

Mastering Model Risk: Assessment, Regulation and Best Practices

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Satyam Kancharla

Robust quantitative models have been an essential component of risk management and analysis for decades, but have dramatically increased in sophistication and complexity over the last few years. Rapidly changing market dynamics and increased regulations demand robust financial models that address a broad range of evolving risks.

Recent high-profile model failures have emphasized the importance of modeling practices that employ stringent implementation, validation and review techniques to manage the hidden risks — risks within models themselves. As a result, model risk is increasingly on every risk manager's radar.

In this article, we explore the evolution of model risk, including regulatory drivers and industry challenges. We also take a closer look at model risk analysis, examining model assessment, validation and review processes. We examine model risk management methodologies, using a case study example involving a large insurer. In conclusion, we outline what we believe are the four best practices for model risk management in today's financial marketplace.

BACKGROUND: WHAT IS MODEL RISK, AND WHY IS IT IMPORTANT?

Model risk is most simply defined as the potential for adverse consequences from decisions based on incorrect or misused model outputs and reports. It holds great relevance in today's markets because quantitative models are behind practically all decision-making in the financial world—from trading and risk, to asset liability management, investment and regulation. Clearly, model risk is not an area that can be ignored without consequence.

Diagram 1. *In recent years, model risk has hit the financial world very hard, with multi-billion (and even multi-trillion) dollar losses resulting, as highlighted below.*

Case	Magnitude	Time	Reason
LTCM	\$4-5 bn	1997	Model Assumption
NAB	\$1-2 bn	2001-2003	Rates Methodology
GFC	\$14 tn	2007-	Correlation Assumptions, Data
JPM	\$5-7 bn	2012	Model Control, Usage

Satyam Kancharla

Chief Strategy Officer &
SVP of Client Solutions Group

satyam@numerix.com

Tel: +1 646 898 1288

Numerix LLC

Corporate Headquarters

150 East 42nd Street

15th Floor

New York, NY 10017

Tel: +1 212 302 2220

“ Model risk can lead to financial loss, poor business and strategic decision making, or damage to a bank's reputation. ”

— FED/OC C Guidance on Model Risk Management (April 2011)

Recent Regulations Related to Model Risk Management

Due to the magnitude of the losses highlighted in the example in Diagram 1, spanning over a decade—from Long Term Capital Management (LTCM) and National Australia Bank (NAB) to the Global Financial Crisis (GFC) and JP Morgan to name a few—it is no surprise that regulators have deemed it necessary to step-in and provide enhanced guidance and regulations surrounding more effective model risk management processes.

Some recent well-known regulations and directives governing the industry include the OCC - Sound Practices for Model Risk Management, (April 2011); the FED - Supervisory Guidance on Model Risk Management, (April 2011); certain FDIC regulations; the Basel II/III - Supervisory guidance for assessing banks' financial instrument fair value practices; Solvency II; and the FAS 157 / IAS 39 Fair Valuation Standards.

A Deeper Dive: What Are Financial Models and Their Related Challenges?

According to the FED/OCC Guidance on Model Risk Management, a financial model is, “a quantitative method, system, or approach that applies statistical, economic, financial, or mathematical theories, techniques, and assumptions to process input data into quantitative estimates.”

It is well understood that financial models can be quite complicated, with model development necessitating the fusion of advanced skills from many disciplines—including finance, mathematics, statistics, economics, computer science and physics. In addition, advanced skills are often required for the interpretation and use of model results. Finding the ‘right’ people and talent to manage the testing, development and overall complexity of financial models can often be challenging for financial institutions. Adding to this complexity, is the fact that financial markets are essentially based on approximations of human behavior—not physical phenomena, which means they can often be unpredictable. And, while model ‘quantitative-ness’ and precision conveys objectivity; models themselves also include a lot of subjectivity. Moreover, the logic embedded in complex programs and spreadsheets often comes with little or no documentation, which can often create further challenges.

How Can Financial Practitioners Live ‘In Peace’ with Financial Models?

