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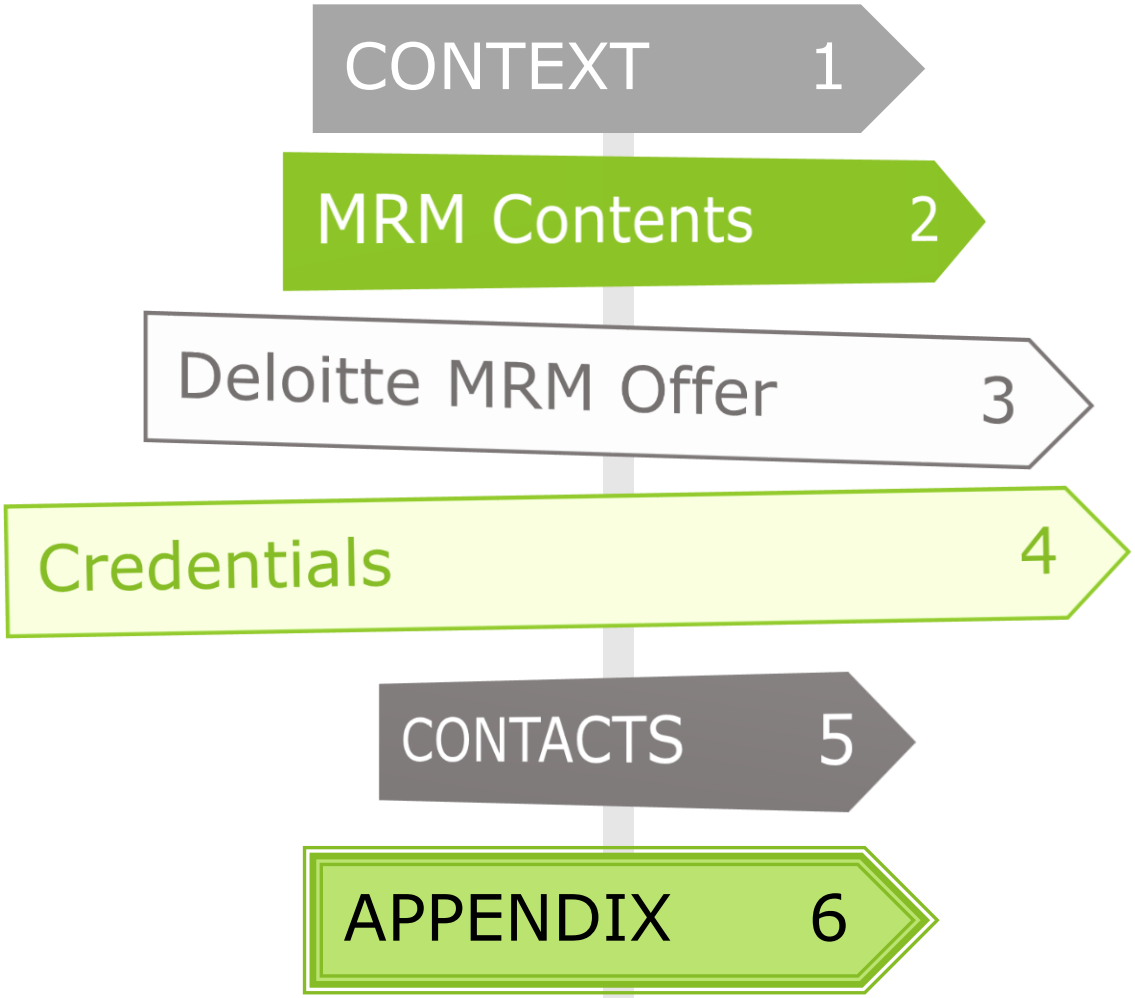
Model Risk Management

Driving the value in modelling

May 2018, Risk Advisory

Agenda



Part 1

Context

How important is model risk ?

Model risk may be particularly high, especially under stressed conditions or combined with other interrelated trigger events.

JP Morgan – The London Whale

Impacts: the bank made losses of £6bn and was fined £1bn

What happened ? The bank's Chief Investment Officer was responsible for investing excess bank deposits in a low-risk manner. To hedge against possible downturns in the economy, the CIO bought synthetic CDS derivatives. Initially intended as an hedging strategy, this portfolio became a speculative source of profit and increased from $4bn in 2010 to $157bn in early 2012. However, the internal risk controllers duly reported those trades as being too risky.

How is model risk involved? Instead of scaling back the risk, the bank changed its VaR metric in early 2012. But there was an error in the spreadsheet used for that purpose and the risk was understated by 50%. This error enabled the portfolio to continue growing, but the bank was then hit by the European sovereign debt crisis.

LTCM – Arbitrage investment strategies

Impacts: the hedge fund lost $4.4bn in 1998, depleting almost its entire capital

What happened ? The hedge fund was established by renowned bond traders and the main shareholders included Nobel prize-winning economists (Myron Scholes and Robert Merton). Investors consisted in high net worth individuals and in financial institutions. The fund had followed an arbitrage investment strategy on bonds, involving hedging against a range of volatility in foreign currencies and bonds, based on complex models.

How is model risk involved? Arbitrage margins are small and the fund took on leveraged positions to maintain or increase profits. At one point, the notional value of the derivative position was $1.25tn. When the Russian crisis kicked off in 1998, European and US markets fell drastically and LTCM was badly hit through market losses and fire sales.

CDO / MBS – 2007 subprime mortgage crisis

Impacts: one of the main cause and source of losses in the 2007 financial crisis. As-of Sept. 2008, bank write-downs and losses totaled $523bn.

What happened ? Rating agencies had provided a AAA rating to a significant portion of securities backed by pools of loans including a significant proportion of loans to homebuyers with bad credit and undocumented incomes (subprime mortgage loans)

How is model risk involved? Between 2002 and 2007, the mortgage underwriting standards had significantly deteriorated. However those loans bundled into MBS and CDO with high ratings which were believed justified by credit enhancement techniques. Investors relied on rating agencies, blindly in many cases. However, a significant portion of AAA CDO and MBS tranches were finally downgraded to junk in 2007 and early 2008, once the housing bubble burst in the 2006 H2.

The US Financial Crisis Inquiry Commission found that agencies' credit ratings were influenced by *"flawed computer models, the pressure from financial firms that paid for the ratings, the relentless drive for market share, the lack of resources to do the job despite record profits, and the absence of meaningful public oversight"*.

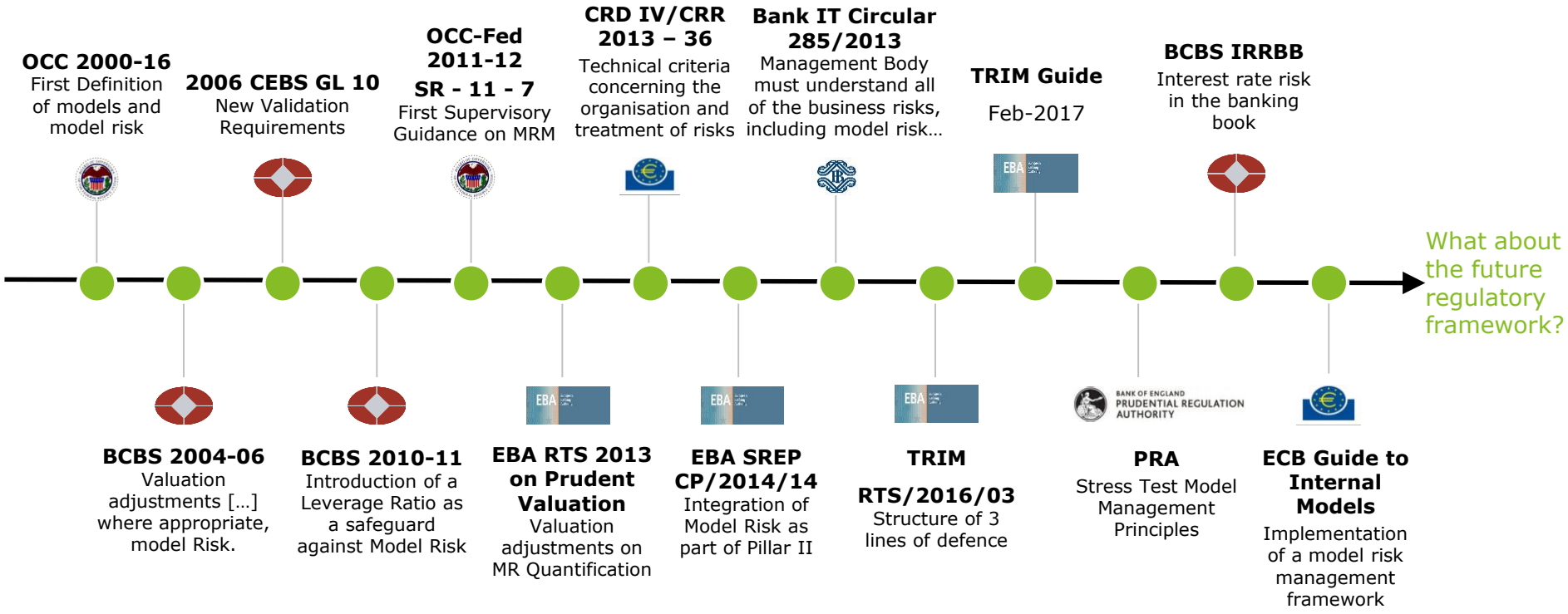
Market risk regulatory pre-crisis models

Impacts: the VaR metrics used before the outburst of the financial crisis did not adequately capture tail-risk events, credit risk events as well as market illiquidity.

What happened ? When the financial crisis arose, essentially driven by credit risk events, a large number of banks posted daily trading losses many times greater than their VaR estimates and quite frequently during that period, in a context where some financial markets became largely illiquid.

How is model risk involved? The market risk model was build upon assumptions that were not reflective of the real world in stressed financial markets (assuming market liquidity and large diversification effects across asset classes, etc.). In addition, tail credit risk events were not adequately modelled, hence underestimating possible losses in stressed conditions.

Main regulatory references on MRM



In Europe, regulatory bodies confirmed that banks need to implement a Model Risk Management comprehensive framework.

Regulatory references in the EU

CRD IV / CRR

Defines Model Risk (Art. 3.1.11) and the process by which the Competent Authorities should assess how the institutions **manage and implement policies and processes to evaluate the exposure to Model Risk as part of the Operational Risk** (Art. 85).

