MRM guidelines for APAC

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Analytical contacts

Anshuman Prasad
Senior Director
anshuman.prasad@crisil.com

Nageswara Ganduri
Director
nageswara.ganduri@crisil.com

Ashok Subramanian
Associate Director
ashok.subramanian@crisil.com

Shashank Rawat
Associate Director
shashank.rawat@crisil.com

Amrit Dash
Lead Analyst
amrit.dash@crisil.com

Executive summary

In this paper, we explore and compare the state of model risk management (MRM) guidelines for banks and financial institutions (FIs) in the Asia-Pacific (APAC) region. It is presented as a comparative study of regulatory frameworks around model risk compared with mature peers, such as the United States (US), the United Kingdom (UK) and the European Union. The aim is to highlight existing model risk frameworks of banks and FIs in APAC and discuss refinement of guidelines for a holistic approach to MRM. We also define a set of general guidelines that firms can adhere to when building their MRM frameworks and suggest process enhancements for efficiency gains in the long run.

Introduction

The US, the UK, and Europe have already established prudent frameworks. While these are well-suited for banks in the west, their implementation and interpretation vary across regions, say in Europe itself. Regulatory authorities in APAC have adopted relevant guidelines from these frameworks and tailored them to their portfolios and financial markets.

Meanwhile, the APAC region, owing to the different financial and banking landscape, will likely have a lower adoption rate. The Covid-19 pandemic, followed by the Russia-Ukraine conflict, has resulted in further delays. Regulators in the APAC region could use the lag in adoption to their benefit and include standards on the new family of models. In recent years, banks and FIs globally have been relying on increasingly complex models for making informed financial decisions. While the scope of models was earlier restricted to regulatory models, it has now expanded to other areas, such as algorithmic trading and anti-money laundering, resulting in a dramatic increase in the number of models in use (10-25% increase at large institutions).

The advent of new technologies, such as machine learning (ML) and artificial intelligence (AI), to achieve high performance standards should exponentially increase this number, as also the complexity of models built on quantitative finance. However, there is a possibility that these complex models may break down in stressed market conditions. This can have dire consequences, with huge financial and reputational losses for the entity, as observed in the recent case of Silicon Valley Bank's failure to manage its asset-liability mismatch and liquidity risk. Insights gained following financial disasters, such as fall of the Long-Term Capital Management hedge fund (1998), the 2007-08 financial crisis, and the 2012 London Whale trading debacle, have taught mature economies that model risk can arise from incorrect use of financial models and defective models as well.

Consequently, regulators have taken charge of such scenarios by publishing guidelines such as the Supervisory and Regulatory guidance on MRM (SR 11-7). The European Central Bank (ECB) and Bank of England (BoE)'s Prudential Regulatory Authority (PRA) have provided further guidance on model risk. This highlights the need for a mature and robust regulator-prescribed MRM framework that governs the overall model risk and regularly monitors the risk and performance of these models.

But this is not the case for APAC …

As per our research, MRM guidelines are majorly treated as a component of the overarching risk management guidelines for most jurisdictions in the APAC region. This is possibly because of the lower number and complexity of models compared with mature economies. The guidelines primarily revolve around regulatory risk models for capital calculation and do not elaborate the various functions of MRM. The benefits of MRM, such as increased risk transparency, efficient resource usage and focused risk reporting, can be reaped in a better manner if there is clarity regarding the MRM guidelines.

In this whitepaper, we undertake a comparative study of MRM in seven major countries across the APAC region, namely Japan, Hong Kong, Singapore, Australia, India, Malaysia, and Thailand.

Comparative study of regulations in APAC

🔴 Japan

The 'Principles of MRM' report by Japan's Financial Services Agency (FSA) has a lot in common with SR 11-7. Although it covers all major aspects of the modern-day MRM framework as mentioned below, it takes a principles-based approach and is less prescriptive.

