RISK MANAGEMENT

A Practical Guide

RISKMETRICS GROUP
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Risk Management: A Practical Guide

First Edition (August 1999)

Foreword

The RiskMetrics Group is best known for its leadership in the development of transparent risk estimation methodologies and easy-to-use software tools. The founders of the Group have long recognized, however, that there is much more to risk management that just risk measurement. Indeed, perhaps too much public focus has been placed on the sophistication and apparent precision of risk estimation models, and not enough on the more important managerial and judgmental elements of a strong risk management framework. These include the clarity of risk policies, the strength of internal control, the degree of management discipline, the level of internal risk transparency, and ultimately, the experience and market knowledge of risk management professionals. No technical document, however complete and rigorous, can impart that experience and knowledge.

To contribute to a better understanding of these broader elements of risk management, and in response to frequent client inquiries, the experienced professionals of the RiskMetrics Group have developed this practitioner's oriented guide to Risk Management. While the details of the subject matter can, at times, be technical and complex, the essence of the guide is helping practitioners to get the right information on the right issues to the right people at the right time. Not with a view to producing a single right answer, but with a confidence that the right questions will then be asked, leading to the best informed, experienced judgments.

As with all other elements of risk management, the state-of-the-art guide will itself need to be open to continuous improvement, as new techniques are developed in response to ongoing innovations in markets and risk products. This first edition of the guide focuses on market risk analysis and reporting, while also touching upon closely related issues of counterpart risk reporting and external risk disclosures.

Stephen G. Thieke
Chairman
RiskMetrics Group

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Introduction

Why we wrote this *Guide*

This *Guide* evolved from common client questions about market risk management. While there is a significant amount of quantitative research and high-level risk management literature, there are few practical resources at the risk manager's disposal. The *Guide* addresses the basic issues risk managers face when implementing a market risk measurement process.

We are publishing the *Guide* in our continuing effort to promote improvements in the discipline of risk management and to help our clients develop better risk reporting processes.

The *Guide* focuses on practical issues that arise in the process of risk analysis and reporting. The three major phases of risk reporting consist of (a) compiling position and market data in a timely manner, (b) applying appropriate methodologies to calculate risk (including stress testing), and (c) summarizing portfolio risks in a concise and complete manner. We also include advice on model backtesting.

The world is moving from reporting risk as a single number to viewing a broader ***Picture of Risk***. We emphasize the importance of applying several methodologies to explore different dimensions of risk.

Who should read the *Guide*

The *Guide* is geared for risk monitors and analysts who are responsible for implementing a risk reporting process. After studying the *Guide*, readers should know (a) how to measure risk, (b) why it's important to measure risk—the "so what" or "value-added" of it, and (c) how to present and communicate risk information to management and other interested constituents.

As an introduction, we review basic principles of market risk measurement without relying heavily on statistics and formulas. Quantitatively oriented readers are encouraged to learn the details of risk methodologies in the *RiskMetrics Technical Document*, which are cited throughout the *Guide*.

Our main focus is on the practical issues of communicating about risk. The application of rules and procedures for risk control, while important, are not part of the *Guide*. Through case studies, we consider the risk reporting needs of several types of financial institutions (banks, hedge funds, and asset managers) and corporations. We show what type of input data is needed and give advice on designing effective risk reports. Throughout the *Guide*, we give practical illustrations of how these concepts and data are implemented in real solutions.

For novice risk managers who wish to get a broad overview of corporate risk management, we recommend our on-line *Managing Risk* course, which features live RiskMetrics tutorial support.

General structure and overview

This document is organized in two sections.

Part I addresses risk methodology and analysis, and consists of Chapters 1 through 3:

Chapter 1 introduces the **Value-at-Risk (VaR)** framework for measuring market risk and highlights key input parameters and assumptions. We review the three major methodologies for estimating VaR: **parametric**, **Monte Carlo simulation**, and **historical simulation.**

Chapter 2 gives an overview of *stress testing*, which is a crucial discipline in risk measurement. We emphasize characteristics of effective stress tests and introduce several approaches for creating stress scenarios, including historical and predictive scenario generation.

Chapter 3 addresses *backtesting* of risk models: why it's important, how to do it, when to do it, and what to look for.

Part II addresses risk management and reporting and consists of Chapters 4 through 10:

Chapter 4 defines common problems risk managers face when implementing market risk reporting processes:

- How to produce relevant market risk reports
- How to use risk information
- How to obtain appropriate data
- How to evaluate software for analyzing and reporting risk
- Whether to build or buy risk solutions

In the following chapters, we address these issues and propose solutions.

Chapter 5 describes best practices for *risk reporting*. We make suggestions for designing risk reports (i.e., format, content, and organization), and show sample case study reports representing four types of companies: banks, hedge funds, asset managers, and traditional corporations.

Chapter 6 addresses *external reporting*. We discuss emerging global standards for public risk disclosures of financial and non-financial companies and show examples of actual risk disclosures from leading institutions. We specifically review BIS disclosure recommendations and SEC disclosure requirements.

Chapter 7 discusses how to use risk information to link risk with performance evaluation and capital. We introduce the Sharpe ratio for measuring return on risk of realized revenues. Then, we discuss BIS regulatory market risk capital requirements, and introduce the topic of economic capital allocation.

Chapter 8 focuses on *market data* needed for calculating risk. We define what constitutes good market data and review best practices for data analysts. We review the process of transforming raw historical rates into volatility and correlation forecasts and discuss the use of implied volatility forecasts.

Chapter 9 reviews the *position data* collection process, and the type of information required from position management systems. To simplify the data management process, we introduce the concept of cashflow mapping for fixed income, FX and commodity instruments and show several approaches for treating equities.

Chapter 10 gives advice on choosing a *risk software* vendor. We emphasize the importance of defining risk management objectives and needs up front and propose key evaluation criteria for risk solutions.

In the **Appendices**, we discuss risk based limits, credit exposure of market driven instruments, and the responsibilities of the independent corporate risk management function. We also

provide a **glossary** of risk terminology and a list of resources that includes risk associations and suggested reading.

Throughout this *Guide* we use the following typographic conventions: **boldfaced** terms are defined in the **Glossary**; underlined text indicates a web site hyperlink in the on-line version of the *Guide*.

All reports and graphs were generated using the RiskMetrics RiskManager application.

Part I

Risk Methodology and Analysis

Chapter 1. Introduction to risk analysis

1.1 History of Value-at-Risk

VaR was pioneered by major U.S. banks in the ’80s, as the derivative markets developed. The birth of derivatives represented a new challenge for risk management because traditional measures of exposure were clearly inadequate. For example, two derivative contracts with the same **notional** value could have very different risks. With VaR, banks had developed a general measure of economic loss that could equate risk across products and aggregate risk on a portfolio basis.

Another important stimulus to the development of VaR was the move toward mark-to-market, both for cash instruments and derivatives. Prior to that, the emphasis was on net interest income, where the common risk measure was repricing gap. As trading increased, duration analysis took over, but duration's inadequacies led to the adoption of VaR.[1]

Definition of VaR

VaR is defined as the predicted worst-case loss at a specific confidence level (e.g., 95%) over a certain period of time (e.g., 1 day). For example, every afternoon, J.P. Morgan takes a snapshot of its global trading positions to estimate its Daily-Earnings-at-Risk (DEaR), which is a VaR measure that Morgan defines as the 95% confidence worst-case loss over the next 24 hours due to adverse market movements.

VaR works on multiple levels

The elegance of the VaR solution is that it works on multiple levels, from the position-specific micro level to the portfolio-based macro level. VaR has become a common language for communication about aggregate risk taking, both within an organization and outside (e.g., with analysts, regulators, rating agencies, and shareholders).

Virtually all major financial institutions have adopted VaR as a cornerstone of day-to-day risk measurement. Below is an excerpt describing Chase Manhattan’s use of VaR.

> *Statistical models of risk measurement, such as VAR, allow an objective, independent assessment of how much risk is actually being taken. Chase’s historic simulation methodology permits consistent and comparable measurement of risk across instruments and portfolios, irrespective of the level of aggregation. Historical simulation also makes it easy to examine the VAR for any desired segment of the total portfolio and to examine that segment’s contribution to total risk. The VAR calculations are performed for all material trading portfolios and market risk-related asset/liability management (“ALM”) portfolios. Results are reported at various levels of detail by business unit and in the aggregate.*
>
> – Chase 1998 *Annual Report*

The application of VaR analysis and reporting now extends to non-financial corporations, which has resulted in the adoption of related “at-risk” measures, such as **Earnings-at-Risk** (**EaR**), **Earnings-Per-Share-at-Risk** (**EPSaR**), and **Cash-Flow-at-Risk** (**CFaR**).

[1] For a more detailed discussion, see the *RiskMetrics Technical Document*, Chapter 2, “Historical perspective of VaR,” p. 21.

These measures take into account special considerations of the corporate environment, such as the use of accrual vs. mark-to-market accounting and hedge accounting for qualifying transactions. Furthermore, non-financial corporations focus on longer-term impact of risk on cash flows and earnings (quarterly or even annual) in the budgeting and planning process. The application of risk measurement in the corporate environment is fully discussed in the *CorporateMetrics Technical Document*.

VaRBaR

Risk measurement in the corporate environment

In the corporate environment, uncertainty in future earnings and cash flow is caused not only by uncertainty in a company's underlying business (e.g., sales volumes), but also by a number of other risks, including market risk. Market risk can arise from a number of factors, including foreign exchange exposures, interest rate exposures, commodity price-sensitive revenues or expenses, pension liabilities, and stock option plans. CorporateMetrics, which focuses on market risk, provides a framework centered on the key financial results that corporations monitor.

To address a company's need to quantify the impact of market risk on earnings and cash flow, CorporateMetrics defines the following measures of volatility:

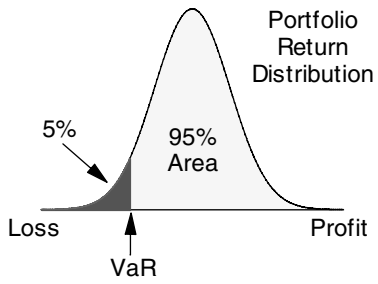
Earnings-at-Risk (EaR). *The maximum shortfall of earnings, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level. Since earnings are also usually reported on a per share of equity basis, many companies may prefer to use an* ***Earnings-per-Share-at-Risk (EPSaR)*** *measure.*

Cash-Flow-at-Risk (CFaR). *The maximum shortfall of net cash generated, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.*

Source: CorporateMetrics Technical Document

1.2 VaR, relative VaR, marginal VaR, and incremental VaR

Assuming 95% confidence and a 1-day horizon, a VaR of $11 million means that, on average, only 1 day in 20 would you expect to lose more than $11 million due to market movements.



This definition of VaR uses a 5% risk level (95% confidence): You would anticipate that losses exceeding the VaR amount would occur 5% of the time (or losses less than the VaR amount would occur 95% of the time).

VaR is a flexible risk measure:

- VaR can be specified for various horizons (generally between 1 day and 1 month) and confidence levels (generally between 90% and 99%).
- VaR can be expressed as a percentage of market value or in absolute currency terms (e.g., USD).

There are three related VaR measures: (a) **relative VaR**, (b) **marginal VaR**, and (c) **incremental VaR**.

Relative VaR

Relative VaR measures the risk of underperformance relative to a pre-defined **benchmark**, such as the S&P 500 Index. It is relevant to many institutional investors, including investment managers and mutual funds, because their performance is often compared to a target benchmark. For example, an Emerging Markets investment manager might have used the J.P. Morgan EMBI+ index as a performance benchmark. If the investment manager's portfolio rose 9% while the EMBI+ index rose 10%, we would say that she underperformed her benchmark by 1%.

Assuming 99% confidence, a 1-month relative VaR of $8 million means that on average, only 1 month in 100 would you expect to underperform your benchmark by more than $8 million due to market movements. Relative VaR is also commonly expressed as a percentage of present value.

An investment manager's risk report might show the following:

Portfolio	VaR*, %	Benchmark†	Relative VaR*, %
U.S. Equities	10	S&P 500 Index	3
Global Equities	11	MS EAFE Index	1
Global Fixed Income	5	JPM GBI+ Index	4
Total Portfolio	8	Custom Global Index‡	3

* 1-month horizon, 99% confidence.

† Refers to the investment manager's target benchmark index used to evaluate relative performance.

‡ Fund managers can have custom benchmarks (e.g., a specific mix of existing benchmarks).

For example, for the U.S. Equities portfolio, the worst-case loss at 99% confidence is equal to 10% of the portfolio's current market value (i.e., 1% probability that losses exceed 10% of market value), whereas the worst-case monthly underperformance, relative to the portfolio's S&P 500 benchmark, is only 3% (i.e., 1% probability of underperforming the benchmark by 3% or more).

This report reveals important differences between *VaR* and *relative VaR*. Global Equities has the highest stand-alone VaR (11%), but considering its benchmark, the smallest relative VaR (1%). On the other hand, the Global Fixed Income portfolio has the smallest stand-alone VaR (5%), but the largest relative VaR (4%).

The 4% relative VaR would be of most concern to a risk monitor, since it deviates most from the benchmark.[2] A large relative VaR may arise when a manager takes positions that do not

[2] Deviation from benchmark could be justified if it is within pre-specified relative VaR limits (and if excess return on risk is acceptably high).

track the benchmark closely. For example, the Global Fixed Income portfolio manager may have underweighted certain countries within the index. As this example shows, portfolio managers using benchmarks should set relative VaR limits (e.g., keep relative VaR below 3%).

Marginal VaR

Marginal VaR measures how much risk a position adds to a portfolio. Specifically, marginal VaR measures how much portfolio VaR would change if the position were removed entirely, (i.e., VaR with position minus VaR without position).[3] Note that marginal VaR can be computed for both absolute VaR and relative VaR.

A marginal risk report might reveal the following:

Position	Market value, MM	VaR, MM	Marginal VaR, MM
Yahoo! Equity	$ 25.1	$ 0.9	$ 0.5
10-year U.S. T-Note	$ 98.2	$ 0.8	$ 0.6

This report implies that, although the Yahoo! stock position has the greater stand-alone VaR (USD 0.9 million), its contribution to portfolio VaR is less than the T-bond's contribution (USD 0.5 million). Often, the largest stand-alone risk positions are not the greatest contributors of risk. This is especially true for hedges, which have a negative marginal VaR.

Marginal VaR is useful for measuring which position (or risk category) is the largest contributor to portfolio risk. It can help answer the question of which position to eliminate **entirely** in order to most effectively reduce risk.

Incremental VaR

Incremental VaR is closely related to marginal VaR. Marginal VaR measures the difference in portfolio risk brought about by removing an entire position, whereas incremental VaR measures the impact of small changes in position weighting. For example, we can estimate incremental VaR by (a) increasing a position weight by 1 dollar and measuring the change in diversified portfolio VaR, and (b) multiplying this change by the position weighting.[4] The sum of all incremental VaRs adds up to the total diversified portfolio VaR. Therefore, incremental VaR may be used to calculate percentage contribution to risk.

One of the most common uses for incremental VaR is to generate reports that rank contribution to risk hedging opportunities. Incremental VaR is useful for identifying best candidates for gradual risk reduction (i.e., where the question is not which position to unwind entirely, but rather which position to partially hedge).

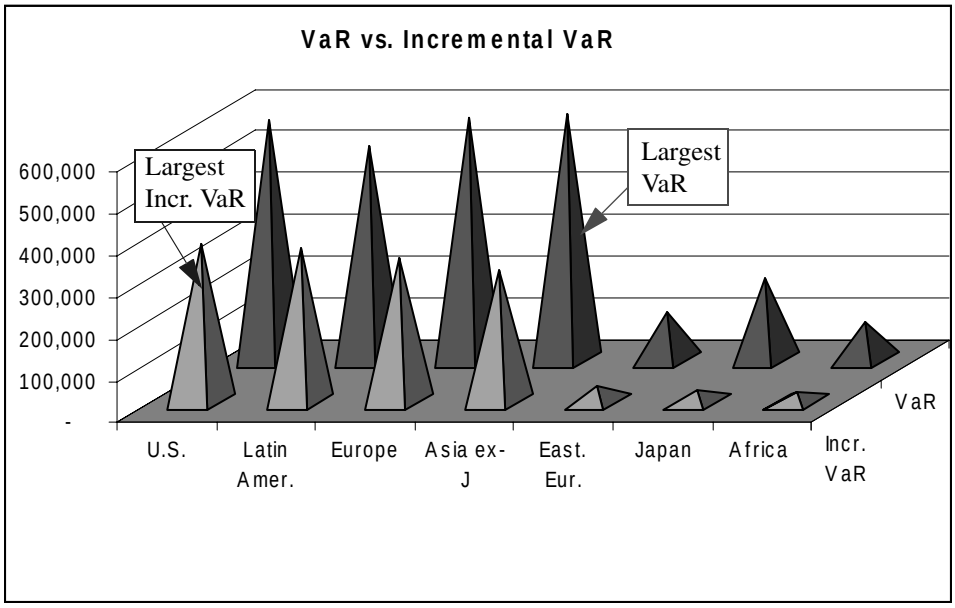
[3] Some practitioners define marginal VaR as incremental VaR.

[4] There is significant confusion in the marketplace about the definition of marginal VaR vs. incremental VaR. Some firms define marginal VaR as the VaR that a position adds incrementally, as measured by the effect on VaR if the position size is increased by a very small amount (this is defined as "incremental VaR" by RMG). Marginal VaR as defined by RMG is the difference in VaR assuming that the position is removed entirely from the portfolio.

The following is a regional risk contribution report, which ranks risk contributors according to their incremental VaR.

Regional Risk Summary **May 1, 1999**

RMG



Risk Contribution Report	Present Value	VaR	Marginal VaR	Incremental VaR	Contribution to Risk
U.S.	71,774,216	574,194	222,075	378,341	25%
Latin America	10,258,887	512,944	220,114	369,626	25%
Europe	64,600,480	581,404	204,358	343,237	23%
Asia ex-Japan	12,693,840	589,734	196,046	317,346	21%
East. Europe	1,948,860	116,932	31,050	40,322	3%
Japan	19,569,450	195,694	48,012	30,068	2%
Africa	4,669,370	93,387	24,423	24,163	2%
Divers. Benefit		*(1,161,186)*			
Aggregate	**185,515,103**	**1,503,103**		**1,503,103**	**100%**

Comments

- Even though Asia ex-Japan is the largest single relative VaR position, it is only the fourth largest contributor to risk, as measured by the percentage of incremental VaR (21%). The best three opportunities for reducing risk through hedges lie in U.S., Latin America, and Europe.
- **VaR** refers to 95% worst-case loss over 1 day due to adverse movements in market rates.
- **Marginal VaR** is the change in aggregate portfolio VaR when the position is taken out of the portfolio.
- **Incremental VaR** is the change in VaR that results when position size is increased by a small amount, multiplied by the portfolio weighting. The sum of all incremental VaRs adds up to total diversified VaR.
- ***Diversification Benefit*** is equal to diversified (aggregate) VaR minus the sum of all individual VaRs. It measures the risk reduction achieved through diversification (i.e., correlation being lower than 1) between risk categories.

1.3 Overview of risk methodologies

Market risk models are designed to measure potential losses due to adverse changes in the prices of financial instruments. There are several approaches to forecasting market risk, and no single method is best for every situation. Over the last decade, Value-at-Risk (VaR) models have been implemented throughout the financial industry and by non-financial corporations, as well. Inspired by modern portfolio theory, VaR models forecast risk by analyzing historical movements of market variables. To calculate VaR, one can choose from three main methods: **parametric**, **historical simulation**, and **Monte Carlo simulation**.[5] Each method has its strengths and weaknesses, and together they give a more comprehensive perspective of risk. Note that we include the **portfolio aggregation** methodology as a subcomponent of historical simulation.[6]

Before comparing these three approaches for calculating VaR, we add a quick note about linear vs. non-linear instruments. A financial instrument is nonlinear if its price changes disproportionately relative to a movement in the underlying asset. The risk of **nonlinear instruments** (e.g., options) is more complex to estimate than the risk of **linear instruments** (e.g., traditional stocks, bonds, swaps, forwards, and futures). To account for the discontinuous payoff of nonlinear instruments like options, risk simulations should use full valuation formulas (e.g., Black-Scholes) rather than first order sensitivities (e.g., **delta**).

The following table describes the three main methodologies for calculating VaR.

Methodology	Description	Applications
Parametric	Estimates VaR with equation that specifies parameters such as volatility, correlation, delta, and **gamma**.	Accurate for traditional assets and linear derivatives, but less accurate for nonlinear derivatives.
Monte Carlo simulation	Estimates VaR by simulating random scenarios and revaluing positions in the portfolio.	Appropriate for all types of instruments, linear and nonlinear.
Historical simulation	Estimates VaR by reliving history; takes actual historical rates and revalues positions for each change in the market.	

Note that Monte Carlo and historical simulations are mechanically identical in that they both revalue instruments, given changes in market rates. The difference lies in how they generate market scenarios. Monte Carlo simulation generates random hypothetical scenarios, while historical simulation takes actual past market movements as scenarios.

From an end-user perspective, the important point to remember is that if you have significant nonlinear exposures in your portfolio, a simulation approach with full position re-pricing will generally be more accurate than a parametric approximation for estimating VaR—however, at the cost of greater complexity.

[5] See the *Managing Risk™ Course*— three methodologies for calculating VaR.

[6] Portfolio aggregation is described by Zangari in the Q2 ’97 *RiskMetrics Monitor* article “A general approach to calculating VaR without volatilities and correlations.”

A summary of the strengths and weaknesses of each methodology is given below:

Methodology	Advantage	Disadvantage
Parametric	• Fast and simple calculation • No need for extensive historical data (only volatility and correlation matrix are required)	• Less accurate for nonlinear portfolios, or for **skewed distributions**
Monte Carlo simulation	• Accurate* for all instruments • Provides a full distribution of potential portfolio values (not just a specific percentile) • Permits use of various distributional assumptions (normal, T-distribution, normal mixture, etc.), and therefore has potential to address the issue of **fat tails** (formally known as "leptokurtosis") • No need for extensive historical data	• Computationally intensive and time-consuming (involves re-valuing the portfolio under each scenario) • Quantifies fat-tailed risk ***only if*** market scenarios are generated from the appropriate distributions
Historical simulation	• Accurate* for all instruments • Provides a full distribution of potential portfolio values (not just a specific percentile) • No need to make distributional assumptions (although parameter fitting may be performed on the resulting distribution) • Faster than Monte Carlo simulation because less scenarios are used	• Requires a significant amount of daily rate history (note, however, that sampling far back may be a problem when data is irrelevant to current conditions, e.g., currencies that have already devalued) • Difficult to scale far into the future (long horizons) • Coarse at high confidence levels (e.g., 99% and beyond) • Somewhat computationally intensive and time-consuming (involves re-valuing the portfolio under each scenario, although far less scenarios are required than for Monte Carlo) • Incorporates tail risk only if historical data set includes tail events

* Accurate if used with complete pricing algorithm.

All three approaches for estimating VaR have something to offer and can be used together to provide a more robust estimate of VaR. For example, a parametric approach may be used for instant risk measurement during a trading day, while a simulation approach may be used to provide a fuller *Picture of Risk* (in particular, nonlinear risks) by the end of the trading day.[7]

Importance of model transparency

At RMG, we emphasize that risk models should not be viewed as black boxes that produce magic numbers. Risk methodologies should be clear, and risk managers should understand the key parameters and fundamental assumptions of each approach. Don't be lulled into a false sense of security through complicated mathematical formulas, even if they were derived by rocket scientists. There is no single correct answer to risk, and risk methodologies are constantly being refined and new approaches invented. This means that risk managers must continually question assumptions, search for new approaches for measuring risk, and keep abreast of the latest research. It's the risk manager—not just numbers— that makes risks transparent.

[7] Distributed computing solutions should eventually enable fast simulation of risks throughout the trading day.

Limitations of VaR

It's important to realize that all three approaches for measuring VaR are limited by a fundamental assumption: that future risk can be predicted from the historical distribution of returns.[8] The parametric approach assumes normally distributed returns, which implies that parametric VaR is only meant to describe "bad" losses on a "normally bad" day. While Monte Carlo simulation offers a way to address the fat-tail problem by allowing a variety of distributional assumptions, volatility and correlation forecasts are still based on statistical fitting of historical returns. While historical simulation performs no statistical fitting, it implicitly assumes that the exact distribution of past returns forecasts future return distributions. This implies that all three approaches are vulnerable to regime shifts, or sudden changes in market behavior. Stress testing should therefore explore potential regime shifts to best complement VaR and create a robust *Picture of Risk.*

Parameters for VaR analysis

Before calculating VaR, we need to specify three parameters: (a) confidence level, (b) forecast horizon, and (c) base currency.

(a) Confidence level

We first choose a confidence level or probability of loss associated with VaR measurement. Confidence levels generally range between 90% and 99%. RiskMetrics assumes 95% confidence as a baseline, but gives users the flexibility to choose other levels. Rather than choose a single parameter, some firms use several confidence levels (e.g., 95% and 99%) and forecast horizons (e.g., 1 day and 1 year).

How to choose a confidence level

There is nothing magical about confidence levels. In choosing confidence levels for market risk, companies should consider worst-case loss amounts that are large enough to be material, but that occur frequently enough to be observable. For example, with a 95% confidence level, losses should exceed VaR about once a month (or once in 20 trading days), giving this risk statistic a visceral meaning. Risk takers are thus encouraged to compare their daily P&Ls against their VaR and consider return on risk.

