

Vendor Analysis: Moody's Analytics

Model Validation Solutions, 2019





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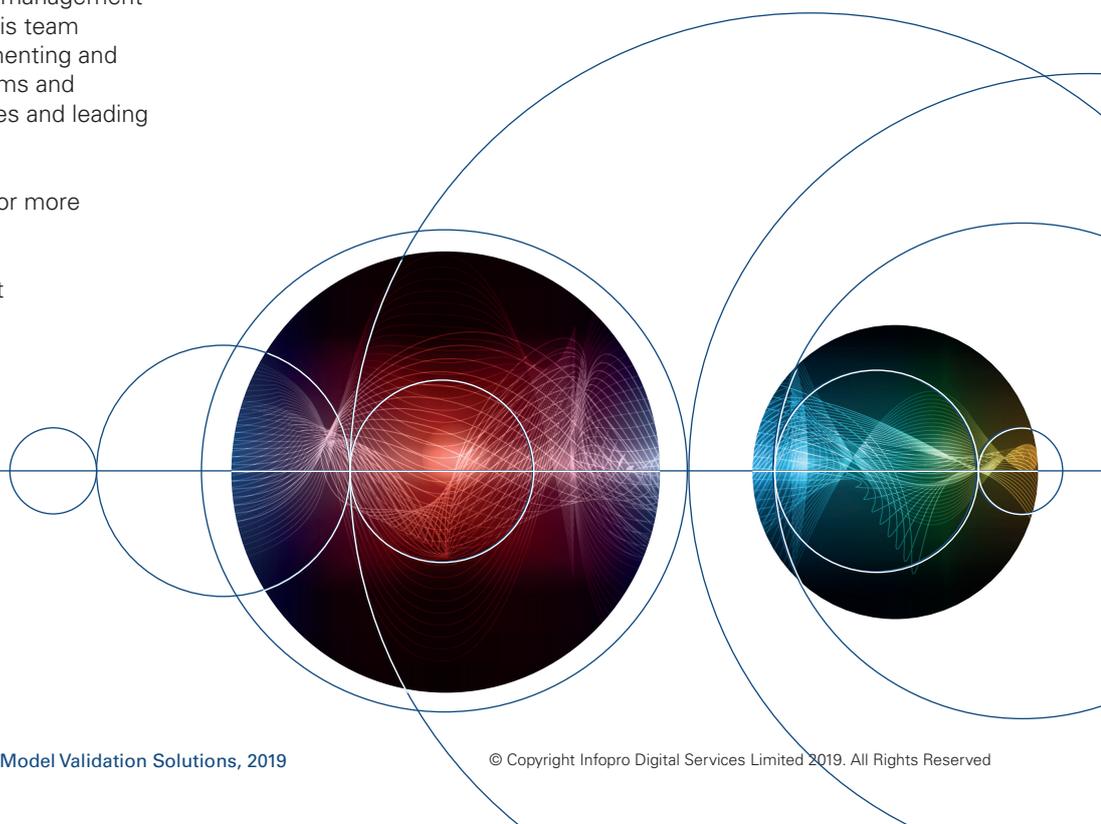


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1. Report context

This Vendor Analysis is based on the Chartis quadrant report *Model Validation Solutions, 2019: Overview and Market Landscape* (published in January 2019). This section summarizes the key theses in that report; subsequent sections take a detailed look at the quadrant positioning and scoring for Moody's Analytics, and Chartis' underlying opinion and analysis.

Key thesis

A new kind of complacency

In analyzing model validation solutions and technology, the main themes are *diversity*, *specificity* and *maturity*. Model validation is a complex area, covering a wide variety of highly specific tools and techniques of varying maturity.

Since the financial crisis of 2008, the way that financial institutions (FIs) view and approach model validation has changed significantly. FIs' models were often complex and hard to understand – but for FIs themselves these traits were examples of the models' effectiveness. As a result, they didn't see much need to validate them, leading to a level of complacency.

All that changed after the financial crisis. Following pressure from regulators, model validation and management were placed firmly in the spotlight, and the accuracy and validation of models became a crucial part of FIs' risk governance processes.

Despite the heightened focus on model validation, however, FIs are still complacent. Now they rely too much on models and the outputs of their often opaque internal processes. But several high-profile incidents (such as the case of the 'London Whale') have highlighted how FIs need a deeper understanding of these processes. And increasingly regulators – frustrated by the opacity of many models, and their results (particularly in financial crime risk management [FCRM]) – want a clearer picture of exactly how FIs' models work.

In a world where models are becoming bigger and more complex, and FIs depend increasingly on quantitative decision-making processes, achieving effective model validation is still a challenge. Although validation processes are continuously developing, there is still some doubt over whether current model validation techniques and processes are *resolving* model risk at a fundamental level or merely *mitigating* it.

Current versus future

In analyzing the overall model validation landscape, it's helpful to view its evolution in two phases: *current* and *future*. Current model validation, using relatively well established technologies and techniques, is not without its challenges: notably around workflow, the ease with which models can be interpreted, and how to tackle the opportunities and challenges presented by data.

But we are also seeing a fundamental shift in the model validation landscape, driven by more sophisticated technology – an evolution that is challenging the structures on which established model validation has been built. As artificial intelligence (AI), machine learning (ML) and natural language processing (NLP) tools and techniques become more prevalent, they will play a vital role in the future of model development and validation.

Much of this evolution is being influenced by the need for *explainability* and *interpretability* now being demanded by regulators and CROs (who increasingly have to understand why a system produced specific results, and be able to defend those results). It is seeing us move – albeit gradually – into a new era of AI development, away from the 'black box' models of the past toward more 'glass box' models (that employ so-called Explainable AI, or XAI). As the overarching imperative for transparency and accountability in FIs develops, XAI could become a critical element in meeting any future regulations and ultimately preventing systemic technological risk.

The problem with progress

FIs are taking their first steps toward more AI-driven validation, and some vendors are exploring this new avenue (particularly in the area of FCRM, where ML tools are being used extensively) – but these technologies are developing fast. While they will likely transform the model validation sector, they also risk increasing the problems of complexity, opacity and interpretability that bedevil the use of models and threaten their credibility.

There are also more practical problems. Because of the heavy investment many FIs have already made in existing AI technologies, when XAI becomes more mainstream, integrating it won't be a simple exercise. To fully embrace the latest wave of AI and ML, FIs will probably need to have a costly rethink; they may even have to roll back their current AI implementations.

A more holistic view

The reality is that a truly interactive relationship between model development, validation and users is still a long way off. At the moment, most validation is carried out using non-AI tools, and will continue to be for some time. Nevertheless, the development of XAI highlights the challenges that affect current non-AI model validation.

For vendors, this presents a problem. Chartis believes that to compete successfully they should start to take a more 'holistic' view and cover both options: ensure they are at the forefront of developing and implementing new validation techniques, while still providing services for traditional models. In our view, effective model risk governance should involve the validation of all aspects of model development and implementation. This is reflected in our definition of 'model validation', which covers data validation, internal model validation, the appropriateness of particular models and their transparency.

Successful vendors of the future, we believe, will offer comprehensive solutions that fit this wider definition of validation. Vendors also have an opportunity to move beyond the labels and restrictions of 'developer' and 'validator' to provide more 'holistic' expertise. Conversely, by treating the development and validation of models as strictly separate activities, vendors risk overlooking the close relationship that validation should have with development at every stage of the process.

Ultimately, however, a fundamental challenge for both FIs and vendors remains. For model validation to be possible and effective in FIs' new, AI-led future, vendors and users will have to dramatically change their attitude and approach to modeling, if they are to make the end-to-end process of model development and validation transparent and effective.

Demand-side takeaways

What is model validation?

Diverse and varied

A 'model' is a computational system capable of interpreting input data and producing quantitative estimates for real-world business decisions. Chartis defines *model validation* as 'the range of processes and tests that demonstrate a model is fit for purpose and falls within the bounds of acceptable risk'. Broadly, model validation is the core technical component of *model risk governance*, which is the management of model risk within the context of a firm's risk appetite.

By its very nature model validation is more quantitative than other areas of model risk and governance, involving complex statistical methods and techniques. These techniques are highly specific to the models they are designed for. Models are not validated generically: their inherent specificity means that model validation tools in one area do not necessarily correlate with those in another. Derivatives pricing models, for example, are validated using specific systems; anti-money laundering (AML) models are validated in the context of AML systems; while credit models are validated according to various characteristics (such as probability of default frameworks and so on).