- **Roll-out approach:** This approach prioritises models based on the materiality of risk and tolerance to model risk

- **The three lines of defence (LoD) model:** This includes model development and the owner, validation and audit functions as the three pillars of MRM, referred to as 1LoD, 2LoD, and 3LoD, respectively

- **Risk rating of models:** Models are assigned a risk rating based on their materiality, complexity and usage, which are key determinants in prioritising revalidation and decisions on levels of control for individual models

- **Model inventory:** FSA requires a firm-wide inventory to be maintained by 2LoD, that is, the validation team

- **Model lifecycle:** FSA has emphasised carrying out effective reviews and anticipating challenges in every step of the model life cycle

- **Documentation:** Comprehensive documentation should be maintained during all steps of the model lifecycle, and processes are to be set out in policies and procedure documents

- **Model validation:** The model validation team must be independent, and have the authority to grant full approval, conditional approval or reject use of the model. Validation should follow a risk-based approach, where the frequency, rigour, and scope of validation are commensurate with the risk of the model

- **Ongoing monitoring (OM):** OM should be performed by 1LoD — that is, the development team — to identify any deterioration in model performance due to macro changes

- **Audit:** The audit team, also referred to as 3LoD, is responsible for verifying the overall effectiveness of the MRM framework

- **Vendor and external resources:** There is an increased focus on selection of appropriate vendors, requesting as much information as possible and performing validation on the same. Contingency plans are needed in case the vendors are not available. For tasks performed by external resources (e.g. outsourcing), the firm should perform thorough due-diligence and have mechanisms in place to understand the results produced

CRISIL's view

- The guidelines explicitly state that 2LoD, the validation team, should maintain firm-wide model inventory, which is not the case for all financial institutions in other geographies

- FSA does not provide guidance on stress-testing under the MRM guidelines, as does SR 11-7

Hong Kong

The Hong Kong Monetary Authority (HKMA) has provided broad guidelines for MRM under the IC-1 risk management framework.

- **Model requirements:** Lists the factors paramount in the model determination process, including the nature, scale and complexity of business, business needs, assumptions for the model, data availability, staff expertise, and sophistication of the management information system

- **Role of the Board and senior management:** Emphasises the importance of the Board and the senior management being familiar with the biases and assumptions embedded in the models. It also stresses the need for them to be satisfied with the "adequacy and appropriateness of key assumptions, data sources, and procedures used to measure or assess risks" (as per IC-1 guidelines) [1]

- **OM:** Requires regular back-testing to verify actual results. Periodic reviews should be carried out to update the model to factor in changing market conditions. Expert judgements, critical analysis, qualitative approaches, and stress tests would complement the quantitative approach

CRISIL's view

- The guidelines explicitly state the factors to be considered in the model determination process, which are used for later development and validation. This is a unique feature of this jurisdiction

- Guidelines specific to a particular risk area cover the corresponding aspects of MRM instead of having separate MRM documentation

Singapore

The Monetary Authority of Singapore (MAS) published a series of risk management guidelines encompassing the role of the Board and senior management and risks covering various areas of MRM, such as credit, liquidity, market, operations, technology, market conduct, and environment

- **Board and senior management:** Responsible for understanding the strength and limitations of the models to determine the risk limits. They also need to ensure that the limitations of the models are understood and provided for

- **Validation:** The models being deployed should have appropriate, consistent and reasonable assumptions and must be validated before going into production. Staff involved in the validation process should be adequately qualified and independent of the trading and model development functions. Models should be periodically reviewed. As per the market risk guidelines, "validation should include verifying the consistency, timeliness, reliability, independence, and completeness of data sources; the accuracy and appropriateness of volatility and correlation assumptions; and the accuracy of valuation and risk factor calculations". [2]

- **Back-testing:** Regular back-testing must be conducted to verify the reliability of models, especially in periods of significant market developments or in case of any major changes to the model methodologies or assumptions

- **OM:** The MAS guidelines highlight the necessity of ensuring periodic review of the methodologies, models and assumptions used to measure risk and limit exposure, performance, and capital position, as well as internal capital procedures. Any deficiencies identified should be promptly remedied

- **Guidance around AI/ML:** MAS has also introduced a set of generally accepted principles for use of AI and data analytics to promote fairness, ethics, accountability, and transparency (FEAT) in the use of AI

CRISIL's view

- The focus around validation of AI/ML for decision making in financial products and services is certainly a forward-looking measure by the regulator

- Again, MAS does not have an overarching MRM framework but has provided guidance on MRM topics in the respective risk management guidelines

India

The Reserve Bank of India (RBI) had prescribed MRM guidelines for credit risk in 2001 and market risk in 2002.