Some maintain that using a higher level of confidence, such as 99.9%, would be more conservative. One might also reason, however, that a higher confidence level can lead to a false sense of security. A 99.9% VaR will not be understood as well or taken as seriously by risk takers and managers because losses will rarely exceed that level (we expect a loss of that magnitude to occur about once in four years). Furthermore, due to fat-tailed market returns, a high confidence level VaR is difficult to model and verify statistically. VaR models tend to lose accuracy after the 95% mark and certainly beyond 99%. Note, however, that when using VaR for measuring credit risk and capital, we should apply a 99% or higher confidence level VaR because we are concerned with low-probability, event-driven risks (i.e., **tail risk**).

We can't rely on models to do all the "thinking" for us. Beyond a certain confidence level, rigorous stress testing becomes more important than statistical analysis. The choice of 95% confidence level at J.P. Morgan goes back to former CEO Dennis Weatherstone, who reputedly said, "VaR gets me to 95% confidence. I pay my risk managers good salaries to look after the remaining 5%."

[8] Some argue that using implied volatilities bases risk prediction on market expectations as opposed to past market movements. For a portfolio view of risk, however, historical correlations of market returns must still be applied, as it is nearly impossible to get such information from option prices.

(b) Forecast horizon

Generally, active financial institutions (e.g., banks, hedge funds) consistently use a 1-day forecast horizon for VaR analysis of all market risk positions. For banks, it simply doesn't make sense to project market risks much further because trading positions can change dynamically from one day to the next. On the other hand, investment managers often use a 1-month forecast window, while corporations may apply quarterly or even annual projections of risk.

VaRBaR

Applying longer horizon for illiquid assets

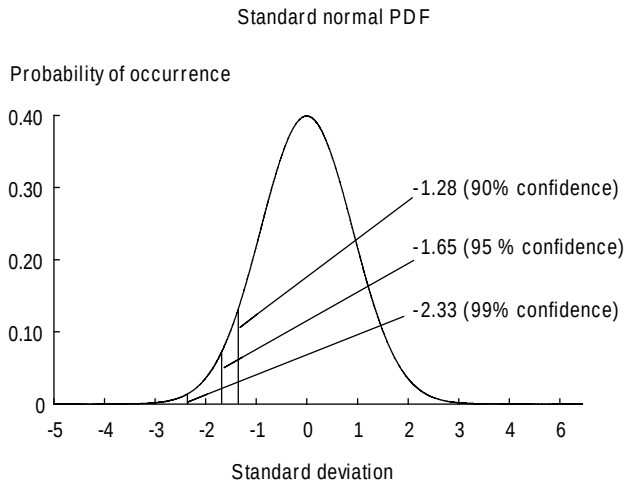
Instead of applying a single horizon, some firms use different forecast horizons across asset classes to account for liquidity risk. One might argue that the unwind period for an illiquid emerging markets asset is much longer than for a G7 Government bond, and that one should therefore use a longer horizon (e.g., 1-week) for emerging markets. However, a better solution is to treat market risk and liquidity risk as separate issues. Currently, the topic of liquidity risk is a hot research topic, and new quantitative methodologies are being developed. Simply using a longer time horizon for illiquid assets is not sufficient, and confuses liquidity risk with market risk. Having a standard horizon for VaR across asset classes facilitates the risk communication process and allows "apples-to-apples" comparison for market risk across asset classes.

(c) Base currency

The base currency for calculating VaR is typically the currency of equity capital and reporting currency of a company. For example, Bank of America would use USD to calculate and report its worldwide risks, while the United Bank of Switzerland would use Swiss francs.

1.4 Confidence level scaling factors

Standard deviations can be used to estimate lower-tail probabilities of loss when the parametric approach to measuring risk is used. Lower-tail probability of loss refers to the chance of loss exceeding a specified amount.



Because returns tend to cluster around the mean, larger standard deviation moves have a lower probability of occurring. To arrive at the tail probability of loss levels and implied VaR confidence levels, we use standard deviations (confidence level scaling factors). This chart shows three confidence level scaling factors and their associated tail probability of loss levels.

Assuming normality, we can easily convert one confidence level (C.L.) to another. For example, we can take J.P. Morgan's 95% confidence level VaR and translate it to the BIS standard of 99% confidence level through a simple multiplication, as shown in the following table.

Reference VaR	C.L.	C.L. scaling factor
JPM VaR	95%	1.65
BIS VaR	99%	2.33
Converting JPM to BIS VaR	95% to 99%	JPM VaR × 2.33/1.65

Views of the U.S. Federal Reserve

For example, in 1998 J.P. Morgan reported that its maximum VaR was USD 55 million, which scales to a VaR of approximately USD 78 million at 99% confidence, assuming normality. Note, however, that regulators, in particular, the U.S. Federal Reserve are increasingly discouraging this simple conversion, because the assumption of normally distributed P&Ls is often an oversimplification (especially when portfolios contain non-linear positions).

1.5 Time scaling of volatility

We know that risk increases with time: the longer we hold a position, the greater the potential loss. But unlike expected returns, volatility does not increase linearly with time. Long-horizon forecasting is complicated due to trending, **autocorrelation**, **mean reversion** of market returns, and the interrelationship of many macroeconomic factors. **Autocorrelation** refers to correlation between successive-days' returns, and **mean reversion** is the tendency for time series to revert to a long-term average (this is observed especially for interest rates). For research on long-horizon forecasting, see the *LongRun Technical Document*.

Square root of time scaling

You may need to time scale VaR estimates, for example when converting a daily VaR to a 10-day horizon regulatory VaR standard. A commonly used method is the **square root of time scaling,** which roughly extrapolates 1-day volatilities as well as 1-day VaR to longer horizons. The method assumes that daily price moves are independent of each other, and that there is no mean reversion, trending, or autocorrelation in markets. Note that we use the number of trading days, as opposed to actual days to scale volatility (5 trading days per week, and 21 days per month).

For example,

- Weekly volatility $= \text{daily volatility} \times \sqrt{5}$
  $= \text{daily volatility} \times 2.24$
- Monthly VaR $= \text{1-day VaR} \times \sqrt{21}$
  $= \text{1-day VaR} \times 4.58$

Views of the U.S. Federal Reserve

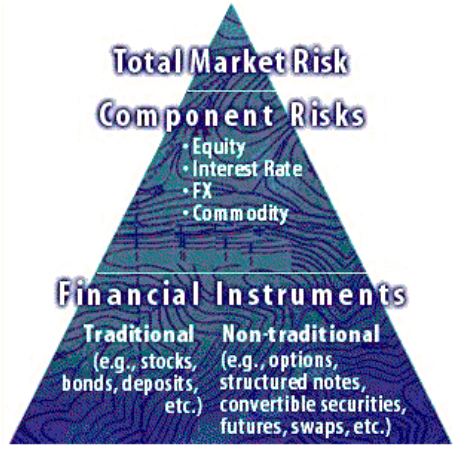
This simple time scaling approach can be useful for converting 1-day management VaR figures to 10-day BIS regulatory VaR standards. Note, however, that the U.S. Federal Reserve is not supportive of this approach, which has prompted some institutions to adopt more accurate methodologies.[9]

[9] For example, the Fed's discouragement of square root of time scaling has prompted J.P. Morgan to calculate 10-day horizon regulatory VaR by basing volatility forecasts on overlapping 10-days of price changes for a 2-year history.

1.6 Components of market risk

Definition of market risk

The BIS defines market risk as "the risk that the value of on- or off-balance-sheet positions will be adversely affected by movements in equity and interest rate markets, currency exchange rates and commodity prices." The main components of market risk are therefore equity, interest rate,[10] FX, and commodity risk.



Source: Managing Risk course

At the top of the pyramid, we have *total market risk*, which is the aggregation of all component risks.

In the middle of the pyramid, we see how financial instruments are driven by the underlying *component risks*.

At the lowest level, market risk arises from fluctuating prices of *financial instruments*.

Residual risks

In addition to market risk, the price of financial instruments may be influenced by the following **residual risks**: **spread risk**, **basis risk**, **specific risk**, and **volatility risk**.[11]

Spread risk is the potential loss due to changes in spreads between two instruments. For example, there is a credit spread risk between corporate and government bonds.

Basis risk is the potential loss due to pricing differences between equivalent instruments, such as futures, bonds and swaps.[12] Hedged portfolios are often exposed to basis risk.

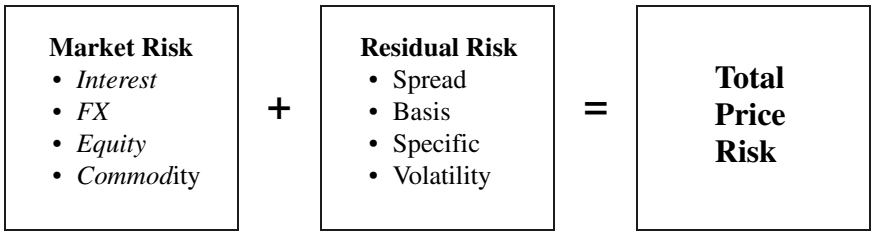
Specific risk refers to issuer specific risk, e.g., the risk of holding Yahoo! stock vs. an S&P 500 futures contract. How to best manage specific risk is a topic of debate. Note that according to the Capital Asset Pricing Model (**CAPM**), specific risk is entirely diversifiable.

Volatility risk is defined as potential loss due to fluctuations in implied option volatilities and is often referred to as "vega risk." Short option positions generally lose money when volatility spikes upward.

[10] Curve risk is a subcomponent of interest rate risk and captures exposure to changes in the shape of a yield curve by calculating interest rate risk for various time buckets.
[11] Some consider credit spread risk and volatility risk to be market risk.
[12] Some consider basis risk as a subcomponent of spread risk.

Total risk

To determine the total price risk of financial instruments, we aggregate market risk with residual risk:



Diversification

Risk is not additive. Total risk is less than the sum of its parts because of diversification between different assets and risk components (i.e., correlation would never be 1). For example, if a USD based investor holds a JPY denominated bond, she is exposed to rising Japanese interest rates and devaluation of JPY relative to USD. Clearly, her total risk is not just the interest rate and FX risk added together, because the likelihood that interest and FX rates both move out of her favor at the same time is less than 100%. This effect is described as **diversification benefit**. Note that we expect high diversification benefit between market and residual risk, due to low correlation.

Definition

Diversification benefit is defined as *total risk* minus the sum of all individual risk components.

Example

The concept of market risk, residual risk and diversification benefit is illustrated in the following risk report:

Portfolio VaR analysis, (All numbers in USD 000s)	**Market risk**				**Residual risk**			***Divers. Benefit***	**Total risk**
	IR	FX	Equity	Cmdty.	Specific	Spread	Vol.		
Aggregate Portfolio	19	94	0	123	400	12	72	***–295***	425
Diversification Benefit	*–198*	*–151*	*–240*	*0*	*–26*	*–2*	*–61*	–	***–266***
Long DAJ Call	2	74	120	–	310	–	50	*–220*	336
Short DAX Call	2	74	120	–	16	–	25	*–114*	123
Long DAJ Callable Bond	111	95	–	–	88	11	20	*-234*	91
Short 5-yr Euro Swap	100	2	–		12	3	–	*–105*	12
Long option on WTI future	2	–	–	123	–	–	38	*–34*	129

Comments

1. Notice how the Short DAX Call hedges the market risk of the long DAJ (DaimlerChrysler) call, but does not affect firm-specific risk ($310). Note that the *Diversification Benefit* reflects the hedge effect between different instruments and risk types.
2. The DAJ Callable Bond is mostly IR hedged with the short Euro Swap, but FX and specific risk is not hedged.
3. The WTI futures position is unhedged.

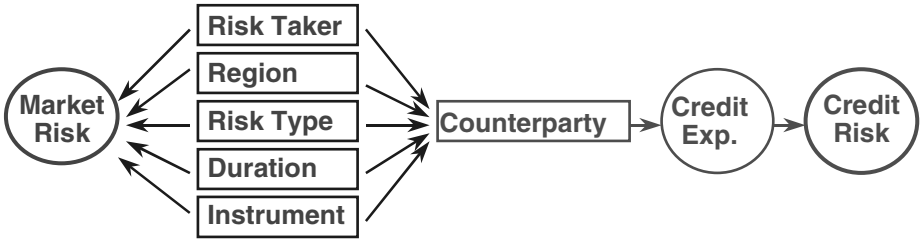
1.7 Basic dimensions of market risk

Risk can be analyzed in many dimensions. Typically, we quantify risk concentrations by:

Dimension	Example
Risk taker	Business unit, desk or portfolio
Risk type	Equity, interest rate, FX, and commodity
Country or region	Europe, Americas, Asia Pacific
Maturity or duration	One week, 1 month, 3 months, 6 months
Instrument type or instrument	Options, forwards, futures, cash
Counterparty	Citibank, Japanese Banks, Thai Corporations

The diagram below illustrates the interrelationship of these risk dimensions. Companies analyze market risk by risk taker, region, risk type, duration (for interest rate risk), and instrument. Fluctuations in market rates can also give rise to counterparty credit exposure and credit risk. Counterparty trading limits should be in place to limit credit exposure due to market driven instruments, such as swaps and forwards. The management of credit exposure for market driven instruments is discussed further in Appendix B.

Key risk dimensions giving rise to market and credit exposures

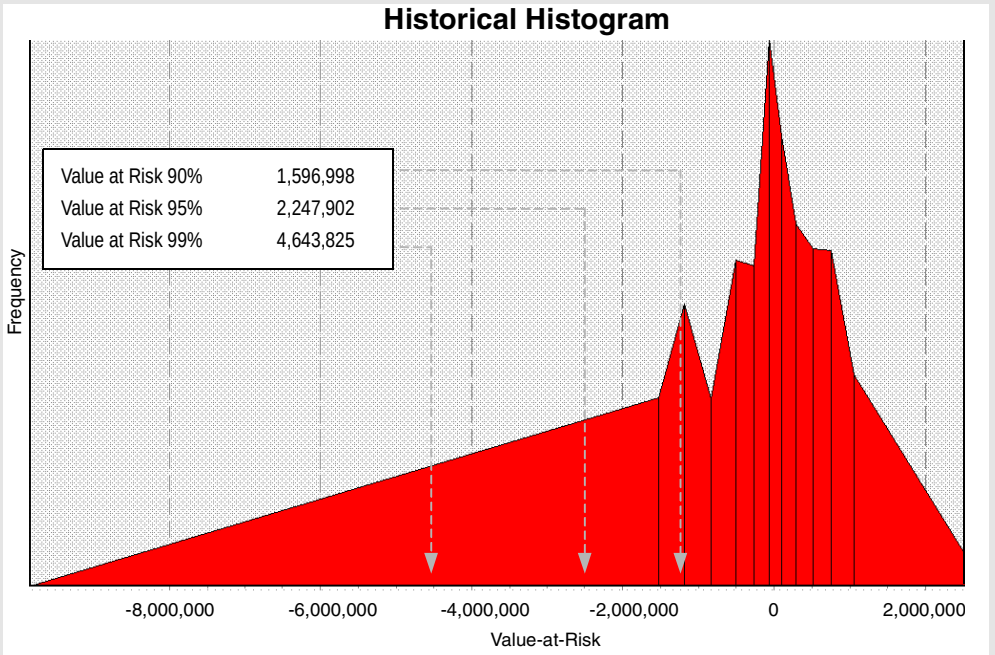


The sample reports in the next pages illustrate different ways to analyze market risk.

Example 1 One of the most common ways to dissect portfolio risk is by region and risk type, as demonstrated below.

VaR: Region vs. Risk Type **April 28, 1999**

RMG



95%, 1-day VaR	Aggregate	*Diversification Benefit*	FX Risk	Interest Rate Risk	Equity Risk
Aggregate	$ 737,190	***–106,562***	178,841	373,118	291,794
Divers. Benefit	***–103,008***		*–2,616*	*–46,981*	*–33,371*
North America	145,729	*–24,054*		97,865	71,919
Europe	165,606	*–120,027*	28,474	82,803	65,191
Japan	104,942	*–121,467*	52,232	52,471	38,334
Emerging Asia	22,727	*–27,185*	12,667	11,364	7,346
Emerging Europe	163,682	*–112,285*	26,552	81,841	61,698
Latin America	187,512	*–171,010*	61,532	93,756	70,676

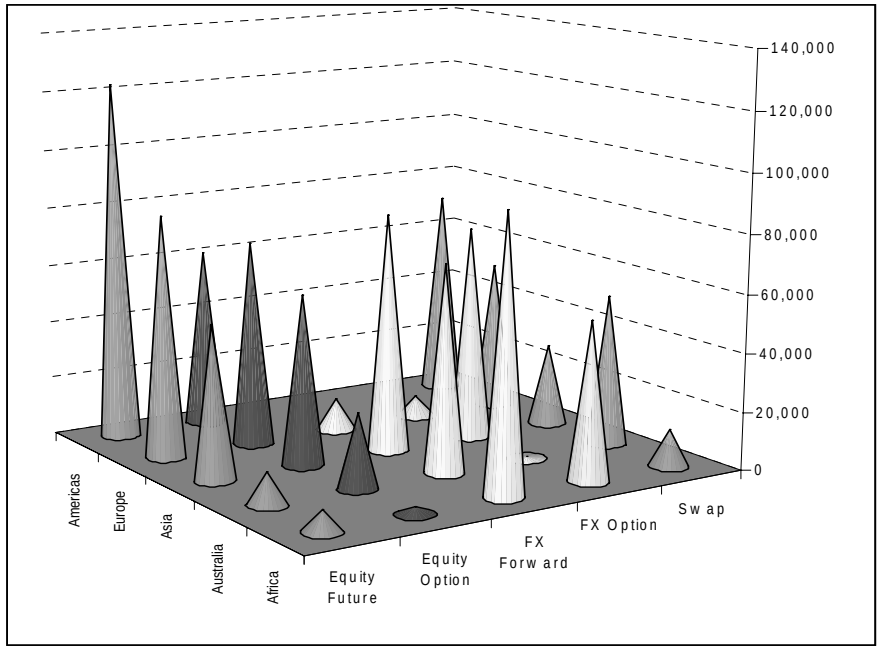
Comments

- Greatest aggregate VaR to Latin America (187,512), followed by Europe (165,606) and Emerging Europe (163,682).
- U.S. shows greatest interest rate risk (97,865) and equity risk (71,919), but no FX risk since base currency is USD.
- Only very small risk positions in Emerging Asia (22,727).

Example 2 Risk can also be analyzed by instrument type, as illustrated below.

VaR by Region and Instrument Type **January 17, 1999**

RMG



99%, 1-day VaR	Aggregate	*Divers. Benefit*	Equity Future	Equity Option	FX Forward	FX Option	Swap
Aggregate	$ 515,085	*–338,234*	220,908	215,598	186,641	101,261	128,910
Divers. Benefit	***–224,643***		*–55,980*	*–3,391*	*–70,996*	*–35,384*	*–88,040*
Americas	186,230	*–70,291*	122,904	61,698			71,919
Europe	145,508	*–78,339*	82,803	70,676	11,364	7,346	51,658
Asia	165,928	*–129,068*	52,471	58,427	81,841	73,783	28,474
Australia	110,681	*–50,129*	11,364	25,569	70,676	969	52,232
Africa	131,381	*–39,554*	7,346	2,619	93,756	54,547	12,667

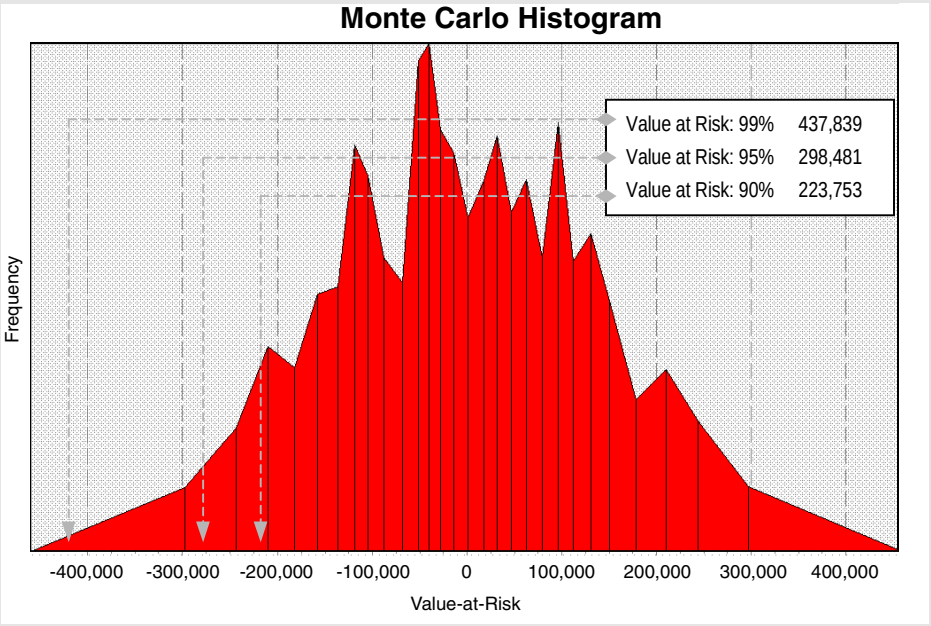
Comments

- The largest instrument risk is to Equity Futures (220,908) and Equity Options (215,598).
- Geographically, risk is well diversified, with the highest activity in the Americas (186,230) and Asia (165,928).

Example 3 Interest rate risk is often presented by maturity or duration bucket to analyze **curve risk**. Curve risk refers to potential losses due to changes in the shape of the yield curve. Below we see a Monte Carlo histogram of returns and a summary of risk vs. instrument type. In this example of a detailed desk level report, swaps and futures are used to hedge the risk of a bond portfolio.

VaR by Maturity **April 28, 1999**

RMG



95%, 1-day VaR	Aggregate	*Divers. Benefit*	Bonds	Swaps	Futures
Aggregate	298,481	***–1,427,188***	914,011	532,429	279,228
Divers. Benefit	*–101,825*		*–783,232*	*–152,032*	*–119,171*
1 to 3 months	12,025	*–200,091*	111,112	101,004	
3 to 6 month	10,957	*–188,618*	103,142	92,136	4,297
6 to 9 months	3,309	*–243,073*	118,810	2,211	125,361
9 to 12 months	137,209	*–119,441*	132,774		123,876
1 to 2 years	67,381	*–26,908*	94,288		
2 to 3 years	34,231	*–289,704*	323,934		
3 to 5 years	2,699	*–332,003*	169,264	165,438	
5 to 10 years	29,643	*–152,508*	152,344	80,867	
10 to 20 years	3,256	*–373,109*	188,111	188,254	
20 to 30 years	99,596	*–454,344*	354,524	54,551	144,865

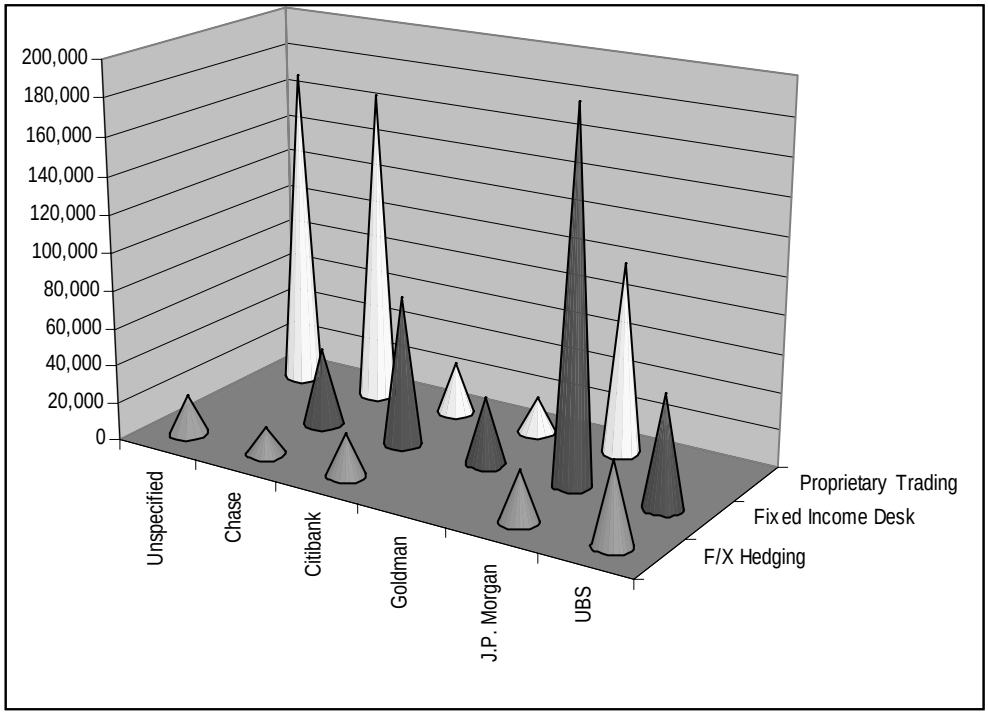
Comments

- In this portfolio, swaps and futures are used to hedge bond positions. For example, see the 1–3 month bucket where bonds and swaps are almost perfectly offsetting (111,112 bond VaR reduced to 12,025).
- Notice the large diversification between instrument types, which indicates hedging activity (–1,427,188 total diversification between instrument types, compared to net aggregate risk of 298,481).