Guidelines on SREP

The '*Guidelines on common procedures and methodologies for the supervisory review and evaluation process*' define the **main activities that the Competent Authorities should assess in the institution's exposure to model risk** arising from the use of internal models in its main business areas and operations. In particular, the Competent Authorities should consider to what extent, and for which purposes, the institution uses models to make decisions and its level of awareness (Management Body and Senior Management) of and how it manages model risk.

According to SREP Guidelines, the model risk can be **split into two distinct forms of risk** with **two different impacts risk profiles.**

	Form of risks	Risk profile
1	"Risk relating to the underestimation of own funds requirements by **regulatory approved models** (e.g. internal ratings-based (IRB) models for credit risk)"	"Competent authorities should consider the model risk as part of the **assessment of specific risks to capital** (e.g. IRB model deficiency is considered as part of the credit risk assessment) and for the **capital adequacy assessment**"
2	"Risk of losses relating to the development, implementation or improper use of any other **models** by the institution **for decision-making** (e.g. product pricing, evaluation of financial instruments, monitoring of risk limits, etc.)"	"Competent authorities should consider the risk as part of the **assessment of operational risk**" and it should be evaluated within this perimeter

ECB Guide to internal models

The guide was drafted in close cooperation with the national competent authorities (NCAs) and draws on the experience gained in the context of the targeted review of internal models (TRIM) project. The guide mainly focuses on: ***overarching principles***, ***internal model governance***, ***internal validation***, ***internal audit***, ***model use***, ***model change management and third-party involvement.***

Effective **model risk management** allows institutions to reduce the risk of potential losses and underestimation of own funds requirements as a result of flaws in the development, implementation or use of the models. To mitigate these risks, institutions should have a model risk management framework in place that allows them to identify, understand and manage their model risk for internal models across the group.

	Elements of an MRM framework	Extract from ECB Guide in Internal models
(a)	*A written **model risk management policy***	"This policy should include a definition of a model, provide the institution's interpretation of model risk and describe the model risk framework with reference to its different components."
(b)	*A **register** of the institution's internal models*	"This register should facilitate a holistic understanding of the application and use of the models and provide the institution's management body and SM with a comprehensive overview of the models in place."
(c)	*Guidelines on **mitigation** actions*	"Identifying and mitigating any areas where measurement uncertainty and model deficiencies are known to exist, according to their materiality, applied consistently across the Group."
(d)	*Guidelines on **model risk quantification***	"Methodologies for the qualitative and/or quantitative assessment and measurement of the institution's model risk."
(e)	*Guidelines with respect to **the model life cycle***	"The model life cycle includes the following steps: requirements analysis, development, implementation, testing, use, validation, maintenance and changes."
(f)	*Model risk **communication** and **reporting***	"Procedures for model risk internal and external communication and reporting."
(g)	*Definition of **roles and responsibilities***	"Definition of roles and responsibilities within the model risk management framework."

Impact of the New Regulations and Standards

- **Impact FRTB**

The FRTB includes updates to both the advanced and standardized models as well as stricter disclosure requirements and validation standards.

- **Impact IRB**

EBA Guidelines on PD, LGD estimation and treatment of defaulted asset as well as new default definition, conservatism margins, NPL assessment, rating process.

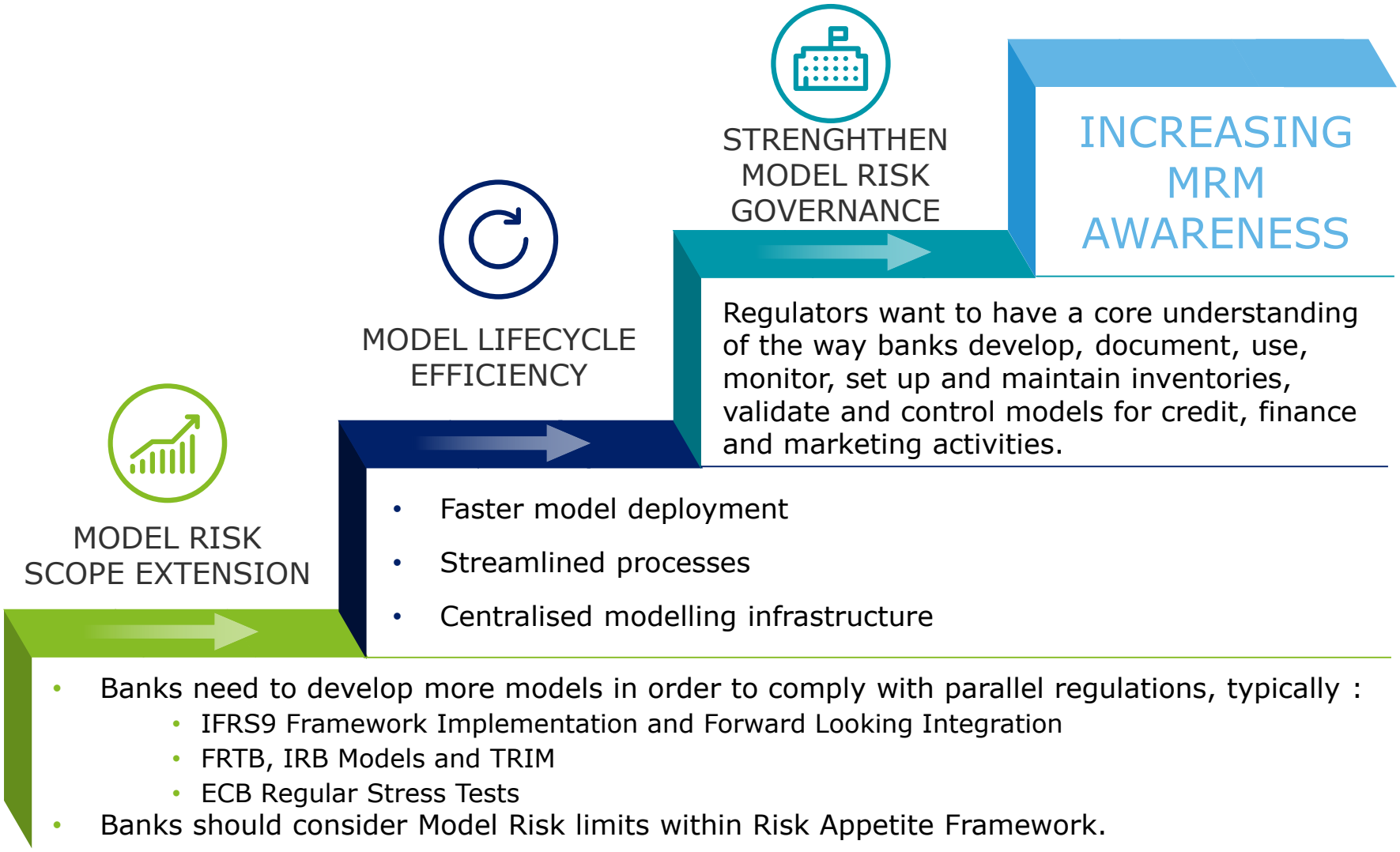
- **Impact of Stress Testing**

New stress testing methodology and principles defined by the PRA and EBA.

- **Impact of IFRS9**

The introduction of the IFRS 9 Impairments standard is demanding that banks use a new set of credit risk models; these models must be developed, deployed and maintained, which will literally double the number of Risk parameters models to manage.

Model Risk: the next risk type



MRM for better business decisions

- Banks are increasingly using decision models in their credit processes such as origination, limit management, collections and recoveries. In the commercial area, customers are able to select a product's characteristics and the system makes a real time decision on viability and price.
- Customer on boarding, engagement and marketing campaign models have become more prevalent for establishing customer loyalty and engagement actions in all stages of the relationship with the institution and at any time in the customer life cycle.
- Another area is fraud and money laundering detection.

Therefore, a clearly defined MRM framework with a strong management insight on monitoring models and their risks will allow institutions to **strengthen their decision making processes** and improve their **profitability**.

1. Access to **trusted**, quality models is essential to effectively using enterprise data – now considered a strategic asset – to drive better decision making and business results.
   - *Banks are heavily dependent on models to help them make the best decisions and navigate an increasingly competitive landscape. Banking executives, for example, are expected to rely on analytical models – not just gut instinct and experience – when making decisions about deploying capital in support of lending and customer management strategies.*
2. As limited expert resources are often an issue in financial institutions, it is important to handle existing resources in the most **cost-efficient** way.
   - *In order to achieve cost efficiency, model risk activities are prioritized and conducted for portfolios that are of higher importance, i.e. that contain strategically relevant positions with substantial position size, significant risk contribution or complex risk profiles.*
3. Model risk management should **add value** to the enterprise as well as reduce risk.
   - *Visibility into the source of data, confidence in the reliability and applicability of the model, and ongoing model improvements all support more effective decision-making for the organization, ultimately protecting its financial position and reputation.*

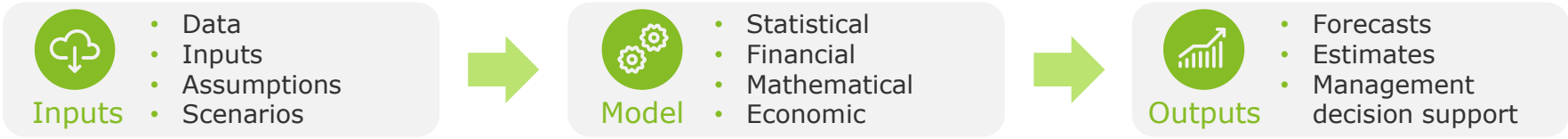
Part 2

MRM Contents

Definitions

Model

A quantitative method* or system that applies theories to process input data into quantitative estimates for decision making (used repeatedly).



*Including also the complex manipulations of expert judgements.

Model Risk

Model Risk can be defined as 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. (CRD IV, Article 3.1.11)

Model Risk Management Framework

Regardless of the organization's size and structure, regulators require that enterprise MRM frameworks encompass all relevant aspects of the MRM life cycle with clearly assigned roles and responsibilities:

- Model Risk Identification and Assessment,
- Model Risk Measurement and Mitigation,
- Model Risk Monitoring and Reporting.

Types of Models in the Scope

Comprehensive Model Coverage

A large global bank has a wide range of model types that are subject to governance and model risk management.