Advanced models are incredibly useful when it comes to dealing with large amounts of complex information and making critical decisions that allow financial markets to function. However, as with any type of risk, our goal for model risk should be ‘risk management’ and not risk elimination. What we can do is manage model risk processes effectively, and make sure that model risk is commensurate with model risk exposures. Overall, we need to realize that effective model risk management has become a key source of competitive advantage, and a necessity, for today's financial institutions to both survive and thrive.

As a result, it is important for today's practitioners to gain a deeper knowledge of effective model risk management. In the diagrams that follow, we break down how models are typically classified, and also take a closer look at a Risk Factor Taxonomy.

Model Classification & Risk Factor Taxonomy

When it comes to best practices, model classification and the taxonomy of risk factors can help an organization to better understand all the risks it is assuming at the holistic level. To begin, let's examine a typical example of how financial models can be classified. In fact, the vast majority of models could fit into the categorization below.

Diagram 2. Model Classification

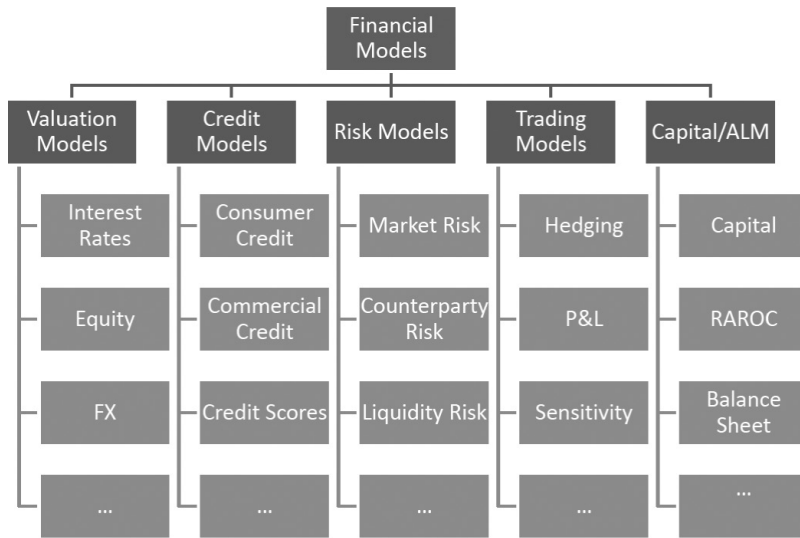
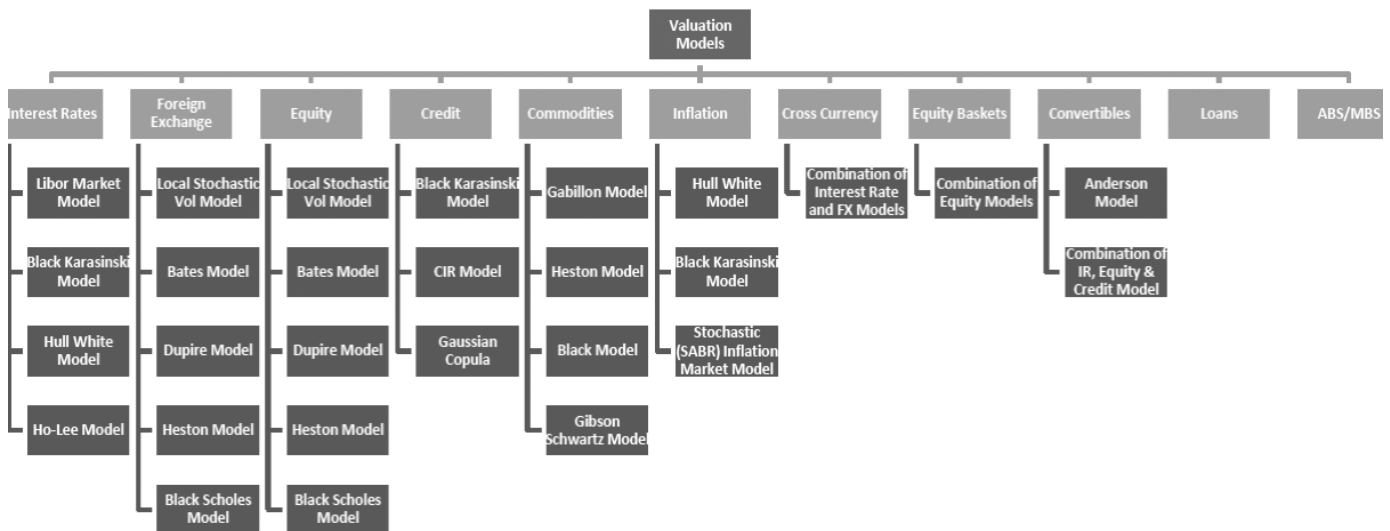