Across this diverse range of model types, model validation activities and capabilities also vary in their *maturity*, depending on the nature of the techniques themselves, the type of model that is being developed and validated, and the regulatory scrutiny in that specific area. So while the techniques used for derivatives and credit models are highly mature and well-established, those in the area of AML, by contrast, vary widely depending on the nature of the statistical model being validated. Regulatory scrutiny also varies widely: again, while the framework around model validation for derivatives pricing is fairly robust, with well-developed theories and data, model validation in AML is relatively untested.

There are several types of model validation (including benchmarking, stress testing and regression), but within those the main validation components that make up the model validation 'value chain' are data validation, suitability assessments, remediation, future performance and regulatory and reporting functions.

The current state of model validation: wider scope, bigger challenges

The growing regulation around models is compelling FIs to introduce more validation processes with wider scope and increased transparency. But in spite of lessons learned, changes to the culture and operations that surround models, and wider acceptance that models are indeed fallible, FIs still treat models – and depend on them – as if they were flawless. Meanwhile, models still make mistakes and continue to produce unexpected outputs, with catastrophic results. Because every stage of model development can be prone to inaccuracies and misjudgments, even diligent model validation can still cause issues, and banks are struggling with several challenges, notably around interpretability, workflow and data.

Moving toward the future: the expanding role of AI

Revolutionary developments in AI technology are pushing the boundaries of what is possible – and acceptable – in model risk management. New technologies, such as AI, ML and NLP, are likely to play a crucial role in model development in the future, and are developing rapidly. AI and ML models already have several applications in financial services, especially in unlocking patterns and insights from unstructured data¹. The key function of ML, for example, is to help a model intuit general concepts from training data. How effective an ML model is depends on how well it can ‘generalize’, or make accurate interpretations from unfamiliar examples, based on its training.

While the opportunities for FIs in AI and ML are developing, there are practical challenges too. These include adversarial attacks, tackling the risk of ‘overfitting’, dealing with the curse of dimensionality, overcoming data bias, and the need to refresh data.

Solving the interpretability problem is a key driver in the development of ‘third-wave’ AI tools², especially XAI. The ‘second-wave’ AI models currently in use employ complex algorithms, with supporting rationale and reasoning that users do not necessarily understand. The widespread use of and dependency on these models for automating decision-making processes exacerbates the interpretability problem. As AI permeates model validation processes themselves, and AI tools

are used to validate other AI systems, these challenges could multiply in an ever-widening cycle. What or who validates the AI validators?

Supply-side takeaways

Vendor landscape

Driven in part by the cultural, operational and regulatory shifts in how FIs view and use models, a growing vendor market has emerged to service the demands of FIs for efficient and accurate model validation. Driven by standards and regulations such as International Financial Reporting Standard 9 (IFRS 9) and the Fundamental Review of the Trading Book (FRTB), FIs increasingly need to outsource their model validation, because achieving robust, independent in-house validation can be both expensive and operationally challenging.

Few vendors provide model validation as an external undertaking. Outsourcing all aspects of model validation is not a straightforward task, because of the proprietary nature of many FIs’ models and their use of third-party tools. Nevertheless, as regulation and attitudes and approaches to model validation continue to shift, FIs are looking for more support and specialist skills from increasingly sophisticated vendors.

A vendor’s ability to develop model validation solutions often stems from its capacity to produce models in certain areas of the financial services sector. Different areas of the sector, such as derivatives modeling and credit modeling, require vastly different data inputs, manipulation methods and outputs. For their validation solutions, vendors tend to employ their own expertise in developing and validating specific specialist models.

As a result, vendors generally provide functionality for specific processes in the model validation value chain, according to their expertise and abilities. The most successful vendors approach validation as a continuous process. The functionality of a solution, and how far it integrates into an FI’s business and regulatory structure, will determine how comprehensive it is.

Pursuing new opportunities

As the model development and validation landscape shifts and the amount of data that has

¹ Unstructured data is data that does not have a clearly identifiable structure (e.g., email text, images and social media posts).

² Research by the Defense Advanced Research Projects Agency (DARPA) has identified three waves of AI development. For more information, see Appendix A of the Chartis report ‘Model Validation Solutions, 2019: Overview and Market Landscape’.

to be validated increases exponentially, fresh opportunities are also emerging for vendors, especially in developing ML techniques to validate models. AI is not only being used in the development of new models, it may also be used as a validation tool itself. ML can identify ineffective or incorrect areas of a model that uses large quantities of complex data, or identify issues within the inputs and outputs of models that would otherwise be indecipherable because of their size and complexity. Example use cases for ML as a validation technique are mortgage-backed securities (MBS) and derivative models. The high dimensionality of data sets required for these financial instruments can prove challenging for error spotting.

Vendors have a particular opportunity to provide FIs with valuable expertise and specialist skills in ML for model risk. Mid-level banks, for example, are unlikely to be able to allocate resources to develop ML tools for model validation in-house.

However, using ML models for validation also raises the specter of systemic technological risk. It is therefore vital to remember that using ML to validate models does not preclude the need for ML tools themselves to be validated. The interactivity of models also provides some opportunities for vendors to develop new solutions. The ubiquity of models across the financial system means it is no longer enough to validate models in isolation. Models can interact in unexpected ways, and future suitability assessments should reflect the ubiquity of model-driven processes across all areas of financial services.

2. Quadrant context

Introducing the Chartis RiskTech Quadrant®

This section of the report contains:

- The Chartis RiskTech Quadrant® for model validation solutions for 2019.
- An examination of the positioning for Moody's Analytics and its scores as part of Chartis' analysis.
- A consideration of how the quadrant reflects the broader vendor landscape.

Summary information

What does the Chartis quadrant show?

The RiskTech Quadrant® uses a comprehensive methodology that involves in-depth independent research and a clear scoring system to explain which technology solutions meet an organization's needs. The RiskTech Quadrant® does not simply describe one technology option as the best model validation solution; rather it has a sophisticated ranking methodology to explain which solutions are best for specific buyers, depending on their implementation strategies.

The RiskTech Quadrant® is a proprietary methodology developed specifically for the risk technology marketplace. It takes into account vendors' product, technology and organizational capabilities. Section 4 of this report sets out the generic methodology and criteria used for the RiskTech Quadrant®.

How are quadrants used by technology buyers?

Chartis' RiskTech and FinTech quadrants provide a view of the vendor landscape in a specific area of risk, financial and/or regulatory technology. We monitor the market to identify the strengths and weaknesses of different solutions, and track the post-sales performance of companies selling and implementing these systems. Users and buyers can consult the quadrants as part of their wider research when considering the most appropriate solution for their needs.

Note, however, that Chartis Research does not endorse any vendor, product or service depicted in its research publications, and does not advise

technology users to select only those vendors with the highest ratings or other designation. Chartis Research's publications consist of the opinions of its research analysts and should not be construed as statements of fact.

How are quadrants used by technology vendors?

Technology vendors can use Chartis' quadrants to achieve several goals:

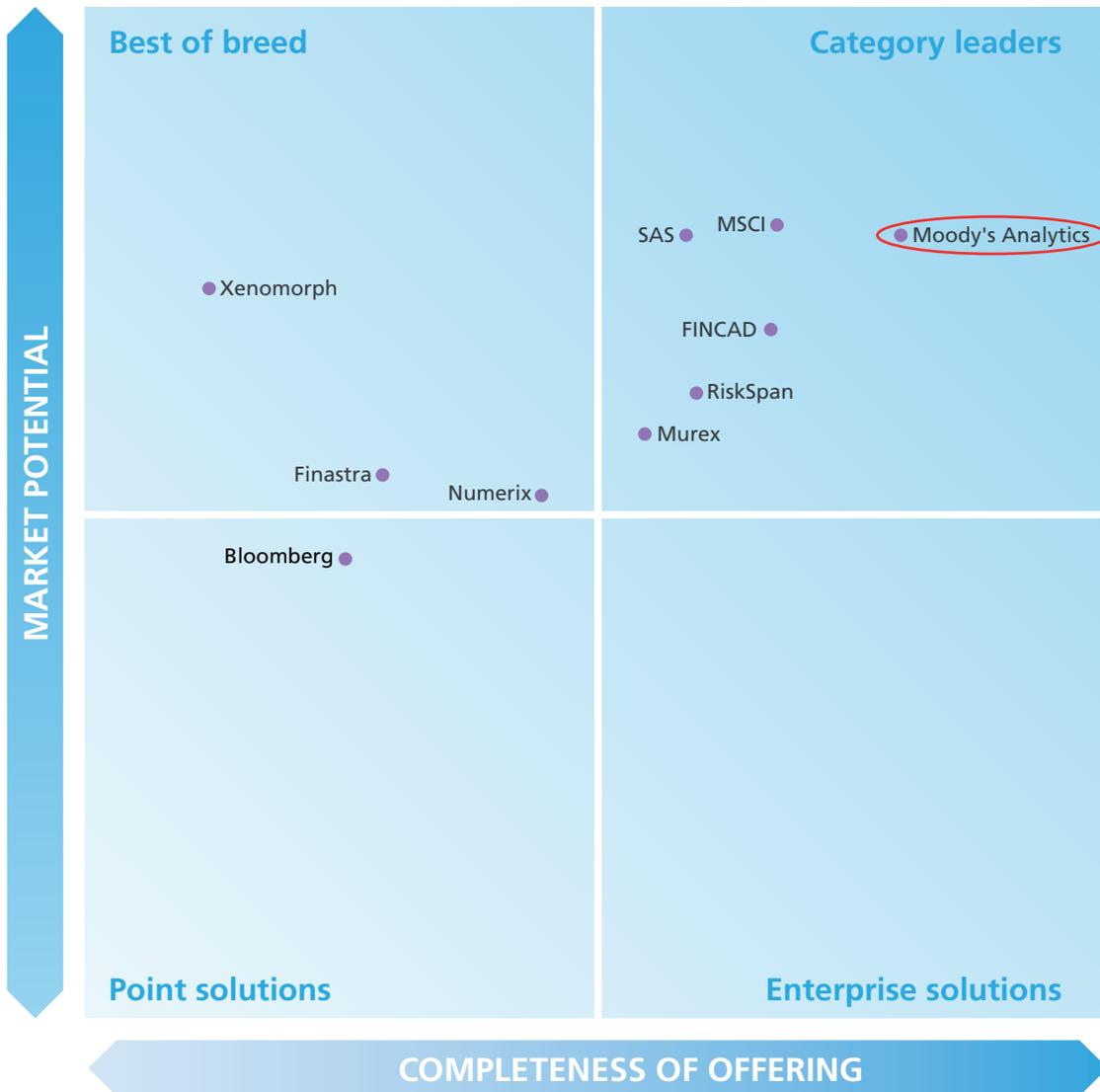
- Gain an independent analysis and view of the provider landscape in a specific area of risk, financial and/or regulatory technology.
- Assess their capabilities and market positioning against their competitors and other players in the space.
- Enhance their positioning with actual and potential clients, and develop their go-to-market strategies.

In addition, Chartis' Vendor Analysis reports, like this one, offer detailed insight into specific vendors and their capabilities, with further analysis of their quadrant positioning and scoring.

Chartis Research RiskTech Quadrant® for model validation solutions, 2019

Figure 1 illustrates Chartis' view of the model validation vendor landscape, highlighting Moody's Analytics.

Figure 1: RiskTech Quadrant® for model validation solutions, 2019



Source: Chartis Research

Quadrant Dynamics

General Quadrant Takeaways

Providing model validation as a solution is a complex undertaking. Although the landscape is growing, the number of vendors that provide model validation as a discrete solution is still fairly limited. Befitting the introductory nature of Chartis' report *Model Validation Solutions, 2019: Overview and Market Landscape*, the functionality we scored was broad in scope. Certain functional aspects (such as workflow, for which several vendors received relatively low scores) can

be considered part of model governance, and were reflected in the scoring to highlight how validation functionality is integrated into more comprehensive, interconnected solutions.

All category leaders received medium to high scores for core aspects of their solutions, such as 'data input', which includes assessments of data validation, data provision and analytics. While category leaders generally scored relatively well across all functional categories, there tended to be one category in which they performed less well, and this varied by vendor. This emphasizes the challenges facing vendors in providing broad model

validation functionality, although few individual areas – except perhaps workflow – stood out as especially problematic.

Vendor positioning in context – completeness of offering

Moody’s Analytics achieved high scores across the completeness of offering categories, highlighting the comprehensiveness of its solution. The company specializes in credit and market risk validation, with solutions tailored to meet multiple regulatory demands. Its strength as a source of macroeconomic data in particular – which powers stress testing, scenario generation and benchmarking – contributed to its high score in model analytics.

Moody’s Analytics also received a high score for workflow, largely because it offers tailored approaches that can adapt to institution type and regulatory requirements. The vendor’s validation process is a mix of qualitative and quantitative techniques with a reporting and disclosure function. Model ratings are given to different parts of the validation process and remedial actions recommended, with results presented as customised interactive reports. The vendor’s remedial process is consistent with Chartis’ view of model validation as a continuous process, while its cloud-based modeling platform automates aspects of validation for real-time monitoring. Its predictable consequence tests, stability tests and scenario tests also contributed to the overall sophistication of its validation technique. Finally, the development of proxy models as a validation technique to highlight inaccuracies in native models helps to illustrate the sophistication of the solution, and contributed to the high score Moody’s Analytics received for model analytics.

Table 1 shows Chartis’ rankings for the vendor’s coverage against each of the completeness of offering criteria.

Vendor positioning in context – market potential

The high market potential score given to Moody’s Analytics is based largely on the size and satisfaction of its client base. Its high market penetration score reflected how it has leveraged its established model development presence in the areas of credit and market risk to support internal institutional validation as well as validation of its own models. The vendor caters to a variety of institution sizes and types, and can customize its solution accordingly.

Table 1: Completeness of offering – Moody’s Analytics (model validation solutions, 2019)

Completeness of offering criterion	Coverage
Data input	High
Model analytics/pricing	High
Results	High
Post-processing/reporting	High
Suitability	High
Workflow	High
Predictive capability = model sensitivity	High

Source: Chartis Research

Table 2: Market potential – Moody’s Analytics (model validation solutions, 2019)

Market potential criterion	Coverage
Customer satisfaction	High
Market penetration	High
Growth strategy	High
Financials	High

Source: Chartis Research

Moody’s Analytics also received a high score for growth strategy as it continues to develop validation techniques that are designed to offer functionality beyond servicing regulatory demand. In line with its ongoing expertise in macroeconomic forecasting, Moody’s Analytics has invested in specialized personnel, with international teams that include a number of economists. Finally, the vendor’s breadth of functionality informed its ‘comprehensive’ categorization, which Chartis has identified as fundamental to market potential.

Table 2 shows Chartis’ rankings for the vendor’s coverage against each of the market potential criteria.

3. Vendor context

Overview of relevant solutions/capabilities

Table 3 gives an overview of Moody’s Analytics and its model validation solution.

In today’s highly regulated financial environment, independent model validation is an integral component of model risk management. Poorly designed and functioning models can undermine otherwise solid financial reporting, underwriting performance, expected loss calculations, capital allocation, and strategic decision making. Regulatory guidance has placed more scrutiny on model validation and model risk management practices, fostering a company-wide view of models, the modeling process, and model governance practices.

The model validation and monitoring services offered by Moody’s Analytics are designed to deliver services for internally developed and third-party quantitative risk models. Validation is applied during the model development phase and ongoing monitoring phase. The vendor evaluates whether the chosen model delivers sound results and meets the requirements for which it was

designed, while helping users improve their governance process.

Moody’s Analytics aims to accommodate a range of user needs and portfolio classes and sizes, and its services are designed to match specific model complexities and model risk management programs (see Figure 2).

Main capabilities and key features

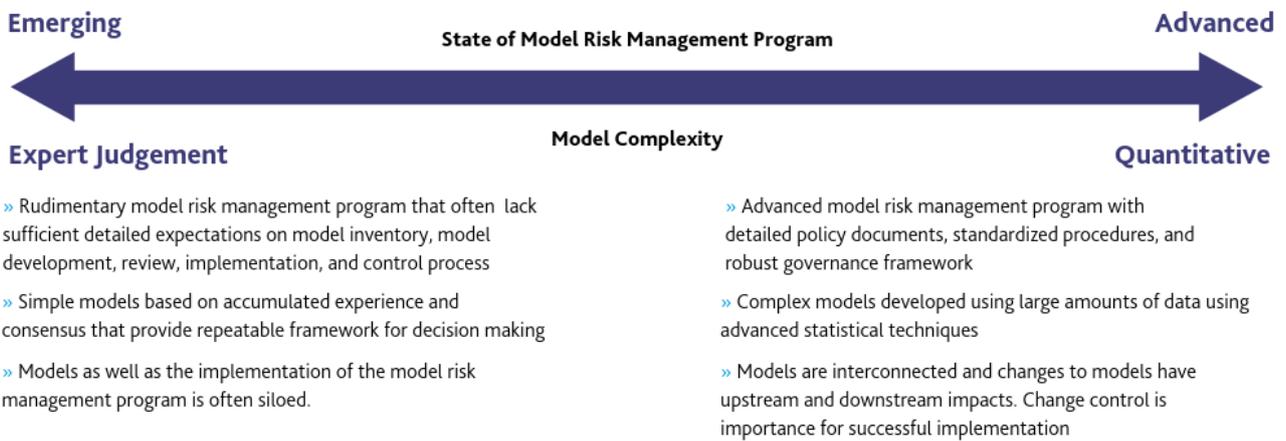
The model validation services that Moody’s Analytics provides for commercial credit risk cover the major concepts of model risk management, including validation, development/enhancement, governance and monitoring (see Figure 3). Users can employ a variety of capabilities, including data validation, model analytics and pricing, remediation, regulatory reporting and documentation, suitability assessments, and workflow, as well as predictive sensitivity testing, design and data review, theory and conceptual analysis, capabilities assessment, assumptions and limitations appraisal, calibration, benchmarking, workflow examination and risk reporting. For