Example 4 VaR can also be analyzed by counterparty to assess potential credit exposure due to market driven instruments. The concept of credit exposure due to market driven instruments such as swaps, forwards and options is explained in more detail in Appendix B.

VaR by Counterparty **June 11, 1999**

RMG



95% 1-week VaR	Total	F/X Hedging	Fixed Income Desk	Proprietary Trading
Total	**476,207**	**64,394**	**341,693**	**294,593**
Unspecified	**170,377**	20,565		170,673
Chase	**166,035**	14,572	40,584	166,026
Citibank	**67,731**	21,837	78,822	27,969
Goldman	**38,943**		35,201	18,578
J.P. Morgan	**208,386**	26,493	192,787	100,558
UBS	**82,094**	43,254	58,647	

Comments

- Largest counterparty exposure is to J.P. Morgan, due to large trades by Fixed Income and Proprietary Trading. There is a 5% chance that our exposure to J.P. Morgan will exceed $208,386 over 1 week.
- Fixed Income Desk is generating the largest total credit exposure ($341,693), followed by Proprietary Trading ($294,593).

1.8 Summary

VaR is a general statistical measure of risk that is used to equate risk across products and aggregate risk on a portfolio basis, from the corporate level down to the individual trading desk. VaR is defined as the predicted worst-case loss at a specific confidence level over a certain period of time.

There are three major methodologies for calculating VaR, each with unique characteristics. Parametric VaR is simple and quick to calculate, but is inaccurate for non-linear positions. The two simulation methodologies, historical and Monte Carlo, capture non-linear risks and give a full distribution of potential outcomes, but require more computational power.

Before calculating VaR, three parameters must be specified: (a) confidence level, (b) forecast horizon, and (c) base currency.

Square root of time scaling of VaR may be applied to roughly extrapolate VaR to horizons longer than 1 day, such as 10 days or 1 month. Square root of time scaling assumes a random diffusion process with no autocorrelation, trending, or mean reversion. Be aware that some regulators are discouraging the use of this simplistic approach. The *LongRun Technical Document* discusses more accurate long-horizon risk forecasting, from 2 months to 2 years.

Financial instruments are subject to both market and residual risks. The four basic components of market risk are interest rate, equity, commodity, and foreign exchange risk. Residual risk includes spread, basis, specific and volatility risk.

Risks can be reported in many dimensions, including risk taker, risk type, region, instrument, and counterparty. In addition, interest rate risk is often analyzed by maturity or duration band.

Chapter 2. Stress testing

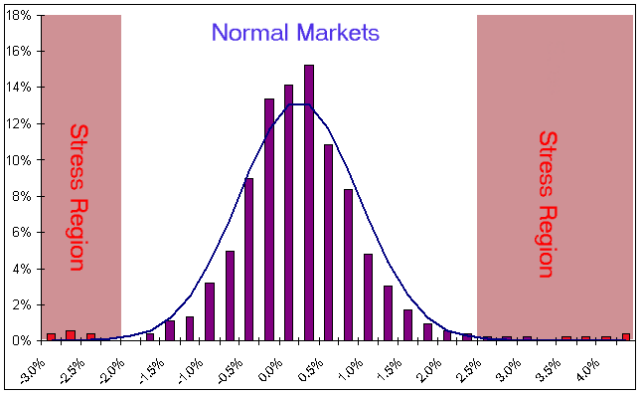
2.1 Why stress test

Stress tests are designed to estimate potential economic losses in abnormal markets. Historical analysis of markets shows that returns have "fat tails," where extreme market moves (i.e., beyond 99% confidence) occur far more frequently than a normal distribution would suggest. Although the discipline of risk management has improved considerably, classical events like natural disasters, wars, and political coups still lie beyond statistical forecasting.

Therefore, regular stress testing is increasingly viewed as indispensable by risk managers and regulators. Stress tests should enhance transparency by exploring a range of potential low-probability events when VaR bands are dramatically exceeded. Stress testing combined with VaR gives a more comprehensive *Picture of Risk*. This sentiment is echoed throughout the risk management community. For example, an excerpt from Chase's 1998 *Annual Repor*t states:

> *Chase's two principal risk measurement tools are VAR and stress testing. VAR measures market risk in an everyday market environment, while stress testing measures market risk in an abnormal market environment…. This dual approach is designed to ensure a risk profile that is diverse, disciplined and flexible enough to capture revenue-generating opportunities during times of normal market moves, but that is also prepared for periods of market turmoil.*
>
> *Source*: Chase Manhattan Corporation

This histogram of the AUD/USD exchange rate illustrates where the focus of stress testing should be. Stress tests should "inspect the tails" of the return distribution. Stress tests could therefore be viewed as a complement to VaR: VaR is for normal markets, and stress tests are for abnormal markets. Together, they paint a broader *Picture of Risk*.

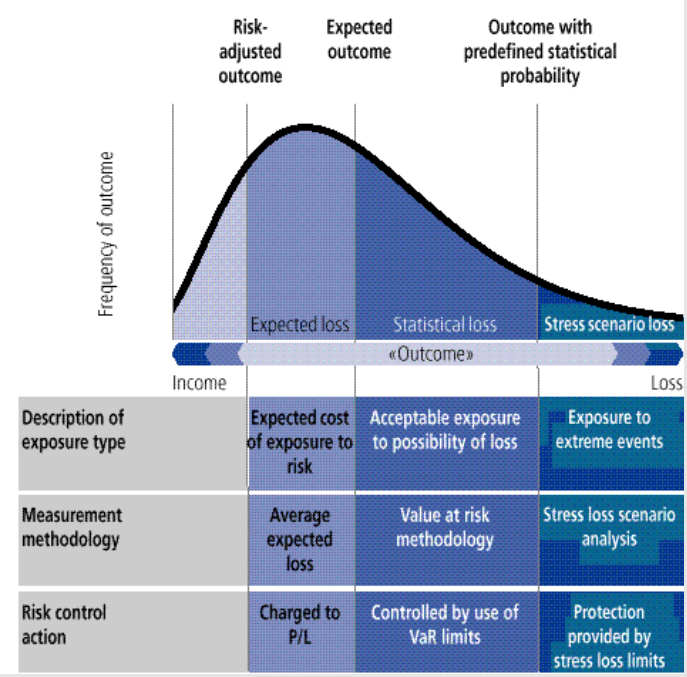


VaRBaR

Stress testing and VaR give a broader *Picture of Risk*

The relationship between stress testing and VaR can be seen in the following diagram, from the UBS Group 1998 *Annual Report*.

Expected, Statistical and Stress Scenario Loss



While UBS uses a value-at-risk measure as the principal measure of its exposure to day-to-day movements in market prices, the experience during the third quarter underlines the fact that these measures are not designed to give an indication of the scale of loss that could occur in the unusual case of extreme market moves. For this reason, UBS supplements its value-at-risk numbers with a system of stress loss simulations in order to monitor its exposure to this type of market shock. These measures seek to assess the scale of loss which UBS might face in the event of large movements in a range of market prices such as equity indices, foreign exchange rates and interest rates. In the light of the events in the third quarter, UBS has revised the range of price changes which it uses to calculate the exposure to stress load and has revised the relevant limit structures.

— UBS Group 1998 *Annual Report*, page 43

2.2 Two central questions for stress testing

Stress tests can be framed around two central questions:

1. **How much** could I lose if a stress scenario occurs, for example the U.S. Equity market crashes?
2. **What event** could cause me to lose more than a pre-defined threshold amount, for example $100 million?

The first question is commonly asked in a top-down approach for stress testing. For example, senior management may ask how much could the firm lose in a major equity market crash.

The second question is best asked at the book or business level. After scenarios are collected from individual risk takers, cross-firm analysis can be done to see if events are diversified or exacerbated. For example, a stress scenario of JPY vs. USD depreciation might be ruled as unimportant due to generally offsetting sensitivities (or no-significant reported sensitivities), while a credit spreads widening scenario could be identified as relevant because many risk-taking units expressed a similar concern. This approach could therefore be viewed as a bottom-

up search for relevant stress scenarios. Relevant stress scenarios should be elevated to the next level of management.

VaRBaR

Searching for vulnerabilities

J.P. Morgan recently introduced a Vulnerabilities Identification (VID) process in which each risk taking unit was asked to (a) qualitatively list what event could cause it to lose more than a specified threshold dollar amount, and (b) assign a probability to each event. The Corporate Risk Management Group (CRMG) polled the entire firm and aggregated the results into a searchable database. CRMG could then conduct cross-firm analysis to see which scenarios were "diversified" away and to identify exacerbating scenarios that many risk taking units were exposed to in common.

Next, J.P. Morgan implemented a web-based VID infrastructure to collect scenarios from risk takers and risk monitors on an ongoing basis. The VID infrastructure reflects hierarchical reporting lines at J.P. Morgan in order to facilitate quick escalation of relevant stress scenarios up the chain of command. For example, with the touch of a button, the head of Fixed Income can log onto the VID system, review stress scenarios submitted by business managers and then escalate relevant stress scenarios to the next organizational level (corporate office). The corporate office therefore receives a filtered collection of critical stress scenarios. Drill-down of stress scenarios, down the reporting line, is also possible. The author of the stress scenario can also be contacted directly for more information.

Efficiently harnessing the firm's collective intelligence, J.P. Morgan's innovative VID process continuously channels relevant stress tests from the bottom up.

2.3 How to use stress tests

The key issue with stress tests is how to create and use them. To be meaningful, stress tests should tie back into the decision making process. Corporate-level stress test results should be discussed in a regular forum by risk monitors, senior management, and risk takers. Just as for VaR limits, companies should have a set of stress loss limits by risk type and risk taking unit. Stress testing should be performed at multiple levels of the micro, macro, and strategic risk pyramid with different frequencies. At a senior management level, stress results should guide the firm's appetite for aggregate risk taking and influence the internal capital allocation process. At the book level, stress tests may trigger discussions on how best to unwind or hedge a position.

VaRBaR

Stress Testing at Chase Manhattan Bank

A descriptive summary of stress testing can be found below in an excerpt from Chase's 1998 *Annual Report.*

Chase's corporate stress tests are built around changes in market rates and prices that result from pre-specified economic scenarios, including both actual historical and hypothetical market events. As with VAR, stress test calculations are performed for all material trading and investment portfolios and market risk-related ALM portfolios.

Stress test scenarios are chosen so they test "conventional wisdom" and focus on risks relevant to the positions taken on Chase's portfolios. A key to the success of stress testing at Chase is continuous review and updating of the stress scenarios. This is a dynamic process that is responsive to changes in positions and economic events, and looks to prior stress tests to identify areas where scenario refinements can be made. Corporate stress tests are performed approximately monthly on randomly selected dates. As of December 31, 1998, Chase's corporate stress tests consisted of seven historical and hypothetical scenarios. These historical scenarios included the 1994 bond market sell-off, the 1994 Mexican Peso crisis and the 1997 Asian markets crisis.

Stress test results are used at all levels of Chase, from the trading desk to the Board of Directors, to monitor and control market risk. Among the controls instituted at Chase are a review of the trading portfolio if potential stress losses exceed Board of Directors-approved advisory limits and the incorporation of stress test exposures into Chase's capital allocation methodology.

2.4 What makes a good stress test

The goal of stress testing is to uncover potential concentrations and make risks more transparent.

Good stress tests should

- be relevant to current positions,
- consider changes in all relevant market rates,
- examine potential regime shifts,
- spur discussion,
- consider market illiquidity, and
- consider the interplay of market and credit risk.

A. Stress tests should be relevant to current positions

Good stress scenarios are designed to stress current positions and probe for portfolio-specific weaknesses. A concentrated portfolio may incur losses from relatively small movements in certain market rates. Therefore, simply stressing portfolios by large movements in generic market rates does not necessarily uncover relevant risks. For example, simulating a simple equity index fall would do little to uncover the risk of a market neutral risk arbitrage book.[1]

In a real world example, Long Term Capital Management (LTCM) had leveraged credit spread tightening positions (i.e., long corporate bond positions were interest rate hedged with short

[1] A market neutral risk arbitrage book would consist of a series of long and short positions, which hedges out market risk but is exposed to firm-specific risk.

Treasurys) in August '98. This portfolio was supposedly "market neutral[2]." A stress test of spread widening (i.e., *flight to safety* phenomenon) would have uncovered the potential for extreme losses.

B. Stress tests should consider changes in all relevant market rates

Stress scenarios should take into account potential changes in a complete set of market rates. A stress scenario in isolation does not reflect reality because market rates don't move in isolation (especially when they are extreme). For example, if we raise the 5-year Euro swap rate by 100 basis points, we need to anticipate potential changes in the rest of the Euro yield curve, other international yield curves, equity markets, and FX rates. Good stress tests represent comprehensive scenarios.

C. Stress tests should examine potential regime shifts

A key question in developing every stress scenario is whether current risk parameters will hold or break down. For example, will observed correlations hold or increase, or could we see a regime shift (i.e., de-coupling of market rates)? For example, during large equity shocks (e.g., '87 crash, '97 and '98 sell-offs), a *flight to safety* often results in a reversal of correlations between stocks and government bonds: as stocks plummet, bonds rise because investors move into safer and more liquid assets.[3] In the market turmoil of September '98, LTCM experienced this problem when credit spreads widened and interest rates fell due to a *flight to safety* [4] (it certainly was not a good time to hedge Corporates with Treasurys). In stress testing, asking the right question (e.g., what could happen), is just as important as providing answers (e.g., what losses would be under those conditions).

D. Stress tests should spur discussion

Stress tests should include some potential rationale for how that adverse scenario could happen, and spur discussion to probe deeper into potential risks. In the case of LTCM, a discussion might have centered on what could happen to cause spread widening and the likelihood of that event. Another discussion might consider how one might best get out of such a concentrated risk position. A good stress test doesn't prevent an event from happening, but it does prepare the risk taker for the possibility and gives the opportunity for taking pre-cautionary measures.

E. Stress tests should consider market illiquidity

Stressed markets are often characterized by significant loss of liquidity. Liquidity can be viewed from two perspectives: the ability to trade positions and the ability to fund positions. Liquidity shocks can be extremely severe in Emerging Markets. For example, Brazilian bond traders reported that bid ask spreads were so wide during the October '97 liquidity crisis that it was unclear whether the local yield curve was upward or downward sloping. When prices in the market place don't exist, it becomes impossible to mark-to-market positions. Furthermore, funding often dries up in these conditions, forcing participants to liquidate positions, which puts even more downward pressure on prices. The inability to fund its concentrated junk bond positions precipitated the demise of Drexel Burnham Lambert in the late eighties. The threat of extreme liquidity risk motivated the recapitalization of LTCM by a consortium of 14 commercial and investment banks in September 1998. In a statement to the U.S. House of Representatives, Chairman Alan Greenspan stated "the consequences of a fire sale triggered by cross-default clauses, should LTCM fail on some of its obligations, risked a severe drying up of market liquidity."[5]

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2 "Market neutral" refers to a trading style that should be uncorrelated to underlying equity and bond markets.

3 Note that correlation between stocks and bonds is generally highly positive.

4 See "Lessons from LTCM" editorial at www.riskmetrics.com.

5 See http://www.bog.frb.fed.us/BoardDocs/Testimony/1998/19981001.htm.

F. Stress tests should consider the interplay of market and credit risk

Stressed markets often give rise to counterparty credit risk issues that may be much more significant than pure market impacts. For example, a market neutral swap portfolio could result in huge credit exposures if interest rates moved significantly and counterparties defaulted on their contractual obligations. While market rates and credit worthiness are unrelated for small market moves, large market movements could precipitate credit events, and vice versa.

2.5 Forecasting time frame

The forecast horizon for the stress scenario should reflect an institution's typical holding period. Banks, brokers, and hedge funds tend to look at a 1-day to 1-week worst-case forecast, while longer-term investors, like mutual and pension funds, may consider a 1-month to 3-month time frame. Corporations may use up to an annual horizon for strategic scenario analysis.

2.6 How often to stress test

It's important to engage in the discipline of regular stress testing and discussion of stress results. Major financial institutions engage in weekly or even daily stress tests. Special stress tests should be performed when there are unusually large or concentrated risk positions and during abnormal market conditions (i.e., when there is unusually high volatility or when there are impending political or economic events). But stress testing should not be performed so frequently and extensively as to become overwhelming and lose meaning.

2.7 Steps for stress testing

There are three basic steps for stress testing.

Step 1: Generate scenarios
The most challenging aspect of stress testing is generating credible worst-case scenarios that are relevant to portfolio positions. Scenarios should address both the magnitude of movement of individual market variables and the interrelationship of variables (i.e., correlation or causality).

Step 2: Revalue portfolio
Revaluing a portfolio involves marking-to-market all financial instruments under new worst-case market rates. Stress test results are generally changes in present value, not VaR.

Step 3: Summarize results
A summary of results should show expected levels of mark-to-market loss (or gain) for each stress scenario and in which business areas the losses would be concentrated.

In addition to summarizing the effect on the present, a comprehensive analysis could estimate longer-term, indirect effects on a firm's well-being. Such business risk analysis would address how a scenario might affect the level of demand for a business's products and services. For example, during an equity market downturn, one might consider the indirect loss from lower demand for equity underwriting in addition to the direct losses on trading and investment positions.

In considering the anticipated short-term and long-term results of the stress analysis, management can decide whether (and how) the risk profile of the firm should be changed.

Example: Brazilian Company

We illustrate the three steps of stress testing with the following example.

You are a Brazilian consumer products company with a significant amount of unhedged USD-denominated liabilities. You are particularly concerned about the stability of the Brazilian Real (R$), because a devaluation would make USD liabilities prohibitively expensive.

Step 1: Generate scenarios

Your economist presents two potential events:

1. A significant widening of the trade deficit, which puts pressure on the local currency, interest rates, and equity market
2. A narrowing of the trade deficit, which is a positive scenario for local markets

Following are the economist's estimates of the effect of each scenario on the local markets over 1 day:

Stress scenarios	Widening trade deficit	Narrowing trade deficit
R$/US$ exchange rate	up to 20% devaluation	no move
R$ yield curve	interest rates up 50%	interest rates down 25%
BOVESPA equity index	15% fall	10% appreciation

Step 2: Revalue position

The next step involves revaluing the company's financial positions given new market rates. Financial exposures would include all USD and R$ assets and liabilities, as well as equity investments.

P&L (in R$ millions)	Widening trade deficit	Narrowing trade deficit
R$/US$ exchange rate	–20	0
R$ yield curve	+ 5	–2
BOVESPA equity index	– 9	+6
Total	**–24**	**+4**

Step 3: Summarize results

A devaluation scenario could result in a direct financial loss of R$24 million for the company, while a narrowing of the trade deficit could yield a financial gain of R$4 million over 1 day.

Furthermore, management should assess how each scenario might affect underlying business. For example, although a devaluation might hurt domestic sales, it could make exports into other markets more competitive.

Management should then discuss whether it should take action to reduce its risk. The largest potential loss comes from the unhedged USD liabilities—for example, this could be reduced through an FX forward hedge or by purchasing a put option on R$ vs. dollar.

2.8 Creating stress scenarios

There are a variety of approaches to generating stress tests, which we discuss in turn: (a) generating historical scenarios based on days when markets moved violently, (b) introducing market shocks and moving risk factors in isolation by large amounts to gauge sensitivity to each risk

factor, (c) creating anticipatory scenarios in which many market factors are moved in a consistent fashion to approximate real moves of all relevant world markets, and (d) setting up portfolio-specific stress tests, which are based on the weaknesses of the portfolio itself.

Within this framework of scenario generation, we discuss three concepts that are relatively new to stress testing: (1) predictive scenario generation in which a subset of stressed risk factors is used with historical correlations to predict the moves of all other market variables, (2) VaR with stressed volatility and correlations, and (3) portfolio weaknesses as determined by Monte Carlo simulation.

A. Using relevant historical scenarios

A natural approach is to base scenarios on historical periods with extreme market conditions. Some infamous events include: the '87 U.S. stock market crash, the ERM crisis, the Fed rate hike in '94, the '95 Tequila crisis, the '97 Asian crisis, the volatile markets in '98, and the '99 Brazil devaluation. In this approach, data is captured from relevant historical stress periods and a portfolio is valued with historical simulation to measure potential losses.

RiskMetrics research has assembled a representative global model portfolio consisting of 60% equities and 40% fixed income to identify pertinent time periods for historical stress tests. Both 1- and 5-day portfolio returns were used to identify extreme loss periods.

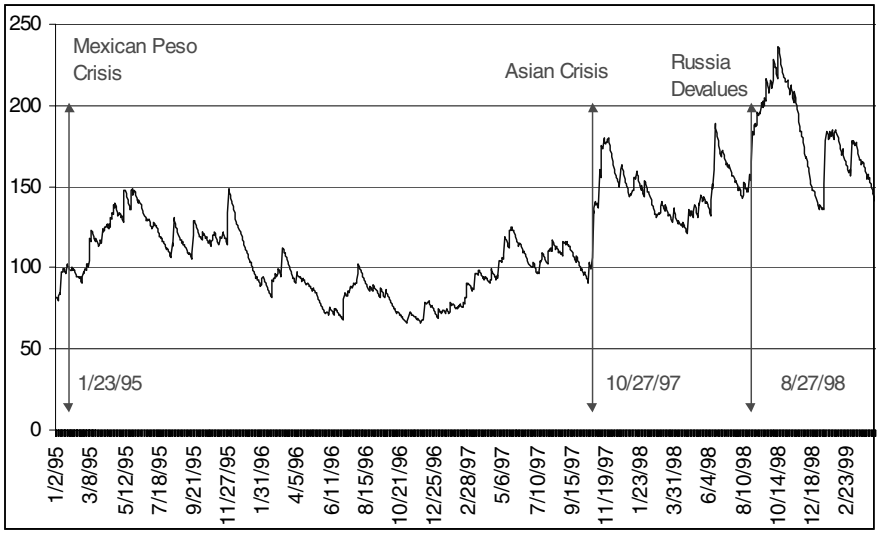
Sample historical scenarios

	Date	1-day return, %	Date	5-day return, %
Black Monday	19-Oct-87	–2.20	20-Oct-87	–5.9
Gulf War	3-Aug-90	–0.90	27-Aug-98	–3.8
Mex Peso Fallout*	23-Jan-95	–1.00	23-Jan-95	–2.7
Asian Crisis	27-Oct-97	–1.90	7-Aug-90	–3.6
Russia devalues	27-Aug-98	–3.80	27-Oct-97	–2.6

* The Mexican peso actually devalued at the end of '94. On 23-Jan-95, the peso lost 6% and several Eastern European markets incurred losses of around 5% to 10%.

Source: A. Ulmer, 1999, unpublished research, RMG

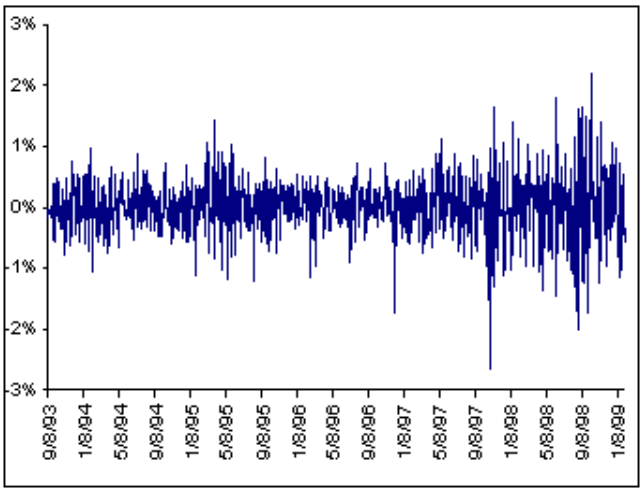
How does the severity of loss depend on global volatility? This figure shows the RiskMetrics Volatility Index (RMVI)[6] for a period which includes three of the historical scenario dates.



Source: DataMetrics

Volatility breeds shocks

Notice that the severity of portfolio losses appears to be related to the level of volatility in the world, as measured by the RMVI. For example, the Mexican peso fallout, which occurred during a period of relative market calm when RMVI was at an average level of approximately 100, only resulted in a 1-day return of –1%, while the Asian Crisis and Russia Devaluation, which occurred while the RMVI was significantly above 100, resulted in more severe portfolio losses of 1.9% and 3.8%. This suggests that it make no sense to run the same static stress tests in all market regimes—more volatile markets require more severe stress tests. To make stress scenarios more responsive to market conditions, the RMVI can be used as a dynamic scaling factor for stress scenarios, as discussed in the next section.