Diagram 3. Model Classification Drill-Down: Valuation Model Hierarchy

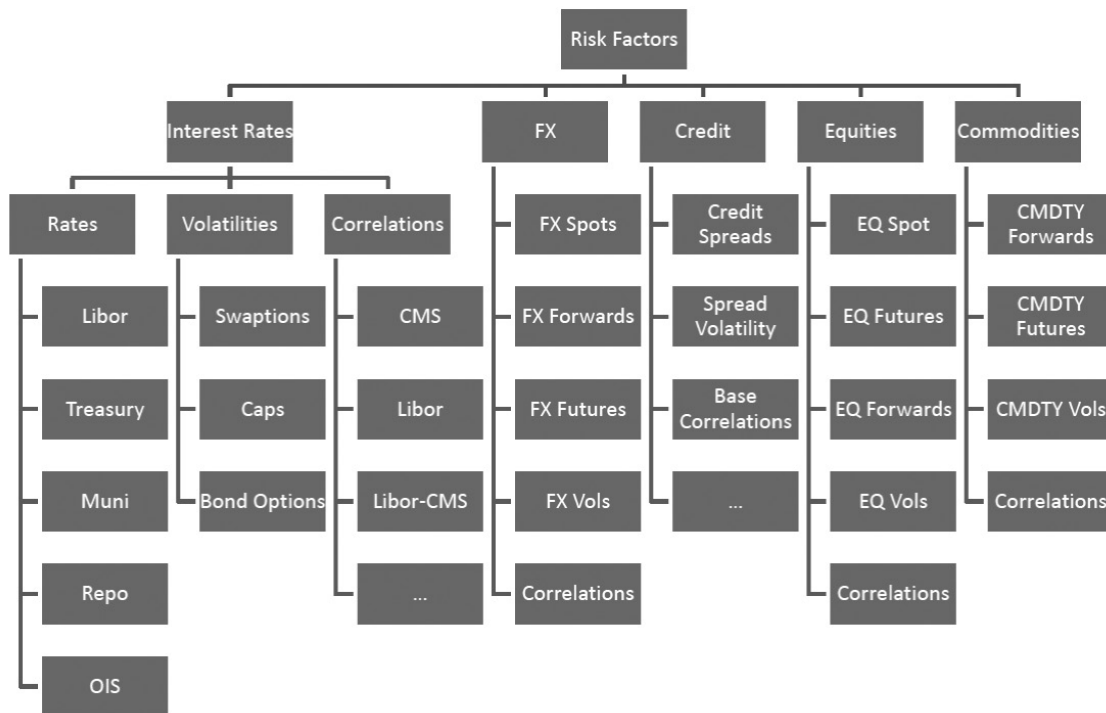
If we take a closer look at just one of these categories (in this case 'Valuation Models') and drill-down deeper, we observe a larger hierarchy of valuation models. As we can see, the complexity involved in this undertaking is huge. However, by combining everything into a hierarchical set of models and risk factors, an institution can more fully understand the risks it is taking; and, practitioners within the organization can view the risks on a holistic basis.



Next, we will examine the Risk Factor Taxonomy. It is important for organizations to understand the risk factors and types of risk that they are exposed to, in a more holistic way. Note that Risk Factor Taxonomy is aligned with, but not the same as the Model Classification. While the former deals with risk factors present in the market, the latter deals with specific models built to approximate those risk factors. Often, several different models can exist in parallel for a single risk factor with model choice dependent on the specific intended usage.