- **Independence of validation:** Though the guidelines do not focus on a separate model validation team, it prescribes that certification of models must be done by someone other than the model developer. Assumptions in the model are to be documented as part of the initial certification and reviewed annually by a qualified validator. Unauthorised changes in models are not allowed

- **Role of the Risk Policy Committee (RPC):** The RPC within a firm is responsible for administering the model control and certification policy and providing any required technical advice. Unusual parameter sourcing conventions are to be approved annually by the RPC. Only persons approved by the RPC and independent of the development team must validate the models in writing

- **Stress-testing:** For both trading and accrual portfolios, stress-testing is to be performed, preferably quarterly or when the underlying assumptions of model/market conditions change significantly

- **OM**: As part of OM, model assumptions need to be reviewed periodically to ensure applicability of the model and its validity for original use

- **Documentation:** Stresses on documentation and minimum standards of documentation to be maintained

CRISIL's view

- The guidelines are broadly defined and can be extrapolated to other models in general, rather than being restrictive for market risk only

- The guidelines have not been updated to a separate MRM framework, which can be attributed to the smaller number and lower complexity of models in the institutions

🇲🇾 Malaysia

The Bank Negara Malaysia (BNM), which is the central bank for Malaysia, formulated regulations pertaining to risk governance in 2013, which covers various aspects of MRM for firms in its jurisdiction.

- **Senior management role:** The senior management must oversee model development and implementation, establish limits on model use, focus on model performance monitoring, and ensure regular and independent validation

- **Validation**: The regulator stresses on the independence of the validation process. It highlights the importance of complementing quantitative methods with expert judgement and critical analysis by the senior management and review by the Board

- **Approaches for validation:** Quantitative approaches including back-testing and stress-testing are to be performed to gauge the appropriateness and effectiveness of risk methodologies

- **External assessments by agencies:** The firm should not solely rely on external assessments (e.g., ratings by rating agencies) but complement them with internal risk assessment processes for decision making

CRISIL's view

- The guidelines around MRM have not been elaborated upon and are left to the discretion of the firm; however, they cover most of the salient points required for MRM

🇹🇭 Thailand

The regulator has a well-defined document outlining the steps for model risk validation, published in 2005.

- **Board and senior management:** They are responsible for prioritising the validation of risk models in accordance with policies, and further ensuring periodic reviews upon changes in the market environment. They must also understand the crucial assumptions and parameters in the models, and the limitations of validation

- **Validation:** Model validation must be independent of the model development function. Both internal and external models are to be validated for input data and quantitative concepts, along with back-testing of outcomes using actual results or similar risk models. Internal controls are to be put in place if any material modification is made to the model. The scope needs to be defined based on the complexity of transactions and existing risks

- **Vendor models:** External models need to be validated as per the generally accepted standards, and vendors must disclose necessary details, methodologies, and outcomes from model validation to the firm. The firm needs to have remedial plans in place in case there is an issue with the accuracy and reliability of risk models

- **Internal audit:** The model validation is to be reviewed by reviewers (i.e., audit function) that are independent of users, developers, and validators. The regulator has issued guidelines for examiners to adhere to while performing the assessment

- **OM:** The regulator prescribes periodic revalidation of risk models and reviews in case of changes in the environment that might affect risk models or changes in crucial assumptions/parameters used in the models (i.e. OM)

> **CRISIL's view**
>
> - Purview of the document is confined mainly to risk models

For the jurisdictions within APAC not covered in this paper, there is lack of specific guidelines with respect to MRM and ongoing model monitoring. However, some firms in the region (e.g., Union Bank of Philippines) have started looking at the SR 11-7 guidance or the ECB's targeted review of internal models document of 2016 for MRM practices. Although the model complexity cannot be compared with that in the advanced economies, which might be the reason for a lack of a separate MRM framework, with increase in the number of models, MRM will become paramount, necessitating proactive measures. Hence, there is a need for a well-articulated set of core principles that firms can use for MRM exercises.