Table 3: Moody’s Analytics – company information

Company	Moody’s Analytics
Headquarters	New York, New York, US
Other offices	San Francisco, West Chester, Toronto, Brussels, Paris, London, Singapore, Hong Kong, Tokyo
Description	Moody’s Analytics provides financial intelligence and analytical tools supported by risk expertise, information resources, and the application of new technology. Its solutions, made up of research, data, software and professional services, are assembled with the aim of delivering a seamless customer experience.
Solution	<p>Moody’s Analytics solution provides validation services for proprietary and third-party risk models. It contains the following:</p> <ul style="list-style-type: none"> • Moody’s Analytics Applicability Analysis solution. • Moody’s Analytics CAP* Solution for model life cycle and monitoring. • Moody’s Analytics custom validation services.

Source: Moody’s Analytics
 *Moody’s Analytics CAP is a trademark of Moody’s Analytics.

Figure 2: Covering a range of needs and requirements



Source: Moody's Analytics

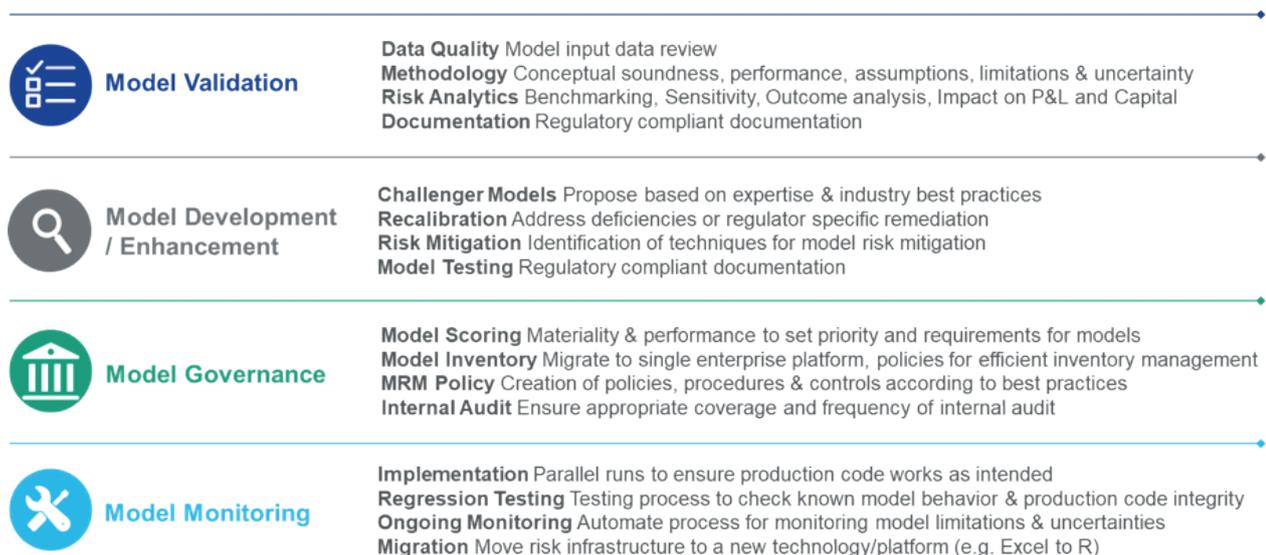
consumer credit, the solution features custom validation and advisory services for all aspects of consumer credit risk management. The robust datasets from Moody's Analytics help clients to supplement internal data for model development, validation, and reporting.

Underpinning its datasets is the Moody's Analytics Data Alliance. This offers more than 100 million commercial and industrial (C&I) private firm financial statements, \$398 billion in commercial real estate (CRE) balances covering 354 metropolitan statistical areas (MSAs), and more than 63% of all project finance loans originated since 1983. Data Alliance members contribute

private firm data such as financial statement, loan, and default metrics. Data Alliance datasets have the depth and granularity to support advanced analytics, covering 150 financial statement line items, 60 detailed C&I loan characteristics on facility level (terms, pricing, collateral, and so on), and facility- and obligor-level default data based on Basel definitions.

Moody's Analytics also has more than 150 risk professionals across the globe with model risk management skillsets. They address several areas, including credit and liquidity strategy, governance, organization, people, process, technology, and data management, and feature internal controls

Figure 3: Coverage of model validation solution



Source: Moody's Analytics

to help FIs manage the associated business and regulatory requirements.

The vendor's model validation services feature the following elements:

Structured processes

- Tested templates and processes for all primary evaluation activities.
- Vetted challenge models and asset valuation tools.
- A project management approach that ensures a timely, quality product.

Experience

- The vendor has experience across all three lines of defense, and in market risk, credit risk, stress testing, liquidity risk, and asset and liability management (ALM) functions.
- It covers all models/components across Basel 2.5 – internal models approach (IMA)/FRTB, derivatives, internal ratings-based (IRB), IFRS 9/Current Expected Credit Losses (CECL), Interest Rate Risk in the Banking Book (IRRBB), and internal liquidity adequacy assessment process (ILAAP).

Scalable staffing

- The vendor offers a balance of specialized and generalist staff, to enable project teams to be scaled quickly to meet schedule requirements.
- It also provides a blend of client-focused, project-specific and flexible staffing located on- and off-site.

Sector experience

- Enables key design issues and assumptions to be reviewed quickly.
- An understanding of niche market characteristics enhances model calibration and testing.
- Examples include physical commodities, power and utilities, oil and gas, marine transportation, and agribusiness.

Robust data and benchmarks

- The vendor's large datasets and robust benchmarks help to speed up calibration and comparative evaluations.

- Historical information specific to regions and subsectors enables more accurate calibration and stronger applicability tests.

The vendor's end-to-end services support a range of model types and risk regulations, shown in Table 4.

With the vendor's model validation and model governance services, users are able to reduce the cost of internal resources and improve their model risk management practices. They can:

- Evaluate the conceptual soundness of their internally or externally built models, using their portfolio's data or an external sample with similar characteristics.
- Assess the performance of the model through leading industry practices that leverage statistical analysis.
- Validate material model assumptions, methodologies and associated parameters on a recurring basis.
- Conduct outcomes analysis to determine the accuracy of the model output based on model objectives.
- Verify that the model assesses the material risks of the portfolio and ensures reasonable mitigation actions.
- Evaluate model interaction and integration within the enterprise-wide risk management system.
- Provide comprehensive documentation for third-party review.
- Assess model compliance with established regulatory guidance on model risk management.

The validation reports delivered by the solution generally include the components shown in Figure 4.

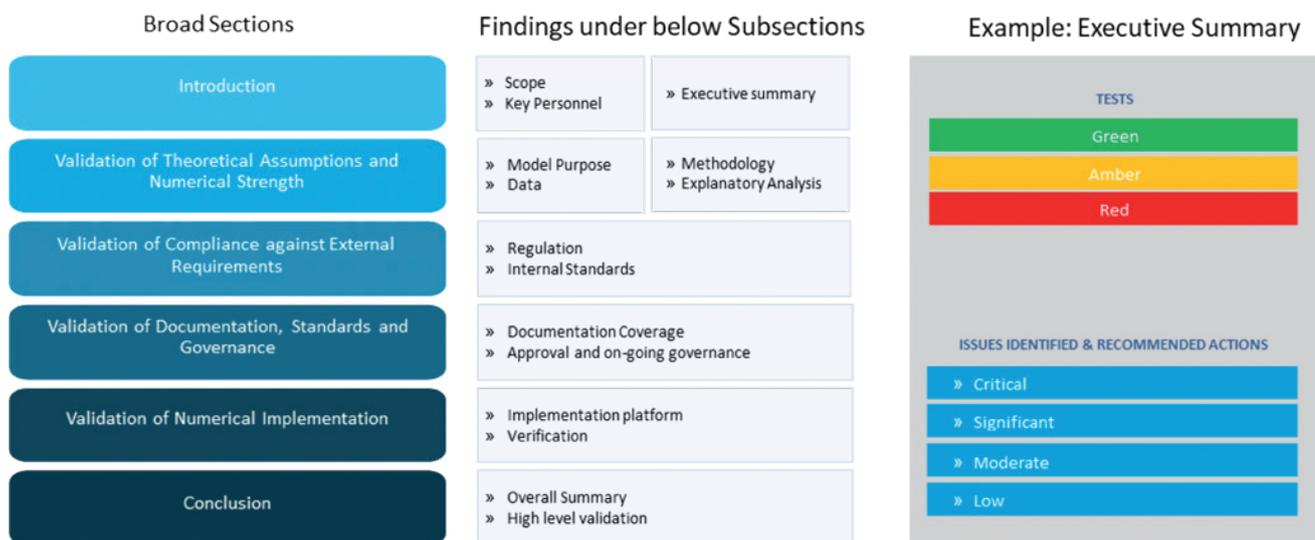
For consumer credit, the solution offers custom validation and advisory services for all aspects of consumer credit risk management (see Figure 5). Moody's Analytics also provides custom validation with qualitative and quantitative analysis compiled in the validation report, for underwriting models, regulatory capital, stress testing, or financial reporting models (see Figure 6). The vendor works with clients to understand the use of each model and its parameters and standard requirements, and runs validation throughout the development and ongoing monitoring phases to ensure optimal model performance.