Looking at this Risk Factor Taxonomy, a Chief Risk Officer for example, could assess the various risk factors the firm is exposed to, and decide if the firm is comfortable taking risks along these dimensions. In addition, a Risk Factor Taxonomy provides a starting point for deeper drill-down and reporting around specific risk factors, as we will see later in this document.

Diagram 4. A Holistic Approach - A Risk Factor Taxonomy



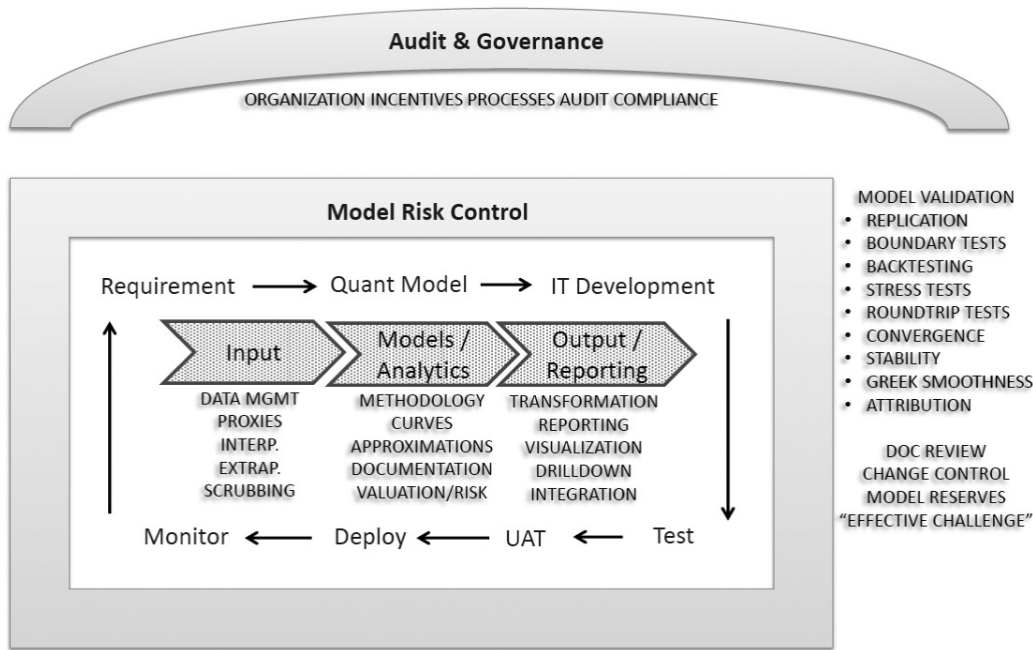
MODEL RISK FRAMEWORK AND PROCESSES

When it comes to the Model Risk Control process overall, there is a model lifecycle that organizations should institute with clear responsibility and ownership at each point of the process. This creates a continuous cycle of development as demonstrated below.

Key aspects of an effective Model Risk Framework include:

- Independence of various functions, in particular, the model development, risk control and audit functions
- Clear definitions of ownership with accountability aligned with incentives and authority
- Effective change management processes with checkpoints and defined criteria at each stage
- Emphasis on documentation at each stage in the model lifecycle
- Dissemination of model risk scores and user education along with model results
- Recognition of models as a “work-in-progress” that need to be continually re-examined and improved, rather than as a one-time effort
- Recognition of the fact that quantitative finance and technology skills are separate, but require close collaboration

Diagram 5. Model Risk Framework



When it comes to best practices for model risk, it is recommended that organizations create “effective challenges” and have a separate model risk control function to oversee the entire process outlined above.