Japan's FSA has set forth a comprehensive set of MRM guidelines, which could be used as a guide by regulators of countries in the APAC region.

Positives from FSA MRM guidelines

- Demarcation of three LoDs for MRM is explicitly observed only in the FSA document

- The maintenance of the firm-wide risk inventory by 2LoD, i.e. second line of defence consisting of the validation function, is unique to the guidelines prescribed by Japan's FSA document.

- The approach is more principles-based and can be adopted internationally

Areas of enhancement

- Validation and OM techniques such as benchmarking, back-testing, and sensitivity analysis that are part of the SR 11-7 document are not mentioned in the FSA guidelines; rather, the approach has been left to the discretion of the firm

- Based on the risk-tiering approach, low-risk models are to be validated on a non-regular basis where the frequency is not defined; however, SR 11-7 requires all models to be revalidated at least annually, with the riskier ones at higher frequencies

- Though stress-testing has become an integral part of the risk management framework in the US and Europe, there is no mention of it in the MRM guidelines

Keeping the above limitations in mind, we conclude that Japan's FSA guidelines are a good starting point to devise MRM guidelines for the APAC region.

Comparison of MRM-related guidelines in APAC region

Year	Publication						Guidelines/ standards
2010				🔵	⚫		**India:** Prudential Guidelines on Capital Adequacy – Implementation of Internal Models Approach for Market Risk **Malaysia:** Risk Weighted Capital Adequacy Framework (Basel II) – Disclosure Requirements (Pillar 3)
2011					🟢		**Thailand:** The Bank of Thailand (BOT) adopted the Basel III framework, adapting it to the Thai context
2013	🔴	🟤		🔵	⚫		**Australia:** Managing Data Risk (CPG 235) **Singapore:** Guidelines on Risk Management Practices: Board and Senior Management, Market Risk, Liquidity Risk, Credit Risk, Operational Risk **India:** Basel III Capital Regulations: Capital Requirements for Credit Valuation Adjustment Risk on OTC Derivatives and for Banks' Exposures to Central Counterparties **Malaysia:** Risk-Weighted Capital Adequacy Framework (Basel II) – Internal Capital Adequacy Assessment Process (Pillar 2), Risk Governance Guidelines
2014	🟤	🟡		🔵			**Singapore:** Guidelines on Risk Management Practices: Internal Controls **Japan:** Inspection Manual for Deposit-Taking Institutions (includes checklist for comprehensive risk management) **India:** Basel III Framework on Liquidity Standards – Liquidity Coverage Ratio (LCR), Liquidity Risk Monitoring Tools and LCR Disclosure Standards
2017			🔴	🔵		🟢	**Hong Kong:** Risk Management Framework (IC-1) **India:** Risk Management Systems – Role of the Chief Risk Officer (CRO) **Thailand:** Updated Basel III Regulations on Supervision of Capital for Commercial Banks
2018	🔴		🔴				**Australia:** The Australian Prudential Regulation Authority (APRA) published guidance to help its regulated institutions comply with the prudential standard CPS 220, and to outline general practices in relation to risk management **Hong Kong:** IRRBB (IR-1), Counterparty Credit Risk Management (CR-G-13)
2019	🔴				⚫		**Australia:** APRA set out standards and minimum requirements in relation to capital, governance, and risk management (CPG 220) **Malaysia:** Guidelines around Anti-Money Laundering, Countering Financing of Terrorism and Targeted Financial Sanctions for Financial Institutions (AML/CFT and TFS for FIs), Guidelines around Credit Risk
2020		🟤	🔴		🟢		**Singapore:** Guidelines on Environmental Risk Management: Asset Managers, Banks **Hong Kong:** Regulatory Framework for Supervision of Liquidity Risk (LM-1) **Thailand:** Updated Basel III Regulations on Components of Capital for Locally Incorporated Banks