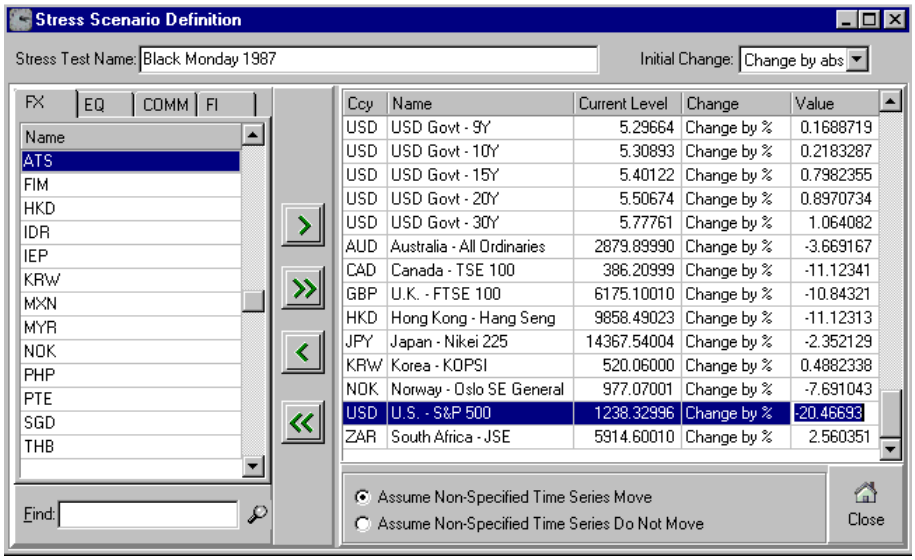
Source: A. Ulmer, 1999, unpublished research, RMG

As further evidence that extreme market moves tend to be larger when market volatility is high, observe the graph of daily returns of our global equity and fixed income test portfolio: large shocks from ’93 to ’96 result in portfolio losses of no more than 1%, while shocks in ’97 and ’98 result in portfolio losses of 2% to 3%. Volatile regimes seem to breed larger shocks.

Historical stress tests and data can be accessed and created in RiskMetrics RiskManager. RM’s stress testing module includes historical stress scenarios tabulated from the perspective of a wide range of base currencies. Because historical data may not exist for all factors (such as many swap rates whose markets were still developing in 1987), RM supplies a method to estimate likely changes in the unknown factors based on present-day correlations. This method is based on the predictive scenario generation, which is described in Section C on page 33, “Anticipatory scenarios.”

In the example below, part of the 1987 Black Monday scenario is presented from an RM screen. Alternatively, one may designate a set of stressed returns based on DataMetrics data by choosing start and end dates for a historical stress test.

[6] The RiskMetrics Volatility Index measures global volatility. The RMVI is composed of equity, fixed income, and foreign exchange markets in 28 countries, as well as three major commodity markets. Observing the daily returns of these 87 markets, we calculate a total volatility across all countries and asset classes and compare it to a historical average. See our web site, http://www.riskmetrics.com and, in particular, the document *RMG Volatility Index: Technical Document,* by Finger, 1998.



B. Applying shocks to market factors or correlations

A second approach to generating stress tests is to shock either market factors or volatilities and correlations by large amounts. This method can provide a good measure of the sensitivity to risk factors and can therefore be useful in identifying trouble spots in a portfolio.

It is straightforward to alter a market rate (e.g., lower the S&P 500 by 10%) or many market rates (e.g., lower all points on the U.S. government yield curve by 50 basis points), but the real challenge is to determine both which market rates to shock and by how much to shock them. In general, these decisions will be based on historical moves, on intuition, and the portfolio itself.

We first illustrate the example of applying shocks to market rates, followed by an example of changing the correlations.

Shocks to market rates example

Below, we show an example of a market shock stress test in which the P/L is considered by both asset class and region. The example shows the effects of both a bull and a bear market on a portfolio.

Geographic region	Interest rates	Equities, %	FX, %
North America	+80bp / –80bp	+/– 8	+/– 10
Europe	+100bp / –100bp	+/– 10	+/– 10
Japan	+50bp / –25bp	+/– 10	+/– 10
Emerging Asia	+250bp / –200bp	+/– 25	+/– 20
Russia & Eastern Europe	+400bp / –300bp	+/– 30	+/– 25
Latin America	+1000bp / –500bp	+/– 35	+/– 20

We can use these scenarios as a basis for stress testing various portfolios. For example, a Global Bank portfolio stress test may look as follows.

Global Bank 1-Day Stress Test ***Tuesday, March 16, 1999***

Global Bank Stress Analysis
(one-day worst-case market moves)

Geographic Region	Interest rates		Equities		FX		Net by Region
	Move, bp	P/L ($mm)	Move, %	P/L ($mm)	Move, %	P/L ($mm)	
North America	80	–5.6	–8	–5.8	–10	–1.5	–10.1
	–80	5.0	8	5.2	10	1.3	12.0
Europe	100	–8.7	–10	–4.6	–10	–1.3	–14.0
	–100	7.0	10	3.7	10	1.1	14.6
Japan	50	4.0	–10	3.0	–10	1.4	9.1
	–25	–3.0	10	–2.5	10	–1.6	–3.5
Emerging Asia	250	–2.0	–25	–3.2	–20	–0.1	–5.0
	–200	1.8	25	2.9	20	0.1	4.9
Russia & Eastern Europe	400	5.0	–30	–3.3	–25	3.1	5.3
	–300	–4.0	30	2.3	25	–2.2	–3.7
Latin America	1000	–12.0	–35	–4.0	–20	5.0	–10.7
	–500	8.0	35	6.0	20	–2.0	13.9
Total	**Up**	**–19.3**	**Down**	**–17.9**	**Down**	**6.3**	**–26.6**
Portfolio	**Down**	**20.8**	**Up**	**17.6**	**Up**	**–3.2**	**37.0**

Stress Test Commentary

- Overall economic sensitivities to stress scenarios are within tolerance limits: daily loss in a global bear market scenario is estimated at $26.6 million, and gain in a global bull market scenario is $37 million.
- Largest asset class exposure is interest rates (–$19.3/20.8), followed closely by equities (–$17.9/17.6).
- Largest regional exposure to a bear market is Europe (–$14.0), followed closely by North America (–$10.1) due largely to corporate bond inventories by N.Y. and London Fixed Income.
- Note net short position in Japan and Russia across asset classes (i.e., losses in a bull market).
- Note also short position in Latin America FX ($5.0) largely through real/USD puts, coupled with long positions in Brady bonds (–$12.0) and equities (–$4.0) by Emerging Markets.
- Note that the individual gains and losses in a row do not, in general, add up to the Net by Region entry (even without non-linear positions), because losses are generally lessened by big moves whereas gains are accented. For example, when the European equities fall by 10% and the FX rate decreases by 10%, the drop in value of a pure equity portfolio when both of these events occur is smaller than 20%, because the equities lose 10% of their value initially, and then lose 10% of their reduced value to FX.

RMVI scaling

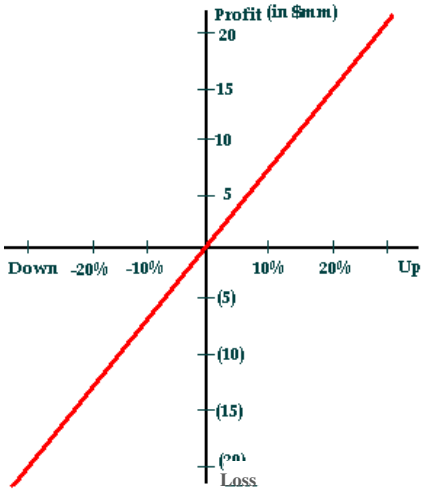
One way to make parameter-shocking better reflect current market conditions is to link the magnitude of extreme market scenarios to the RMVI level. More severe stresses would be applied during volatile markets, and smaller stresses in calm markets. For example base case stress scenarios could be developed for an RMVI level of 100 and scaled linearly to reflect higher or lower volatility (e.g., RMVI level of 150 could reflect stress scenarios of 1.5 times base case).

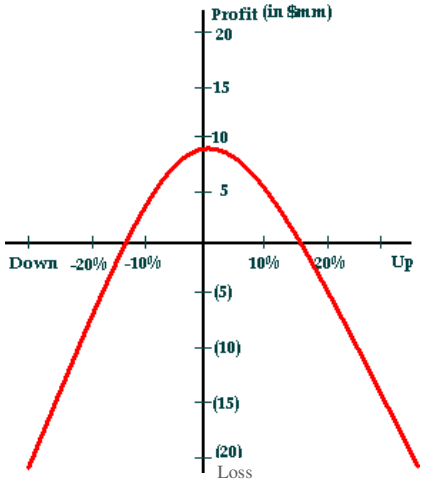
Sliding scales

Another approach to stress testing is to create a sliding scale of P&L vs. key market variables. The Y-axis shows P&L and the X-axis shows change in benchmark market variables: equity, interest rate and commodities indices, and FX rates. Sliding scales are very useful for complex positions with non-linear payoffs long or short option combinations. Sliding scales can be used to test portfolio vulnerabilities: particularly for derivatives portfolios, it is important to understand sensitivities to key market rates and parameters.

For example, a hedge fund may show the following sliding scales for its proprietary positions:

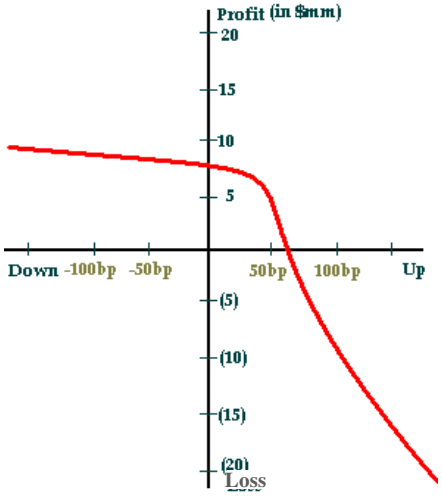
Comments:
This is a classic long asset position, where profits rise and fall linearly with markets.

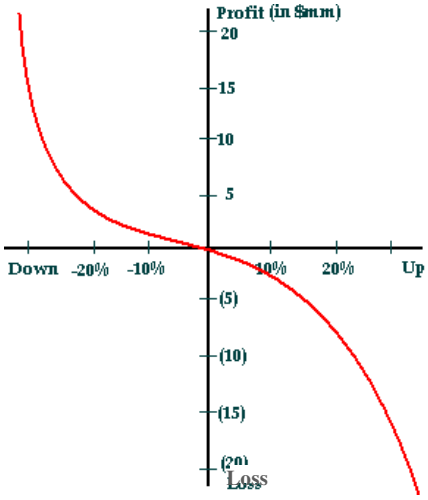




Comments:
This payoff resembles a short strangle (short call and put). The position is profitable if the market stays calm, but loses money if there are large movements either way.

Comments:
This position is sensitive to U.S. rates rising by more than 50 basis points. This could be due to a short cap, or a short put on a bond.





Comments:
This payoff resembles a short out-of-the money call and a long out of the money put. This bearish position makes money if oil futures fall and loses if oil prices rise.

Shocks to volatilities and correlations

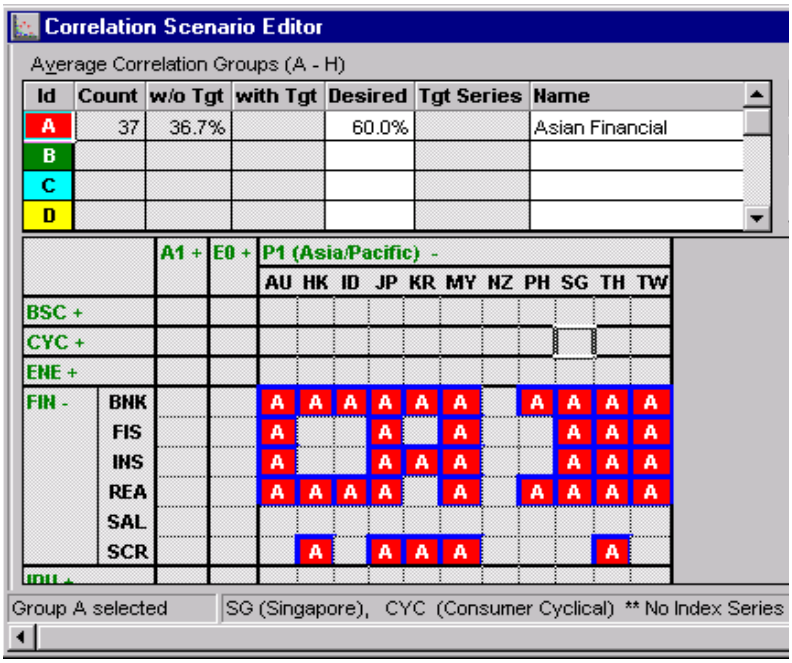
VaR estimates can be stressed by applying shocks to volatilities or correlations. While volatilities can be adjusted up and down like market rates, special care must be taken with correlation matrices because nonsensical correlation structures can often be created from the interrelationship between factors. These correlation structures can, in turn, result in nonsensical VaRs (imaginary).

For example, consider a three-party government. If party A and party B always vote in opposite directions (correlation of –1), it is impossible for party C to be positively correlated with both A and B. RiskMetrics research has published a methodology to adjust correlations in a mathematically consistent fashion. The general idea is to mix in an average correlation term into a prespecified group of assets, and then to adjust all diagonal terms (see the *RiskMetrics Monitor*, Q4 ’97).

Correlation example

This methodology is implemented in CreditManager, where it can be used to change the average correlation among industries and countries. In the example below, we show a stress test where the average correlation between Asian financials is increased from 37.6% to 60%. The boxes marked “A” indicate the factors that were selected to be in this group of increased correlation.

Detail from CreditManager Correlation Scenario Editor



C. Anticipatory scenarios

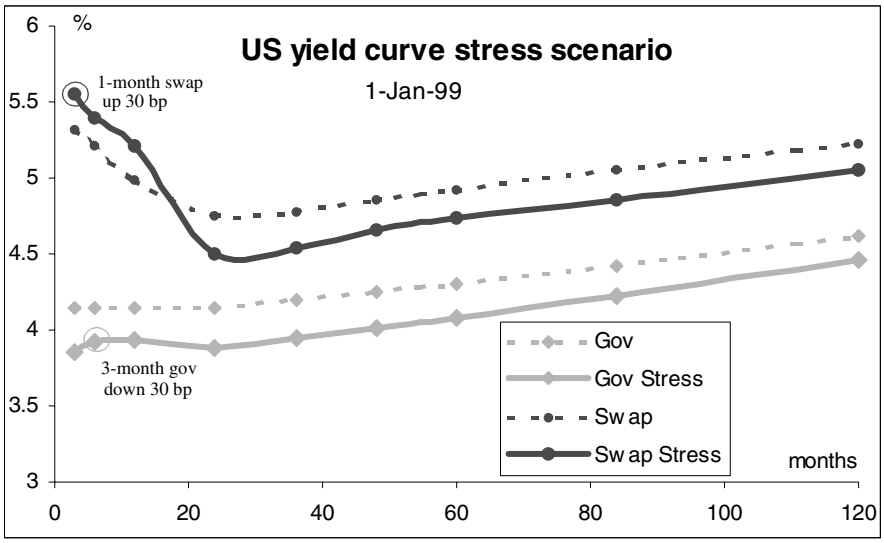
In generating an anticipatory scenario, a risk manager must determine (1) the event of interest (e.g., flight to quality within Asian markets, stock market crash), (2) the severity of the event, (e.g., from once-in-a-year to once-in-a-decade), and (3) the effects of such an event on the global market. For the third determination, it is essential to move all market rates in a consistent fashion, e.g., in a flight to quality, not only will government/corporate spreads widen, but equity prices will fall.

Generating a stress scenario

Below we conduct a stress test of short-term swap spreads widening on January 1, 1999, in order to forecast 1-day portfolio losses using the RM stress module. Note that a swap spread widening scenario is a simulation of the *flight to safety* phenomenon, where we would expect risky assets to fall. We increase 1-month swap rates by 30 basis points, lower 3-month government rates by 30 basis points, and let RM estimate the likely effect on other yield curve points and market rates based on historical correlations from January 1, 1999 to July 1, 1998.

Estimating impact on relevant market variables

Below are the original and stressed government and swap yield curves. Observe how the swap yield curve twists around the 18-month mark, with short-term yields higher and longer-term yields lower.



Forecasted stress effects on other market variables are given by the 1-day returns in the table below:

1-day return, %	Asset class
–7.80	U.S. - S&P 500
–8.76	Spain - IBEX 35
–17.59	Argentina - SE Blue Chip
–6.44	THB
–5.44	Sweden - OMX
–5.23	Mexico - IPC
–5.22	Singapore Dollar
–4.23	Germany - DAX
0.42	Japan - Nikei 225
–5.00	France - CAC 40
–3.79	JPY
–0.95	GBP
0.22	FRF
0.22	DEM

This stress scenario is largely consistent with a *flight to safety* phenomenon.

The impact on equity markets is bearish: U.S. equity markets plummet by 7.8%, and Europe and Latin America also suffer large losses.

In FX, Thai baht, JPY, and Singapore dollar depreciate significantly (vs. USD). FRF and DEM move by the same amount due to Euro peg, while GBP depreciates by 0.95%.

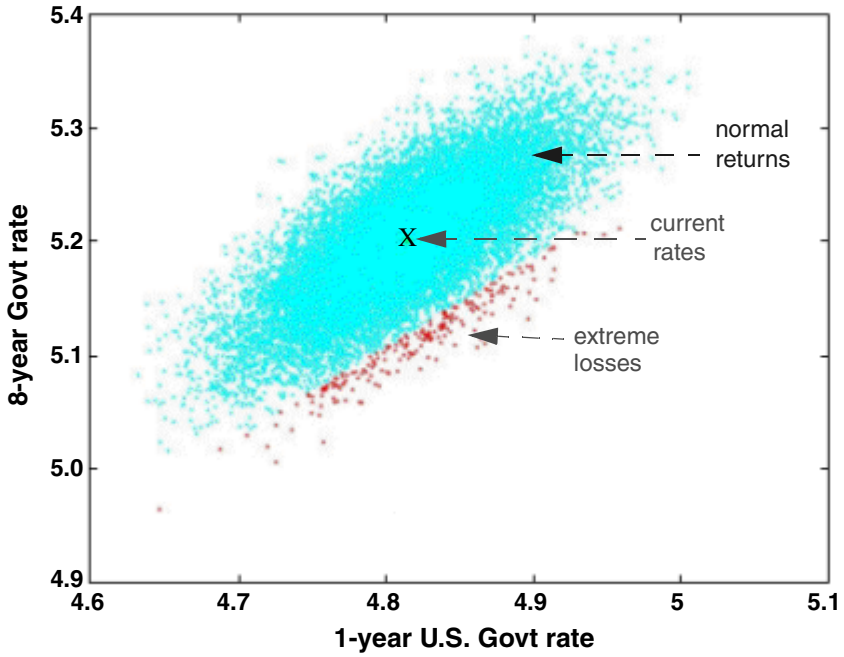
The next step in the stress test would be to re-value the portfolio under the above scenario, and to analyze sensitivities and summarize the results.

D. Applying portfolio-specific stress tests

Another stress testing approach searches for stress scenarios by analyzing the vulnerabilities of the specific portfolio in question. One way to discern the vulnerabilities is by conducting a historical or Monte Carlo simulation on a portfolio, and searching for all scenarios that could cause a loss exceeding a defined threshold amount. Instead of specifying the scenario and calculating potential losses as in the three approaches described previously, we specify what constitutes a severe loss and search for scenarios.

To illustrate this approach, consider a long 1-year note and a short 8-year note position. We run a Monte Carlo simulation and highlight the 5th percentile worst-case losses. We can see that losses are worst when long-term rates fall relative to short-term rates—that is, we are exposed to a tilt in the yield curve. In more complex portfolios, the tail events may cluster into a number of groups. These weak spots should be considered in stress tests.

Monte Carlo simulation result of 1-year vs. 8-year rates



VaRBaR

External disclosures of stress tests

To provide investors with greater risk transparency, companies may provide stress scenarios and sensitivities.

1. Citicorp interest rate stress test

Citicorp Earnings-at-Risk (impact on pre-tax earnings)

In Millions of Dollars at December 31, 1998	Assuming a U.S. Dollar Rate Move of Two Standard Deviations Increase	Assuming a U.S. Dollar Rate Move of Two Standard Deviations Decrease	Assuming a Non-U.S. Dollar Rate Move of [1] Two Standard Deviations[2] Increase	Assuming a Non-U.S. Dollar Rate Move of [1] Two Standard Deviations[2] Decrease
Overnight to three months	$ (85)	$ 87	$ (23)	$ 23
Four to six months	(34)	38	(30)	30
Seven to twelve months	(29)	31	(40)	40
Total overnight to twelve months	**(148)**	**156**	**(93)**	**93**
Year two	(28)	22	(51)	51
Year three	12	(22)	17	(16)
Year four	54	(64)	22	(21)
Year five	119	(152)	24	(23)
Effect of discounting	(29)	39	(26)	26
Total	**$ (20)**	**$ (21)**	**$ (107)**	**$ 110**

(1) Primarily results from Earnings-at-Risk in Thai baht, Singapore dollar and Hong Kong dollar.
(2) Total assumes a standard deviation increase or decrease for every currency, not taking into account any covariance between currencies.

In its 1998 *Annual Report*, Citicorp discloses a simple interest rate stress test, which consists of perturbing interest rates by 2 standard deviations. Although this simple analysis is not comprehensive, shareholders and analysts get a rough perspective of Citicorp's Net Interest Earnings (NIE) sensitivity to domestic and foreign interest rates.

2. UBS Group stress scenarios

Country	Foreign exchange	Interest rates	Equity
	Price	Libor/Govt.	Price
Europe	+/– 10%	+/– 100 bps	+/– 15%
North America	+/– 5%	+/– 120 bps	+/– 15%
Japan	+/– 15%	+/– 100 bps	+/– 25%
Emerging markets	+/– 40%	+500/– 300 bps	+/– 40%

(+) = Market appreciation. (–) = Market depreciation.

UBS Group reveals a sample of its stress scenarios in its 1998 *Annual Report*. However, loss levels are not indicated.

2.9 Summary of stress tests

Most models make assumptions that don't hold up in abnormal markets. Stress tests are therefore essential for a comprehensive *Picture of Risk* and should be an integral component of the risk analysis and communication.

As with VaR analysis, stress testing must be done at different levels of the organization. The organizational hierarchy for stress testing is even more important than for VaR reporting. At the

desk level, traders are interested in stressing individual positions and specific risk factors. On a corporate level, senior management is concerned about macro stress scenarios that could pose a threat to firmwide operations.

The process of generating and discussing stress scenarios is a collective exercise in risk analysis. Stress tests are an opportunity to consider scenarios that most view as unlikely, but are possible. Make stress tests workable, realistic, and timely. Rather than stress everything, focus on relevant position-specific stresses. It is important for stress tests to tie back to the decision making process: stress results should guide corporate risk appetite decisions, impact limits, and be a judgmental factor in capital allocation.

Stress testing can be viewed from two perspectives: what would be the potential losses if certain events occurred, or what stress events could lead to losses of a certain magnitude? There are four major approaches for generating stress scenarios. The first uses historical scenarios and the second shocks market rates to examine portfolio sensitivities and concentrations. The third approach considers hypothetical future scenarios, based on current market conditions. The fourth approach searches for stress scenarios by analyzing portfolio vulnerabilities.

Chapter 3. Backtesting

3.1 Why backtest

Models are designed to reflect reality. **Backtests** compare realized trading results with model-generated risk measures, both to evaluate a new model and to reassess the accuracy of existing models. Although no single methodology for backtesting has been established, banks using internal VaR models for market risk capital requirements must backtest their models on a regular basis. The BIS imposes a penalty on institutions whose VaR models perform poorly. Banks generally backtest risk models on a monthly or quarterly basis to verify accuracy. In these tests, they observe whether trading results fall within pre-specified **confidence bands** as predicted by VaR models.[1] If the model performs poorly, they probe further to find the cause (e.g., check integrity of position and market data, model parameters, methodology).

Risk measurement can always be improved. The pragmatic question is whether the improvement in performance is worth the investment. Backtesting can help in this cost benefit analysis.

Example

For example, due to data constraints a dealer might be forced to use the HKD swaps yield curve to approximate the risk of HKD government bonds. Hypothetical backtests of VaR vs. P&L could show the difference between using a swaps or government curve. If VaR using actual government yields is not noticeably better, it may not be worth upgrading the data model.[2]

To mirror the three levels of internal VaR reporting, backtesting of risk models should be performed from the corporate to the desk level. The most important backtest is that of total diversified trading revenues at the corporate level—it shows how well the total aggregation of VaR estimates works. Corporate level backtesting is also necessary when using VaR to comply with **BIS market risk capital requirements**. The BIS outlines backtesting best practices in its January 1996 publication *Supervisory framework for the use of 'backtesting' in conjunction with the internal models approach to market risk capital requirements.*[3]

Some key issues to consider for backtesting include the following:

- What P&L measures to use?
- What to compare VaR against? Zero P&L or expected P&L?
- How to treat market-making businesses vs. pure proprietary trading businesses

3.2 Backtesting VaR vs. actual P&L

Financial control should keep a database of daily VaR and mark-to-market trading revenues for all trading desks and business units. Trading revenues should be defined as the change in mark-to-market in positions, plus any trading-related interest income or other revenue. The most straightforward way to backtest is to plot daily P&L against predicted VaR and to monitor the number of **excessions**, or departures, from the confidence bands. Hypothetical results, or "No-action P&Ls" may also be used for backtesting. No-action P&L assumes that we keep today's positions until the forecast horizon, at which point they are re-valued. Preferably, 90 days or

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1 See the *RiskMetrics Technical Document*, pp. 219–223.

2 Note that positions reflecting typical trading strategies should be used for backtesting; a portfolio where HKD swaps are hedged with HKD government bonds (e.g., long and short positions) is different from a long swaps and bond portfolio. In the hedged portfolio, we have basis risk between swaps and government bonds, which can only be captured if you have both swaps and government curves. A backtest would show this.