Diagram 6. Model Risk: Backtesting As a Tool for Model Validation

Never mind the quality 3
 CDOs of subprime-mortgage-backed securities
 Issued in 2005-07, %

	Estimated 3-year default rate	Actual default rate
AAA	0.001	0.10
AA+	0.01	1.68
AA	0.04	8.16
AA-	0.05	12.03
A+	0.06	20.96
A	0.09	29.21
A-	0.12	36.65
BBB+	0.34	48.73
BBB	0.49	56.10
BBB-	0.88	66.67

Source: Donald MacKenzie, University of Edinburgh

(Source: The Economist)

Note the large difference between the estimated default rate and the actual default rate.

MODEL RISK CATEGORIES AND MEASURES

Significant model risk can occur due to one of the following four reasons, which we will categorize as follows: 1) bad data; 2) incorrect assumptions/methodology; 3) bad implementation; and 4) bad usage.

The first challenge that we will examine below is data quality and the use of 'bad' data (a.k.a. 'garbage-in, garbage out.'). It is important to be aware of all of these sources of bad data in order to prevent and correct any problems, as needed.

Poor Data Quality

There are a wide range of reasons for poor quality data, which can include any of the following:

- Proxies
- Incorrect data for security
- Positions and counterparty data
- Volatility and correlation
- Interpolation and extrapolation
- Using historical data
- Lack of sufficient history
- Unobservable data (*including risk appetite; macroeconomic and geopolitical risks; behavioral factors*)
- Aggregating 'good' and 'bad' data
- The way that ratings are interpreted

Incorrect Assumptions and Methodology

Secondly, we'll take a look at the plethora of bad assumptions and methodology that can occur in the model risk process. Bad assumptions can include any of the following:

- Missing or incorrect modeling of certain factors
- Regulatory actions (trading rules)
- Correlation in VaR Model (e.g. JP Morgan)
- Assumption of market liquidity and efficiency
- Assumption of Gaussian/Normal distributions
- Assumptions on materiality of payoff factors
- Incorrect mathematics
- Choosing false accuracy over model simplicity and parsimony (*being 'precisely wrong vs. approximately right'*)

Bad Implementation

Next, we'll examine some of the causes of bad implementation. These include:

- Making approximations and ignoring intermediate errors and warnings
- Bad efficiency vs. accuracy tradeoffs
- Incorrect extensions (*covering unintended products and features*)
- Bugs

Bad Usage

Finally, bad usage of data often occurs, and can include any of the following:

- Using models beyond their original intent (*for example, using an FX option model for FX barriers, or using a VAR model that does not capture a new and relevant risk factor—such as Libor/ OIS spread risk*)
- Interpreting results incorrectly (*for example, interpreting VaR as 'maximum possible loss'*)
- Knowingly using an incorrect model to cover up losses or show gains
- Using simplistic modeling, despite markets 'moving on' to a newer model (*'regime change'*)
- Using models designed for liquid market factors for illiquid market factors

MODEL RISK CONTROL

Model Validation

Model Validation involves a variety of sanity checks against the model to ensure that the model behaves as per expectations, under both normal and stressed conditions, including:

- Replication – Replicating the model calculation in a well-known environment like Microsoft Excel for specific special cases
- Boundary Tests – Testing the model under extreme conditions, where the model should behave in a simpler way in theory. (*e.g. Zero Volatility Assumption*)
- Backtesting – Comparing predicted results with out of sample, actual results
- Stress Testing – Ensuring model provides meaningful results in situations of market stress (*e.g. high volatility or high correlation.*)
- Roundtrip Testing – Checking internal model consistency to calibrated instruments (*e.g. model calibrated to FX options should exactly replicate the FX options volatility levels*)
- Convergence – Testing convergence of numerically computed results by varying Monte Carlo seed, number of paths or using finer time grids
- Stability – Checking to ensure that small numerical noise does not produce large variations in output or calibration state
- Greek Smoothness & Stability – Checking stability of Greeks and overall continuity
- P&L Attribution to Greeks – Testing the predictive power of Greeks typically used for hedging. A large residual indicates weak predictive power.

Documentation Review

In addition to all of the above methodologies, documentation review is a key step and a necessity when it comes to maintaining efficient model risk management processes. This includes a review of quantitative methodology, assumptions, model validation tests, etc. It is possible to create very simple 'cheat sheets' that can be quite useful, as we will explore further in the following case study.