Table 4: Model types and risk regulations supported by the solution

Trading book market risk	Banking book market risk
<ul style="list-style-type: none"> • Pricing models • Market risk models • Counterparty Credit Risk models • Basel 2.5, FRTB, Monitoring and Reporting Regulation (MRR), Targeted Review of Internal Models (TRIM) 	<ul style="list-style-type: none"> • Interest rate (IR) models: non-maturity deposit (NMD), behavioral models • Net interest income (NII)/economic value of equity (EVE), funds transfer pricing (FTP) • Liquidity risk models • IRRBB, ILAAP
Credit risk	Stress testing
<ul style="list-style-type: none"> • Probability of default (PD), loss given default (LGD), exposure at default (EAD) • Scorecards, ratings • Impairment models • IRB, IFRS 9, CECL, TRIM 	<ul style="list-style-type: none"> • Internal scenario models • Loss estimation: market, credit, operational • Pre-provision net revenue (PPNR) models • Comprehensive Capital Analysis and Review (CCAR), Dodd-Frank Act Stress Tests (DFAST), Prudential Regulation Authority (PRA), European Banking Authority (EBA), Internal Capital Adequacy Assessment Process (ICAAP)

Source: Moody's Analytics

Figure 4: Components of validation reports for commercial credit



Source: Moody's Analytics

Figure 5: Custom validation and advisory services offered for consumer credit



Source: Moody's Analytics

The qualitative review includes an evaluation of the documentation, methodology, data description and treatment, regulatory compliance, and model governance. The quantitative assessment is tailored to the model at hand, and includes data analysis, variable selection assessment, model replication, model performance evaluation (out-of-sample, out-of-time, etc.), robustness, and stability tests.

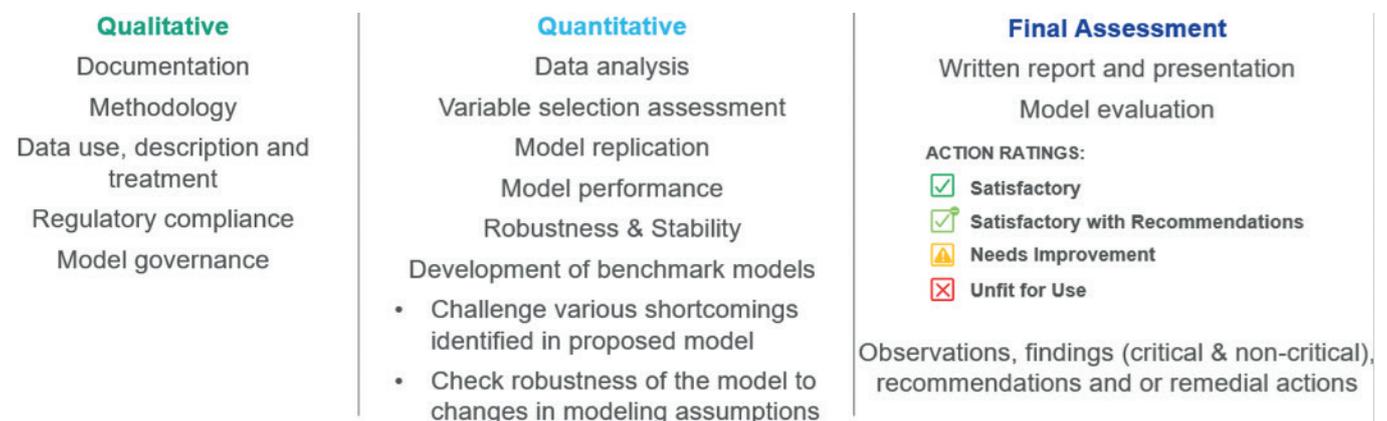
Moody's Analytics also offers the development of challenger models to address shortcomings that model validators may have identified. Lastly, the validation report includes a model evaluation with four possible action ratings, and provides a score breakdown of the different risk categories, along with observations, findings (critical and non-critical), and recommendations (see Figure 7).

The Moody's Analytics Applicability Analysis solution

Internal and external stakeholders often want to understand if a vendor model is appropriate for evaluating an institution's portfolio, and whether it is fit for purpose for the intended use case. Applicability Analysis Services, while not intended to offer exhaustive model validation, can be an integral part of meeting an institution's model risk management requirements, especially when there is a lack of relevant data or expertise. Moody's Analytics can provide quantitative and qualitative analysis to support users' risk management function.

The primary value is in showing personnel and external stakeholders (bank examiners and auditors, for example) that a particular institution is responding to potential concerns around vendor

Figure 6: Consumer credit custom validation: qualitative and quantitative analysis



Source: Moody's Analytics

models. This type of engagement can provide a deeper dive into model inputs and model performance within the target portfolio (see Figure 8). As a result of conducting this analysis, users often develop a better understanding of the model, an important part of any fit-for-use discussion.

Moody's Analytics begins the process by conducting practical and theoretical training, enabling the institution to be a partner in analyzing applicability, and providing institution-specific insights. The model's development dataset is then compared to that of the user's target portfolio along several key dimensions. Rather than providing a simple go/no-go answer, these comparisons can reveal insights about potential strengths and weaknesses in the model's use.

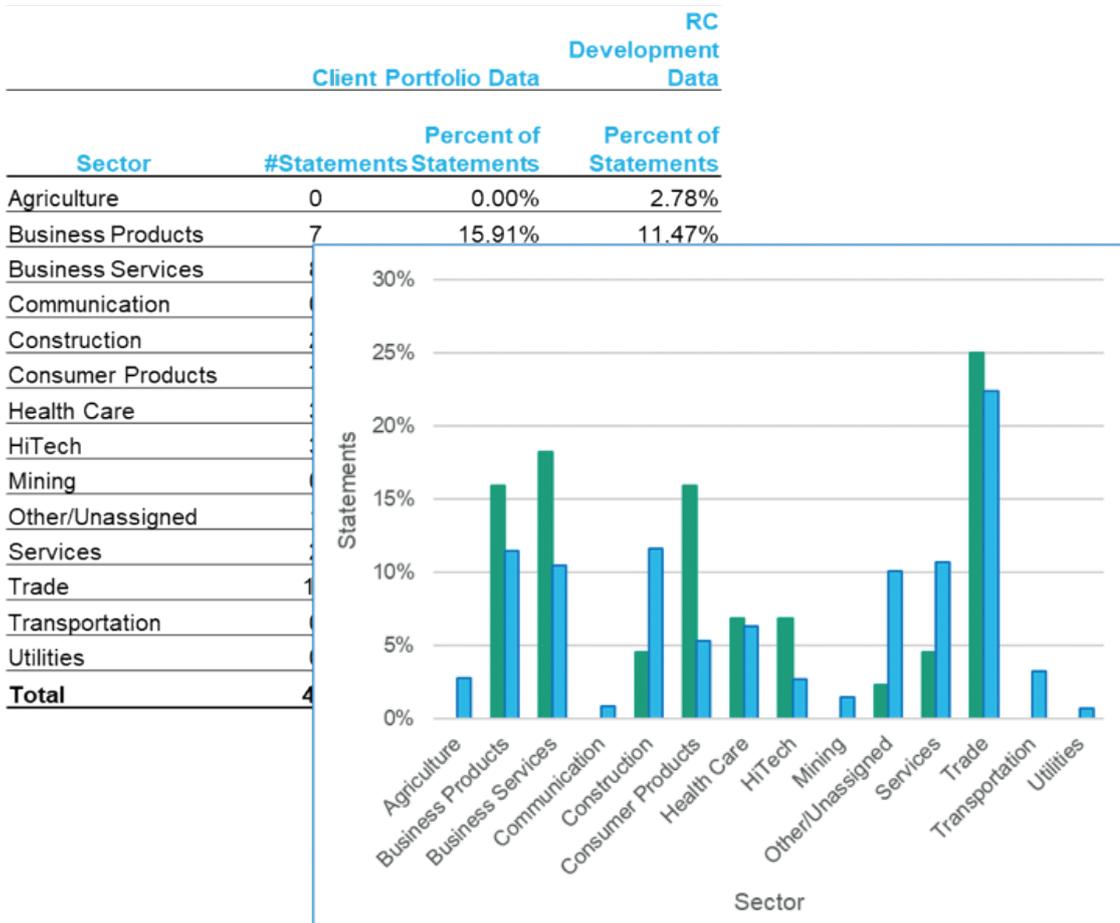
Figure 7: Action ratings in the consumer credit validation report

Overall Rating

Risk Category	Rating	Comments
Documentation		...
Data		...
Variable Selection		...
Segmentation		...
Model Performance		...
Model Replication		...
Monitoring and Performance Tracking		...

