A Closer Look
Financial Services Regulation

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Model risk mitigation and cost reduction through effective documentation

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This *A Closer Look* is the second in a series providing recommendations on mitigating model risks and improving the efficiency of various model governance activities. The first, *Model Risk Mitigation and Cost Reduction through Effective Design*, focused on risk mitigation and cost reduction strategies targeted at model implementation and operation.[1] Here we discuss regulatory requirements and leading practices around model documentation, and how high-quality documentation can help mitigate model risk and reduce model-related costs.
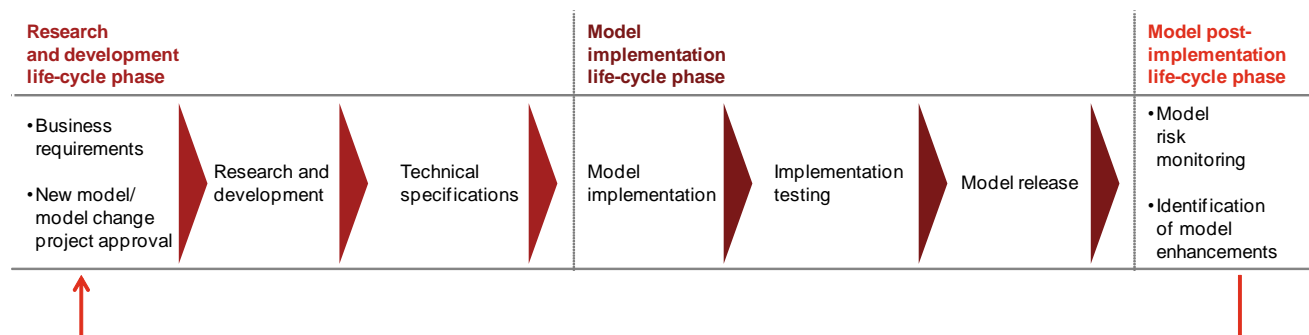
Introduction

As financial institutions in the US and around the globe strengthen their model governance programs, high-quality model documentation has become increasingly important as the foundation for well-controlled model development, testing, implementation, use, and validation. Despite its widely recognized importance, we find that firms tend to under-invest in writing complete, accurate, well-organized, and up-to-date model documentation. This continues despite a significant emphasis placed on model documentation by the regulators, including the OCC[2], Federal Reserve, and FDIC.[3]

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[1] Article available at www.pwc.com/modelrisk

[2] OCC Bulletin 2011-12 / Federal Reserve Bulletin SR 11-7, "Supervisory Guidance on Model Risk Management," (April 4, 2011) is the authoritative guidance on model risk management; http://www.occ.gov/news-issuances/bulletins/2011/bulletin-2011-12a.pdf

[3] See "Model Governance" in *FDIC Supervisory Insights - Winter 2005*; http://www.fdic.gov/regulations/examinations/supervisory/insights/siwin05/article01_model_governance.html

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A comprehensive model documentation package encompasses the three phases of the model life-cycle – research and development, model implementation, and post-implementation on-going model governance – depicted in the following diagram:

Research and development life-cycle phase	Model implementation life-cycle phase	Model post-implementation life-cycle phase
• Business requirements • New model/ model change project approval → Research and development → Technical specifications	→ Model implementation → Implementation testing → Model release	• Model risk monitoring • Identification of model enhancements

In this article we provide detailed documentation recommendations for each of the above three phases of the model life cycle.

Although producing model documentation can be admittedly burdensome, high-quality documentation provides a number of important benefits to help mitigate model risk and reduce model maintenance and testing costs, including:

- Allowing model users and developers to form a good understanding of the models, thereby helping reduce key-person dependencies.

- Helping improve efficiency and reducing the cost of independent model validation and testing by internal and external auditors.

- Increasing the efficiency of the model change process, and reducing the risk of incorrect model changes, or changes that have unintended consequences.