Year	Publication						Guidelines/ standards
2021	●	●	●				**Australia:** Prudential Guidelines – Credit Risk Management (APG 220) **Singapore:** Guidelines on Risk Management Practices: Technology Risk, Board and Senior Management **Japan:** Principles for MRM, Comprehensive Guidelines for Supervision of Major Banks, Guidelines for AML and Combating the Financing of Terrorism
2022	●			●	●	●	**Australia:** Australian Treasury issued its Climate-Related Financial Disclosure Consultation Paper **Hong Kong:** Risk-based Supervisory Approach (SA-1), Operational Risk Management (OR-1), Climate Risk Management (GS-1), FX Risk Management (TA-2) *Market risk management guidelines are under preparation **India:** RBI issued discussion paper on Climate Risk and Sustainable Finance **Malaysia:** Malaysia's Joint Committee on Climate Change released new guidance outlining recommendations for financial institutions on the implementation of climate-related disclosures that are aligned with the recommendations of the Task Force on Climate-related Financial Disclosures, Capital Adequacy Framework (Basel III – Risk-Weighted Assets) for Operational Risk
2023	●					●	**Australia:** APRA published standards on Governance (CPS 510), Credit Risk Management (APS 220), Large Exposures (APS 221) **Thailand:** SEC launched Guidelines on Management and Disclosure of Climate-related Risk by Asset Managers

● Australia (APRA) ● Singapore (MAS) ● Japan (FSA)
● Hong Kong (HKMA) ● India (RBI) ● Malaysia (BNM)
● Thailand (BOT)

CRISIL's view on regulatory guidelines in APAC region

Year	Publication	Guidelines/ standards
2010	● (Malaysia) ● (India)	
2011	● (Thailand)	**India:** Banks in India were mandated to comply with Basel III regulations, which were tailored to the Indian banking industry by RBI. The guidelines on capital adequacy (market, credit, and liquidity risks) were set for banks in India over 2010 to 2017. However, the original deadline (in 2019) was repeatedly extended.
2013	● (Australia) ● (Singapore) ● (Malaysia) ● (India)	
2014	● (Singapore) ● (Japan) ● (India)	
2017	● (Hong Kong) ● (Thailand) ● (India)	

Australia: APRA has been actively updating the regulatory guidelines over the past few years. It has updated regulations on general risk management practices (2018), minimum requirements in relation to capital, governance and risk management (2019), and guidelines around credit risk management (2021).

Japan: FSA brought out the most comprehensive document on MRM in 2021, and also guidelines around AML and combating finance terrorism. However, Basel III implementation was delayed to January 2023 from January 2022 due to the Covid-19 pandemic.

Singapore: General guidelines on risk management practices (Board and senior management, market risk, liquidity risk, credit risk, operational risk, and internal controls), which were set out in 2013-2014, formed the foundation for the guidelines published by the regulatory body (MAS) over the subsequent years.

Hong Kong: HKMA published a comprehensive risk management framework (IC-1) in 2017, encompassing most aspects of risk management. Post this, the regulator has been proactive in updating and publishing revised guidelines around credit, liquidity, operational, climate, and FX risk management, with market risk guidelines under development.

Malaysia: BNM published guidelines in 2005 for investment banks and set out regulations for implementation of Pillar 2 and 3 of Basel II, details around implementation of Basel III, and risk governance guidelines between 2010 and 2013. BNM has also set guidelines around AML, CFT, and targeted financial sanctions for financial institutions. The regulator recently released updated guidelines for credit and operational risks in Basel III as well, and disclosures around climate risk.

Thailand: Banks in Thailand were proactive in their approach to implement guidelines and regulations around risk management in accordance with the initial Basel accords. BOT also adopted Basel III regulations in 2013, with further updates on the regulations in 2017 (for commercial banks) and 2020 (for locally incorporated banks). Most banks in Thailand are adhering to Basel III disclosures, as outlined by BOT.