Source: Moody's Analytics

Figure 8: Comparison of model dataset with target portfolio



Source: Moody's Analytics

Next, a series of follow-up analyses are conducted. These include:

- Benchmarking the model's output to historical credit risk measurements.
- Comparing the model's results to a user's internal ratings.
- Investigating any 'outlier' or surprising results.

Based on the results of this analysis testing and the user's regulatory requirements, Moody's Analytics can then provide optional services such as model configuration or customization. Regardless of the overall scope of services, Moody's Analytics will provide a detailed write-up describing the steps followed, the results, and the key points or takeaways. This is intended to be a

standalone document that users can provide to internal and external stakeholders.

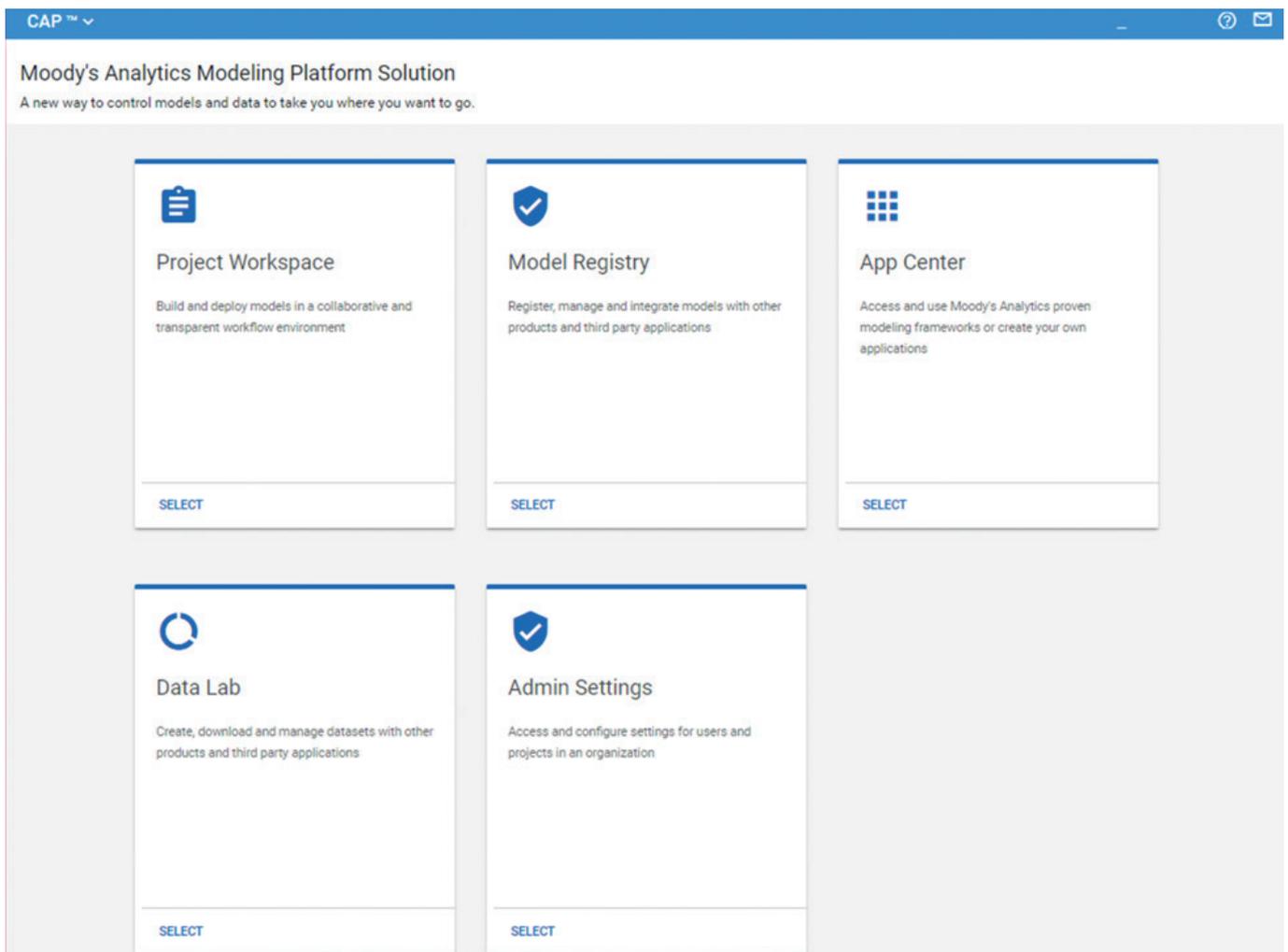
The Moody's Analytics CAP Solution

Powered by proprietary data from Moody's Analytics and proven modeling frameworks, the CAP solution enables firms to tailor the vendor's models to their experiences, and to build, validate, and monitor models quickly and at scale (see Figure 9).

The CAP solution offers the following capabilities:

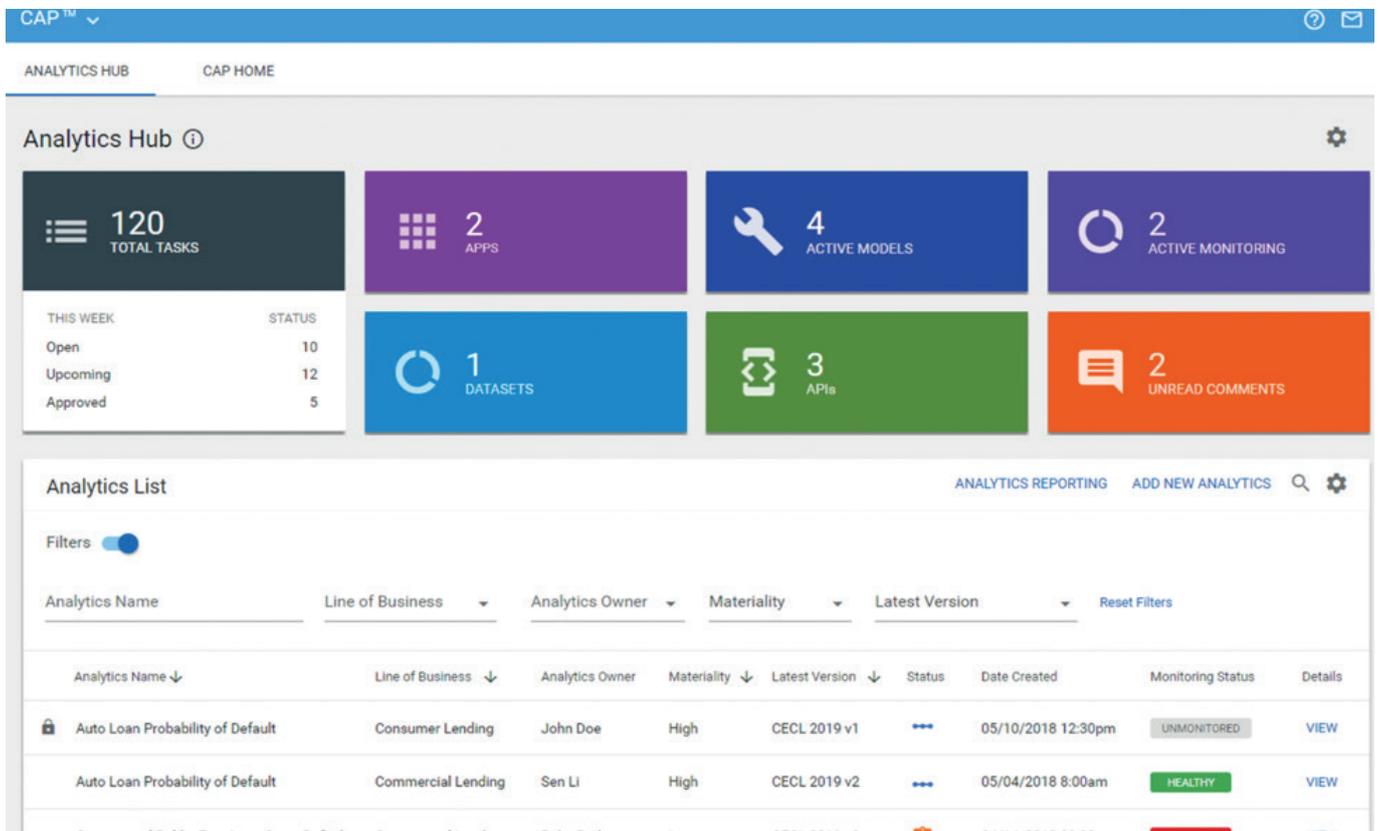
- Access to the vendor's proprietary data in a centralized location for model development, calibration, verification and monitoring.