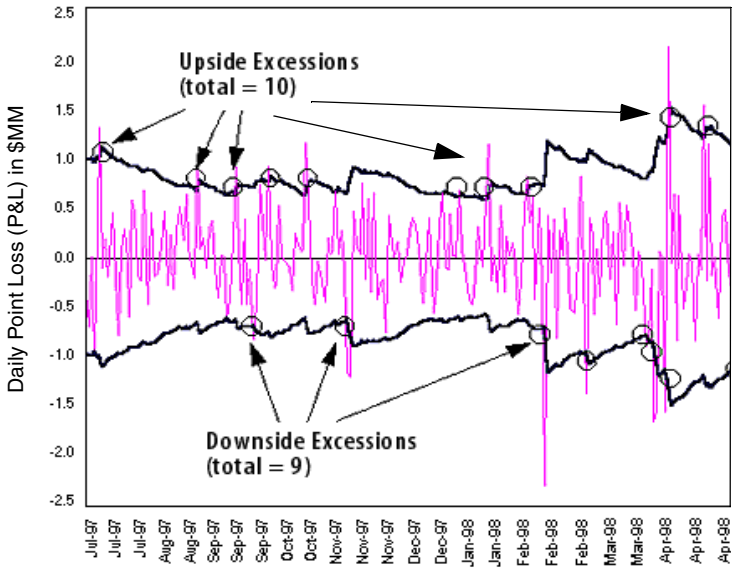
3 Document is available at http://www.bis.org/publ/index.htm.

more of history should be available for backtesting. According to the BIS, national regulators should use the number of excessions over the most recent 12 months of data (or 250 trading days) as the basis for supervisory response. Excessions should be within confidence level expectations: if you have a 1-day 95% confidence VaR, you should expect about 5% downside excessions over time. If actual excessions are significantly different, you can take steps to track down the source of error.

Example

In the example below, we see that the backtest results for Global Bank are reasonably close to expectation: 4% downside excessions instead of 5%.

Daily P&L (–) vs. predicted 95% confidence VaR (▬)



	Upside excessions	Downside excessions
Number	10	9
Percentage	4%	4%

VaRBaR

Confidence levels and backtesting

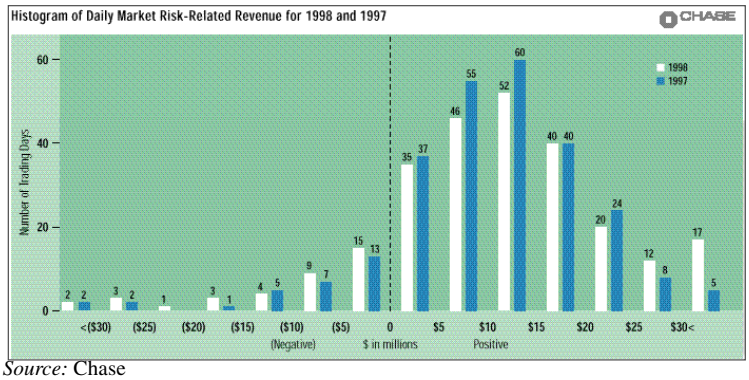
A 95% daily confidence level is practical for backtesting because we should observe roughly one excession a month (one in 20 trading days). A 95% VaR represents a realistic and observable adverse move. A higher confidence level, such as 99%, means that we would expect to observe an excession only once in 100 days, or roughly 2.5 times a year. Verifying higher confidence levels thus requires significantly more data and time. Even if your firm calculates VaR based on a high confidence level, it may make sense to test at other confidence levels as well in order to dynamically verify model assumptions (e.g., test at 90%, 95%, 97.5%, 99%).

An even better test would be to compare the actual distribution of returns against the predicted distribution of returns (i.e., how close is the picture of predicted risk to the actual risk). Such an approach for testing VaR models was proposed by Drachman and Crnkovic of J.P. Morgan. Instead of just checking excessions at a specific confidence level (e.g., 95%), the model tests all confidence levels, compares the distribution of forecasting errors against the uniform distribution, and assigns a "Q-Test" score between 0 and 1, with a lower score being better. For a full description of the methodology, see "Quality Control" in the September 1996 issue of *Risk Magazine*.

3.3 Accounting for non-position-taking income

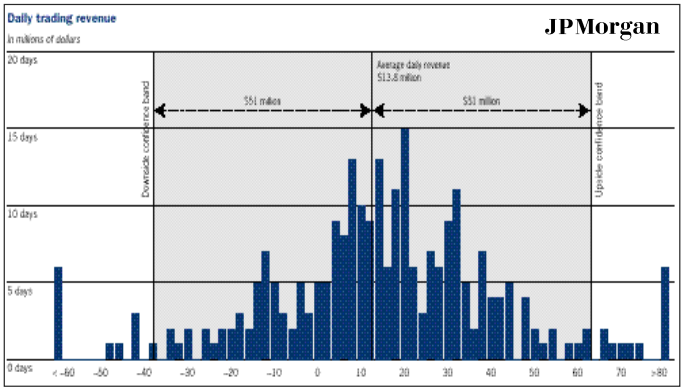
One debate among risk practitioners centers on how to account for non-position-taking income, such as fees. When backtesting VaR models, many financial institutions find that VaR tends to overestimate losses when compared against zero expected revenues, particularly on market-making books. Market-making books derive significant revenues from client flows, where firms can often earn a spread without taking directional views. To account for such non-position-taking franchise revenue, revenues can be backtested against VaR relative to expected revenues, instead of zero.

For example, if 95% confidence VaR on March 24, 1999 is $3 million, and average daily revenues are $0.5 MM, the 95% confidence bounds for that day would be –$2.5 million and +$3.5 million (not –$3 million and +$3million). It makes theoretical sense to take into account expected revenues because risk can be defined as unexpected loss, or deviation from expectation.

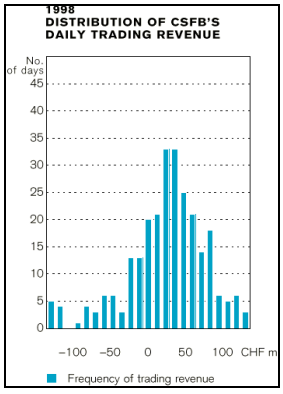


Source: Chase

Non-position-taking factors are significant especially for banks with strong market-making franchises. For example, notice the positively centered revenue distributions of Chase, CSFB, and J.P. Morgan, as published in their respective annual reports.



Source: J.P. Morgan



Source: CSFB

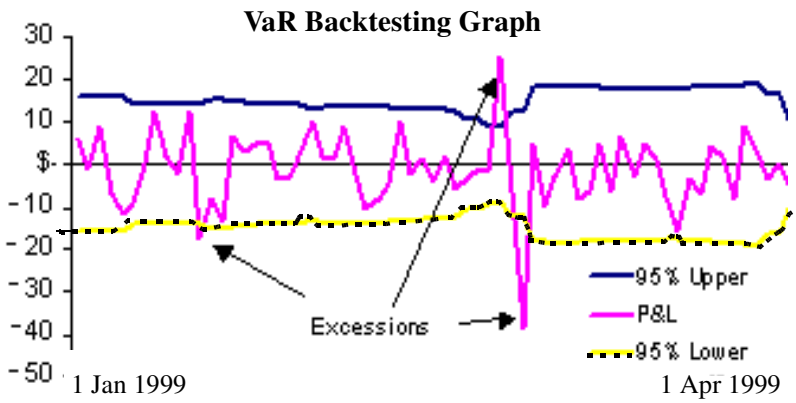
3.4 Backtesting VaR vs. hypothetical trading outcomes

The Basle Committee encourages financial institutions "to develop the capability to perform backtests using both hypothetical and actual trading outcomes." Hypothetical results, or "No-action P&Ls," are particularly useful for longer-horizon VaR estimates. For example, backtesting a 10-day horizon VaR for banks makes more sense with No-action P&Ls than with actual trading results because positions vary greatly on a daily basis.

Backtesting against No-action P&Ls follows the same format as testing against actual trading results.

Example **VaR vs. No-action P&L**

This test of hypothetical trading revenues shows only one upside (1.7%) and two downside excessions (3.3%) in over 60 trading days. Even though this model seems conservative in terms of percentage excessions, the actual excessions are large and clustered.



VaRBaR

Should VaR be conservative or accurate?

Risk managers may be tempted to excuse VaR models if they err on the side of conservatism. However, VaR should be accurate, not conservative. People don't pay attention to overly conservative models because they often are unrealistic. Supposedly conservative models may actually lead to excessive risk taking by giving a false sense of security.

When building models, it can be tempting to include many conservative assumptions. But when conservatism is layered upon conservatism inside the model, the result is unclear. Is it 99% VaR? 99.5% VaR? The important thing is to first get a precise VaR. If we then want to be more conservative, for example to estimate capital requirements, we can apply a transparent multiple to VaR (e.g., the Basle Committee specifies a multiple of 3 times the 99% confidence 10-day VaR as minimum regulatory market risk capital).

3.5 Interpreting backtesting results

How can we tell if the backtesting results are reasonable? Note that even if you sample a perfectly known distribution, where you are absolutely sure about the 5% level, and you take 100 samples, there is a reasonable probability of 4 or 6, or even 3 or 7 exceptions. In backtesting, we have two possible errors. Type 1 errors refer to rejecting a theoretically sound model that performed poorly due to chance. Type 2 errors refer to accepting a flawed model that performed well due to chance.

Given these anomalies, the Basle Committee recommends classifying outcomes in three categories: green, yellow, and red zone. Green indicates high probability of model validity, while red implies high probability of model flaw. Yellow is an ambiguous zone where "a supervisor should encourage a bank to present additional information before taking action."[4]

For a further discussion of this topic, refer to the BIS document.

[4] Document is available at http://www.bis.org/publ/index.htm.

3.6 Other factors to consider in analyzing backtests

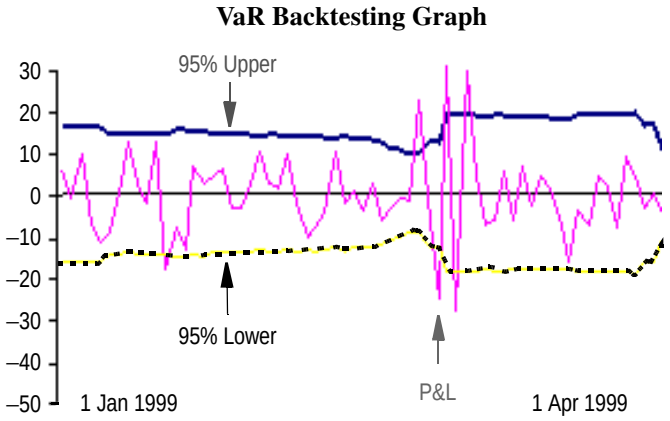
Even if excession percentages are within tolerance, it may make sense to probe further.

A. Look for clustering of excessions

In addition to counting the percentage of VaR band excessions, risk monitors should watch out for excession clustering. For example, even if a quarterly backtest shows exactly 5% upside and 5% downside excessions, it would be a disturbing sign if these excessions were clustered in one narrow time period. Clustering of excessions could imply high autocorrelation in risks, which may manifest itself as a losing streak.

Example **P&L vs. VaR test: clustered excessions**

In this graph of P&L vs. VaR, both upsides and downside excessions are within tolerance: we have three upside and three downside excessions in 65 trading days (i.e., 4.6% excessions each for upside and downside). Notice, however, the clustering of excessions in the beginning of March, when VaR was unresponsive to the increased revenue volatility. This may be due to a missing risk factor (e.g., spread risk) or poor parametrization (e.g., exponential weighting).



Ideally, one would see an even distribution of excessions through high- and low-volatility regimes, which would demonstrate that the VaR model is responsive to a variety of market conditions.

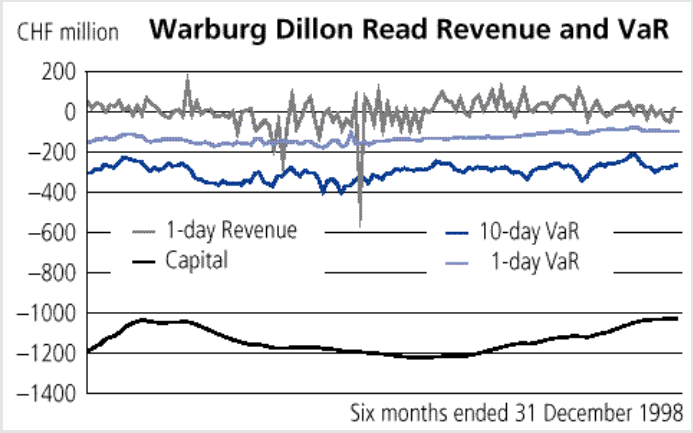
B. Examine magnitude of excessions

Another factor to consider when analyzing backtests is how large are excessions when they do occur. Extreme excessions (e.g., $5MM for $1MM VaR) are a red flag and point to the high probability of event risk. Thorough stress testing of extreme market moves should be performed regularly to estimate event risk. In the longer run, researchers might look at improving distributional assumptions to include event risk.[5]

[5] See the *RiskMetrics Monitor,* Q4 ’96 and Q4 ’97.

P&L vs. VaR test: large excessions

In this backtest of UBS Warburg Dillon Read's published trading revenues vs. VaR, we see two large clustered excessions and one extreme loss during the global market rout from August to October '98. These three excessions during this 6-month observation period total 2.4%, which is larger than expected, given UBS's 99% VaR confidence level. Also noteworthy is the size of the excessions. The graph reveals a 1-day loss of close to CHF 600 million, which is almost half of the CHF 1.2 billion capital allocated for market risk. Such results may prompt UBS to examine its VaR model's responsiveness to extreme market volatility and also continue its focus on stress testing.



3.7 External disclosures of backtests

Several major global banks have led the way in disclosing VaR and backtesting results. Below is one example.

From Chase Manhattan's 1998 *Annual Report*:

The Chase VAR methodology assumes that the relationships among market rates and prices that have been observed over the last year are valid for estimating risk over the next trading day. In addition, Chase's VAR estimate, like all other VAR methodologies, is dependent on quality of available market data. Recognizing these shortcomings, Chase uses diagnostic information to continually evaluate the reasonableness of its VAR model. This information includes the calculation of statistical confidence intervals around the daily VAR estimate and the use of daily "backtesting" of VAR against actual financial results.…

Chase conducts daily VAR "backtesting" for both regulatory compliance with the Basle Committee on Banking Supervision market risk capital rules and for internal evaluation of VAR against trading revenues. During 1998, a daily trading loss exceeded that day's trading VAR on 2 days. This compares to an expected number of approximately 3 days.

Considering the unsettled markets of 1998, Chase believes its VAR model performed at a very high level of accuracy during 1998.

3.8 Backtesting summary

Practitioners use backtesting to verify the accuracy of VaR models and to help analyze the costs and benefits of improving VaR models. Regulators require regular backtesting from banks that

they approve to use internal models for calculating market risk capital requirements. Voluntary disclosure is also becoming prevalent, as evidenced by several leading banks disclosing their trading revenues and VaR backtests.

Although there is no broadly established standard for backtesting, tests generally compare actual or hypothetical trading results against VaR bands to help determine if percentage excessions are within tolerance. Clustering and magnitudes of excessions are also informative and worth examining. Causes of outliers should be analyzed, and attributed to changes in volatility, correlation, or other factors.

Part II

Risk Management and Reporting

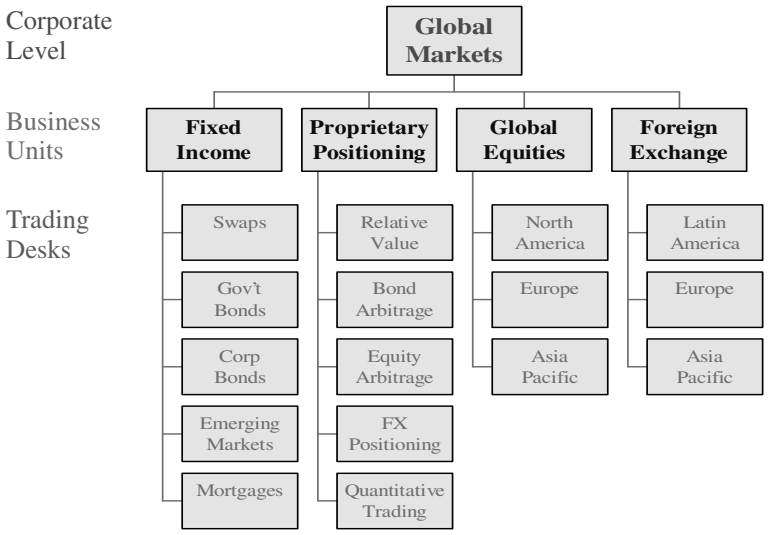
Chapter 4. Practical problems risk managers face

4.1 Risk reporting

Internal reporting

An efficient risk reporting process is the foundation for clear and timely communication of risk across an enterprise. Risk reports must be produced and distributed to many individuals and businesses. Risk reporting generally occurs at three organizational levels: the corporate level, the business unit level, and the individual trading desk level. Many risks that are managed at the trading desk level must be summarized in order to create meaningful information for management. Risk professionals design the format and content of these risk reports to suit the specific needs of each organizational level.

Typical organization of a global financial institution



Risk communication across the enterprise is summarized by the following table:

Level	Aggregation	Report focus and content
Corporate	Firmwide	Senior managers focus on the total earnings volatility, market risk concentrations between business units, and stress testing. In addition to VaR numbers, senior managers appreciate written commentary on daily reports.
Business Unit	Across trading desks	Business managers monitor risky outliers, large exposures, and yield curve positioning across trading desks.
Trading Desk	Across accounts	Traders are interested in detailed risk summaries, hedging, marginal risk analysis, diversification, and individual risk positions.

In addition to reporting on the three organizational levels, companies may have regional reporting (e.g., Deutsche Bank Asia) and legal entity reporting (e.g., J.P. Morgan Securities, Morgan Guaranty Trust Company).

Time scale

Reporting risk to senior management involves many time scales. Active financial institutions produce same-day market risk reports for discussion by senior managers, risk takers, and risk

monitors. A company's Risk Management Committee (RMC) generally meets on a weekly to monthly basis to discuss macro risk exposures and trends in global financial markets. On a quarterly basis, board presentations analyze the firm's overall risk and performance relative to markets and peers.

External reporting

In addition to internal management reports, firms may be subject to regulatory risk reporting. There is also a clear trend toward greater voluntary disclosure of risks, as exemplified by the decision of several leading financial institutions to reveal VaR statistics and histograms of trading results in their annual reports.[1] External reporting tends to be highly aggregated rather than instrument- or desk-specific.

Independent risk oversight

At many organizations, an independent risk oversight group is responsible for firmwide risk reporting. The typical organizational role of this group is discussed in Appendix C.

4.2 How to use risk reports

Risk managers use firm-wide risk reports to quantify sources of risk across an organization and to estimate total exposure to financial markets. Risk reports at each level of the organization show whether risks are taken within prescribed **internal management limits** and **regulatory capital** constraints. Risk reports are also useful for evaluating risk-adjusted trading performance. Furthermore, risk reports are used for external disclosures to regulators, analysts, credit rating agencies, creditors, and the public.

VaRBaR

An eagle-eye view of risk concentrations

Risk reporting is most useful at the corporate level because it can show the aggregation of risk across the entire firm and highlight risk concentrations arising between separately managed business groups. For example, a daily report may point out unusually high exposure to European interest rates, due to similar positions in several trading desks in Paris, London, and New York. With comprehensive macro risk reporting, risk monitors have an eagle's perspective for identifying risk concentrations across the firm.

Macro risk analysis allows for more targeted and stable risk taking. For instance, if several desks are taking similar risks, risk managers may recommend unwinding or hedging of core positions. On the other hand, if many positions are offsetting, excess risk-taking capacity may be quickly allocated to select trading desks.

4.3 What type of information is required

Significant investment in information infrastructure goes into building a sound risk measurement process. For measuring risk, two basic types of information are necessary: (a) position feeds and (b) market data.

a. Position feeds
   Risk reporting systems require collecting position information for all portfolio positions. Given the sheer number of different financial instruments and transactions, this task can become overwhelming. Furthermore, positions may be tracked by many

[1] For example, see the 1998 annual reports by Chase Manhattan Bank, Citigroup, UBS Group, Credit Suisse First Boston, and J.P. Morgan.

different systems, each with its own method of organizing information. For example, a risk manager of a large Canadian bank reported that his market risk system extracts position data from 70 different systems on a daily basis. In addition, feeds may be delayed or may provide insufficient information.

In practice, it is not possible to assure a 100% accurate report of all positions at any point in time. Nonetheless, risk managers need to be confident that they can get a snapshot of the most significant portfolio risk exposures. A risk manager's ideal information infrastructure would include a comprehensive and real-time position data warehouse.

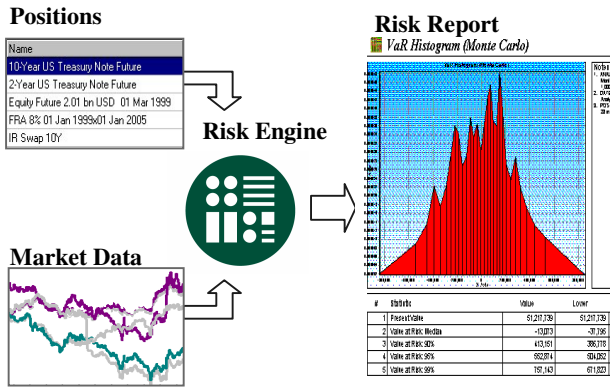
b. Market data

Market data consists of raw time series of **market rates**, **index levels**, and **prices**, and derived time series of **benchmark yield curves**, **spreads**, **implied volatilities**, **historical volatilities**, and **correlations**. Clean, complete, and timely market data is imperative for measuring risk.

Often, data must be collected from several sources, then scrubbed to eliminate **outliers** and adjusted for **missing data points**. Furthermore, data should be snapped at the same time of day whenever possible. Procuring, cleaning, and organizing appropriate market data is a challenge for all active financial institutions.

Risk information flow

Portfolio positions and market data are fed into a risk engine to generate risk reports, as illustrated in this chart.



4.4 What risk solutions to choose

A. Risk software solutions

Historically, leading financial institutions developed their own risk systems. Smaller companies generally had none. Today, an increasing number of companies out-source risk technology development to leverage the work that has already been put into developing standard risk analytics and to avoid costly mistakes.

Now the pertinent question is what system to buy. Choosing the right risk management software is an important investment decision with long-term implications. Risk managers should be clear about what they are looking for in a risk application, taking into consideration current and projected business needs.

In evaluating risk software, firms should consider the following:

Software performance	Comments
• Breadth of functionality	Ability to provide appropriate risk methodologies and measures
• Instrument coverage	Ability to correctly handle required financial instruments
• Ease of integration	Speed of integration into existing IT platform and data feeds
• Speed and power	Ability to efficiently handle required calculations and transactions
• Underlying research	Quality of research and analytics driving the risk application
• Ease of use (interface)	Whether the user interface is intuitive and simple to learn
• Reporting capability	Variety of reports, graphs, and ability to customize
• Regulatory compliance	Whether approved by regulators to generate regulatory risk reports
• Reliability and robustness	How rigorously the software is tested
• Customization	Support for customized reporting, data input, and analytics
Vendor	
• Quality of support	Responsive and knowledgeable staff
• Costs	Up-front and maintenance costs, plus integration
• Commitment to innovation	Continuous upgrades to new and improved methodologies

B. Risk data solutions

Risk software can't run without its life-blood: data. Traditionally, leading financial institutions had dedicated data groups to source, collect, clean, organize, process, and distribute market data for internal risk applications. As with risk research and analytics, financial institutions are increasingly considering external solutions for their data needs. Most firms derive risk data from several raw data sources. DataMetrics is the first service designed to provide institutions with one source for all of their risk data.

In choosing data vendors, firms should consider the following:

Risk data	Comments
• Coverage	Is the coverage of countries, assets, and instruments sufficient?
• Availability	How broad is data coverage?
• Quality	Is the data clean, consistent, and synchronized?
• Reliability of data delivery	How reliable are daily feeds?
• Usability of data interface	Can data be viewed, analyzed, and manipulated?
• Quality of data analytics	Can data be processed and analyzed for risk purposes?
• Customization of data service	Can data delivery and value-added services be customized?
• Integration of data	Can the data be integrated into the risk system?
Vendor performance	
• Quality of support	Is the staff responsive and knowledgeable?
• Costs	Are the cost for service and price per time series reasonable?
• Contingency and indemnification	How reliable is the vendor and its information network?
• Commitment to expand coverage	Are new markets and rates added as they become available?

Data analysts face the Sisyphean task of continually searching for time series and collecting data. Combining time series from different sources requires special precautions to ensure data integrity. The data analyst's perfect scenario would be to have a single comprehensive and

synchronous market risk data source and time series database. This is the mission of DataMetrics.

4.5 Summary of issues facing risk managers

Risk reporting is an integral component of the risk communication process. Risk managers use risk reports to quantify sources of risk across the organization, to analyze return on risk, to monitor risk limit and regulatory capital usage, and to make external risk disclosures. Active financial institutions produce daily risk reports at different levels of the organization. For dynamic management of risks, risk reports should be timely, accurate, and comprehensive.

To produce relevant market risk reports, risk managers must have access to reliable sources of position information and market data. DataMetrics was designed to provide risk managers with a complete solution for market data.