Timeline rows (2018–2023):

Year	Publication
2018	● (Australia) ● (Hong Kong)
2019	● (Australia) ● (Malaysia)
2020	● (Singapore) ● (Hong Kong) ● (Thailand)
2021	● (Australia) ● (Singapore) ● (Japan)
2022	● (Australia) ● (Hong Kong) ● (Malaysia) ● (India)
2023	● (Australia) ● (Malaysia) ● (Thailand)

Legend:
- ● Australia (APRA)
- ● Hong Kong (HKMA)
- ● Thailand (BOT)
- ● Singapore (MAS)
- ● India (RBI)
- ● Japan (FSA)
- ● Malaysia (BNM)

Components of MRM framework as outlined by FSA (Japan)

Governance

- **Board of Directors and senior management:** Responsible for establishing the MRM. The overall model risk and compliance with policies is to be periodically reported to the Board

- **MRM framework:** The framework should be in line with the firm's risk profile, nature and tolerance of model risk, and consistent across jurisdictions

- **Policies and procedures:** The MRM framework is to be standardised with detailed policies and procedures, highlighting model definition, roles and responsibilities, model inventory, and model development, implementation and validation. The outputs need to be documented as well

- **Roles and responsibilities:** Clearly defined the owner and validators of models. The model owner is typically from 1LoD, whereas 2LoD is responsible for the maintenance, validation, and oversight of the MRM framework

Model development

- **Model development:** Appropriateness of the model for the intended use, mathematical and statistical soundness, and data quality are to be assessed. The firm should hire individuals with technical knowledge and modelling skills for the analysis and development of models

- **Model document:** As highlighted before, granular model documentation must be maintained at the development phase and also keep stakeholders (users and validators) informed about the methodology, assumptions, limitations, and weaknesses

- **Model testing:** 1LoD needs to undertake testing to verify proper functioning of the model before it goes to 2LoD for validation. The results must be documented in a detailed manner

Model identification, inventory, and risk rating

- **Model identification:** 1LoD is to identify the models, and this is to be assessed by 2LoD

- **Model inventory:** Model inventory is to be maintained by 2LoD, which must be comprehensive, containing all necessary information

- **Risk rating:** Each model is to be assigned a risk rating after risk assessment, which determines the level of controls on the models. The firm should consider materiality, complexity, and usage of the model to determine the rating. Periodic validation must be undertaken to determine if any change should be made to the rating of the model

Model approval

- **Model approval:** The model is to be approved by 2LoD. In case of revalidation, the model should be validated internally again. The model can be approved, conditionally approved with restrictions, or outrightly rejected

- **Exception to approval:** Some models might be temporarily excluded from being approved. This is subject to strict controls by 2LoD, and the model should not have high risk

OM

- **OM:** 1LoD should monitor models regularly to ensure that it is performing as intended. The frequency should be commensurate with the nature of the model, availability of new data, and its materiality

- **Approach:** Some general approaches, such as sensitivity monitoring by stressing the input values and benchmarking with known outputs, are to be carried out to ensure that the model is valid in the current market environment. The outcomes should be adequately documented for all stakeholders

- **Analysis of overrides:** If a model output has been overridden by expert judgement of end-users, the limitations are to be monitored on an ongoing basis. If the number of overrides are high, the model needs to be modified or decommissioned

- **High-frequency monitoring:** Firms need to increase the frequency of monitoring as the OM process matures, for early identification of any deterioration in model performance

Model validation

- **Model validation:** Validation functions must be independent of other functions, with separate reporting lines. The validators are responsible for verifying the model design and concept, appropriateness of the model, and required restrictions. Model inputs and reporting are also subject to validation

- **Authority of validation function:** Has the authority over 1LoD to direct actions based on its findings

- **Types of validation:** The model is validated on initial usage, revalidated in case of any material changes, and periodically revalidated once it is put in use to verify its performance