Figure 9: The Moody's Analytics CAP solution



Source: Moody's Analytics

Figure 10: The CAP analytics hub



Source: Moody's Analytics

- It uses the vendor's frameworks for model development, validation and monitoring of probability of default (PD), loss given default (LGD), market risk, and machine learning models.
- The model deployment and integration tools within the software publish models as APIs that can integrate with internal systems and other solutions from Moody's Analytics.
- The solution can generate automated model documentation for models developed within the platform, using a step-by-step model builder.
- It can streamline model management for the registry and inventory of models and their validation status; access controls for varying levels of users; and audit trails of modeler actions and model runs.

The CAP solution is cloud-based and encompasses the lifecycle of risk and finance modeling (see Figures 11 and 12).

- Users can build more robust models by augmenting internal data with data from Moody's Analytics.
- Model development and deployment processes can be accelerated to help meet business priorities and deadlines.
- Users can benchmark models against off-the-shelf models from Moody's Analytics, and machine learning models, to improve their model performance.
- With embedded step-by-step model builders, users can also develop custom models tailored to their organization's footprint.
- They can also monitor their model performance using methodologies from Moody's Analytics.

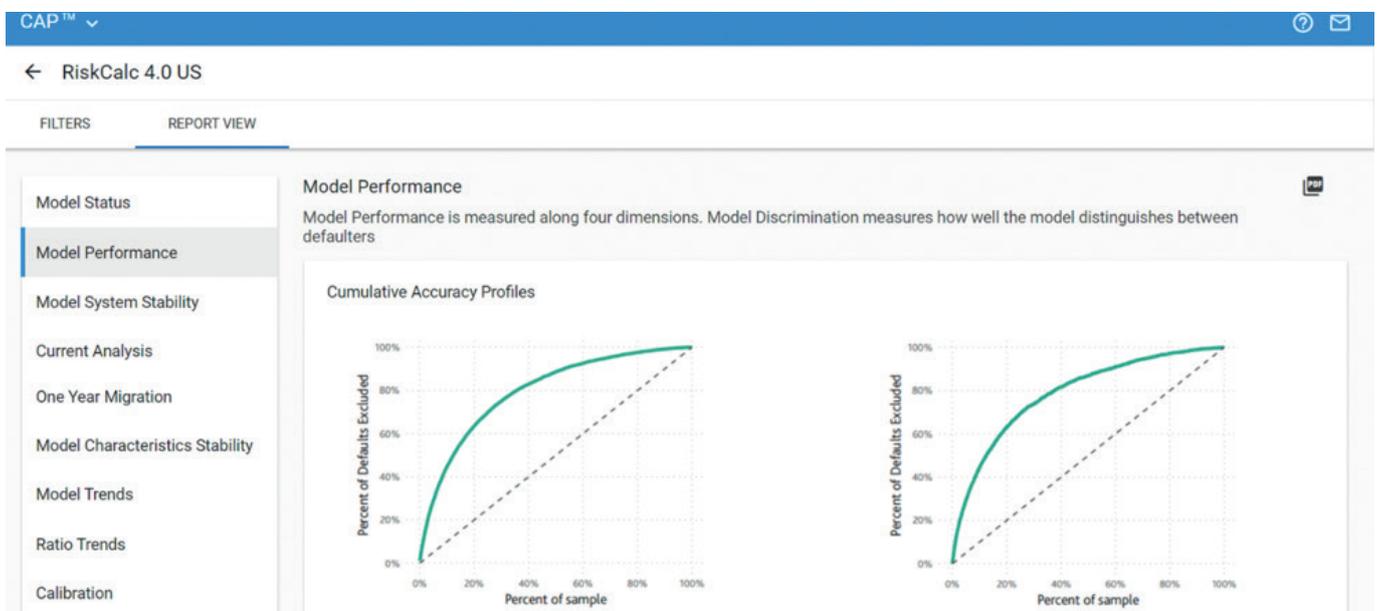
The solution can also enable an interactive and collaborative environment throughout the modeling lifecycle for project and information-sharing using tags and comments (see Figure 10).

Figure 11: The CAP model monitoring app

Model Name	Model Version	Applied Portfolio	Snapshot Date	Latest Report Date	Created By	Monitoring Status	Report
RiskCalc Emerging Market	3.0	C&I Mexico	05/10/2018	05/10/2018 12:30pm	Sen Li	HEALTHY	VIEW
RiskCalc Singapore	4.0	C&I Singapore	05/04/2018	05/04/2018 8:00am	John Doe	HEALTHY	VIEW
RiskCalc U.S.	4.0	C&I U.S.	04/14/2018	04/14/2018 00:30am	Bob B	ATTENTION	
RiskCalc Emerging Market	3.0	C&I Mexico	04/14/2018	04/14/2018 11:02am	Suriyanto B	HEALTHY	VIEW
RiskCalc U.S.	3.0	C&I U.S.	03/23/2018	03/23/2018 8:30am	Sen Li	DEACTIVATED	VIEW
RiskCalc Emerging Market	4.0	C&I Mexico	03/23/2018	03/23/2018 8:30am	John Barber	UNMONITORED	
RiskCalc Singapore	4.0	C&I Singapore	04/14/2017	04/14/2017 11:02am	Sen Li	ATTENTION	
RiskCalc U.S.	4.0	C&I U.S.	01/20/2017	01/20/2017 07:02am	Irina R	HEALTHY	VIEW

Source: Moody's Analytics

Figure 12: Example model performance calculations from the CAP solution



Source: Moody's Analytics

The CAP solution aims to help users automate the modeling lifecycle, enabling them to build and deploy models quickly, and at scale. It also provides access to proprietary data sets, modeling expertise, and validation and deployment toolkits from Moody's Analytics. The platform enables

modelers to expedite time-consuming processes, to help mitigate financial and regulatory risk.

4. Methodology

Overview

Chartis is a research and advisory firm that provides technology and business advice to the global financial services industry. Chartis provides independent market intelligence regarding market dynamics, regulatory trends, technology trends, best practices, competitive landscapes, market sizes, expenditure priorities, and mergers and acquisitions. Chartis' RiskTech and FinTech Quadrant reports are written by experienced analysts with hands-on experience of selecting, developing and implementing financial technology solutions for a variety of international companies in a range of industries including banking, insurance and capital markets. The findings and analyses in our quadrant reports reflect our analysts' considered opinions, along with research into market trends, participants, expenditure patterns, and best practices.

Chartis seeks to include RiskTech and FinTech vendors that have a significant presence in a given target market. The significance may be due to market penetration (e.g., a large client base) or innovative solutions. Chartis uses detailed 'vendor evaluation forms' and briefing sessions to collect information about each vendor. If a vendor chooses not to respond to a Chartis request for information, Chartis may still include the vendor in the report. Should this happen, Chartis will base its opinion on direct data collated from technology buyers and users, and from publicly available sources.

Chartis' research clients include leading financial services firms and Fortune 500 companies, leading consulting firms and financial technology vendors. The vendors evaluated in our quadrant reports can be Chartis clients or firms with whom Chartis has no relationship.

Chartis evaluates all vendors using consistent and objective criteria, regardless of whether or not they are Chartis clients. Chartis does not give preference to its own clients and does not request compensation for inclusion in a quadrant report, nor can vendors influence Chartis' opinion.

Selection criteria

In selecting vendors for this report, Chartis took a broad view, including aspects of model risk and

model governance in assessing model validation as a discrete solution. Vendors were selected for the quadrant if they provided model validation as a solution, rather than providing aspects of functionality. Those that operated exclusively in the model governance or risk space were not selected.