MODELS USED FOR « REGULATORY, MANAGERIAL AND ACCOUNTING » PURPOSES

Market and Liquidity Risk Models

- VaR (inc. Stressed VaR, IRC)
- ALM & Liquidity Risk
- Expected Shortfall

Credit & Counterparty Risk Models

- PD, LGD and EAD
- Risk rating models
- Exposure and CVA
- IFRS 9 Impairment

Operational Risk Models

- Loss Distribution Approach Model
- Integration Model

Compliance Models

- Anti-Money Laundering (AML)
- Anti Fraud
- Trader surveillance

Portfolio & Financial Risk Models

- Capital forecasting
- Stress testing
- Econometric models

Decision Support Models

- LOB models for customer targeting-marketing
- Credit underwriting
- Risk based collection models

Valuation & Pricing Models

- Derivatives
- Structured products
- Risk based pricing tools/models

Finance Models

- P&L Attribution
- Cash flow /NPV/Ratio Analysis

MODELS USED FOR OTHER PURPOSES

Marketing Models

- Marketing models
- Client Targeting

Insurance Models

- Actuarial models
- Loss Forecasting
- Reserving models

Investment Management

- Trading
- Security / Asset Pricing
- Portfolio Allocation

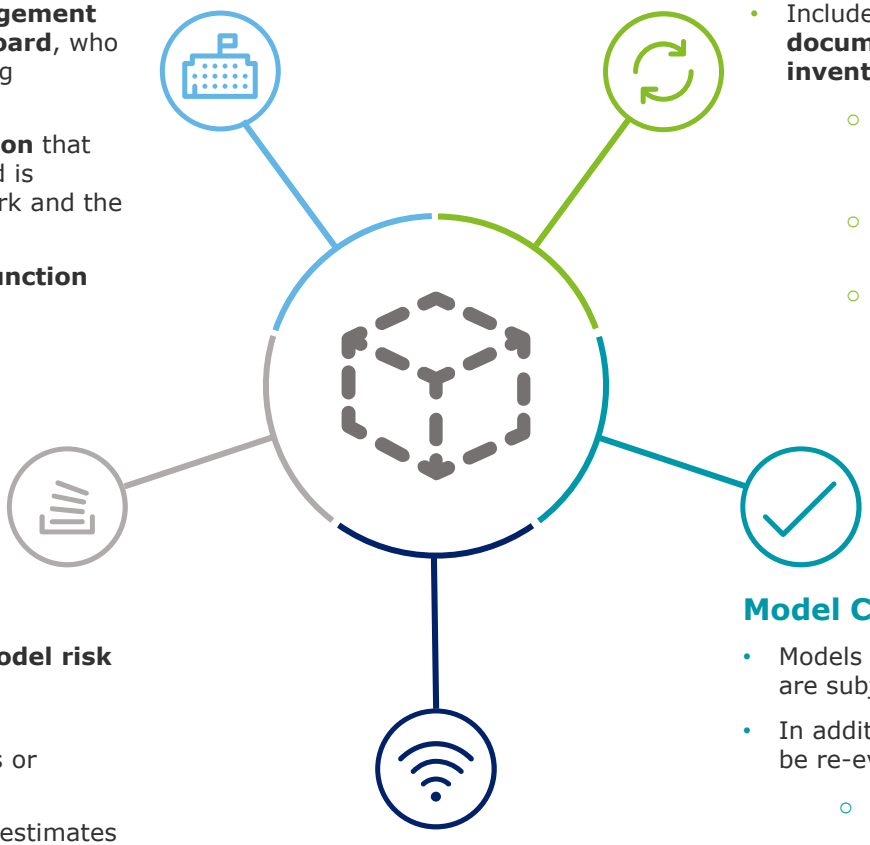
Other Models

- Corporate Finance Models (e.g. M&A, LBO, MBO)

Elements of an objective MRM framework

Organisation and Governance

- Existence of a **Model Risk Management** that has been approved by the **Board**, who receive periodic **reports** regarding compliance.
- Existence of a **Model Risk function** that **reports directly to the CRO** and is responsible for the MRM framework and the governance.
- Existence of a model validation **function** responsible for the **independent validation of models**.



Model Lifecycle Management

- Includes the **model development, documentation, classification, inventory** and **follow-up**:
  - **Comprehensive inventory** covering all existing models and framework scope.
  - Models are classified according to the level of risk.
  - The documentation should include description, key variables, assumptions and algorithms.

Model Risk Quantification

- **Quantitative techniques for model risk mitigation** (beyond regulatory requirements) regarding:
  - **Data**, sensitivity to errors or absence of variables;
  - **Estimates**, sensitivity of estimates (maximum impact, alternative models);
  - **Uses**, predictive power evolution, impact of erroneous use, etc.

Model Risk Management Processes & Technology

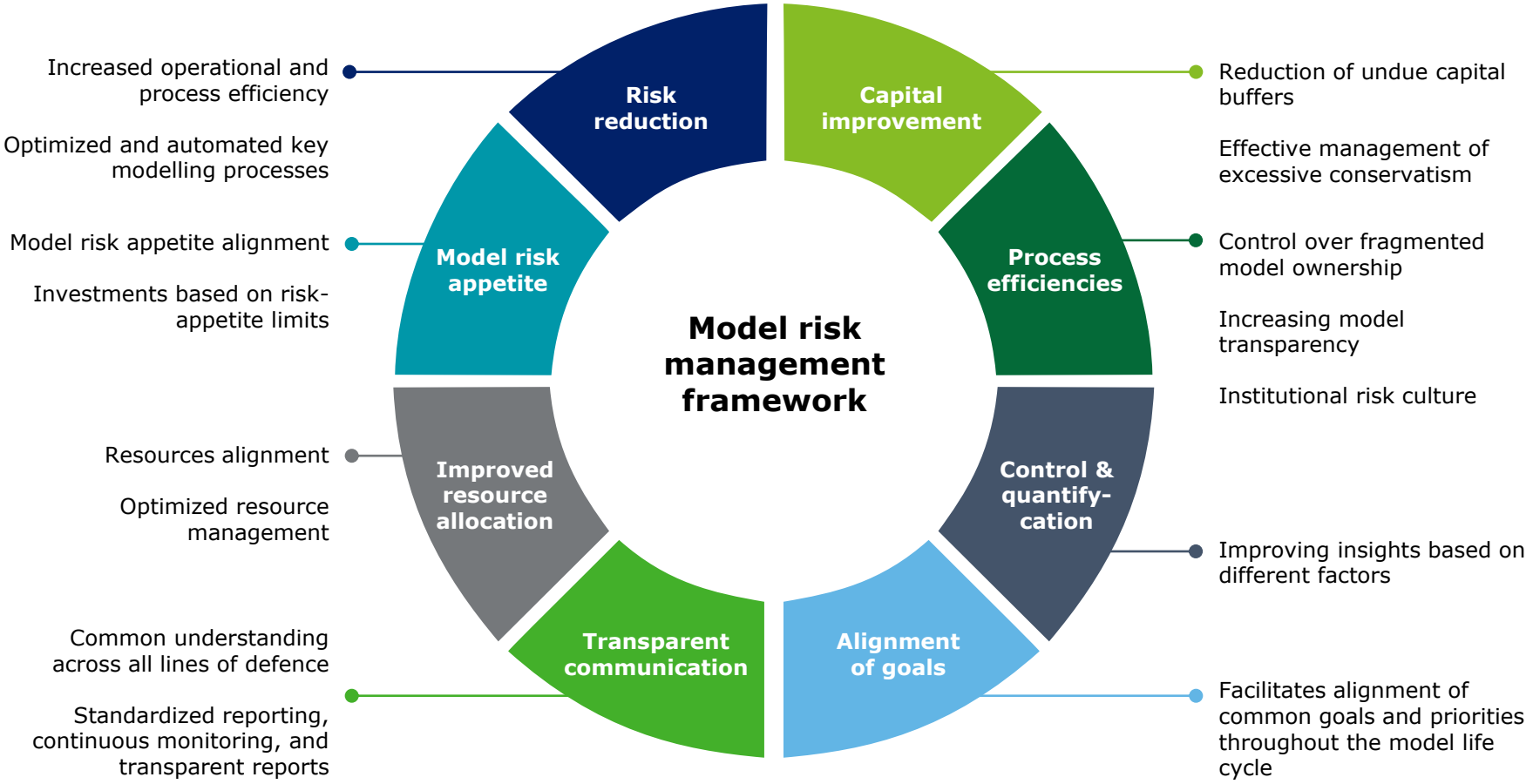
The MRM framework should be supported by optimized processes and a technological platform.

Model Control Framework

- Models assigned the **highest level** of risk are subject to **continuous assessment**.
- In addition to the above, all models should be re-evaluated by Validation:
  - Annually.
  - If they undergo material changes.
- **Before they are deployed to production, they should have been approved.**

Strategic MRM benefits

An effective and robust MRM framework improves earnings through cost reduction, loss avoidance, and capital improvement



Building Model Risk Management

Given the risk appetite and ambition level for model risk management, building the framework consists of three maturity stages

	Stage 1	Stage 2	Stage 3
	Foundation *Lay the foundation of MRM framework*	**Implementation** *Implement the key functions of MRM*	**Integrated MRM** *MRM value creation via integrated platform*
Governance, Policies and Controls	• Basic MRM policy • Roles and responsibilities	• Updated MRM control framework and rationalization	• Strategic integration with Model risk appetite • Continuous MRM monitoring • MRM risk awareness & mind-set
Development Implementation and Use	• Model definition • Periodical model discovery • Basic model inventory	• Basic model categorization and model risk quantification	• Continuous model risk quantification enhances MRM analytics and reporting and capabilities
Model Validation process	• Documented validation procedures • Separate model development and validation team	• Periodical coordination between MRM, development and validation processes	• Clear model prioritization throughout organization • Optimal use of process automation / robotics
MRM platform	• Scattered platforms	• Basic, but centralised • Start with tooling requirements and vendor selection	• Integrated MRM platform 

The Future of MRM: Approaching a Steady State

1st Line of Defence
Model Development / Use

- Complete ownership of Model Risk as an exposure class
- More robust and automated controls around model development and use
- Performing more vigorous model testing during the implementation phase
- Ongoing monitoring of models performance
- Post implementation and testing
- Introducing an IT infrastructure allowing for model user feedback

2nd Line of Defence
Model Validation / Control

- Expanding the Coverage of Models
- More focused on model validation rather than development (i.e. no co-development)
- Enhanced focus on efficiency (core teams supplemented by seasonal pools, and/or offshore resources)
- Efficiency through the use of technology platforms
- Introducing stricter controls and documentation standards

3rd Line of Defence
Internal Audit

- More focused on processes and controls
- Less focus on model-level content (e.g. mathematics, theory)
- More focus on the first line – development, documentation implementation & use of models
- Continuous / BAU instead of event-based
- Internal Audit Findings should be clearly documented and reported to Senior Management and the Board
- Assessment of the process for establishing and monitoring limits on model use

