sound MRM.

Technological and analytical advancements are contributing to increased model complexity and use. For example, some artificial intelligence (AI) use cases, meet the definition of a model noted in the MRM regulatory guidelines, while AI outputs are not always quantitative in nature, AI is typically based on complex mathematical techniques. Regardless of how AI is classified (i.e., as a model or not a model), the associated risk management should be commensurate with the level of risk of the function that the AI supports.

This growing model landscape within organizations calls for the need to find ways to integrate inventory tracking, stress testing, and scenario analysis into the model validation process through the latest technology paradigms and solution providers. This provides a structured approach to operationalizing all types of models that are tracked as a part of a central inventory. Tracking and testing becomes increasingly complex as model dependencies grow, with a series of upstream models impacting downstream model outcomes. One of the solutions often proposed leverages blockchain technology's decentralized and immutable features, which can help provide secure and transparent tracking of models throughout their lifecycle. Additionally, integrated stress testing programs can help simulate complex scenarios and assess the resilience of models in dynamic and unpredictable environments.

Future trends

The MRM space is set to see both new technologies and new complexities approaching the scene soon. These changes will impact three key areas of the practice:

Enhanced efficiency

The MRM practices offer a wide range of applications that could benefit from groundbreaking technologies like Generative AI — streamlining labor-intensive tasks like documentation and reporting, for example.

Technology-driven initiatives can also help enhance processes in inventory management and continuous monitoring. However, initial implementation could face challenges, including regulatory uncertainties, concerns about data confidentiality, and considerations of accountability. Avoiding these drawbacks will require companies to employ strategic approaches when integrating secure large-language model APIs for internal use.

MRM leaders can work proactively to help minimize overlaps, optimize processes, and cultivate a risk-aware culture throughout their organizations.

Continuous Monitoring

The current trend towards continuous monitoring of models is expected to increase. Institutions will need to leverage real-time data for frequent testing to maintain a proactive and agile approach to risk management practices. However, regulatory expectations are still evolving to prefer a real-time and adaptive approach to MRM. Regulators increasingly emphasize the importance of attentiveness and timely addressing issues and tracking risks which might merge. Continuous monitoring can bring into line these expectations and demonstrate the commitment to strong risk management practices.

Technology Enablement

The use of robust model monitoring tools is expected to play an important role in enhancing the transparency and building scale for model risk management. Usage of these tools will contribute towards the development of a systematic and consistent approach toward the management of model risks for a bank. Technology is expected to become a crucial ingredient in ensuring standardization, building transparency and stakeholder trust, enhancing regulatory compliance, helping address ethical considerations, and facilitating effective collaboration between the three lines of defense.

Potential regulatory changes impacting MRM

As the regulatory landscape around MRM is still evolving, with new regulations and guidelines emerging to address the increasing complexity and reliance on models within the financial services industry. Here are some potential regulatory changes that could significantly impact MRM:

- Model validation and documentation requirements**
 Regulators may introduce stricter requirements for model validation, including more comprehensive testing methodologies, independent validation by qualified experts, and detailed documentation of model development and validation processes. This will increase the burden on financial institutions to ensure their models are robust and reliable.
- Interpreting models**
 There is a growing emphasis on the enhancing model's explaining and interpreting capacity, particularly for complex models like machine learning algorithms. Regulators may require financial institutions to demonstrate that they understand how their models work and can explain their outputs to stakeholders. This would necessitate the development of techniques for interpreting model results and communicating them effectively.
- Evaluation of model governance and oversight**
 Regulators may increase their inspections of model governance frameworks, including the roles and responsibilities of different stakeholders across the 3 LoD involved in model development, validation, and deployment. This would require financial institutions to strengthen their governance structures and ensure clear accountability for MRM.
- Global MRM standards**
 There is a trend towards the adoption of MRM standards, such as the Basel III Accord's new, comprehensive framework for MRM that requires banks to put in place robust processes for validating their models' accuracy and reliability. This would harmonize MRM practices across different jurisdictions and facilitate cross-border collaboration.
- Regulatory tools for model innovation**
 Regulators may introduce tools to allow financial institutions to test and experiment with innovative models in a controlled environment. This would encourage innovation in MRM and facilitate the adoption of new technologies.

Table 3: Challenges for implementation



Segregation of quantitative and non-quantitative methods

Financial Institutions shall identify 'non-models' that are critical to business decisions and start governing them to higher MRM standards. This poses several challenges, ranging from firms' ability to identify these 'non-models'; criteria for determining complexity and materiality of 'non-models'; and enhancing existing controls around these 'non-models'.



Risk aggregation

Financial Institutions shall provide an aggregated view of model risk at a Group level. This is not always easy, as identifying direct and indirect model interdependencies is often hard to assess, which is a significant driver of overall model risk.