CASE STUDY: MODEL VALIDATION FOR A LARGE INSURANCE COMPANY

Background

In the case study that follows, we look at a large insurance company with a diverse portfolio of assets—including swaps and bonds, with many of the positions linked to foreign exchange rates, equity indexes, as well as interest rate curves. There are also several structured trades with embedded calls, amortization, etc. The portfolio includes mostly long-dated positions.

Case Study Challenge

To validate the valuation and risk analytics and provide independent model assessment to the risk group.

Case Study

After Numerix Quantitative Services team completed the analysis, certain validation issues were raised. In this project, we focused on issues relating to methodology and assumptions, which we discovered did not conform to market best practices. Our findings are summarized below:

- **Data Challenges:** Not in Project Scope, Limited to independent verification via alternative data sources

- **Methodology and Assumption Challenges**

Issues were identified in the following areas:

- Curve Construction, interpolation, extrapolation
- Model selection, calibration issues
- Long-dated notes and swaps not accounting for full-rate risk
- Libor-based modeling, not the market standard multi-curve/OIS
- Modeling

- **Implementation Challenges:** Not in Project Scope for this particular study

- **Usage Challenges:** Not in Project Scope for this particular study

As part of the analysis, we summarized these issues in an Outcome Dispersion table as shown below.

Results Summary (sample data, in '000s) – Outcome Dispersion Analysis

Diagram 7. Best Practices: Outcome dispersion is one way that practitioners can take a look at these issues and combine them into quantitative results

Metric	Base	Data	Assumptions	Implementation	Usage	Total
PV	341,253	17062	25593	0	0	42656
IR Delta – USD	23,021	1151	1726	0	0	2877
IR Delta – EUR	17,231	861	1292	0	0	2153
IR Vega	12,312	615	923	0	0	1539
FX Delta USDEUR	-37,213	-1860	-2790	0	0	-4651
FX Vega	10,847	542	813	0	0	1355
VAR	29,758	1487	2231	0	0	3719

Using the outcome dispersion chart helps us to quantify the data, methodology and assumption challenges—and most importantly, make appropriate recommendations for change.

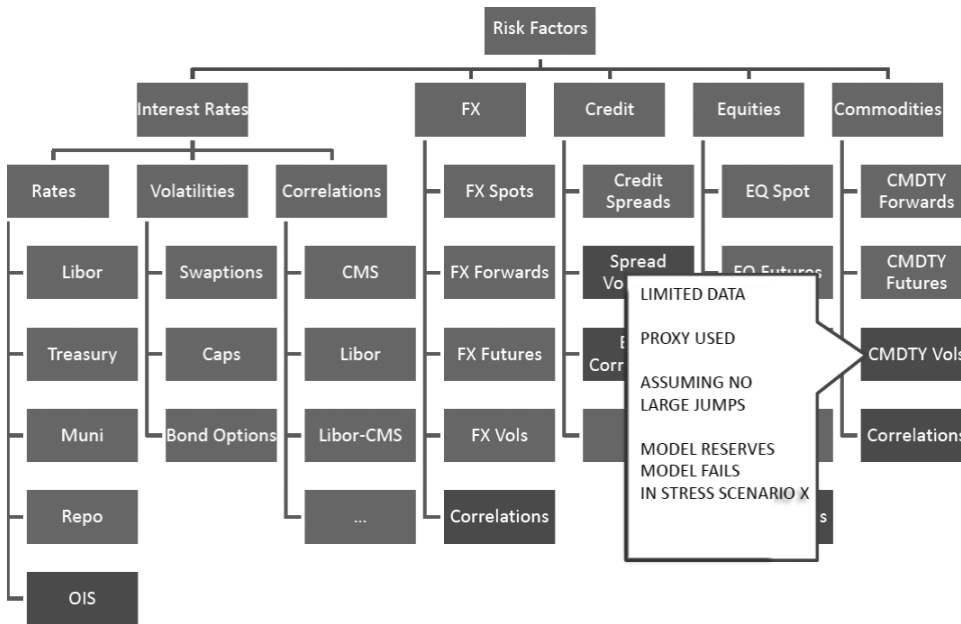
BEST PRACTICES AND RECOMMENDATIONS FOR MODEL RISK

In the section that follows, we conclude by highlighting what we believe to be the four key best practices for effective model risk control.