In developing an enterprise-wide risk reporting system, companies must decide whether to build or buy risk solutions. From a business perspective, while there may be a competitive advantage to having a *proprietary pricing system*, there is no strategic need for a *proprietary risk system*. Indeed, outsourcing risk data and technology development allows companies to focus on their core business and leverage outside expertise.

Chapter 5. Generating a risk report

5.1 What makes a good risk report

Risk reports should enhance risk communication across different levels of the firm, from the trading desk to the CEO. In this chapter, we focus on daily management VaR reporting. Public risk disclosures are discussed in Chapter 6, risk performance and capital reporting in Chapter 7, and credit exposure reporting in Appendix B.

In order of importance, senior management reports should

- be timely,
- be reasonably accurate,
- highlight portfolio risk concentrations,
- include a written commentary, and
- be concise.

(a) Risk reports must be timely

Risk management is a proactive discipline, and the time decay in the value of daily risk reports is high. Risk reports must therefore be timely and reflect current risk positions. For example, traders may look at instantaneous risk calculations, while senior trading desk managers may review risk snapshots throughout the day. At J.P. Morgan, senior managers review the daily cross-firm risk report before close of business; it gives a rough snapshot of market risks toward the end of the trading day, when guidance can be provided to managers in the next time zone on risk appetite, position unwinding, or macro hedges.

(b) Risk reports should be reasonably accurate

Risk management is not a precise science. The accurate prediction of risk is complicated by theoretical and practical constraints (e.g., unexpected events occur, certain risk factors may not be quantified due to expense or lack of data, market and position data may be delayed or incomplete, and risk methodologies are still evolving). Nonetheless, risk managers should strive to be as accurate as possible, given these constraints. The credibility of the risk management effort suffers if reports are considered inaccurate or unrealistic.

Timeliness vs. accuracy

Risk managers may need to sacrifice some accuracy for timeliness. For example, many financial institutions use a same-day report for management purposes, even though they cannot reflect 100% of their positions. A financial control group generally processes a more complete next-day report to verify the accuracy of the previous same-day report. Red flags come up only if there are glaring differences between reports.

The chairperson of one global bank's daily market risk meeting puts it succinctly: "Having mostly accurate information and people in the meeting who know what's missing is better than a fully accurate report one day too late." Or, as J.P. Morgan's former CEO Dennis Weatherstone famously said: "I'd rather be approximately right than precisely wrong."

This practical focus illustrates an important difference between accounting and risk measurement: whereas accounting seeks to represent the past as accurately as possible, risk measurement seeks to capture conditions on the fly.

(c) Risk reports should highlight risk concentrations

Risk reports should show risk concentrations by risk taking unit, asset class, and country. For fixed income, it may be useful to look at risk by maturity bands to quantify yield curve risk. Risk can be viewed down to the instrument level and trader. Total portfolio VaR should be prominently displayed, and graphs of the entire distribution of potential returns should be available. VaR vs. limits is also useful to include for management control.

The specific information in each internal management report varies by level of organization, from macro risk summaries at the corporate level, to detailed risk reports by specific instrument at the desk level, as shown in the following table.

Report type	Content
Corporate Level	• Shows total firmwide risk and summary of risk concentration among different business units, asset classes, and countries. • Breaks down VaR vs. limits by business unit, asset class, and country. • May include commentary on size of market risk, significant risk concentrations, and interesting market developments. • May include legal entity and regional reports.
Business Unit Level	• Summarizes risk by trading desks, country, maturity band, and instrument type. • Reports VaR vs. limits by total business and individual desks. • Optionally includes - **Marginal VaR*** report by desks, country, maturity band, and instrument type. - **Cashflow Map**† or **Present Value Report**† by currency.
Desk Level	• Shows detailed risk summary by instrument, position, and maturity band. • Includes - VaR vs. limits by desk and trader. - **Marginal VaR** report by instrument or instrument type. - **Instrument Summary**† report. - **Cashflow Map** by currency.

* See page 58.
† See page 59.

Specific risk reports are described in Section 5.2. Regulatory reporting and external VaR disclosures are discussed in the next chapter.

(d) Daily risk reports should include written commentary

Daily risk reports can be enhanced with a qualitative market risk commentary emphasizing notable market developments and risk positions. Often, risk monitors add the commentary after participating in a daily market risk discussion with risk takers and business managers. Commentaries should be brief and to the point (... and distribution of the reports should not be slowed while a risk manager struggles with writer's block).

VaRBaR

A sample daily market risk commentary:

Market Risk Commentary, Wednesday, March 17, 1999

Global market volatility has continued to increase, with widening credit spreads and decreased liquidity for risky assets across Europe and the Americas. Trading volume across U.S. fixed income was unusually low, and corporate bond traders note declining liquidity and increasing spreads due to a flight to quality. The firm's large inventory of corporates could suffer from further widening of spreads. Brazilian markets continue to bleed, with uncertainty surrounding impending fiscal reforms. While mostly FX hedged, the Emerging Markets desk is close to its $2MM VaR limits and could suffer large bond losses if Brazil is forced to raise interest rates to stem capital flight. A Latin American liquidity crunch could put pressure on Emerging Asia again, where the firm has long positions in THB, MYR, and SGD government paper. The FX desk reported significant trading by macro hedge funds, mostly short interest in long dated JPY/USD forwards and options. U.S. equity markets continue to be volatile, with Internet stocks racing ahead. However the bank's direct equity exposure is currently low due to short SPX futures positions in proprietary trading which offset some systemic risk in market making books.

Written commentary is considered especially important for corporate managers, who may not be in touch with minute-by-minute developments on the trading floor. Written commentary adds color from the front lines, improves communication between the trading floor and the corporate office, and facilitates centralized risk management with decentralized position taking.

(e) Risk reports should be concise

Keep summary risk reports to one page containing only essential risk information. No one has the time to be overwhelmed by thick reports full of numbers.

VaRBaR

J.P. Morgan's 4:15 Report

Within our eight market-related global products, we have more than 120 risk-taking units spread over 14 locations spanning the globe. Our chairman rather likes the diversification this affords, but has a simple request: "At the end of each day, tell me what our risks are and how we did." Our answer is what we call our 4:15 Report—creatively named after a daily meeting at that time, which I typically chair, with senior managers from the main market units.

In a one-page snapshot, we have information on our positions and risk levels in every major market across all our products. There is also information on limits, P&Ls, and commentary on significant developments—all in plain English. And it is delivered each evening to all members of the corporate office, as well as to other key senior managers. This has proven to be a useful process to keep risks transparent, to keep communication flowing, and to keep all the key business managers' eyes focused on the same ball—our overall risk levels and performance.

—Steve Thieke, J.P. Morgan

5.2 What are the major types of risk reports

There are a several types of risk reports and measures, each with its own perspective of risk.

- The four major risk measures are **VaR**, **relative VaR**, **marginal VaR**, and **incremental VaR**.
- If Monte Carlo simulation or historical simulation is used to calculate risk, a full distribution of potential returns can be plotted to obtain a more elaborate perspective of potential outcomes.
- Stress test reports provide a measure of downside potential due to extreme market movements without pre-specified loss probabilities.
- **VaR by counterparty** can be used to quantify potential credit exposure through market driven transactions.
- Seven basic report types are widely used:

Report type	Content and application
VaR	• VaR Reports - estimate the worst-case loss over a defined horizon with a specified confidence level; generally, a 1-day to 1-month horizon is used, and confidence intervals range from 90% to 99%; - are used to measure portfolio risk concentrations; - may include VaR vs. pre-specified limits. • VaR may be - analyzed in various dimensions: risk type (or asset class), country or region, maturity or duration band, instrument type or individual instrument, and counterparty; - expressed in base currency or as percentage of notional or market value.
Return Histogram	• When Monte Carlo simulation or historical simulation is used, risk reports often show a full histogram of simulated returns. The histogram's advantage is that it shows the full range of potential gains and losses, as opposed to only one specific loss statistic (e.g., a VaR number at 95% confidence yields no information about likely losses beyond that point, whereas a histogram enables you to calculate VaR at any confidence level).
Relative VaR	• Relative VaR - measures risk relative to a pre-specified benchmark and is expressed in absolute base currency amount or as a percentage; - is commonly used by investment managers with relative return objectives, such as mutual funds that track specific equity indices.
Marginal VaR	• Marginal VaR - measures marginal contribution to portfolio risk and can be analyzed in the same dimensions as VaR; often graphed as a scattergram (e.g., marginal VaR vs. VaR or PV); - is useful for identifying and quantifying risk concentrations.
Incremental VaR	• Incremental VaR - measures incremental contribution to portfolio risk and can be analyzed in the same dimensions as VaR; - is useful for identifying hedging opportunities, and for quantifying percentage contribution to total portfolio VaR.

continued on page 59

Report type	Content and application
Stress Test	• Stress Test Reports - show the potential present value impact of pre-specified scenarios or extreme market movements; - are used to better capture event risk and are a useful complement to VaR analysis.
VaR by Counterparty	• Reports VaR by trading counterparty, for estimating potential short-term credit exposure for market driven instruments such as swaps, forwards, and options. • VaR by counterparty is used to monitor credit line usage. • For best practices recommendations, see *Improving Counterparty Risk Management Practices*, by Counterparty Risk Management Policy Group, 1999.

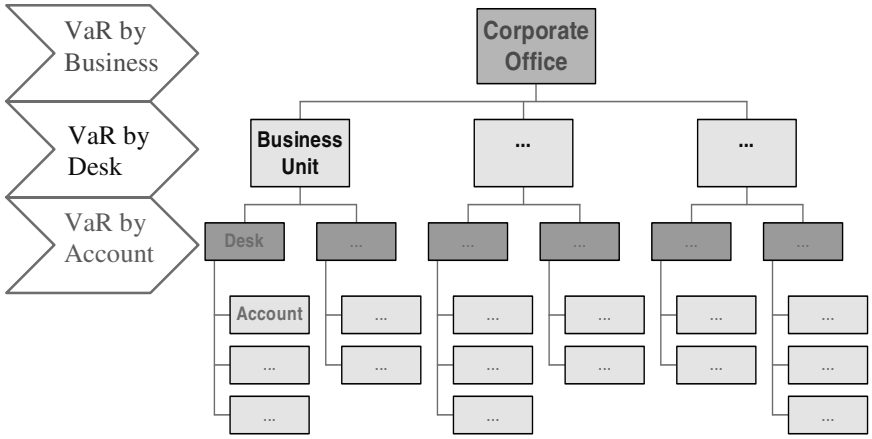
A number of closely related reports are commonly used with risk reports:

Report Type	Content and application
Present Value Report: provides the discounted net present value of cash flows	• Shows present value of cash flows in the same dimensions as VaR. • Can be used to estimate VaR as a percentage of PV.
Instrument Summary Report: shows instrument-specific information	• Shows information, such as price, notional value, net present value, duration, delta, vega, theta, and gamma. • Used by traders or desk managers interested in specific information.
Cashflow Map: summarizes net mapped cash flows for each currency	• Shows cash flows in designated maturity and currency buckets. • Is useful in understanding net yield curve positioning and can be used to design **macro hedges**.
Credit Exposure Report: shows credit exposures for market driven instrument	• Shows current and potential future credit exposure for market driven instruments, such as swaps, forwards, and purchased options. The three main exposure measures are *current*, *average*, and *peak exposure*. • Used by credit officers to monitor counterparty credit limit utilization.
P&L Report: shows daily mark-to-market (MTM) P&Ls of risk takers	• Compares the returns against the risks taken. For example, if a trader has a VaR of $1MM at 95% confidence and a 1-day horizon, actual returns should exceed VaR with 5% probability or about once in 20 trading days. • The returns are also used in backtesting the accuracy of VaR models.
Position Report: shows size and direction of positions	• Shows internal sources of risk: what positions generate the risk. • Often uses benchmark equivalents to reduce information overload (e.g., 2-year equivalents, C-Bond equivalents).
Market Information Report: shows market rates and indices	• Shows external sources of risk: what market changes generated P&Ls and risk. • Useful for understanding historical evolution of the markets and current conditions.

5.3 How to organize a risk report

Risk reporting depends on how a firm is organized, and is customized for each level of the organization. Risk reports should show which business units or desks are responsible for positions because it is important to connect exposures back to the risk taker. Therefore, risk reports must specify the most detailed level and then aggregate upwards.

Risk reporting from the bottom up



5.4 Time dimensions in risk reporting

A company's risk exposures should be communicated on a regular basis. Nonfinancial companies should have at least monthly reviews of financial risks, while active financial companies should have daily discussions of risk taking.

Below we show the time dimensions of risk communication at a generic corporation:

Enterprise-wide risk communication

Frequency	Risk forum
Monthly	• Corporate office and senior risk managers meet to discuss firmwide market risk profile (this is known as a "market risk committee"). • Business risk reviews: The independent corporate risk management group and business managers perform these reviews.
Quarterly	• Firmwide risk profile review occurs at a board of directors meeting. • Risk return performance review is handled by a senior management group.
Ongoing	• Stress testing—Business level and firmwide (see Chapter 2). • Backtesting—Business level and firmwide (see Chapter 3). • Model risk reviews—Evaluation of pricing and risk models. • New product reviews—Evaluation of proposed new financial instruments.

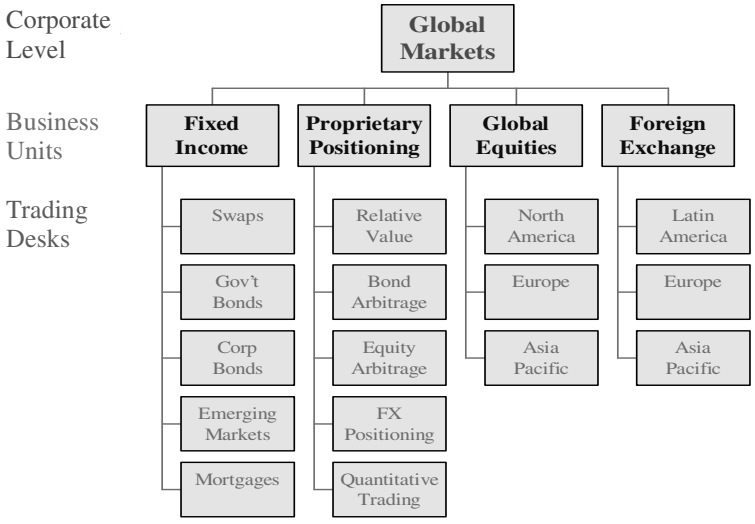
In addition to these discussions, active financial institution may have meetings on a daily or weekly basis.

Frequency	Risk forum
Daily	• Management of risks by traders, businesses, and divisions • Same-day risk report of positions, risks, and total returns of global businesses • Meetings to discuss the same-day risk report, market events, and strategies
Weekly	• Local market risk committee meetings by regional office • Conference calls among senior risk managers • Review of counterparty credit exposure reports for market driven instruments

5.5 Global bank case study

Background information

The VaR concept was pioneered by several leading U.S. banks in the ’80s, and is now implemented in most global banks. In 1995, the Basle Committee on Banking Supervision approved VaR to satisfy market risk capital requirements.[1] Large banks tend to have the greatest market exposure to global interest rates and to a lesser extent FX and commodities. Equity market risk is growing as banks merge to become full-service financial institutions with equity underwriting and brokerage. Matrix organization structures are often used between regional and product managers. For example, Hong Kong equities trading may be the responsibility of the Asian regional manager and the Global Equities product manager.



VaR reporting is typically done at the corporate, business unit, and desk levels of the organization. Daily regional risk reports may also be produced in regional offices (e.g., Asia, Europe, and Americas).

For example, to the left is the organizational chart of a fictitious company, Global Bank, which is organized by product group and function. All business units are **market-making** groups, except Proprietary Positioning.

In addition to daily risk reporting, banks have less frequent reporting that analyzes market trends, limits usage (see Appendix A), risk performance, and projected credit exposure for market driven instruments (see Appendix B).

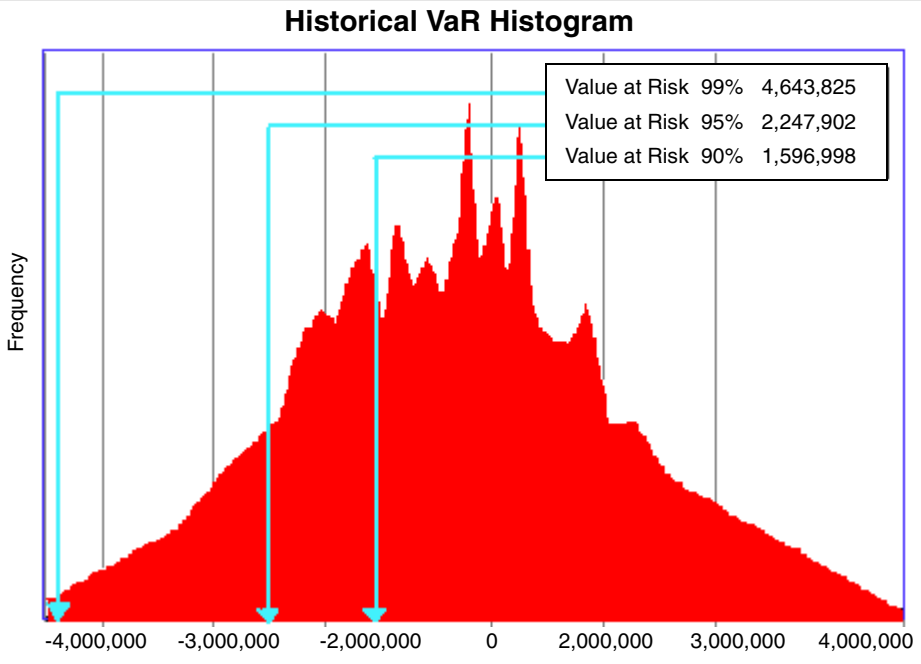
[1] An amended rule was issued in 1996 and went into effect in 1997. See BIS publications at http://www.bis.org/publ/index.htm.

Corporate Level Report

The corporate level report is discussed in a daily meeting by senior business managers, risk takers, and independent risk monitors, and then delivered to the CEO.

Daily Corporate VaR Report **June 8, 1999**

RMG



95% VaR, (1-day)	Aggregate	*Divers. Benefit*	Emerging Markets	Fixed Income	Foreign Exchange	Global Equities	Proprietary Positioning
Aggregate	2,247,902	*–1,516,014*	758,348	381,807	181,207	877,660	1,564,894
Diversification Benefit	*–268,153*	*–284,076*			*–22,294*		*–843,558*
FX Risk	354,187	*–93,236*			79,449		367,974
Interest Rate Risk	1,307,719	*–979,818*	758,348	381,807	124,052		1,023,330
Equity Risk	595,424	*–1,040,659*				877,660	758,423
Commodity Risk	258,725						258,725

Comments

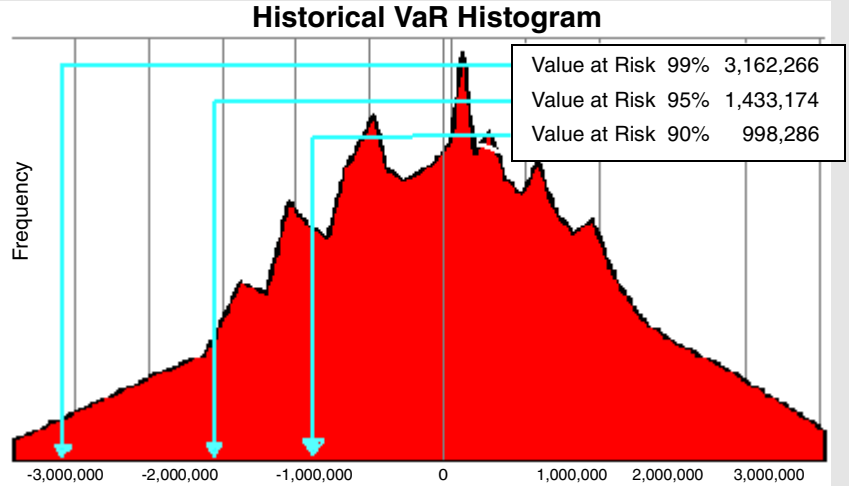
Proprietary Positioning is taking large short positions in European interest rates ($1,023,330 VaR) and equities ($758,423 VaR). On a firmwide basis, these short positions offset inventories held in Emerging Markets, Fixed Income, and Global Equities. Hence the large *Diversification Benefit* in the Interest Rate Risk and Equity Risk categories.

Regional Report

Additionally, regional reports are discussed by regional managers, risk takers, and risk monitors on a daily basis.

Daily European VaR Report **May 11, 1999**

RMG



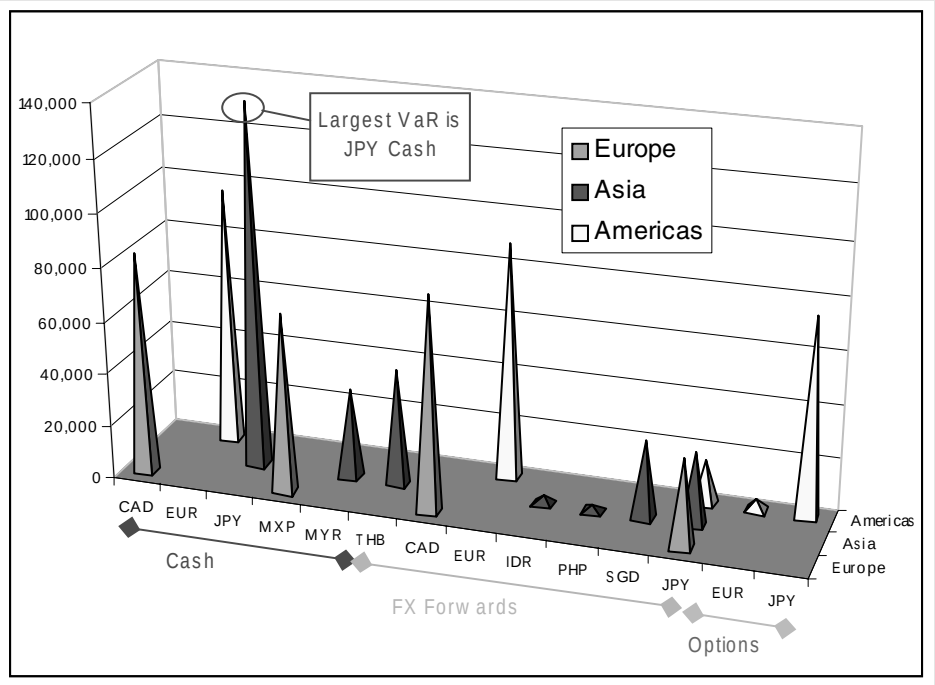
95% VaR (1-day)	Aggregate	*Divers. Benefit*	Fixed Income	Foreign Exchange	Global Equities	Proprietary Positioning
Aggregate	*1,433,174*	*–807,236*	*500,116*	*327,826*	*474,153*	*938,315*
Divers. Benefit	*–58,114*		*–131,422*	*0*	*–107,890*	*–20,256*
BEF	77,515	*–6,808*	17,819		66,505	
CHF	55,205	*–269,500*	139,500			185,205
DEM	33,179	*–14,348*	4,451		12,783	30,292
DKK	221,540	*–9,370*	9,577			221,333
ESP	615	*–25,211*			3,475	22,351
EUR	567,650	*–117,737*	139,004	327,826		218,557
FIM	56,163	*–5,225*	13,852		47,535	
FRF	264,341	*–39,404*	118,787		178,101	6,857
GBP	215,080	*–521,088*	188,548		273,644	273,976

Comments
Large diversification benefit between Proprietary Positioning and Global Equities due to offsetting positions in GBP.

Business Unit Report Business unit reports may show more detail, for example VaR by instrument type and country.

Global FX VaR Report **April 23, 1999**

RMG



95% VaR, (1-day)	Aggregate	*Divers. Benefit*	FX Americas	FX Asia	FX Europe
Aggregate	298,533	*–152,263*	196,261	180,531	74,004
Divers. Benefit	*-494,541*		*–69,207*	*–98,381*	*–208,113*
Cash	214,011	*–133,228*	114,747	135,823	96,669
CAD	83,460		83,460		
EUR	96,669				96,669
JPY	137,209			137,209	
MXP	67,381		67,381		
MYR	34,231			34,231	
THB	43,883			43,883	
FX Forward	132,444	*–75,048*	83,392	38,000	86,100
CAD	81,268		81,268		
EUR	89,157				89,157
IDR	3,309			3,309	
PHP	2,698			2,698	
SGD	29,644			29,644	
JPY	44,617	*–33,422*	33,359	27,938	16,743
FX Option	79,071	*–63,361*		62,906	79,525
EUR	4,210				4,210
JPY	75,338				75,338

Comments

- Largest single FX exposure is unhedged long JPY cash position.
- FX Americas has concentrated CAD cash and forward positions.
- FX Europe has large long-dated JPY-options positions.
- Notice significant diversification within FX Europe, due to offsetting Euro Cash and Forward positions.