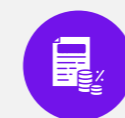
Skilled resources

Financial Institutions need strengthen their three lines of defense with respect to MRM. They will need to reconsider the size and experience of their teams and may need to think innovatively about headcount through direct recruitment and managed services.



Leadership at BOD Level

Financial institution's BODs are expected to set the strategic direction of MRM and challenge material models. This will require careful consideration of what boards can delegate appropriate metrics for boards to monitor MRM effectiveness and education on technical matters as required.



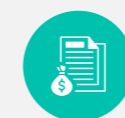
Data robustness

Financial Institution's senior management is expected to take a more active role in ensuring robust data for models. The scope of MRM in relation to data has long been debated and, in the absence of effective collaboration and alignment, there is potential for duplication of work.



Model adjustments

Financial Institutions shall strengthen governance around model adjustments and specifically post model adjustments and other model risk mitigants. This creates challenges in terms of setting materiality thresholds for model adjustments, documenting these adjustments and their impact, especially in interconnected models, and quantifying, aggregating, and reporting the impact of model adjustments on a common basis at a firm-wide level.



Model documentation

Financial Institutions shall enhance model documentation for both internally developed models and third-party vendor models. Even the relatively simple requirement of model replication will create the need for considerable uplift for several model types. Meanwhile, the need to ensure third party models' appropriateness for their intended use will lead to revised documentation requirements.

Conclusion

Upcoming SAMA regulations combined with increasing complexity of the models used by banks require them to enhance their MRM practices. Key challenges faced by banks in implementing MRM framework include deficiencies across model identification, tiering and inventory, gaps in data management, lack of robust model documentation, and deficiencies in model risk governance, skills and capacity within the banks.

This requires banks to undertake actionable steps to ensure readiness for compliance with the upcoming regulations, including the ones outlined below.

-  **1 Investing in a more sophisticated model validation, data management and documentation processes.**
-  **2 Developing techniques for explaining and interpreting model outputs.**
-  **3 Strengthening model governance frameworks and oversight mechanism.**
-  **4 Alignment with international MRM standards.**
-  **5 Adoption of automated MRM solutions to enable scale.**

By proactively addressing these potential regulatory changes, banks can ensure that their MRM practices remain compliant and effective, mitigating model risk and fostering a culture of responsible model use.

Annexure 1: MRM framework features

A typical model risk framework requires following features which the global regulator and most other leading regulators have adopted and defined to form part of the framework:

FEATURE	BASEL III, PRA, OCC, ECB, CB-UAE
Scope	Credit risk, operational risk, market risk
Model definition	Any quantitative technique used to assess risk
MRM Framework	Requires banks to have a comprehensive framework for managing model risk
Model Validation	Requires banks to validate models regularly
Model Governance	Requires banks to have a strong governance structure for MRM
Model Documentation	Requires banks to document their models adequately
Model Monitoring	Requires banks to monitor models on an ongoing basis
Model Reporting	Requires banks to report on their MRM activities to regulators

All regulators require financial institutions to:

- have a comprehensive framework for managing model risk;
- validate models regularly;
- have a strong governance structure for MRM;
- document their models adequately;
- monitor models on an ongoing basis;
- Report on their MRM activities to regulators.

However:

- The scope of the regulations varies slightly. Basel III covers credit risk, operational risk, and market risk, while the PRA, OCC, ECB, Central Bank of UAE, and also cover other types of risk.
- The level of detail required in the MRM framework varies. Basel III provides a high-level framework, while the PRA, OCC, ECB, Central Bank of UAE, and provide more specific guidance.
- The frequency of model validation varies. Basel III requires models to be validated at least annually, while the PRA, OCC, ECB, Central Bank of UAE, and require more frequent validation.
- The reporting requirements vary. Basel III requires banks to report on their MRM activities to regulators on an annual basis, while the PRA, OCC, ECB, Central Bank of UAE, and require more frequent reporting.

Annexure 2: Abbreviations

ABBREVIATION	FULL FORM
AI	Artificial Intelligence
AML	Anti-Money Laundering
API	Application Programming Interface
BIS	Bank for International Settlements
BOD	Board of Directors
CB - UAE	Central Bank of the United Arab Emirates
CECL	Current Expected Credit Loss
COO	Office of the Comptroller of the Currency
EAD	Exposure at Default
ECB	European Central Bank
FCC	Financial Crime Compliance
FI	Financial Institution
FSDP	Financial Sector Development Program
IRB	Internal Ratings-Based Approach
KYC	Know Your Customer
LGD	Loss Given Default
ML	Machine Learning
MMS&G	Model Management Standards and Guidance
MRM	Model Risk Management
SAMA	Saudi Arabian Monetary Authority
OCC	Office of the Comptroller of the Currency
PD	Probability of Default
PMA's	Post-Model Adjustments
PRA	Prudential Regulation Authority
TRIM	Targeted Review of Internal Models
TRIM	A Guide for the Targeted Review of Internal Models

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