- Facilitating better understanding of models and model risks by model users and management, leading to better-informed decision making and reducing the risk of model misuse.

- Facilitating review of certain models by government regulators, and reducing the risk of negative actions by the regulator.

We note that the OCC, Federal Reserve and FDIC offer only high-level guidance with respect to model documentation, indicating the general types of information that should be provided for a given model. While our recommendations reflect this guidance from the regulators, we go beyond the guidance to offer suggestions based on what we consider to be leading industry practices.

Business and technical requirements

Business and technical requirements documentation is designed to ensure that model development is aligned with its intended use, preventing costly redesigns late in the model development and implementation cycle. This document is expected to cover the following areas:

- Overall business purpose of the proposed new model or significant model change, as well as the expected business benefits.

- Functional/business requirements, including the description of the portfolio/assets/products to which the model will be applied, specifications for the desired model output(s) and associated reporting functionalities, description of applicable regulatory/accounting/legal/compliance rules that may impact the model design, and any specific *a priori* requirements for the modeling methodology.

- Technical requirements, including the production application performance characteristics (execution speed/time, throughput, response time, availability, etc.), computational platform requirements, production data requirements, as well as any desired user interface functionalities.

Model development documentation

This documentation category provides information about the model development process, including the model purpose, theory and approach, and information about the testing by the model developers to ensure model robustness and stability. Model development documentation serves several purposes:

1. It is used internally within the model development group to ensure continuity of knowledge about the model and to minimize key-person dependency risk.

2. It is used by the users of the model to help them obtain sufficient understanding of the model necessary for its effective use that also minimizes model risks.

3. It is used by various parties tasked with managing model risk, e.g., the company's model validation group, the internal audit department, and the external auditor.

4. It facilitates accountability of the first line of defense for evidence that their models meet corporate model risk management guidelines and standards.

Considering the various uses for the model development documentation described above, this documentation has a significant risk mitigation value. In addition, it has a potential for helping reduce model testing cost and time by reducing the need for extensive interactions between the model developers and independent testers while the testers build their understanding of the model.

The following is a list of sections typically included in the model development document:

Executive summary

An executive summary is a concise description of various aspects of the model designed to communicate key information about the model to the company's management, model users, and other stakeholders in a manner that is not too technical.

An executive summary frequently includes the following information:

- Model purpose and overview of the approved use(s).
- High-level description of the modeling approach.
- Summary of the model structure and features, e.g., the list of risk drivers.
- Information about any notable model limitations or weaknesses, as well as the details of how the model risks that stem from these limitations/weaknesses are being mitigated by the model developers and users.
- List of key personnel, including the model owner, developer, user(s), etc.

In our experience, the model limitations and weaknesses section – which we consider to be one of the key parts of the model documentation – is commonly overlooked, misunderstood, or thinly documented, increasing model use risk. Model weaknesses/limitations documentation should list unique and specific items, as opposed to generic limitations such as "the methodology is based on the assumption that future behavior will be similar to past behavior." The following table shows an example of documentation of model weaknesses and limitations, and associated risk mitigants.

Model limitations and weaknesses	Model risk	Risk mitigants
The model output is heavily impacted by several judgmental management assumptions, including x, y, and z. The model developers did not provide sufficient support for the assumptions.	Use of judgmental assumptions increases the risk of poor model predictions/measurements and unsupported model estimates, which may lead to inappropriate business decisions.	Following are the agreed-upon **near-term** risk mitigants: 1. The judgmental assumptions will be subject to oversight by the governance committee X that will review and challenge the model owner's support for the assumptions on a monthly basis. 2. The model output will be benchmarked to the output from the alternative model Y on a quarterly basis. Significant divergence in the outputs will be investigated. Following are the agreed-upon **longer-term** risk mitigants: 1. The model owner will investigate the possibility of obtaining empirical support for the assumptions x and y once an additional six months of data are collected. 2. The model owner will investigate the possibility of modifying the modelling approach to reduce the reliance on judgmental assumptions.