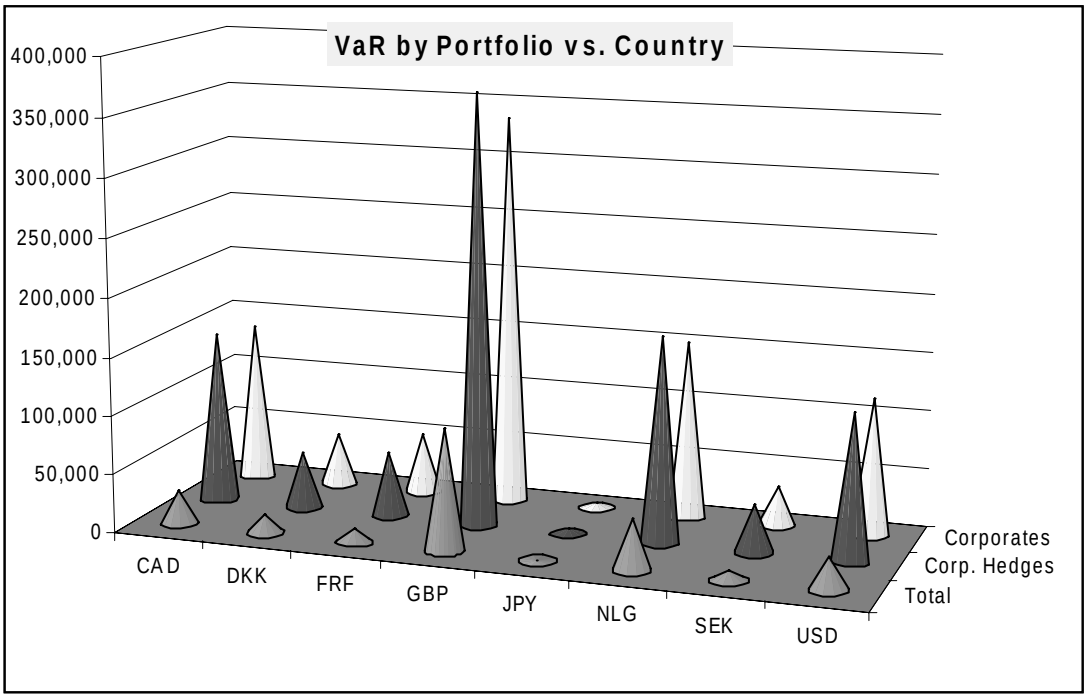
Desk Level Report

Desk level reports often contain specific information on positions.

For example, see the VaR report for Corporate Bond Trading, which consists of two accounts: (a) Interest Rate Hedges and (b) Corporates. Notice the underlying position and corresponding swap or futures hedge on the graph, and the summary VaR table showing the risk of each position in the Hedges and Corporates portfolios.

Corporate Bond Trading Daily VaR **June 23, 1999**

RMG



95% VaR	Total	*Divers. Benef*	Hedges	Corporates
Total	157,365		677,000	633,065
Divers. Benef.	*–84,736*		*–286,324*	*–242,115*
CAD	29,172	*–255,453*	147,169	137,456
DKK	16,351	*–77,233*	49,423	44,161
FRF	11,828	*–94,516*	55,317	51,027
GBP	104,211	*–599,962*	368,691	335,482
JPY	684	*–7,178*	4,093	3,769
NLG	43,559	*–282,760*	174,408	151,911
SEK	8,447	*–65,126*	39,855	33,718
USD	27,849	*–214,175*	124,368	117,656

Comments

- All corporate bond positions are partially interest rate hedged, using swaps or futures. This can be seen from the large diversification benefit between Hedges and Corporates.
- Largest market risk is to GBP, due to large positions and significant spread risk between government and corporate issuers.

Stress Reports

Banks perform regular stress tests from the desk to the corporate level. Traders may focus on the behavior of hedged portfolios by shocking specific market variables (such as instrument specific spreads) and the so called "greeks" of option portfolios (e.g., delta, gamma, vega). Corporate level stress scenarios often consider broader macro scenarios that could have exacerbating effects throughout the firm's businesses.

Below is a sample corporate level stress test for Global Bank.

Quarterly Global Stress Scenario Analysis **Wednesday, March 17, 1999**

Severity of Event	**Sample Scenario**	**Likely Market Impact**	**Portfolio Impact** (in $ millions)
Once in a year	Liquidity crisis (e.g., Oct '97 HKD attack and Brazil rate hike, Sep. '98 market turmoil and LTCM blowup)	Rates rise (50 to 100 bp) Spreads rise (20 to 100 bp) Equity indices drop (6%–10%) *RMVI** increases (20%)	–25 –12 +20 –5 –21 Total
Once in 5 years	Major currency devaluations and Emerging Markets turmoil (e.g., Brazil '99, Russia '98, S.E. Asia '97, Mexico '95)	Rates rise (100 to 200 bp) Spreads rise (40 to 200 bp) Equity indices drop (10%–20%) *RMVI* increases (30%)	–57 –22 +38 –8 –48 Total
Once in a decade	Major financial sector crisis (e.g., U.S. S&L '80s Crisis, Japan '90s, Asia '97)	Yield curve steepens (–100 to 300 bp) Spreads rise (60 to 300 bp) Equity indices drop (15%–25%) *RMVI* increases (40%)	–80 –43 +55 –15 –80 Total
Once in 30 years	Major stock market crash (e.g., U.S. '04, '29, '87)	Yield curve steepens (–100 to 400 bp) Spreads rise (100 to 500 bp) Equity indices drop (20%–30%) *RMVI* increases (60%)	–112 –61 +92 –23 –101 Total
* RiskMetrics Volatility Index			

Comments

- The above stress tests reflect the firms's estimated exposure during a series of gross bear market events. Shocks assume daily worst-case movements, with no position unwinds. Stress tests only account for direct MTM changes of positions held in inventory and do not account for potential changes in underlying business volume (e.g., lower underwriting and secondary trading), or credit losses due to counterparty defaults. Note that totals add up to less than the individual components because individual losses are not simply additive.
- RMVI (RiskMetrics® Volatility Index) was used as a proxy to model implied volatility shocks on options positions (e.g., vega risk).
- Notice large positive gains in equity bear market scenarios, which is due to a very large short equity index futures position by the Proprietary Positioning group.
- The firm's largest bear market exposure comes from a large inventory of unhedged Eurobonds, which gives exposure to both interest rate and spread risk.
- Total direct exposure to extreme bear market scenarios is moderate with respect to capital, due to offsetting short equity positions by Proprietary Positioning. Indirect business volume exposure and credit concerns, however, may be substantial.

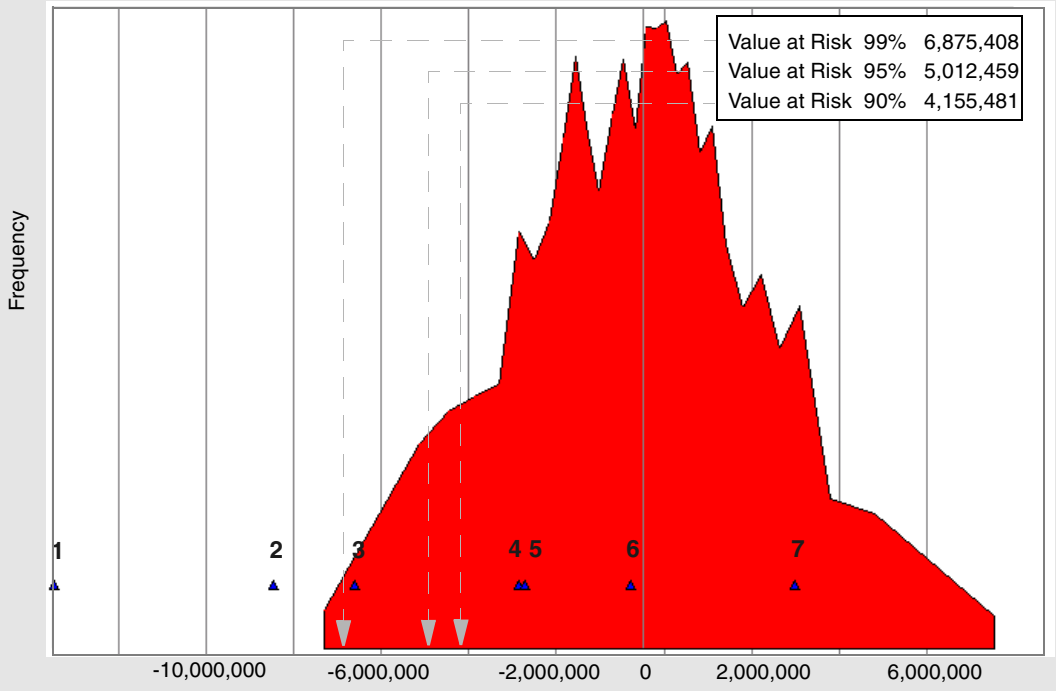
Picture of Risk

Picture of Risk reports allow visualization of VaR and stress tests in an integrated manner, on a single page. The projected earnings impact of pre-defined stress scenarios can be plotted on the distribution.

Corporate Level Picture of Risk Report **August 11, 1999**

Picture of Risk

RMG



Stress Scenarios - PV Changes	
1. July 1998 Turmoil 1-day	–13,478,941
2. Russian Devaluation (1998) 1-day	–8,467,208
3. Asian Crisis (1997) 1-day	–6,597,188
4. Gulf War (1990) 1-day	–2,839,852
5. Mexican Peso Fallout (1995) 1-day	–2,702,207
6. US Gov +50bp	–284,264
7. Black Monday (1987) 1-day	3,496,649

Comments

- Firmwide stress results show greatest exposure to July 1998 turmoil, which was marked by significant swap spread widening, bearish equity markets and emerging markets capital flight. The firm is exposed to swap and corporate bond swaps widening, due to a large inventory of Euro issues. The firm's Latin American, Eastern European and Southeast Asian bond positions are vulnerable to an emerging markets liquidity crisis.
- The overall book is relatively interest rate neutral, as shown by the low PV impact of a parallel increase in US yields.
- Short US equity positions by proprietary trading contribute to a net positive impact in the event of a US equity market sell off.

5.6 Leveraged fund case study

Background information

There is a large variety of leveraged funds (or hedge funds), from the large Global Macro funds (e.g., Quantum, Tiger), to more specialized quantitative funds (e.g., DE Shaw, LTCM), regional funds, and risk arbitrage funds.

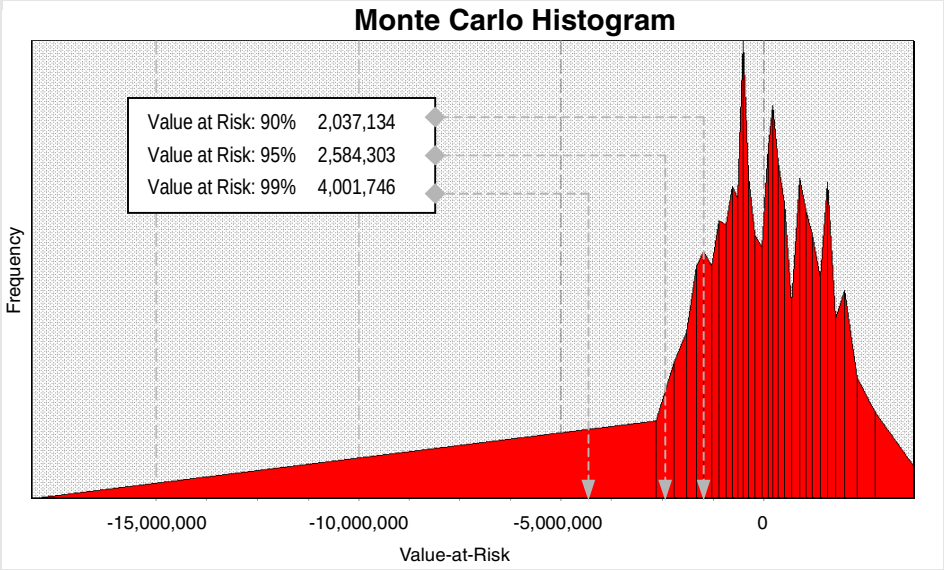
Leveraged funds are sophisticated investors with dynamic and complex trading strategies that can employ a full range of financial instruments. Since many funds are active users of derivatives, traditional notional measures of exposure are meaningless. Rigorous risk measurement and reporting is an essential discipline for these fund managers. Furthermore, in the aftermath of several spectacular fund blow-ups in 1998, regulators, lenders, and investors are requiring greater disclosure of risks.

External reporting

For reporting risk to lenders and investors, hedge funds need to give a broader overview of risks without divulging specific instrument risks and directionality. For example, based on the internal management report pictured below, a hedge fund could choose to disclose only the total VaR of $4,001,746 without revealing regional risk details.

Global Macro Fund: Regional VaR Analysis **April 27, 1999**

RMG



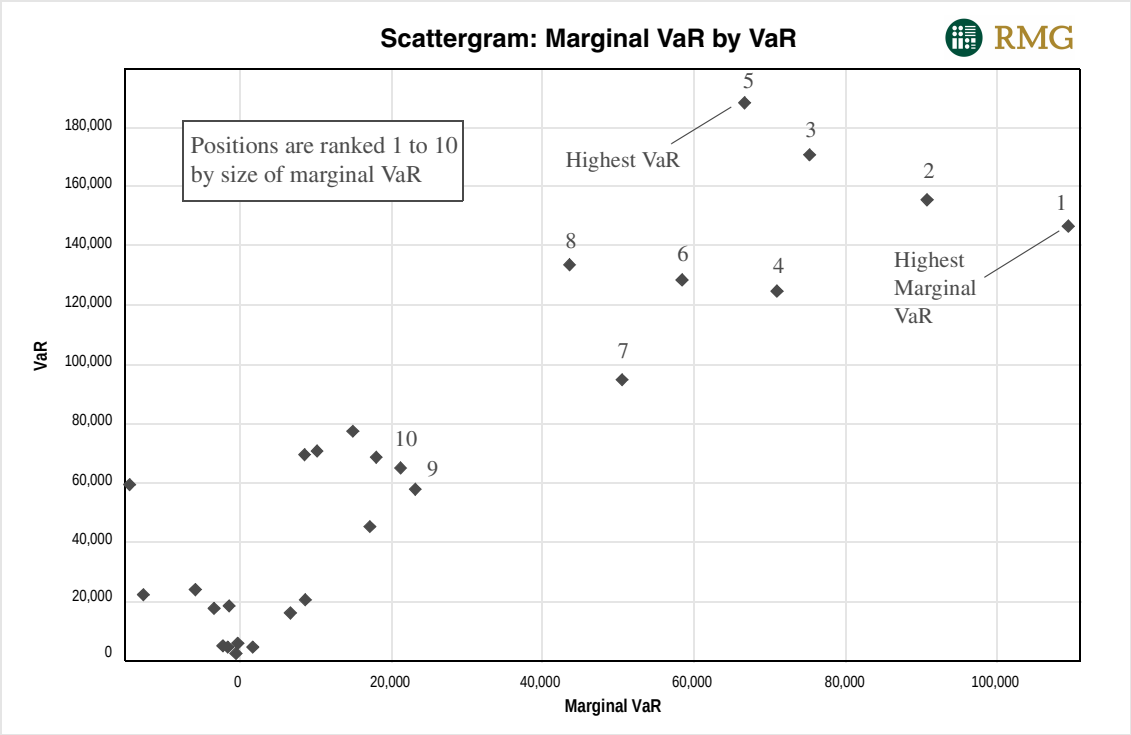
99% VaR, (1-day)	Aggregate	*Divers. Benefit*	FX Risk	Interest Rate Risk
Aggregate	4,001,746		2,790,699	3,643,519
Divers. Benefit	*–4,636,288*		*–1,967,820*	*–2,667,189*
North America	2,819,160	*–541,971*	608,404	2,752,727
Central Europe	2,594,426	*–1,007,867*	2,149,562	1,452,731
Japan	406,618	*–88,710*	102,091	393,237
Australia	2,168,901	*–650,670*	1,735,121	1,084,451
Emerging Asia	446,255	*–96,523*	110,393	432,385
Latin America	11,343	*–583*	851	11,075
Mid East & Africa	191,331	*–44,868*	52,097	184,102

Comments
Long skewed tail due to short interest rate options. There is the potential for large losses if there is extreme divergence between U.S. and European rates. However, overall VaR is well within tolerance. Large regional diversification is due to offsetting directional positions between U.S. and Europe.

Internal management reporting

For internal management purposes, daily reports analyzing risk in several dimensions should be generated. Hedge funds often have very concentrated risks by position, so risks are often viewed down to the instrument level. Hedge fund managers can use marginal VaR analysis to identify opportunities for unwinding positions to become more diversified (see the risk report below to identify the 10 highest contributors to risk). Note that the highest stand-alone VaR (#5) is only the fifth highest contributor to risk.

Marginal VaR Analysis **Wednesday, April 28, 1999**



#	Marginal VaR	VaR	Position
1	110,357	144,941	GBP 5Y Note
2	91,761	153,574	IEP 5Y Swap
3	76,052	169,057	GBP 5Y Swap
4	71,756	122,659	EUR 5Y Swap
5	67,462	186,275	IEP 5Y Note
6	59,199	126,304	AUD 5Y Note
7	51,168	93,128	AUD 5Y Swap
8	44,246	131,947	EUR 5Y Note
9	23,675	55,657	NLG 5Y Swap
10	21,784	62,714	DEM 5Y Swap
11	18,544	66,755	DEM 5Y Note
12	17,734	43,255	USD 5Y Swap
13	15,304	75,613	CAD 5Y Note
14	10,995	68,818	NLG 5Y Note
15	9,286	18,694	FRF 5Y Swap

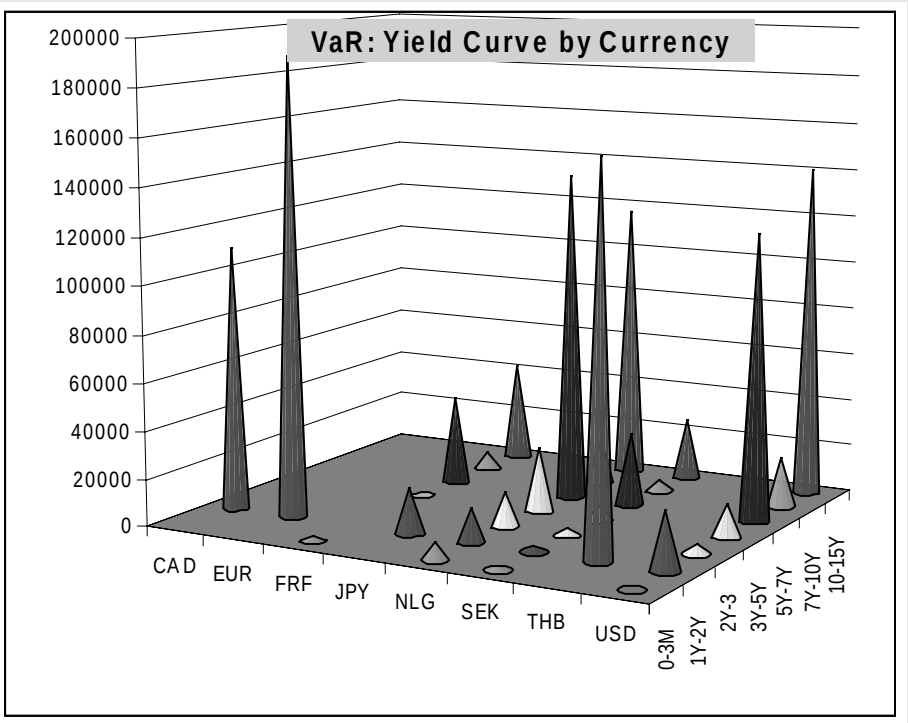
#	Marginal VaR	VaR	Position
16	9,077	67,669	CAD 5Y Swap
17	7,385	13,955	DKK 5Y Swap
18	2,280	2,618	JPY 5Y Note
19	297	3,040	BEF 5Y Swap
20	71	737	ESP 5Y Swap
21	4	61	ITL 5Y Swap
22	−16	71	ITL 5Y Note
23	−147	814	ESP 5Y Note
24	−1795	1,662	JPY 5Y Swap
25	−1834	16,459	SEK 5Y Swap
26	−11,730	3,339	BEF 5Y Note
27	−12,810	15,984	SEK 5Y Note
28	−15,278	21,883	FRF 5Y Note
29	−112,089	20,297	DKK 5Y Note
30	−113,996	57,444	USD 5Y Note

VaR by maturity

For yield curve positioning, hedge funds are also interested in VaR by country and maturity band. Sometimes, curve risk is analyzed by duration instead of maturity band.

Global Yield Curve Risk Report **January 27, 1999**

RMG



	Total	0–3M	1Y–2Y	2Y–3	3Y–5Y	5Y–7Y	7Y–10Y	10–15Y
Total	491,379	6,176	283,242	16,653	34,896	249,031	29,388	192,808
CAD	111,366		111,366					
EUR	191,925		191,925					
FRF	15,927	2,534				37,524	7,162	42,295
JPY	19,394		19,394					
NLG	336,498	7,366	14,521	14,330	27,341	138,783	19,775	117,195
SEK	73,095	1,475	2,821	2,853	5,732	30,755	4,502	26,117
THB	158,966		158,966					
USD	273,146		24,151	4,074	14,251	120,211	21,158	140,837

Comments

- VaR generated using RiskMetrics Monte Carlo simulation, 1-day horizon, 95% confidence.
- Largest exposure in Euro due to large short 2Y-position in asset swaps.
- Also significant exposure to Kingdom of Thailand due to 2Y government bond position.

5.7 Investment manager case study

Background information

Investment managers can use VaR for asset allocation and risk-adjusted performance analysis. Many investment managers are evaluated by Sharpe Ratio analysis, and have fixed assets that must be allocated to achieve a high return on risk. Investment managers therefore often analyze positions using Marginal VaR and VaR as a percentage of present value. Investment managers weigh expected returns of investments against incremental portfolio risk.

Investment managers also commonly use VaR to assess risk relative to a pre-specified investment benchmark, such as the S&P 500 Index. VaR is a useful measure for both investment managers and upper management because it allows benchmark definition in risk terms, which eliminates the need to create and rely on arbitrary percentage investment guidelines.

For example, to guide an investment manager using the S&P 500 benchmark, upper management can provide her with a single VaR limit instead of many figures defining a percentage maximum and minimum investment in every industry group. A relative VaR limit implies that deviation from a benchmark must remain below a threshold risk level.

While there are still no regulatory disclosure requirements, voluntary VaR disclosure can be a competitive advantage for investment managers who wish to differentiate themselves by providing clients with useful information. Some institutional clients specifically ask for VaR analysis, usually through custodians.

Relative VaR

For investment managers with a defined benchmark, relative VaR may be more relevant than stand-alone VaR. Relative VaR between two portfolios can be measured by calculating the net VaR of going long the original portfolio and shorting the benchmark portfolio. The performance of investment managers can be evaluated by comparing excess benchmark returns against relative VaR.[2]

Example

Below is an example of an asset manager with three types of funds, each with its own benchmark.

Fund	Investment objectives and constraints	Benchmark
Capital Preservation	Low risk profile, only short-term interest rate positioning allowed	US 3-month T-Bill
Global Bond Fund	Moderate risk profile, short- and long-term interest rate positioning and FX positioning	GBI+ Index*
Global Equities Fund	Aggressive risk profile with global equity and FX exposure	EAFE Index†

* GBI+ Index (Global Bond+ Index) is published by J.P. Morgan.
† EAFE Index (Europe Australia Far East Index) is published by Morgan Stanley.

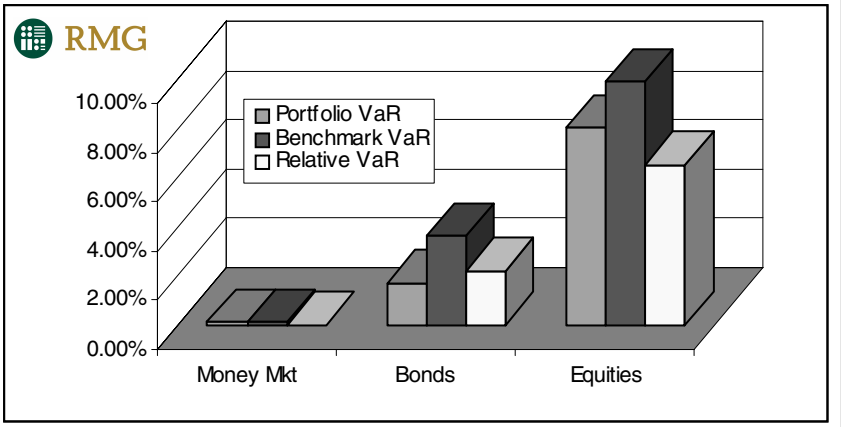
The reports on the following pages show how risk could be reported for these funds.

[2] This is a measure related to the Sharpe ratio of excess return over risk, as discussed in Chapter 7.

External reporting

Below is a graph of VaR, benchmark VaR, and relative VaR for each of the three asset classes listed in column 1 of the table in the report. VaR is expressed as a percentage of market value.

Investment Manager Monthly VaR Summary **May 31 1999**



1-month, 95% CL	Portfolio VaR	Benchmark VaR	Relative VaR	Relative VaR limit
Money Mkt	0.1%	0.1%	0.0%	0.1%
Bonds	1.7%	3.6%	2.2%	3.4%
Equities	8.0%	9.9%	6.5%	6.7%

Comments
All portfolios are less aggressive than the benchmark in absolute VaR, indicating a cautious market view. While portfolios would outperform benchmarks if markets turn bearish, portfolios would underperform benchmarks in a bull market scenario. The relative VaR on equities is close to limits, showing that asset allocation deviates significantly from the benchmark. Deviation from the benchmark is due to under-weighting of Japanese equities.