Best Practice #1: Risk Factor Taxonomy

We recommend creating and publishing a common Risk Factor Taxonomy that the institution can standardize on and can report risks associated with each risk factor. This would enable Risk Managers and C-level executives to be aware of the risks being taken, and establish a common terminology for discussing risk issues.

This chart breaks down the key risk factors in great detail.



Best Practice #2: Model 'Cheat Sheet'

The model cheat sheet below speaks to the end-user by highlighting broad categories, and providing a single view—without including complicated math. Basically, it answers the following questions, “What is the model about, and what is it trying to cover?”

“What Is This Model About?”

<p>MODEL OVERVIEW</p> <p>Classic Black Scholes [73] model extended to cover time-varying rates, dividends and volatilities.</p> <p>Volatility skews not incorporated.</p> <p>Extremely fast model implementation</p>	<p>ASSUMPTIONS/LIMITATIONS</p> <ul style="list-style-type: none"> • Volatilities constant across strikes • No jumps in volatility • No support for stochastic volatility • No interest rate dynamics
<p>USAGE</p> <ul style="list-style-type: none"> • Used as the quote conversion model • Can be used for simple short dated European options • Not appropriate for American options • Not appropriate for KOKIs or any other payoff • NOT appropriate for long-dated European options 	<p>DIAGNOSTICS</p> <p>(Date of Run – 1/30/2013)</p> <ul style="list-style-type: none"> • Stability Test – High • Greek Smoothness – High • Hedge Effectiveness – Low • Calibration Test – Low

Best Practice #3: Presenting Results

Next, we recommend presenting results in ranges (rather than a single number) to create a healthy skepticism and promote questioning in the user’s mind. It is important for a risk manager, or head of the desk, to have the same sense of where the ‘real’ range is—instead of living with a false sense of security.

Present Results in Ranges, Rather Than A Single Number

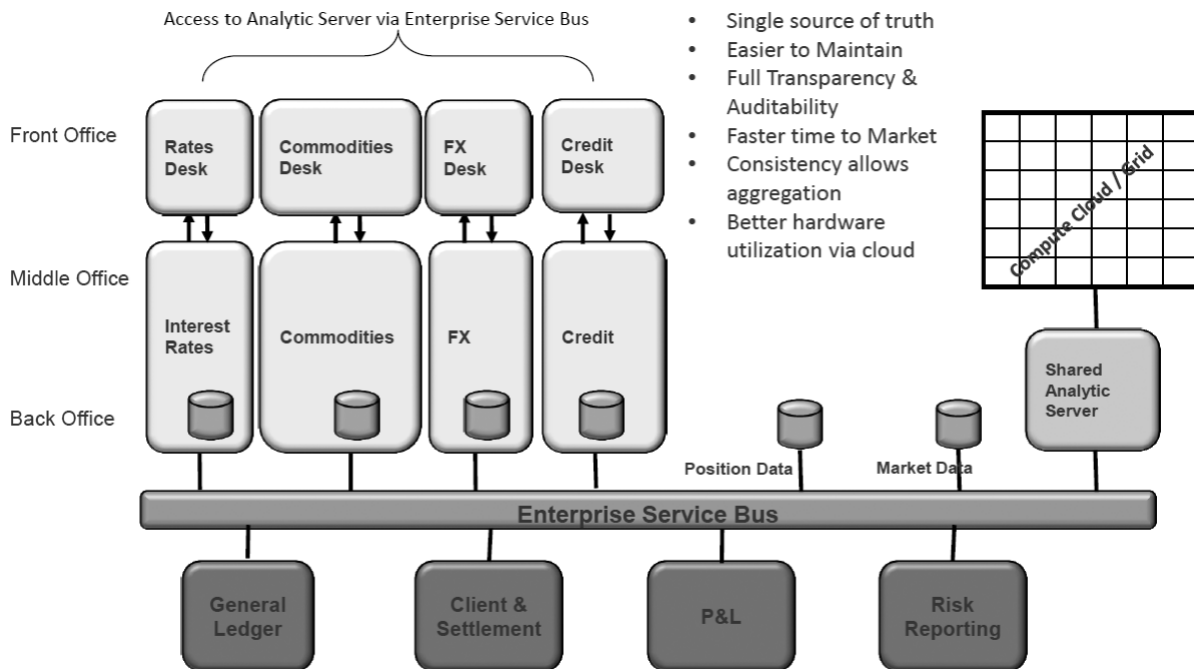
JPY CC Swap Book	Metric
PV	273,345,123
FX Delta	9,421,222
IR Delta - USD	12,324,112
VAR	28,324,141