Model development data

Many models are developed with the help of historical data. Modeling data can be obtained from either the company's internal data sources, external parties, or a combination of both. Model development documentation should provide detailed information about the following aspects of the model development data set:

- Description of the data used in model development, e.g., the products, exposures, and risks covered by the data, the time periods reflected in the data, and geographic distribution of the records.

- Description of sources of the data, e.g., the specific corporate data warehouse tables, desktop databases, and text files (including references to the departments/individuals providing these databases or files).

- A data dictionary providing field definitions and detailing data formats, allowable values, and ranges, as applicable.

- If multiple sources of data were used in the development of the model, a process flow and description of how those sources were combined.

- Details of the filtering rules applied to the source data, and any significant exclusions of records that may potentially introduce model bias.

- Description of data segmentation, cleaning, and transformation logic.

- Details of statistical sampling, if any, performed to create the model development and testing datasets.

- Information about known data limitations and weaknesses, and their impact on the final model output.

- If external data are used in the model development, details of why these data are considered relevant and appropriate for the institution's products, exposures, and risks.

Model theory and approach

Complex models typically rely on economic, financial, statistical, and mathematical theories and algorithms. Development documentation should include a section that explains and supports the model's underlying theory, estimation technique (if applicable), and principal formulas and equations used. This section should also discuss alternative approaches explored (when multiple competing alternatives are used by industry participants), and the reasons why such approaches were rejected. Additionally, this section should discuss the consistency of the selected methodology with industry practices for similar models, and provide rigorous support for approaches that are non-standard or innovative.

The theory and approach section should also detail the key assumptions embedded in the selected modeling approach and estimation technique. These include not only the assumptions and parameters explicitly selected by the model developers, but also any assumptions that are implicit in the selected approach or technique. Examples of the former would be a portfolio growth rate, loan loss severity rate, path of future interest rates, or house prices. An example of the latter type of implicit assumptions would be the statistical assumptions associated with the Ordinary Least Squares regression technique, e.g., independence and constant variance of the error terms, and how violations of these assumptions may impact model output.

Finally, this section should discuss any known limitations and weaknesses associated with the selected modeling approach and technique, and provide details on how the resulting model risks are being mitigated by the model developers and model users. Potential mitigants may include establishing limits on the model use, implementing a rigorous governance and oversight process over model outputs, and frequent monitoring of model performance.

Model estimation

Additional information should be provided for models that use statistical estimation techniques. For such models, estimation documentation typically covers the following topics:

- Approach for selecting variables for inclusion in the model.

- Statistical estimation results for the final model, as well as other model structures that were considered to be final candidates. Developers should document the rationale for selecting the final model over these alternative specifications. Statistical estimation results should include not just the estimated coefficients, but the associated statistical measures, e.g., the t-statistics and the associated p-values, test statistics for overall model fit and goodness of fit measures, diagnostic statistics designed to detect estimation problems, such as multicollinearity and heteroskedasticity, as well as impact of outliers and highly influential observations.

- Documentation and support for any judgmental overrides of statistically estimated parameters.

- Evaluation of estimated statistical relationships for consistency with expectations, business intuition, and effects observed in similar industry models.

Model testing

Model developers are typically required to thoroughly test their model before it is subjected to independent validation (if required by the company's policies and procedures) and production implementation. Such testing can include:

- Back-testing, i.e., using the model to predict past outcomes, and comparing the predictions to actual observed events in sample, out of sample, and out of time.

- Benchmarking of model predictions against other models or data.

- Analysis of sensitivity of model predictions to shocks in model inputs and changes in model parameters, including extreme values of the inputs designed to detect potential weaknesses of the model specification.

- Stress testing of model predictions against changes in key assumptions, such as economic drivers.