To reflect this, and because our introductory report provides a broad overview of model validation types and processes, we scored the vendors in the quadrant according to general criteria – only those vendors that offered validation according to our criteria were briefed. Note also that some vendors did not respond to our invitation to brief for this report, and some we contacted declined to brief us.

Briefing process

We conducted face-to-face and/or web-based briefings with each vendor³. During these sessions, Chartis experts asked in-depth, challenging questions to establish the real strengths and weaknesses of each vendor. Vendors provided Chartis with:

- A business update – an overview of solution sales and client satisfaction.
- A product update – an overview of relevant solutions and R&D roadmaps.
- A product demonstration – key differentiators of their solutions relative to those of their competitors.

In addition to briefings, Chartis used other third-party sources of data, such as conferences, academic and regulatory studies, and publicly available information.

Evaluation criteria

We develop specific evaluation criteria for each piece of quadrant research from a broad range of overarching criteria, outlined below. By using domain-specific criteria relevant to each individual risk, we can ensure transparency in our methodology, and allow readers to fully appreciate the rationale for our analysis. The specific criteria

³ Note that vendors do not always respond to requests for briefings; they may also choose not to participate in the briefings for a particular report.

used for model validation solutions are shown in Table 5.

Completeness of offering

- Depth of functionality.** The level of sophistication and amount of detailed features in the software product (e.g., advanced risk models, detailed and flexible workflow, domain-specific content). Aspects assessed include: innovative functionality, practical relevance of features, user-friendliness, flexibility, and embedded intellectual property. High scores are given to those firms that achieve an appropriate balance between sophistication and user-friendliness. In addition, functionality linking risk to performance is given a positive score.
- Breadth of functionality.** The spectrum of requirements covered as part of an enterprise risk management system. This will vary for each subject area, but special attention will be given to functionality covering regulatory requirements, multiple risk classes, multiple asset classes, multiple business lines, and multiple user types (e.g. risk analyst, business manager, CRO, CFO, Compliance Officer). Functionality within risk management systems and integration between front-office (customer-facing) and middle/back office (compliance, supervisory and governance) risk management systems are also considered.
- Data management and technology infrastructure.** The ability of risk management systems to interact with other systems and handle large volumes of data is considered to be very important. Data quality is often cited as a critical success factor and ease of data access, data integration, data storage, and data movement capabilities are all important factors. Particular attention is given to the use of modern data management technologies, architectures and delivery methods relevant to risk management (e.g., in-memory databases, complex event processing, component-based architectures, cloud technology, and Software as a Service). Performance, scalability, security and data governance are also important factors.
- Risk analytics.** The computational power of the core system, the ability to analyze large amounts of complex data in a timely manner (where relevant in real time), and the ability to improve analytical performance are all important factors. Particular attention is given to the difference between 'risk' analytics and standard 'business' analytics. Risk analysis requires such capabilities

Table 5: Evaluation criteria for Chartis' model validation solutions report

Completeness of offering	Market potential
<ul style="list-style-type: none"> Data input Model analytics/pricing Results Post-processing/reporting Suitability Workflow Predictive capability = model sensitivity 	<ul style="list-style-type: none"> Customer satisfaction Market penetration Growth strategy Financials

Source: Chartis Research

as non-linear calculations, predictive modeling, simulations, scenario analysis, etc.

- Reporting and presentation layer.** The ability to present information in a timely manner, the quality and flexibility of reporting tools, and ease of use, are important for all risk management systems. Particular attention is given to the ability to do ad-hoc 'on-the-fly' queries (e.g., 'what-if' analysis), as well as the range of 'out of the box' risk reports and dashboards.

Market potential

- Business model.** Includes implementation and support and innovation (product, business model and organizational). Important factors include size and quality of implementation team, approach to software implementation, and post-sales support and training. Particular attention is given to 'rapid' implementation methodologies and 'packaged' services offerings. Also evaluated are new ideas, functionality and technologies to solve specific risk management problems. Speed to market, positioning, and translation into incremental revenues are also important success factors in launching new products.
- Market penetration.** Volume (i.e. number of customers) and value (i.e. average deal size) are considered important. Rates of growth relative to sector growth rates are also evaluated. Also covers brand awareness, reputation, and the ability to leverage current market position to

expand horizontally (with new offerings) or vertically (into new sectors).

- **Financials.** Revenue growth, profitability, sustainability, and financial backing (e.g. the ratio of license to consulting revenues) are considered key to scalability of the business model for risk technology vendors.
- **Customer satisfaction.** Feedback from customers is evaluated, regarding after-sales support and service (e.g. training and ease of implementation), value for money (e.g. price to functionality ratio) and product updates (e.g. speed and process for keeping up to date with regulatory changes).
- **Growth strategy.** Recent performance is evaluated, including financial performance, new product releases, quantity and quality of contract wins, and market expansion moves. Also considered are the size and quality of the sales force, sales distribution channels, global presence, focus on risk management, messaging, and positioning. Finally, business insight and understanding, new thinking, formulation and execution of best practices, and intellectual rigor are considered important.

Quadrant construction process

Chartis constructs its quadrants after assigning scores to vendors for each component of the Completeness of Offering and Market Potential criteria. By aggregating these values, we produce total scores for each vendor on both axes, which are used to place the vendor on the quadrant.

Definition of quadrant boxes

Chartis' quadrant reports do not simply describe one technology option as the best solution in a particular area. Our ranking methodology is designed to highlight which solutions are best for specific buyers, depending on the technology they need and the implementation strategy they plan to adopt. Vendors that appear in each quadrant have characteristics and strengths that make them especially suited to that particular category, and by extension to particular users' needs.

Point solutions

- Point solutions providers focus on a small number of component technology capabilities, meeting a critical need in the risk technology market by solving specific risk management

problems with domain-specific software applications and technologies.

- They are often strong engines for innovation, as their deep focus on a relatively narrow area generates thought leadership and intellectual capital.
- By growing their enterprise functionality and utilizing integrated data management, analytics and Business Intelligence (BI) capabilities, vendors in the point solutions category can expand their completeness of offering, market potential and market share.

Best-of-breed

- Best-of-breed providers have best-in-class point solutions and the ability to capture significant market share in their chosen markets.
- They are often distinguished by a growing client base, superior sales and marketing execution, and a clear strategy for sustainable, profitable growth. High performers also have a demonstrable track record of R&D investment, together with specific product or 'go-to-market' capabilities needed to deliver a competitive advantage.
- Because of their focused functionality, best-of-breed solutions will often be packaged together as part of a comprehensive enterprise risk technology architecture, co-existing with other solutions.

Enterprise solutions

- Enterprise solution providers typically offer risk management technology platforms, combining functionally rich risk applications with comprehensive data management, analytics and BI.
- A key differentiator in this category is the openness and flexibility of the technology architecture and a 'toolkit' approach to risk analytics and reporting, which attracts larger clients.
- Enterprise solutions are typically supported with comprehensive infrastructure and service capabilities, and best-in-class technology delivery. They also combine risk management content, data and software to provide an integrated 'one stop shop' for buyers.

Category leaders

- Category leaders combine depth and breadth of functionality, technology and content with the required organizational characteristics to capture significant share in their market.
- They demonstrate a clear strategy for sustainable, profitable growth, matched with best-in-class solutions and the range and diversity of offerings, sector coverage and financial strength to absorb demand volatility in specific industry sectors or geographic regions.
- They will typically benefit from strong brand awareness, a global reach, and strong alliance strategies with leading consulting firms and systems integrators.

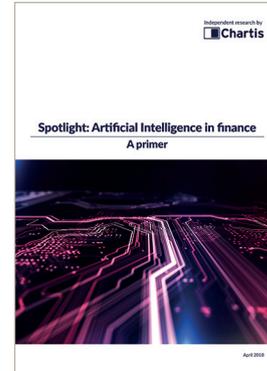
5. Further reading



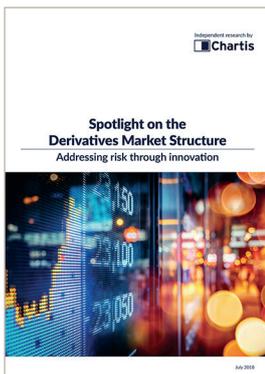
Model validation solutions, 2019: Overview and market landscape



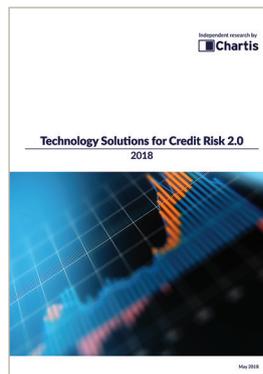
Data Integrity and Control in Financial Services: Market Update 2018



Spotlight: Artificial Intelligence in finance – A primer



Spotlight on the Derivatives Market Structure



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For all these reports, see www.chartis-research.com