JPY CC Swap Book	Metric
PV	273,000,000 +/- 4,000,000
FX Delta	9,400,000 +/- 500,000
IR Delta - USD	12,300,000 +/- 200,000
VAR	28,000,000 +/- 2,500,000

RESULT RESERVES & DIAGNOSTICS:
 DATA – 700,000
 ASSUMPTIONS - ...
 IMPLEMENTATION - ...
 USAGE - ...

Best Practice #4: Model/Analytic Server - Defragmented, Service Oriented Architecture

Finally, from the technology standpoint, having a centralized architecture enables greater transparency and effectiveness when it comes to managing risk.



CONCLUSION AND BEST PRACTICES SUMMARY

As we have seen, model risk is an inherent part of day-to-day life for today's financial institutions. Sources of this risk include bad data, incorrect assumptions and methodology, and poor implementation and usage. In order to more effectively manage model risk, an *independent* model risk control function is essential—whether it is internal or external to the institution.

When it comes to best practices, model risk control should be focused on presenting an 'effective challenge' to model development. Model validation and measurement of model risk / reserves should be conducted regularly. Documenting the risk factors and models for end-users, and then presenting the results fully and completely, is also recommended. A central analytic server with a service-oriented architecture (SOA) and rapid application development (RAD) tools enables better model control, auditability, and scalability—in addition to analytic agility when it comes to managing model risk.

AUTHOR BIOGRAPHY



Satyam Kancharla, Chief Strategy Officer & SVP of Client Solutions Group, Numerix LLC

Mr. Kancharla is currently the Chief Strategy Officer, as well as head of the Client Solutions Group responsible for Product Management, Requirements Gathering and Business Analysis. Prior to this, he has served in various roles in Quantitative Software Development, Financial Engineering and Pre-Sales at Numerix.

Before joining Numerix in New York, he was the CTO for Numerix Japan LLC in Tokyo, heading the Pre-Sales and Financial Engineering teams for Asia. Earlier in his career, Mr. Kancharla also worked with Merrill Lynch and GE Capital in Quantitative Finance and Product Development roles. He holds a MS degree in Applied Statistics and Informatics and a BS in Mathematics and Computers.

Corporate Headquarters

New York

150 East 42nd Street
15th Floor
New York, NY 10017
Tel: +1 212 302 2220

Sao Paulo - Brasil

Avenida Brigadeiro
Faria Lima, 3729
5 Andar
Sao Paulo
04538905, Brasil
Tel: +5511 3443 7331

London

Numerix Software Limited
41 Eastcheap, 2nd Floor
London, UK EC3M 1DT
Tel: +44 20 7648 6100

Singapore

8 Eu Tong Sen Street
#24-85 The Central
Singapore 059818
Tel: +65 6501 0788

Hong Kong

Level 16
Man Yee Building
60-68 Des Voeux Road
Central
Central, Hong Kong
Tel: +852 3796 2720

Tokyo

Marunouchi Trust
Tower Main, 20th Floor
1-8-3 Marunouchi,
Chiyoda-ku
Tokyo, Japan 100-0005
Tel: +81 3 5208 1130

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