Part 3

Deloitte MRM Offer

Deloitte MRM Offer

Deloitte proposed services

ORGANISATION AND GOVERNANCE	***MRM Organisational Design :*** *Role profiles according to the 3 lines of Defence, Internal Structuration, Outsourcing of some activities (model validation), Change Management, Creation and facilitation of MRM live training / e-learning modules, Peer benchmark assessment, Model Risk Attestation* ***MRM Policy:*** *Creation of policies, procedures, practices & controls according to regulatory guidance,* ***MRM Program:*** *Set-up effective MRM program, PMO activities* ***MRM Governance:*** *Define Model Risk Appetite, MR reporting, Guidelines for model usage and limitations*
MODEL LIFECYCLE MANAGEMENT	***Model Inventory:*** *Migration of multiple model systems into a single enterprise platform* ***Model Classification:*** *Assistance in classifying models (complexity, sophistication, materiality)* ***MR Documentation:*** *Standardized documentation templates including MR evaluation, Documentation review, Development of MRM life-cycle process flow charts with narratives* ***Model Follow-Up:*** *Design of reporting routines & ad-hoc reporting capabilities, Model Monitoring* ***Model Assessment****: Assessment of model implementation*
MODEL CONTROL FRAMEWORK	***Data Quality Review:*** *Model input data review* ***Validation Approach:*** *Design of appropriate model validation methodology* ***Model Independent Review:*** *Perform independent review and deliver model review report* ***Model Control Process Optimization:*** *Analyze and streamline the existing control processes, Design and adjust processes* ***Model Risk monitoring****: Model performance monitoring, KRI's and KPI's, Model Risk Appetite*
MODEL RISK ASSESSMENT	***MRA Development:*** *MR Source identification, Qualitative Assessment: Model Risk Scorecard, Quantitative Assessment: Model Uncertainty measurement, Model Risk incident database* ***Model Risk Analytics:*** *Sensitivity Analysis, Measuring MR impact on P&L and Capital* ***Model Risk Mitigation:*** *Identification of techniques for MR Mitigation*
MODEL RISK TECHNOLOGY	***Platform Design:*** *Set up & implementation of the MRM platform core functionalities & technology infrastructure, workflow process management* ***Platform Selection:*** *Assistance for choosing a MRM technological solution* ***Data Quality Management:*** *MRM data quality management for accuracy, consistency & completeness initiatives* ***Automation:*** *Automation of repeatable areas processes and activities (RPA)*

Structure Organisation and Governance

Deloitte can assist institutions with defining and implementing the MR functions and the associated governance within the organisations.

Cross-cutting nature

- Business Lines,
- Risk, Finance,
- Model Validation,
- Internal Audit,
- Technology

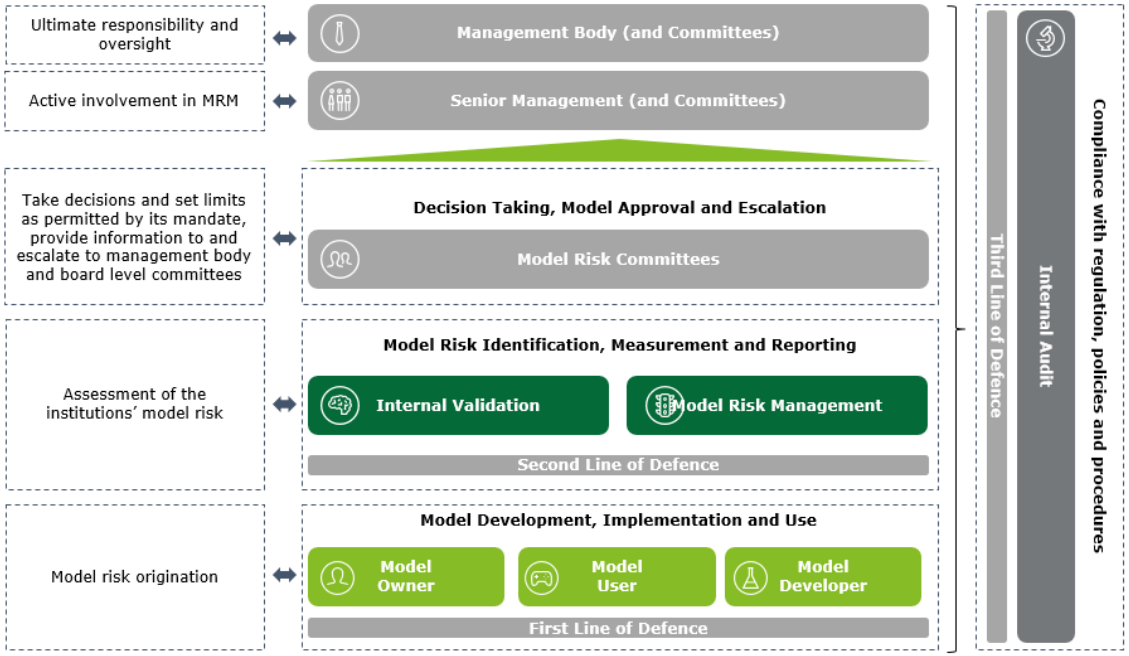
Roles

- Ownership : use of the model
- Control : measure, limits and monitoring
- Compliance : policy compliance

MRM Function

- Maintain an updated inventory
- Validate classified models
- Approve the use and limitations
- MR policy preparation

Model Risk Function should be independent of the other Validation, Audit and Model Development functions in the company.



- The **day-to-day management** of inherent model risk is delegated to the first, second and the third lines of defense.
- The **Board of Directors** is responsible for the approval of the MRM framework, receiving regular reports on the implementation of the MRM Policy.
- **External Resources** may be commissioned by banks to supplement internal capabilities for model validation and review, compliance functions, or other activities in support of internal audit or other lines of defence.

Structure Organisation and Governance

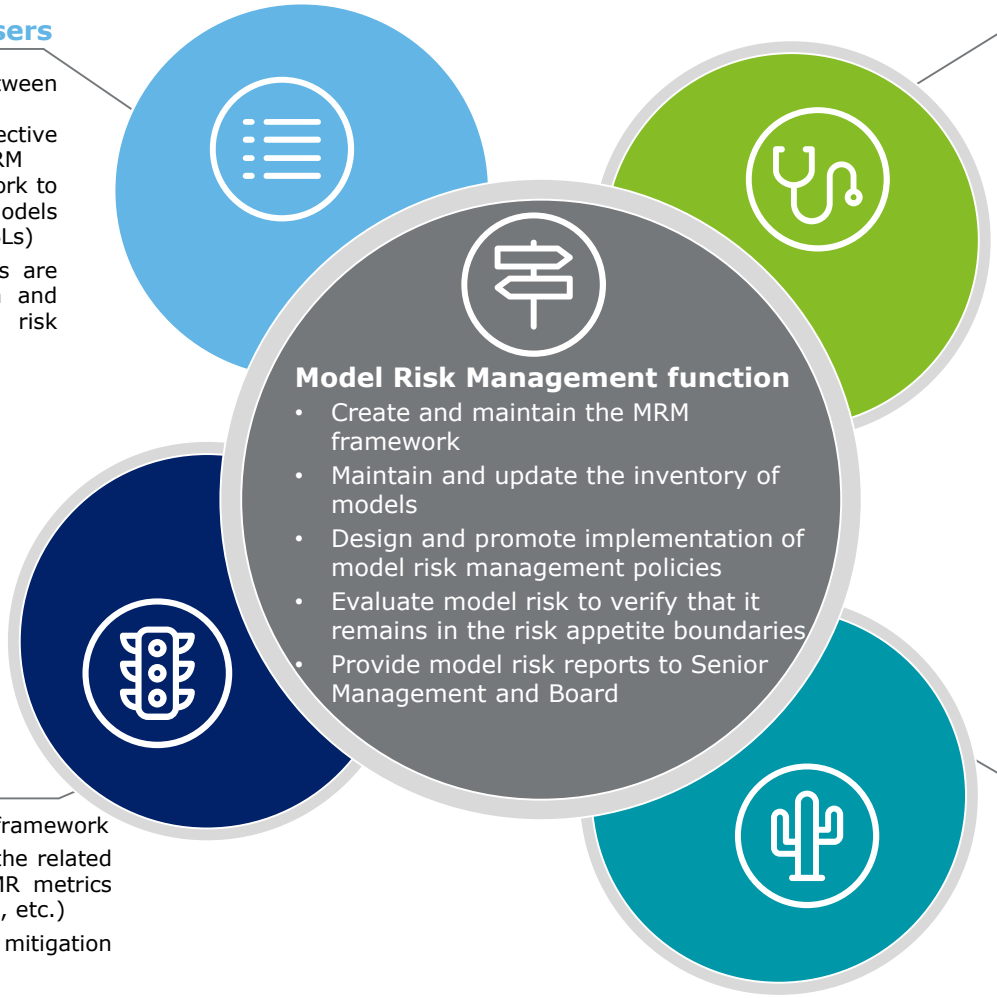
✓ If the establishment of a MRM function plays a central role in the implementation of a robust MRM framework, there might be various organisational options to consider with each having its pros and cons: the MRM function may be (i) a separate function within the 2nd LoD, (ii) grouped with / reporting to the model validation function.

Model builders / model users

- Distinction to be made between model builders and users
- Clearly establish their respective duties and responsibilities in MRM
- Clear model ownership framework to be established (especially for models used in a number of entities / BLs)
- Both model builders and users are subject to model construction and MRM policies (incl. model risk assessment)

Model validation

- Perform model validation tests and performance review for models whose model risk is deemed significant or high
- If model health is 'poor' or 'fair', is empowered to propose model risk mitigants and quantification of model risk, in liaison with model owners and with the MRM function
- As an outcome of model validations and performance reviews, confirm or amend model risk ratings
- Strong integration of model validation into a firm's risk culture



Three lines of defence

- Implement a model risk control framework
- Report to the MRM function on the related control KPIs feeding the key MR metrics (model materiality, model health, etc.)
- Verification that model risk mitigation requirements are in place

Operational risk managers

- Capture model risk events in the OR database events
- Report model risk events to the MRM function

Model Lifecycle Management

Our Model Lifecycle approach includes the following activities :

- **Model inventory** covering all of the organization's models by type and goal;
- **Model classification and prioritisation** according to the risk posed to the bank, which will be required in the monitoring, validation and documentation of models;
- **Model documentation** requires a comprehensive documentation that provides evidence of the diligence used to create the model, captures the findings of the validation, and clarifies the intended use and limitations of the model;
- **Model follow-up scheme** for the early detection of both deviations from target performance and model misuse, in order to act accordingly.