Detailed documentation of the model tests such as those listed above, and interpretation of the results, is a key component of a comprehensive documentation for complex models.

Sensitivity analysis and stress testing helps determine the level of uncertainty associated with the outputs of a given model. A measure of model uncertainty can be very helpful for model users who may wish to consider model outputs to be a range of potential values as opposed to a point estimate.

Model implementation documentation

This type of documentation provides information about the model implementation into production and its on-going use. The development, implementation, and use phases of the model life-cycle are usually handled by different groups of individuals within a company. Hence, risks associated with the implementation and use of the models are elevated due to the handing off of the model to different stakeholder groups. The purpose of the model implementation documentation is to help mitigate these risks.

Technical specifications

A model specification document is usually created by the model developers in order to communicate the details of the model to the production implementation team. However, this document is also frequently used by other parties, including the model validation group, and internal and external auditors, to help them understand and, sometimes replicate, the model as part of their independent model testing work. As such, this document has not only a significant risk mitigation value, but also a potential for helping reduce model testing cost and time by reducing the need for extensive interactions between the model developers and independent testers while the testers build their understanding of the model.

A comprehensive technical specifications document typically includes the following information:

- Description of the model structure and process/data flow.
- Input data specifications (data dictionary) and processing rules.
- Details of the model calculation algorithms and formulas.
- Listing of all assumptions and parameter values.
- Specifications and explanation of the model outputs and reports.

User's guide or operating procedures

A user's guide should be created to provide model users with detailed instructions on how to use the model, especially if the model interface is fairly complex. In some cases, an operating procedure or operating checklist might be offered in place of, or in addition to, the user's guide. This checklist would lay out concise step-by-step procedures for executing the model, including, for example, the steps for:

- Supplying input data to the model.
- Setting or updating the values of various assumptions and parameters.
- Running the model.
- Confirming successful completion of the model execution.
- Extracting model output or producing standardized reports.
- Performing required control checks to ensure integrity of the input data, assumptions and parameters, and model outputs.

In some cases, it may be appropriate to include certain information about model weaknesses and limitations into the User's Guide to ensure that these are not overlooked by the model users.

Computer code annotation

In addition to the various documents detailed in this paper, another critical type of model documentation is annotation within the computer code of the model. Detailed and extensive comments within the code have a number of risk mitigation and cost reduction benefits, including reducing key person dependency, reducing the possibility of an error when implementing model changes, and improving the efficiency of code review by testers outside of the developers group (such as the model validation group and the auditors).

Implementation testing documentation

A model is usually subjected to different types of testing before it is approved for use. This may include a systems implementation testing ("SIT"), as well as user acceptance testing ("UAT"). SIT and/or UAT information should appear as part of a comprehensive model implementation documentation package. We note that when it comes to models, the line between SIT and UAT is frequently blurred; both refer to the verification that the developed model is correctly implemented into the appropriate production system, and is producing results considered to be usable and reasonable by the intended users.

A leading practice includes documenting and retaining the following types of information associated with the implementation testing:

- Testing plan that specifies test cases, expected outcomes, and parties responsible for executing the test cases.
- Results of the test cases execution (pass/fail), and the associated log of issues and subsequent resolutions.
- Testing results summary and sign-offs by appropriate stakeholders.

Business continuity planning

To mitigate operational risk, documentation should include a plan for the eventualities when a model cannot be executed in a timely manner under normal operating conditions. This may occur, for example, as a result of a critical computer hardware failure. The level of business continuity planning depends on the importance of the model to the company's operations. Consequently, this type of documentation is generally reserved for the most critical applications, e.g., an automated underwriting system, or a real-time fraud detection model.

On-going model governance documentation

The previous two sections covered our recommendations for the documentation associated with the first two phases of the model life-cycle: model development and implementation. In this section we discuss recommendations for post-implementation documentation. This category of documentation covers the following three key areas:

- Plans for on-going model performance and model risk monitoring.
- Plans for maintaining and updating key modeling assumptions.
- Process for managing model changes.