- **Methods of validation:** Comparison with alternative theories and approaches need to be done. Sensitivity analysis and stress-testing to assess the impact of small changes on the model output and outcome analysis to verify the model with actual data should also be carried out

- **Risk-based approach:** Low-risk models can be validated on a non-regular basis, whereas high-risk models should be prioritised and revalidated regularly

Vendor products and external resources

- **Vendor products:** Even with opacity of product information, firms need to manage and mitigate risks based on their tolerance level

- **Risk management of vendor products:** Firms should focus on the selection of appropriate vendors by gaining the best possible amount of information as possible. This can be done by asking for developmental evidence from the vendors and their testing results to assess if the product is suitable for the firms. Model limitations and assumptions, along with OM results, must be disclosed by the vendor

- **Use of external resources:** Firms should understand and evaluate results of the services provided by external resources. The due diligence should be consistent with the firm's existing third-party framework

Internal audit

- **Roles of internal audit:** It is responsible for the oversight of the MRM framework and for ensuring that the practices are rigorous, complete, and effective. Internal audit must document findings and present these to the Board. It must verify if model validation is being done on a timely basis and that the models have been subject to controls based on their limitations. It should also verify that policies are in place and are being complied with. Internal audit must ensure accuracy and completeness of the model inventory as well. Finally, it must ensure that the procedures are being updated on a timely basis, and that all LoDs are meeting the documentation standards

How CRISIL can help

CRISIL can assist firms in setting up the MRM framework based on the guidelines presented above. The firms can be proactive in filling the gaps to comprehensively manage their model risk. CRISIL has identified the following areas in the MRM framework that can be enhanced further:

Code standardisation	Similar models can be grouped together, i.e., tiering of models, which can, therefore, utilise a standard software package for MRM via automated test selection
	CRISIL's view: Standardisation of the code incentivises reuse, thus avoiding redundancy in the codebase and ensuring efficient model development
Key performance indicators (KPIs)	A library of KPIs can be maintained as output of standard codes on an MRM dashboard
	CRISIL's view: The KPIs present an objective approach to quantitatively validate the models. These can also be used for analysis during development of new models
Reporting	Automation of OM reports and documentation can be instrumental in avoiding any operational risk and saving time
	CRISIL's view: Report creation and documentation take up considerable time of analysts, mainly because of inefficiencies in the process as it involves manual work. Automation ensures more time is directed for the analysis of issues
Data quality standardisation	Testing of the input data for models can be automated using standard libraries. Moreover, ML techniques can be used to quickly assess big data. The firm only needs to focus on the remaining grey areas
	CRISIL's view: Data quality is one of the major hindrances in the model monitoring process, as incorrect data might lead to erroneous output. Comprehensive automation of the data cleaning process, which covers all corner cases, leads to correct input for the models
Workflow validation	Develop a model validation workflow that automates all steps of the model lifecycle
	CRISIL's view: The purpose behind automating the validation workflow is to avoid manual intervention to the best possible extent in the MRM process and, thereby, reduce operational risk
High-frequency monitoring	As the validation and OM processes mature, firms can focus on monitoring models at a higher frequency, which is prioritised based on the model-tiering process
	CRISIL's view: The results of high-frequency monitoring can act as early warning indicators for any deterioration in model performance

Regulation references

The reader may refer to the following reference sites pertaining to the whitepaper.

US

- Federal Reserve (https://www.federalreserve.gov/supervisionreg.htm)
- Office of the Comptroller of the Currency (https://www.occ.treas.gov/index.html)

Japan

- Financial Services Agency (https://www.fsa.go.jp/en/)

Australia

- Australian Prudential Regulation Authority (https://www.apra.gov.au/)

India

- Reserve Bank of India (https://www.rbi.org.in/)

Hong Kong

- Hong Kong Monetary Authority (https://www.hkma.gov.hk/eng)

Malaysia

- Bank Negara Malaysia (https://www.bnm.gov.my)

Singapore

- Monetary Authority of Singapore (https://www.mas.gov.sg)

Thailand

- Bank of Thailand (https://www.bot.or.th/en/home.html)

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