MODEL DEVELOPMENT AND USE

- Models with clear objective usage
- Data Sources
- Model Calibration

MODEL INVENTORY

- Record uses and changes of the model
- Record approval status
- Be supported by a technological tool
- Keep track of all versions
- Link with the register of rating systems requested by EBA

MODEL CLASSIFICATION

- Depends on :
  - **Materiality** as economic consequences
  - **Sophistication**
  - **Impact on decisions**

MODEL DOCUMENTATION

- Data sources
- Model Methodology
- Test plan
- User's manual
- Technological Environment

MODEL FOLLOW-UP

- **Statistical model** (performance of the algorithms)
- **Decision strategies** (the decision rules)
- **Expert adjustments**

The MRM should be assured by **a suitable tool that keeps track of all changes and versions of the models.**

Model Lifecycle Management

Inventory of the models supposes the detection of the perimeter of the models potentially impacted by the risk, through the identification of:

- **The type of model** (i.e. regulatory vs. model used for "managerial" or decision-making purposes)
- **The goal of the model** (e.g. risk management, budgeting, planning, product pricing, etc.)

Classification of the models according to the risk they bear, typically including tiers corresponding to high, medium, and low levels of model risk , based on certain criteria, or a combination of them :

MODEL CLASSIFICATION (TIERING)

- Model Materiality
- Model Complexity
- Model Impact
- Model Significance for enterprise decisions
- Availability of model Decisions
- Model Quality

VS

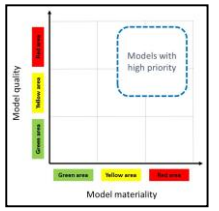
MODEL RISK PRIORITISATION

Definition of a ranking for the interventions on the models based on priority criteria on the main metrics.

Models inventory → **Models assessment** → **Models prioritisation**

Model type	Model	Potential loss impact		Quality	Vintage
		Material	Non material	Performance	Years
Regulatory	Credit				
	Operational				
	…				
Used for managerial purposes	Credit				
	Planning				
	…				

Model Risk Identification



Model Lifecycle Management

Enhance the workflow efficiency through streamlined lifecycle management

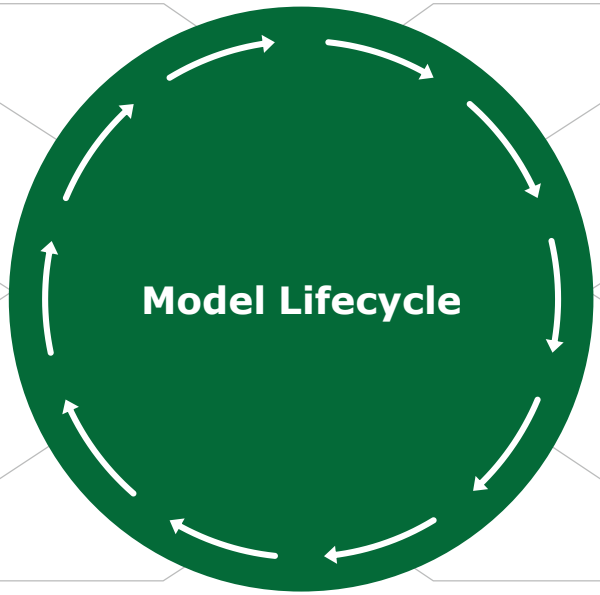
Decommissioning: Revoke permission of use for non-performing or unused/ outdated/ replaced models

Reporting: Performance monitoring; Consolidated model risk

Model Planning: Propose (re)development of new and existing models

Performance Monitoring: Periodic review which may trigger (re)developments and (re)validations

Use: Ensure that model is only used for the intended purpose; Control of post model adjustments



Specification: Define model requirements

(Re)development: Model design, choice of methods; Identification of model weaknesses and limitations; Documentation

Validation: Classifications and individual risk assessment (categorisation, quality/ rating, materiality; Initial and recurrent validations

Approval: Permission to use the model for the intended purpose

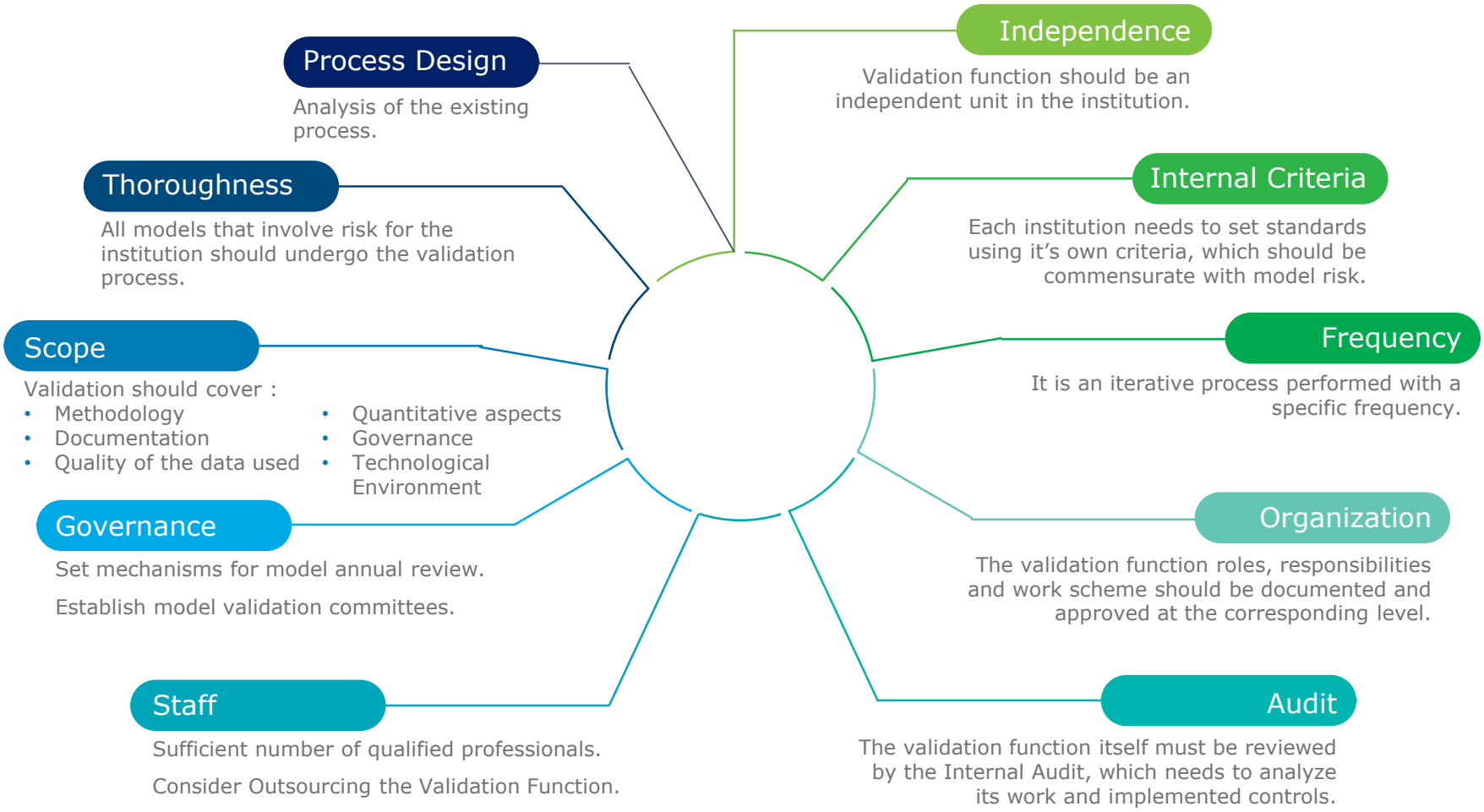
Implementation: Implementation on delivery platform; Functional and user acceptance testing; Defined change control process

Workflow

- Role-based responsibilities at each control point in the workflow process
- Issue management and resolution
- Planning of resources
- Workflow oriented deadlines for each task
- Status reporting to the model inventory

Model Control Framework

The key part of a MRM framework is establishing a **strong and independent monitoring and validation function**. This function should be able to address the quantitative and qualitative review of models across the areas of data, methodology, documentation, processes and governance.



Model Control Framework

"Banks should have a more holistic approach to Model Validation. Not only the mathematics, but also the process and the data quality".

INITIAL MODEL VALIDATION AND REVIEW

Validation KPIs and activities :
- Actual vs. Estimation analysis
- Stability Tests
- Discriminatory Power
- Concentration analysis
- Source Code Tests
- Sensitivity tests
- Benchmark tests
- Stress tests
- Convergence Tests
- Counter-checking with expert judgment

MODEL APPROVAL

Internal Model Approval Process:
- Model Approval requires the model validation to be completed
- Further approval from the senior risk and/or board risk committees

ONGOING REVIEW AND VALIDATION

Ongoing model validation and review are essential to assessing whether models are continuing to perform as expected new model limitations. Typically, model review and revalidation include :
- Material model changes
- Significant market changes
- Significant product or portfolio changes
- Change in the model risk ranking
- Backtesting
- Model performance deterioration detected by ongoing performance monitoring
- Regulatory and audit concerns

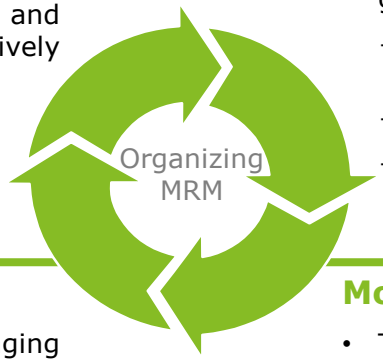
Model Risk Assessment

Key questions: What is your appetite regarding model risk and how to quantify it?

Ability to provide a comprehensive and consistent view on model risk at a defined level of aggregation is an important goal of a MRM framework.

Model risk appetite

- The expression of the Board's appetite for model risk is one of the crucial steps in robust model risk management.
- As for any other risks, model risk appetite is articulated in the form of appetite statements and of risk tolerance limits applied to effectively monitored model risk metrics.