On-going performance and risk monitoring

Periodic monitoring of model performance is required by the regulators and by many institutions' model governance policies and procedures. A leading practice is to formalize these procedures in a plan that describes what performance measures will be monitored and how, acceptable ranges for these measures, and remediation actions in the event of model performance deterioration.

The regulators also expect institutions to have a formal plan for the on-going monitoring of model risks that includes:

- Assessment of the continued effectiveness of the existing risk mitigants for known model weaknesses and limitations.

- Identification and mitigation of new risks resulting from changes in the institution's use of the model, changes in the market or regulatory environments, or other internal and external factors.

- Evaluation of the process risks associated with the model use, and assessment of the continued effectiveness of the existing operational controls.

Assumptions management

As noted previously, model development documentation is expected to cover key model assumptions and parameters. However, in many cases such assumptions are not expected to be static, and are updated periodically based on the changes in the economic environment or management's views. A leading practice is to formalize the procedures for maintaining and updating key modeling assumptions in a plan that describes the process for updating the assumptions and the parties responsible for approving the changes.

Model change management

Depending on the organization, the process for managing model changes may be defined at the enterprise or department level, or can be model-specific. In the latter case, a leading practice is to formalize change management procedures in a plan that covers the following aspects of the change management process:

- Individuals that are allowed to request a model change.

- The types of information that must be documented as part of the change request.

- Individuals that are allowed to approve a model change for implementation.

- Procedures and requirements for implementing and testing the change.

- List of model users that must be notified of the change.

- Guidelines for performing impact analyses for model changes.

We also recommend maintaining a change log documenting the full history of changes to the model, and referencing the associated change management documentation. Development and production documentation should also be continually updated as model changes occur. Our experience has shown that some institutions tend to rely on an archive of memos and emails to supplement the original development or production documentation, as opposed to keeping an integrated up-to-date document, which ultimately leads to a lack of model transparency.

A note on vendor model documentation

The OCC's 2011-12 guidance on model risk management acknowledges that vendors frequently do not reveal proprietary information such as the modeling approach, numerical algorithms, or modeling assumptions. However, use of vendor models does not relieve the model owner and user of the responsibility to produce documentation that supplements the documentation available from the vendor. Such additional documents may include, for example:

- Documentation of the model owner's understanding of the underlying model theory and assumptions, if such documentation is not available from the vendor, as well as the explanation of the rationale for why the vendor model is considered applicable to the institution's products, exposures, and risks.

- Documentation of the results of the model owner's testing of the vendor model on the company's products, exposures, and risks, which may include back-testing, benchmarking, and sensitivity analysis.

- Explanation of the choices for the user-supplied assumptions and parameters selected by the model owner/user.

- Support for any model tuning parameters selected by the model owner/user in order to improve the vendor model fit for the company's products, exposures, and risks.

- Results of the testing of correct deployment of the vendor model in the company's IT environment.

- On-going model performance monitoring, assumptions management, and change management plans.

Conclusion

This *A Closer Look* provides recommendations for developing model documentation that reflect regulatory guidance and leading industry practices with the goal of mitigating certain model risks, reducing validation costs, and improving the efficiency of the model change process. While writing documentation is considered by many model developers to be a "necessary evil", we hope that this article not only comprehensively describes model documentation requirements, but also helps communicate the great importance of high-quality documentation. Companies following our recommendations may find that the investment associated with creating good documentation has significant future returns.

About the PricewaterhouseCoopers Model Risk Team

PricewaterhouseCoopers offers a full range of Advisory services to assist you in identifying and managing the complex risks associated with the development, deployment, and maintenance of complex models used for risk management, valuation, and financial/regulatory reporting purposes. Visit www.pwc.com/modelrisk for more information, or contact Ric Pace, Principal at +1 703 918 1385.

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