Model risk policy

- An overarching Model Risk Policy sets out the roles and responsibilities of the various stakeholders in the MRM framework, including those of the 3 lines of defence and of model owners, accompanied with the group-wide modelling and MRM standards:
  - model risk definition and identification tailored to the bank
  - monitoring of MRM: model risk KPIs and metrics
  - specific requirements for the development, validation and use of model

Model risk reporting

- The Board has ultimate responsibility for managing the firm's model risk. It is therefore important that information provided to the Board and BRC enables effective oversight of that risk:
  - Model risk profile against model risk appetite boundaries
  - Qualitative information (outcomes of model validations)
  - Model risk assessment

Model risk mitigation

- To reduce exposure to model risk and to ensure the bank constantly operates within the boundaries of its risk appetite, model risk mitigants are to be prescribed when model health is weak or deteriorating:
  - A broad range of model risk mitigants are available depending on model types concerned, its purpose and the modelling issues met.
  - Appropriate checks should be performed by the 3 lines of defence

Integrated Approach for Model Risk Assessment

- ✓ Assessment of model materiality helps in prioritising actions and in rolling-out the MRM framework. There might not be a unique view of what are the most significant drivers of model materiality, although the regulatory context and possible operational / compliance risks should be seen as key drivers.
- ✓ The health assessment framework in place should enable to highlight the most important causes or issues met ("root cause" approach instead of a mere assessment). It should capture the feedback received from Supervisors, Auditors and other lines of defence.
- ✓ Model risk inherent to models used for multiple purposes may vary depending on each particular context of use, which need to be inventoried.

		Regulatory models	Risk management models	Financial reporting	First line models
Model materiality	Volume	▪ Gross exposure amounts	▪ Gross exposure amounts	▪ Gross exposure amounts	▪ Frequency and number of decisions taken
	Context of use	▪ Compliance with regulation ▪ Dependence of other models or activities ▪ Automated decisions vs. overrides able to challenge model outputs	▪ Supervision / regulation ▪ Dependence of other models or activities ▪ Automated decisions vs. overrides able to challenge model outputs	▪ Financial statements ▪ Compliance with standards ▪ Dependence of other models or activities ▪ Automated decisions vs. overrides / challenge	▪ Dependence of other models or activities ▪ Automated decisions vs. overrides able to challenge model outputs
	Financial impacts	▪ Significance / weight in regulatory ratios ▪ Volatility of gains / losses of relevant activities ▪ Impacts if supervisory model approval is removed	▪ Operational & non-compliance risks ▪ Volatility of gains / losses of activities concerned ▪ Reputation risk	▪ Operational & non-compliance risks ▪ Volatility of gains / losses of activities concerned ▪ Reputation risk	▪ Operational & non-compliance risks ▪ Proportion of P/L dependent on model for decision-making ▪ Opportunity costs ▪ Reputation risk
Model health assessment	Data	▪ Data quality and integrity, wrong data inputted in models ▪ Other data limitations: availability / scarcity, use of external data, changes in definitions over time, etc.			
	Modelling choices	▪ Theory: non-standard & emerging model theory, un-tested limitations in underpinning theories/assumptions, proxies ▪ Obsolescence, non-approved material changes ▪ Modelling complexities, missing variables, misspecifications			
	Model uncertainties	▪ Scenario analyses: model behaviour in stressed or extreme conditions ▪ Sensitivity analyses: sensitivity to variations in estimations of input parameters, to available data and to changes in assumptions ▪ Benchmarking analyses: comparison of outputs and theories to alternative modelling choices ▪ Stability & robustness: population stability, input and output stability, etc.			
	Model accuracy	▪ Backtesting: actual performance vs. past experience ▪ Discrimination power (if applicable) ▪ Limited range of validation techniques used (incl. expert-judgments, reasonableness checks, etc.)			
	Model environment and use	▪ Model infrastructure: (resources, systems / processes) ▪ Model governance: model challenges, permanent controls, on-going accuracy checks ▪ Model not used as intended ▪ Model interconnections: upstream and downstream dependencies to other models			

Model risk rating	Model materiality			
Model health assessment	Low	Moderate	Significant	High
Very good				
Good				
Fair				
Poor				

Illustration – Model Risk Quantification

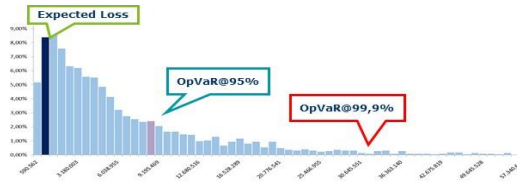
SCENARIO OVERVIEW

Product/Client	Model	Risks

• Scenario is aimed at analyzing and measuring the "Pricing Model Risk" relate to Forward Start Options for UE CIB	• Client counterparties (Market best practice) usually measure FwStart options market values with Heston model
	• Client Murex release, do not include Heston model, thus option market price is obtained as a sum of two separate deals:
	  ○ One priced with Black&Scholes model, which generates a price different from the market one
	  ○ A dummy deal manually booked and calculated "out of the box" just to measure the difference between the B&S price and the Heston one
	• The Heston value is obtained with external model (xls based) with manual input of main parameters
		• Risks arise from model design - key measurement phase manually managed - and is related to manual input of parameters
		• The loss could occur if there is a lack of the parameters' upgrade and in the same time, the counterparties ask the deal closing

QUANTIFICATION

"Pricing Model Risk" is measured with a Statistical/Actuarial Approach (LDA) used for operational risk measurement, based on separate modeling of:

Frequency	Severity
Count of the lack of recalibration, in the past 5 years, of the model's parameters and the early termination of deals, then the joint probability of occurrence Investigation about the occurrences in the past, with the aim to make a prediction for the next year analyzing budget volumes and expert opinions	Sample of potential losses: difference between the FWstart option price calculated with client model with no parameter recalibration and the FWstart market value Investigation about the most frequent impact and the worst one in the past, with the aim to make a prediction for the coming year, asking for confirmation to the experts
	As result of the analysis the costumer has decided to: • Evaluate the integration of Heston model directly, or of other models, currently not included in Murex • Extend the existing controls for deals measured with Heston models

Integrated MRM Platform (1/3)

Four coherent dimensions that structure the model life cycle management in a MRM platform

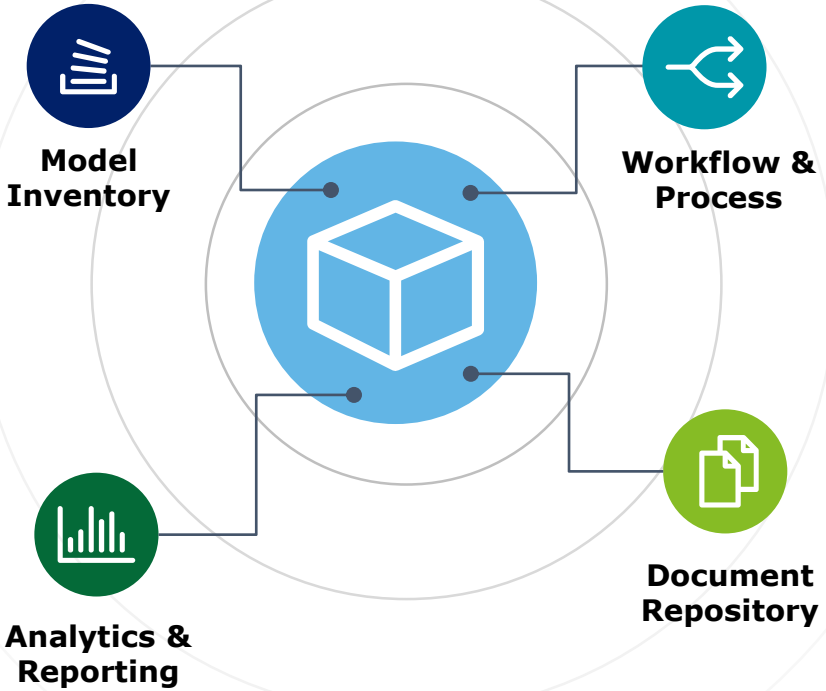
- A successful model risk management platform integrates model lifecycle workflow, a model inventory, a document repository, and analytical/reporting capabilities
- While most organizations have some form of the below components, the industry is moving towards a centralized system that integrates and connects all components into a single robust Model Risk Management platform.

Model Inventory Database

- Store and maintain standardized and non-standardized model-specific information
- Complex querying

Reporting Capabilities

- Board and regulatory reporting
- Operations/workflow reports
- Administrative reports



Model Lifecycle and Workflow Capabilities

- Role-based model validation workflow
- Issue management and resolution
- Role-based responsibilities

Centralized Document Storage

- Upload and download documentation
- Documents linked to model inventory
- Document version control

Integrated MRM Platform (2/3)

Stage 3: MRM best practices of the four coherent dimensions

Model Inventory

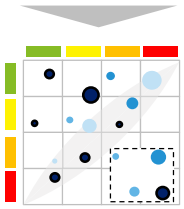
- Enhanced inventory/model data through automation capabilities
- Integrated inventory data for centralization on a single platform
- Standardized data dictionary across entire inventory (e.g. model types, assumption types, input types)
- Enhanced model inventory controls to minimize model data issues

Workflow & Process

- Enhanced workflow processes to stream-line MRM activities (e.g. model eligibility)
- Defined governance responsibilities at each control point in the workflow process
- Specific interfaces for each control point across the workflow process, enabling governance with clearly defined handoffs

Analytics & Reporting

- Enhanced reporting capabilities through templates and automated reporting
- Ongoing monitoring capabilities by connecting testing results to recurring monitoring processes
- Model risk aggregation capabilities using standardized metrics and scoring methodologies



Document Repository

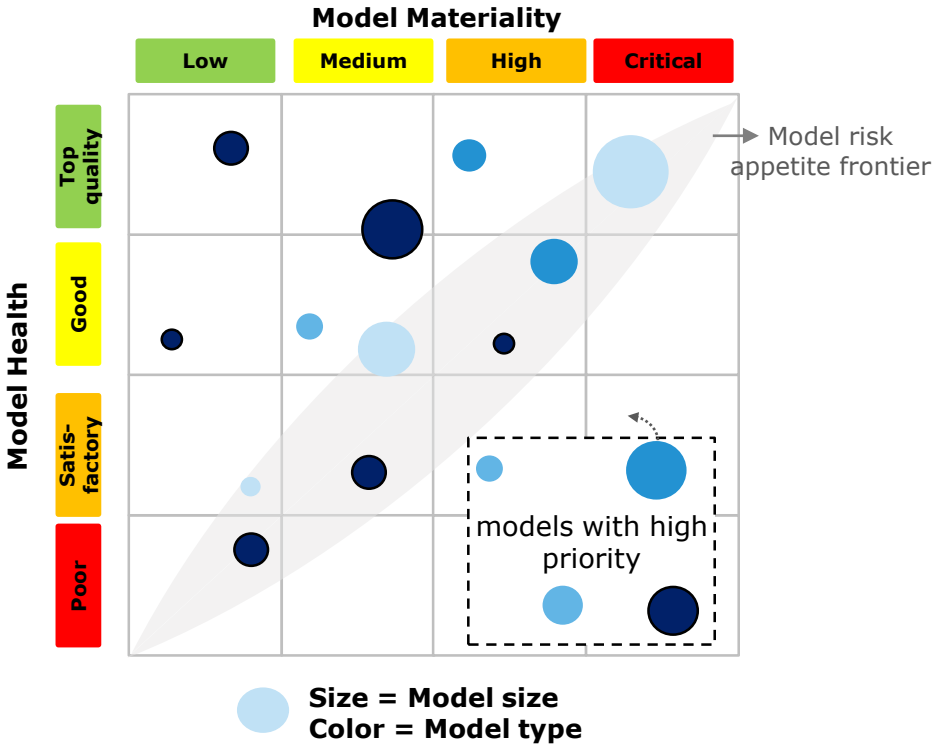
- Enhanced and standardized existing model documentation
- Automated components of validation report generation process
- Enhanced document repository (e.g. organization, versioning)

Integrated MRM Platform (3/3)

Stage 3: Model risk quantification enhances analytics and reporting and capabilities with a means to identify the level of model risk

Model Inventory | Workflow & Process | **Analytics & Reporting** | Document Repository

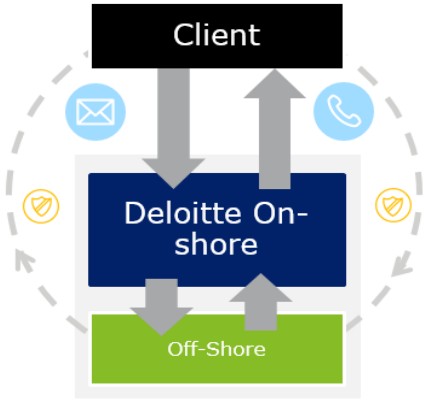
- Model risk quantification provides insight into model risk for analytics and reporting purposes
- Each model is scored individually on three criteria using a measurable scoring system
- The aggregation framework transforms individual model risk scores into model area risk scores
- The resulting model risk scores are visualized in a model risk matrix as seen on the right



Off-shore support

Driving "around the clock" progress and meaningful cost savings

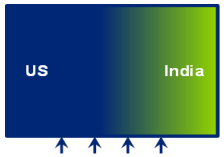
Operating Strategy



- Deloitte professionals manage workload, communication and handoffs with off-shore resources, with no requirement for the client to interact with the off-shore team.
- The degree of direct communication and interaction between the client and off-shore resources can be customized to the client's preference.

Benefits

Degrees of Involvement

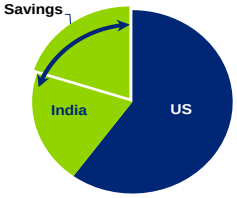


Degree of involvement is tailored based on complexity, type of models, and preferences.

Time Efficiency

Validation activities performed around the clock – 24-hour validation cycle

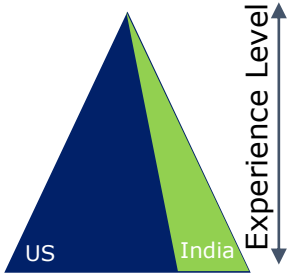
Cost Efficiency



Component of work in India leads to meaningful cost savings

Our Off-Shore Team At a Glance

- 150+ validation, MRM, data analytics, and quantitative modeling professionals
- Extensive experience with: Stress tests, Basel, Credit / Market / Operational / Liquidity Risk
- Programming skills include: SAS, R, Matlab, Python, SQL, C++
- A large, structured and leveraged team that includes a combination of senior resources with 5-10+ years of US experience leading staff teams with strong industry experience and educational credentials (economics / econometrics, math / statistics, and quantitative finance)



Part 4

Credentials

US Credentials

- Assistance to top 5 Banks with the enhancement of its MRM framework
- More than 100 professionals are helping or have helped the Bank comply with U.S. regulatory guidance related to models
- Project activities include MRM planning, model validation, technology enhancement, & process improvement

 MRM PLANNING	***Gap Assessment:*** *Comparison of governance, practices, & controls to regulatory guidance* ***Benchmarking:*** *Analysis & presentation of the differences in industry practices for MRM* ***MRM Program Design:*** *Development of a multi-year plan for enhancing MRM*
 MODEL VALIDATION	***Staff Augmentation:*** *100+ professionals serving as an extension of the Bank's validation team* ***Academic Research:*** *Assistance with the creation of modeling "white-papers"* ***Peer Review:*** *Secondary review of internally performed model validations*
 TECHNOLOGY ENHANCEMENT	***Model Inventory:*** *Migration of multiple model systems into a single enterprise platform* ***Platform Development:*** *Enhancement of the MRM platform & workflow, prototype development* ***Data Quality Management:*** *MRM data for accuracy, consistency, & completeness initiatives*
 PROCESS IMPROVEMENT	***Practice Development:*** *Creation of MRM practices (e.g., Risk Classification Methodology)* ***Reporting & Analytics:*** *Design of reporting routines & ad-hoc reporting capabilities* ***Documentation:*** *Creation of policies, procedures, & standardized documentation templates*

EU Credentials

Mission name / perimeter	Project type	Details	Period	Country
Credit Risk	**Internal rating system authorized by Local Authority**	Updating of the Validation Framework for Credit Risk	4 months	Italy
	Internal rating system authorized by Local Authority	Support to Basel II Project PMO: management of the workstreams; coordination and communication to Directors and Corporate Bodies	LTS (project with an elapsed time higher than 2 years)	Italy
	Internal rating system authorized by Local Authority	Internal Rating System validation (using SAS), with focus on: PD models for Corporate and Retail portfolios LGD models for Corporate and Retail portfolios and LGD for Defaulted Asset Structured Finance models Models for Banks and Public Sector Entities portfolios Processes IT Systems II Pillar Risks	LTS (project with an elapsed time higher than 2 years)	Italy
Credit Risk	**Internal rating system authorized**	Development (using SAS) of the rating system: Support in development of PD, LGD and EAD centralized models for Corporate portfolio Personal loans, Mortgages, Salary Loans PD and LGD models development	LTS (project with an elapsed time higher than 2 years)	Italy
Credit Risk	**Basel II roadmap in place**	Internal Rating System validation (using SPSS), with focus on: Validation Framework definition PD models for Corporate and Retail portfolios LGD models for Corporate and Retail portfolios	LTS (project with an elapsed time higher than 2 years)	Italy
Credit Risk	**Basel II roadmap in place**	Rating system review: Internal Auditing Framework definition Quantitative aspects – Corporate and Retail models Organizational aspects/governance IT systems and Data Quality	LTS (project with an elapsed time higher than 2 years)	Italy
	Basel II roadmap in place	Rating system development: Defaulted Assets LGD model development EAD model development	LTS (project with an elapsed time higher than 2 years)	Italy
Operational Risk	**AMA Development and validation**	Review of Risk Classes for AMA capital calculation Support to validation of AMA calculation model Support to validation of AMA capital allocation methodology Support to Audit Unit on AMA process and validation calculation Support to AMA framework validation	LTS (project with an elapsed time higher than 2 years)	Italy

EU Credentials

Mission name / perimeter	Project type	Details	Period	Country
Operational Risk	**AMA Design and Implementation**	AMA framework designed by Deloitte for EIB resulted won the "European Operational Risk Awards 2006" for the category "Best AMA Framework of the year" during the OpRisk Europe Conference in London in 2006	4 months	Italy
Operational Risk	**ORM framework development**	Definition of methodology and validation instruments for ORM framework	7 months	Italy
Operational risk	**AMA model validation**	(i) stress-testing of the model under a variety of conditions, (ii) in-depth technical analysis of the code used by the client to compute the capital requirement and (iii) benchmark survey of the market practise of AMA models across 10 Deloitte member firms	2 months	Belgium
Counterparty Credit Risk	**CVA model review for collateralized exposures**	In the context of the Asset Quality Review, the National Bank of Belgium asked Deloitte to review the	1 month	Belgium
Credit Risk	**Development a credit scoring model for acceptation of private loans**	Development of a credit scoring model that is used to give a probability of default to consumer loans. The model uses logistic regression and is developed in R. The model can be used by the bank to assess the health of the current portfolio or the probability of default of new "through-the-door" customer.	6 months	Belgium
Market risk	**Review of the valuation of complex equity swaps and interest rate derivatives**	In the context of audit mandates within the Fund Industry, Deloitte reviews the valuation of complex equity swaps and interest rate derivatives by full revaluation using in-house built models (Black, Heston, Variance Gamma, SABR, Hull White).	6 months	Belgium
Market risk	**Development of a valuation model for interest rate derivatives under the negative rate environment**	Development of the shifted SABR model. The model consists of a calibrator that generates the SABR parameters and a pricer that uses the SABR parameters in order to price. The pricing covers most of the vanilla products, such as caps, floors, swaptions, CMS caps.	6 months	Belgium
Market risk	**Model validation of a prepayment risk model for mortgage loans**	Statistical analysis of historical prepayment rates across various clusters of clients and timeperiods. The institution is using this analysis as a back up to their expert-judgement	6 months	Belgium
Market risk	**Review of the collateral haircut methodology**	Review of the collateral haircut methodology	1 month	Belgium
Market risk	**validation of a number of models used to value vanilla instruments (swap, FRA, swaptions, ZC inflation swaps)**	Validation of a number of models used to value vanilla instruments (swap, FRA, swaptions, ZC inflation swaps)	3 months	Belgium

EU Credentials

Mission name / perimeter	Project type	Details	Period	Country
Market risk	**Validation of the valuation model for a synthetic CDO**	Validation of the valuation model for a synthetic CDO, including derivation of the default intensities from bond spreads; loss distribution and simulation based on Gaussian copula to generate the time to default.	2 months	Belgium
Credit Risk	**Internal rating system authorized by Local Authority**	Review of measures to solve regulatory findings	LTS (project with an elapsed time higher than 2 years)	Germany
Credit Risk	**Internal rating system authorized by Local Authority**	Validation of Corporate Rating Model (PD) (using SAS)	2 months	Germany
	Internal rating system authorized by Local Authority	Re-Development of Ratingmodel for Factoring including initial valdidation (PD, LGD, CCF, dilution) (using SAS)	LTS (project with an elapsed time higher than 2 years)	Germany
	Internal rating system awaiting approval by Local Authority	Support of rating model development for overdraft portfolio (PD, LGD, CCF) including initial validation. Additionally validation after first year (PD) (using SAS)	LTS (project with an elapsed time higher than 2 years) .	Germany
	IFRS 9 Impairment model	Development of IFRS 9 impairment methodology including implementation of validation/Re-calibration process/methods	LTS (project with an elapsed time higher than 2 years).	Germany
Counterparty Credit Risk	**Internal Model Method (IMM) authorized by Local Authority**	Qualitative and quantitative validation of the stochastic processes, risk factors and dependencies including benchmarkings with historical data	4 months	Germany
	Internal Model Method (IMM) awaiting approval by Local Authority	Qualitative and quantitative validation of the market implied exposure simulation including independent implementation and exposure benchmarking	1,5 years	Germany
Credit risk	**Support for the definition and the establishment of the Basel II IRBA project on factoring and leasing activities**	Project framework (Factoring & Leasing) Management and monitoring of Basel II project (governance project structuring, PMO, quality assurance, progressive validation of the approval file, skills transfer) Methodologies definition and risk parameters estimation : o Framework – Review of the existing model and development plan definition o Model design Model development within information systems Operational integration of model within process and organization	3 years	France

EU Credentials

Mission name / perimeter	Project type	Details	Period	Country
Market Risk	**Assistance in the approval process of the internal model**	Monte Carlo VAR - Assistance in the approval process by the French supervisor Cartography of the business Iines / desks (type of instrument, P&L, risk limits) Writing of the model documentation provided to auditors and to the French supervisor Governance & Organization of the Market Risk department Market Risk monitoring : limits framework, model validation, reserves calculation Perimeter covered by internal model Monte Carlo VAR methodology : instruments re-pricing, scope of the risk factors, design of the scenarii, calibration of the correlation matrix IT architecture, workflow, definition of the controls to ensure the quality of the data Back testing framework Reportings (including stress tests) Follow up of the recommendations issued by the supervisor after its review	6 months	France
Market Risk	**Internal Model Approval - on site inspection**	Organisational structure : charts, sizing and roles of the involved departments (FO, Risk, Product Control, Finance) Governance around model changes & validation Model use & outputs : internal use of risk measurement system (including market risk management & limits setting), internal reportings, calculation of own funds requirements, capital allocation, stress testing Back testing process & results	2 months	France
MRM	**Gap analysis and road map definition**	MRM maturity stage target definition Identification of the main gaps between the target and the existing and the formulation of generic recommendations that are deduced directly from the gap analysis. Recommendations for model validation practices	2 months	France
Credit Risk	**Model risk quantification framework design**	Model Identity card definition Model Risk Scorecard definition with regard to three main axis : materiality, health and costs Model Aggregation methodology definition	3 months	France
Credit Risk and Investment Fund manager	**MRM gap analysis and best practice recommendations**	Definition of a groupwide (bank and investment fund manager) model risk framework with focus on validation of internal models. ascertaining the different regulatory requirements (between bank and ifm per risk category) and comparison with their internal processes. Definition f the framework document containing the regulatory validation requirements (roles, governance, reporting, tasks, …) with a general section and risk model specific parts.	3 months	Germany

EU Credentials

Mission name / perimeter	Project type	Details	Period	Country
Credit risk	**Independent audit of Credit Risk Model Management and Quality Control processes (Retail models)**	- Review of the governance supporting Model Management, including maintenance, monitoring, model change management, back testing, use test and stress tests. - Review of the quality control in place that cover data quality management, internal credit risk reporting, calibration of risk parameters.	3 months	Luxembourg
Credit risk	**Independent validation of the CVA internal model**	Critical analysis of the methodology Review of the process for calculating CVA Review of compliance to best banking practices	3 months	Luxembourg
Credit risk	**Independent validation of the LGD Retail model**	Critical analysis of the methodology Review of the process for calculating LGD Review of compliance to CRD IV requirements	2 months	Luxembourg
Credit risk	**Audit outsourcing for Credit Risk Model (PD, LGD, CCF) and Market Risk Model Validation Processes**	Review of the Model Validation life cycle, including Coverage, Governance, Documentation, Methodology and Maitenance of the Model Validation process.	3 months	Luxembourg
Credit risk	**Independent review of IRB models for Corporate, PSE and Institutions counterparts (PD + LGD)**	Four-year audit program covering all IRB models of the Bank (model and methodology, governance, use test) Benchmark against best banking practices	4 months	Luxembourg
Market risk	**Review and validation of the securitisation internal rating model**	External, independent review of EIF's rating model with emphasis on the operating structure of the model and the model's underpinning assumptions and rating assignment mechanism.	4 months	Luxembourg

EU Credentials

Mission name / perimeter	Project type	Details	Period	Country
IFRS9	**IFRS9 Risk Models**	Development (using SAS) of the IFRS9 risk models: Support in definition and implementation of PD, LGD and EAD models for credit portfolios.	1 year	Spain
Credit Risk RDA Framework review	**Data and processes review**	Analysis of Business Processes supported in IT systems, according to RDA Framework, reviewing Source Data and Derived Data (calculations in loads, ETLs, transformations, etc.) for Credit Risk information.	1 year	Spain
Data issues Management	**Data and processes review**	Development of a methodology and an integrated tool to manage, from their identification to their solution, Data Quality issues for Credit Risk information.	6 months	Spain
Data Models review	**Data and processes review**	Definition and development of a Testing Plan and Controls over Data Models to ensure the correct functioning of consolidation and reporting engines (reconciling with general ledgers, error reviews, etc.) using IT solutions.	6 months	Spain
AQR review	**Capital requirements**	Support (using IT tools) of the analysis of Capital requirements under the AQR stress test methodology	3 months	Spain
Market Risk	**Pricing Validation & Fair Value Audit**	Development of Pricing Models to validate and audit the fair value of financial instruments (Level 1, Level2 and Level 3) using Montecarlo techniques, Gaussian Copulas, Black-Sholes among others..	6 months	Spain
Market Risk	**Pricing Validation & Fair Value Audit**	Development of CVA models to use them as a proxy for the validation of the credit risk adjustment reasonability	6 months	Spain
Market Risk	**Pricing Validation & Fair Value Audit**	Risk Sensitivity Analysis regarding risk model such as: liquidity analysis (inputs variations more than 95% of the standard deviation, quoted prices, bid/ask spread..), analysis of fair value impact considering changes in the key inputs (correlations, beta parameter, volatility due to market price uncertainty), close-out cost, CVA-FVA analysis.	6 months	Spain
Market Risk	**Pricing Validation & Fair Value Audit**	Validation of the whole internal control environment related to fair value process from the inputs capture to the accounting of the fair value	6 months	Spain
Credit risk, market risk, operational risk, model risk	**Assessment on governance and control environment associated to all risks**	Evaluation of the adequacy of the governance and control level established for the Entity All Risks (credit risk, market risk, operational risk, etc.) were under the scope, including model risk 'Work methodology was based on the revision of written policies and procedures.	4 months	Spain

EU Credentials

Mission name / perimeter	Project type	Details	Period	Country
Internal Control Framework	**Risk Control Function (RCF)**	Assessment of the internal control framework and its compliance with EBA guidelines - Apropiate organisational framework and structure (independence and proporcionality) - Composition, Responsibilities - Ensure there is a clear, transparent and documented decision-making process (reporting).	2 months	Spain
Internal Control	**Support in the definition of internal control model and the SAP GRC system structure to manage it**	Assistance in the definition of the internal control model in a systemic financial organization, based in the international standard COSO 2013:	1 year	Spain

Part 5

Contacts

Contacts

Please do not hesitate to contact your relevant experts.

MRM EMEA lead

Marc Van Caeneghem
Partner
mvancaeneghem@deloitte.fr

France

Nadège Grennepois
Director
ngrennepois@deloitte.fr

Michel Guidoux
Senior Manager
mguidoux@deloitte.fr

Anca Alvirescu
Senior Consultant
aalvirescu@deloitte.fr

Germany

Thomas Moosbrucker
Director

Florian Wilbert
Senior Manager

Netherlands

Koen Dessens
Partner

Sjoerd Kampen
Senior Manager

Austria

Kurt Blecha
Partner

Ute Romana Schoeggl
Manager

Italy

Francesco Zeigner
Partner

Vincenzo Cosenza
Manager

Belgium

Nicolas Castelein
Director

Roeland Baeten
Director

United Kingdom

Thomas Clifford
Director

Henry Jupe
Associate Director

Luxembourg

Jean-Philippe Peters
Partner

Arnaud Duchesne
Director

Spain

Cesar Gurrea
Partner

Oriol Arnau
Partner

Portugal

Miguel Morais
Partner

Vitor Lopes
Partner

Central Europe

Adam Kolaczyk
Partner

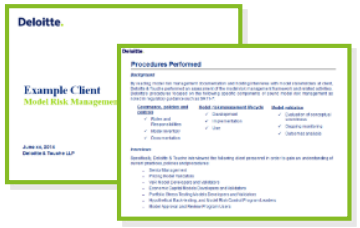
Marcin Gadomski
Director

Part 6

Appendix

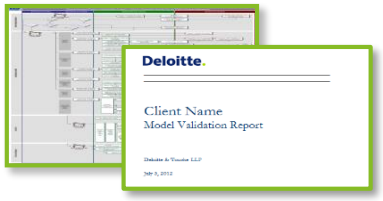
Tools & Methodologies

Validation Playbooks

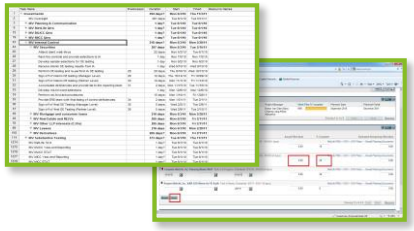


Validation Tools

Validation Templates



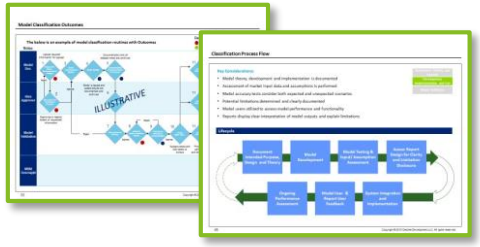
Project Management Tools



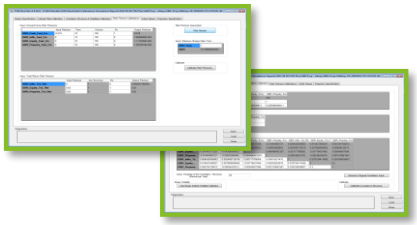
Training Materials

Reporting Templates

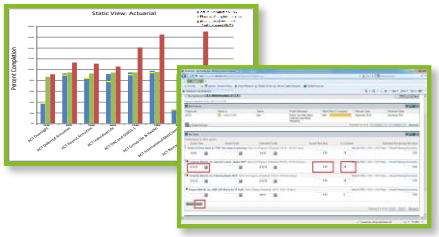
Risk Classification Methodology



Scenario Generators



Ongoing Monitoring Templates



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