Internal management reporting

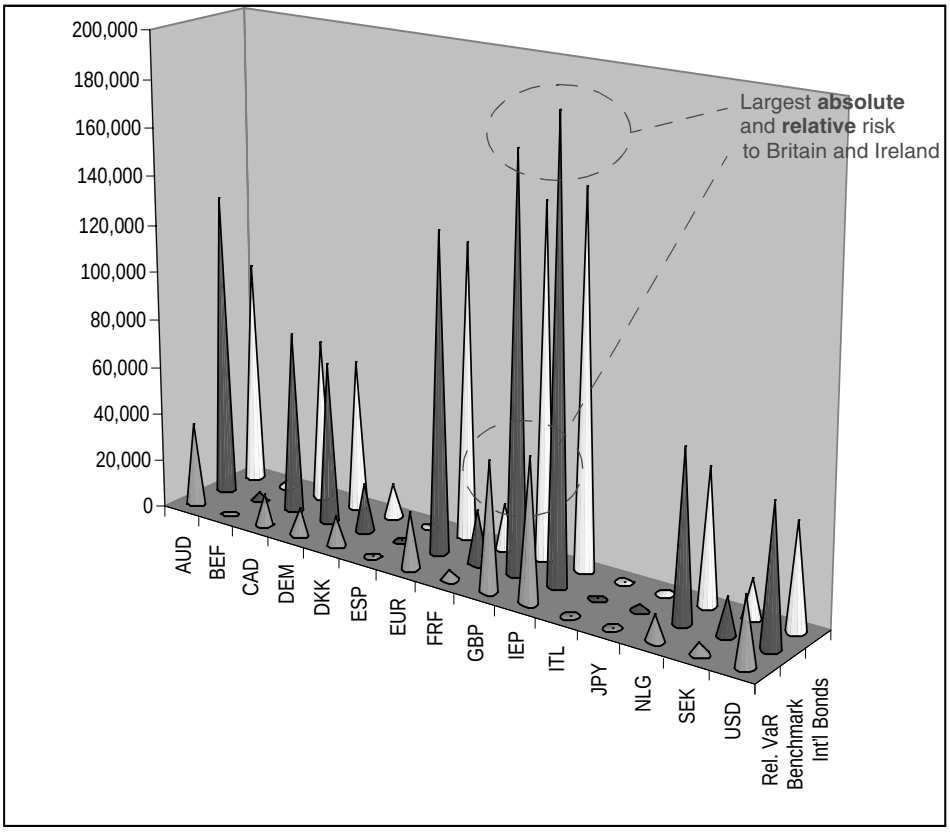
Relative VaR is useful for internal management reporting of positions. Deviations from benchmarks can be analyzed in many dimensions: deviation by duration, country allocation, and risk type (equity vs. FX).

Example: Management Report

In our example, we analyze how our international bond portfolio deviates from its benchmark country allocation.

Risk by Country Summary Report **April 28, 1999**

RMG



95% VaR, (1-month)	Relative VaR	*Divers. Benefit*	Int'l Bond Benchmark	Int'l Bonds
Aggregate	98,504	*–1,055,612*	656,783	497,333
Divers. Benefit	*–155,702*		*–290,437*	*–300,872*
AUD	34,528	*–184,904*	126,304	93,128
BEF	559	*–5,820*	3,339	3,040
CAD	12,696	*–30,586*	75,613	67,669
DEM	11,226	*–118,244*	66,755	62,714
DKK	12,558	*–21,694*	20,297	13,955
ESP	142	*–1,409*	814	737
EUR	23,383	*–231,222*	131,947	122,659
FRF	4,116	*–36,461*	21,883	18,694
GBP	52,864	*–261,134*	169,057	144,941
IEP	58,237	*–281,612*	186,275	153,574
ITL	11	*–121*	71	61
JPY	356	*–3,923*	2,618	1,662
NLG	10,563	*–113,912*	68,818	55,657
SEK	4,836	*–27,607*	15,984	16,459
USD	28,129	*–72,569*	57,444	43,255

Comments

- Largest relative VaR positions are in GBP and IEP, due to country under-weighting.
- Overall VaR is lower than benchmark portfolio, expressing the fund's bearish view on the bond markets.
- Net relative VaR is well within the limit of USD 200,000.

5.8 Corporate case study

Background information

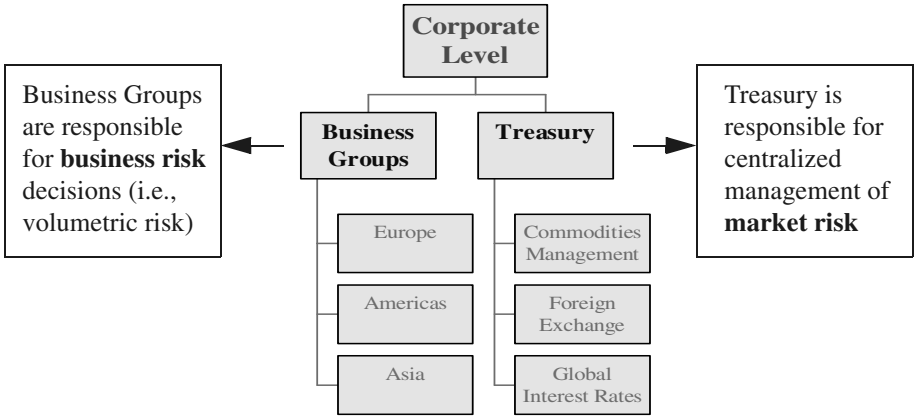
Fueled by globalization, capital markets fund raising, and regulatory prodding, VaR is making inroads with corporations. Enterprise-wide risk measurement is often more complex for corporates because of significant underlying non-financial exposures and accounting considerations. In addition to VaR, corporates may apply several related "at-Risk" measures: Earnings-at-Risk (EaR), Earnings-Per-Share-at-Risk (EPSaR), and Cash-Flow-at-Risk (CFaR). Longer-horizon forecasting complications also arise, as corporations are interested in making quarterly or even annual projections of earnings volatility. These issues are addressed further in the *CorporateMetrics Technical Document* and the *LongRun Technical Document*.

VaR has the most straightforward internal management application in a global corporate treasury, to measure FX and interest rate exposure. VaR can also be useful for companies that are sensitive to changes in commodity prices, such as airlines, manufacturers, steel producers, mining companies, and freight and shipping companies. For external disclosure requirements, VaR has been approved by the SEC as a measure of the risk of derivative positions.[3] One key advantage of using VaR for external reporting is that instrument-specific information need not be revealed.

Airline example

Let's consider a fictional U.S. based airline, Global Airlines, which is exposed to a host of business and financial risks. The airline has a centralized Treasury, which manages all financial risks, and three regional business groups, which are responsible for managing business risks (i.e., "volumetric" risk related to operations and ticket sales). Each regional business is responsible for its own jet fuel procurement, while the Treasury's Commodities Management group manages firmwide fuel price exposure centrally, with a mandate to keep annual Earnings-at-Risk (EaR) due to fuel price changes below a threshold amount. The Foreign Exchange group manages centralized FX exposures arising from international revenues and costs, and the Global Interest Rates group manages interest rate risk due to liabilities.

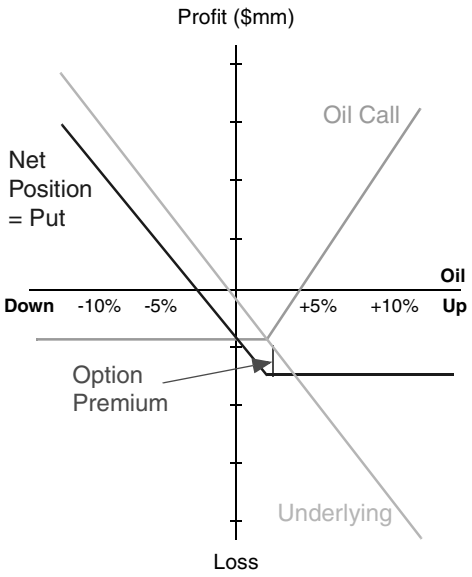
Global Airlines organizational chart



We will focus on the market risks that Global Airlines faces. First, we will quantify EaR due to oil price sensitivity, then EaR due to all relevant market variables.

[3] SEC disclosure requirements are further discussed in the next chapter.

Airline sensitivity to oil price changes



The Commodities Management trader in charge of designing a hedging program projects jet fuel consumption 1 month ahead, which is modeled as a short position in crude oil and unleaded gasoline. This assumes that the airline's P&L changes linearly with fuel prices[4] (i.e., all fuel price increases are absorbed by the airline, and fuel price decreases are direct savings to the airline). To cap downside, the trader purchases call options on oil futures. Instead of selling a put, she leaves the upside potential of fuel prices falling uncapped. The payoff of this position is illustrated in the sliding scale: losses are capped after approximately 5% increase in oil prices, while profits from fuel depreciation are uncapped. As the payoff diagram illustrates, the net position after hedges resembles a long put option on oil. Notice that the airline only profits after a 2% depreciation, due to the premium paid on the purchased call option on oil futures.

Both underlying fuel price sensitivities and derivatives hedges are entered into the RiskManager application for quantification of risk. The following risk reports analyze the net risk of this position.

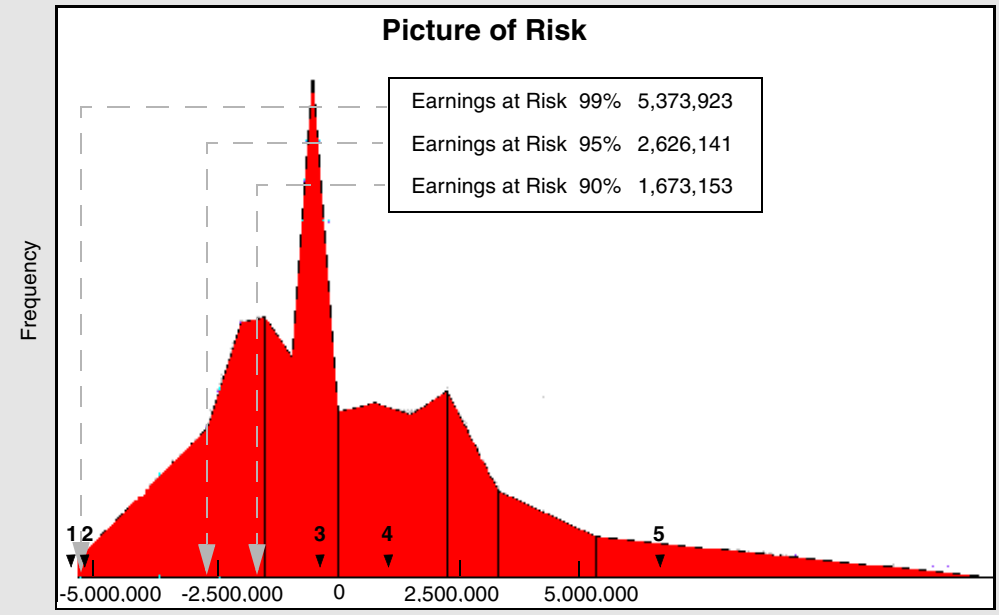
[4] A more sophisticated analysis would also account for the fact that large changes in fuel prices would be passed on to consumers (e.g., higher fuel prices imply more expensive tickets, and lower fuel prices mean cheaper tickets). The net position would thus be: short oil, long out-of-the-money call, short out-of-the-money-put. The next level of analysis might also take into account the changing demand for airline tickets, given pricing and competition.

Fuel VaR

The non-linear payoff from this exposure can be seen in the airline's commodity EaR report below:

Total Fuel EaR **April 27, 1999**

RMG



Stress Scenarios - PV Changes	
1. Gulf War (1990) 5-day	–5,392,980
2. Fuel prices up 8%	–5,322,403
3. Mexican Peso Fallout (1995) 5-day	–199,063
4. Black Monday (1987) 5-day	846,617
5. Fuel prices down 8%	6,900,736

95% EaR (1-month)	Aggregate	Underlying	Commodity Insurance
Aggregate	$ 2,626,141	12,618,318	4,319,514
Short crude oil	3,761,890	3,761,890	
Short unleaded	8,933,096	8,933,096	
Long Crude Call	1,560,172		1,560,172
Long Unleaded Call	2,967,781		2,967,781

Comments

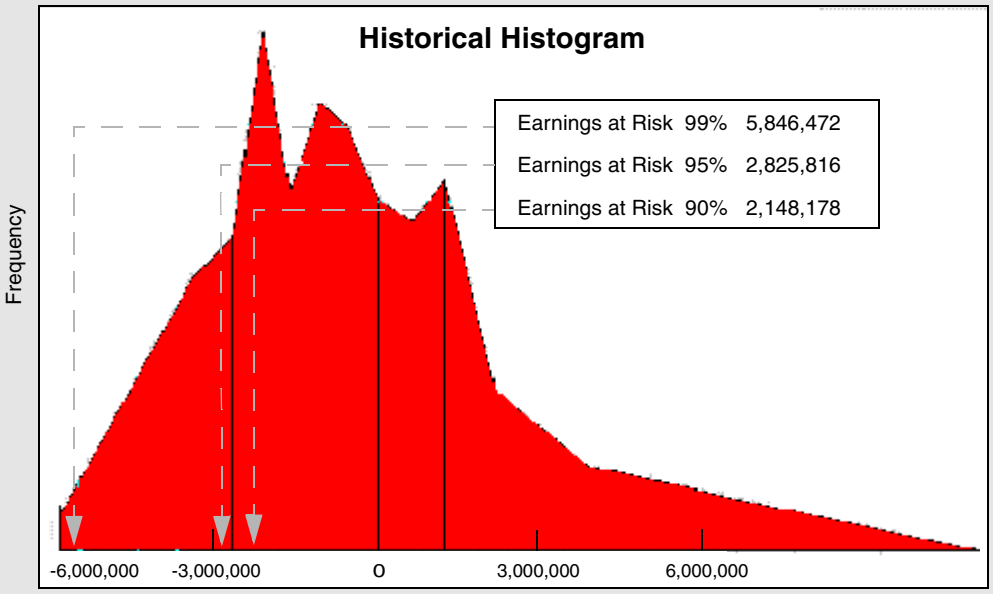
- Downside from Underlying positions (i.e., short fuel) is insured with long calls. Commodity Insurance reduced Underlying EaR by almost 80%, from 12,618,318 to 2,626,141. Notice that oil calls (i.e., insurance) reduces EaR by a greater amount than its stand-alone EaR (Commodity Insurance VaR = 4,319,514, EaR reduction = 9,992,177). Options have limited downside (i.e., the option premium) and unlimited upside (or insurance effect).
- Upside from oil prices falling is left uncapped, as shown by the long positive tail (right).

Total market risk

Next, we can aggregate FX risk from underlying operations and interest rate risk from the liabilities portfolio to calculate total market risk. We can then calculate the airline's total exposure to market risk.

Firmwide EaR **April 27, 1999**

RMG



95% EaR (1-month)	Aggregate	*Divers. Benefit*	Net Commodities	Foreign Exchange	Liabilities
Aggregate	2,825,816	*–1,686,054*	2,626,141	1,102,734	782,994
Divers. Benefit	*–1,554,109*				*–318,736*
Commodity Risk	2,626,141		2,626,141		
Interest Rate Risk	495,300				495,300
FX Risk	1,258,483	*–450,681*		1,102,734	606,430

Comments

- The airline's largest concentration remains in commodities, even after hedges (2,626,141). The airline is also significantly exposed to foreign exchange (1,102,734) and, to a lesser extent, interest rates (781,994).
- Notice the large diversification benefit between risk classes due to low correlation between commodity, interest rate, and foreign exchange rates (1,554,109).
- The distribution is positively skewed because losses due to rising oil prices are capped through call options, while gains due to falling oil prices are left open.

External disclosure of VaR

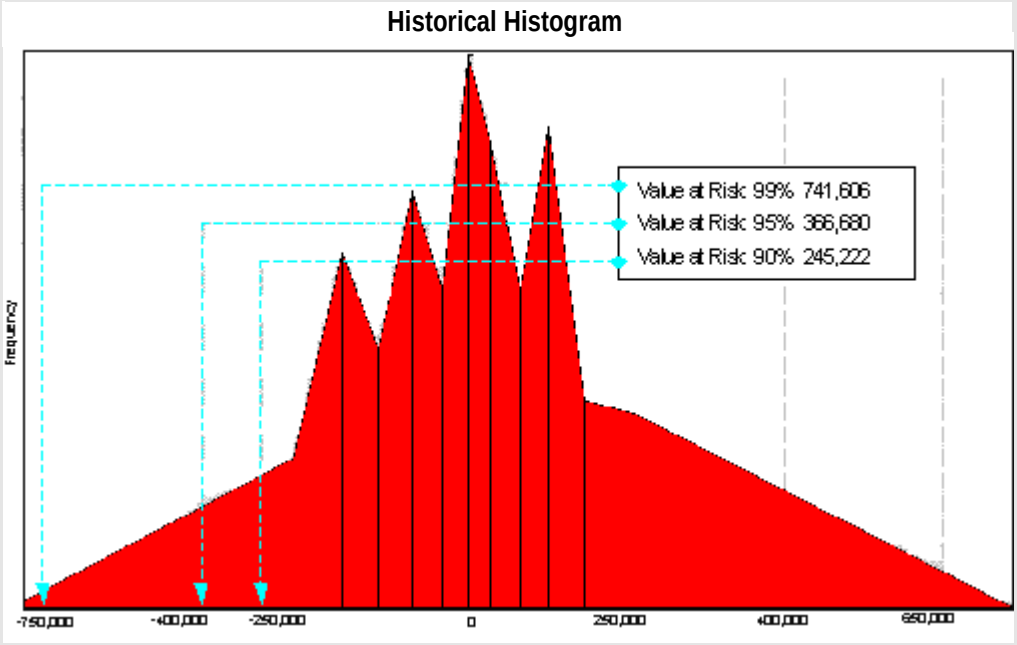
According to SEC disclosure requirements, a company has flexibility in how to disclose the VaR of its equities positions in terms of horizon and confidence level. Directionality and position-specific VaR need not be disclosed.

The following might be the annual report disclosure of VaR for the airline:

The firm is exposed to several market risks: commodity risk due to fluctuating jet fuel prices, foreign exchange risk from foreign operations and unhedged foreign liabilities, and interest rate risk from liabilities. The firm engages in an active hedging program using derivative instruments to reduce the market risk arising from its underlying operations. It is the firm's policy to use derivatives solely for hedging of underlying exposures, not for speculation.

As of December 31, 1998, the total daily 95% confidence VaR of the firm's derivatives positions is $366,680. This means that the firm's net derivatives positions have a 5% probability of losing more than $366,680 over a 24-hour period.

VaR of Derivatives **As of December 31, 1998**



95% VaR (1-day)	Dec. 31 '98	Avg. '98	Max. '98	Min. '98
Commodity Risk	$181,818	226,304	338,694	167,669
FX Risk	$285,734	240,955	362,714	143,255
Int. Rate Risk	$139,542	144,941	223,737	122,659
Divers. Benefit	*($240,414)*	*($241,256)*	*NA*	*NA*
Aggregate	**$366,680**	**370944**	**586,275**	**221,883**

Comments
RiskMetrics historical simulation is used to calculate market risks, using 1 year of historical data.

5.9 Summary of risk reporting issues

To promote risk communication across the firm, risk reports should highlight risk concentrations in a timely and accurate manner. Keep daily summary reports to one page and consider enhancing it with a written commentary. There is an important organizational hierarchy to risk reporting, in that significant risk exposures must be channeled up from the risk taker to senior management through efficient risk reporting. Risk information should be customized for different levels of the organization, highlighting relevant dimensions of risk and identifying the risk taking units.

There are different time dimensions to risk reporting. Active financial institutions use daily reports for active management of risks and monitoring of limits. Senior management looks at monthly or quarterly reports for a more strategic view of risk performance, trends, capital allocation, and competitor analysis. Market risk reporting has become a necessity for banks, and is increasingly implemented by asset managers, hedge funds, and insurance companies, as well as traditional corporations.

Chapter 6. External risk disclosures

6.1 Introduction

In addition to internal management reporting, companies are increasingly disclosing market risk to external entities: shareholders, regulators, analysts, lenders, and credit rating agencies. External disclosures vary greatly by country, industry, and company. Each central bank may impose risk reporting requirements on financial institutions within its jurisdiction. For example, in the United States, the Federal Reserve Bank regulates banks, and the SEC regulates securities firms and corporations. Beyond complying with required regulatory reporting, several major institutions[1] have led the way with voluntary disclosures on market risk.

6.2 Emerging global standards for public disclosures

While there is no single global regulatory standard for risk reporting, the BIS has actively promoted risk disclosures by global financial institutions. Jointly with the Technical Committee of the International Organization of Securities Commissions (IOSCO), the BIS issued *Recommendations for Public Disclosure of Trading and Derivatives Activities of Banks and Securities Firms*[2] with the following two general guidelines:

- *First, institutions should provide financial statement users with a clear picture of their trading and derivatives activities. They should disclose meaningful summary information, both qualitative and quantitative, on the scope and nature of their trading and derivatives activities and illustrate how these activities contribute to their earnings profile. They should disclose information on the major risks associated with their trading and derivatives activities and their performance in managing these risks.*

- *Second, institutions should disclose information produced by their internal risk measurement and management systems on their risk exposures and their actual performance in managing these exposures. Linking public disclosure to the internal risk management process helps ensure that disclosure keeps pace with innovations in risk measurement and management techniques.*

Recommendations center on qualitative and quantitative disclosures of market risk, as shown in the next two sections.

A. General qualitative disclosures of market risk

Qualitative disclosures focus on the model and parameters used to measure risk and are based on the following guidelines:

- *Discuss the Methods used to measure and manage market risk*
- *Discuss how performance in managing market risks is assessed*
- *Describe the Major assumptions and parameters used by internal models necessary to understand an institution's market risk disclosures:*
  - *Type of model used*
  - *Portfolios covered by the model*

[1] Examples are Dell, Sony, J.P. Morgan, Chase Manhattan, Citigroup, UBS Group and CSFB.
[2] http://www.bis.org/publ/index.htm

- *Holding period*
- *Confidence level*
- *Observation period*

- *Discuss the Method of aggregating risk exposures*
- *Discuss the Method used to recognize correlations between market factors (e.g., correlation assumptions)*
- *Provide an overview of Policies and procedures for validating internal models*
- *Provide an overview of Policies and procedures for stress testing market risk*
- *Discuss Changes in market risk exposure and risk management strategies from previous year*

As an example of a qualitative disclosure, see Chase Manhattan's description of the risk measurement methodology from its 1998 *Annual Report*:

Chase Manhattan 1998 *Annual Report*

The VAR, a dollar amount, is a forward looking estimate of the potential for loss. The VAR looks forward one trading day, and is calculated as the loss level expected to be exceeded with a 1 in 100 chance. The VAR methodology used at Chase is called historical simulation. Historical simulation assumes that actual observed historical changes in market indices such as interest rates, exchange rates and commodity prices reflect the future possible changes in those same rates and prices. In its daily VAR calculations, Chase's historical simulation provides different views of market risk in end-of-day positions, by aggregating positions by business, geography, currency or type of risk.

B. General quantitative disclosures of market risk

Quantitative disclosures center on providing summary trading results and VaR statistics.

- *Provide Summary quantitative information on market risk exposure based on internal methods used for measurement, with information on performance in managing those risks*
- *Provide Daily information on profits and losses on trading activities, combined with daily value at risk numbers*
- *Provide Summary VAR results on a weekly or monthly basis*
- *For those disclosing VAR data, Provide High/Low VAR*
- *For those disclosing VAR data, Provide Average VAR*
- *Discuss the Results of scenario analysis or impact of rate shocks for traded portfolios*
- *Discuss the Number of times (days) actual portfolio loss exceeded VAR*
- *For non-traded portfolios: provide summary VAR or EAR*
- *For non-traded portfolios: provide summary results of scenario analysis of impact of rate shocks*

Sample quantitative risk disclosures

This table outlines the major public market risk disclosures that are presented in the 1998 annual reports of Chase Manhattan, Citigroup, J.P. Morgan, UBS Warburg Dillon Read, and Credit Suisse First Boston.

Public disclosures	Chase	Citi	JPM	UBS	CSFB
Confidence level	99%	99%	95%	99%	99%
Forecast horizon	1 day	1 day	1 day	1 day	1 day
Base currency	USD	USD	USD	CHF	CHF
Average, high, low VaR	Yes	Yes	Yes	Yes	Yes
VaR by risk category	Yes	Yes	Yes	Yes	Yes
Daily VaR graph	No	No	Yes	Yes	Yes
P&L vs. VaR graph	No	No	No	Yes	Yes
Backtesting statistics	Yes	No	Yes	Yes	Yes
Histogram of daily P&L	Yes	No	Yes	Yes	Yes
Scenario analysis	No	Yes	No	No	No

Risk disclosures that exemplify reporting trends across the financial industry are highlighted on the next pages.

(a) Average, high and low VaR statistics are commonly disclosed:

Citigroup (Citicorp and Salomon): One-day 99% VaR vs. risk type

	Citicorp			Salomon Smith Barney		
In Millions of Dollars	**Dec. 31, 1998**	**1998 Average**	Dec. 31, 1997	**Dec. 31, 1998**	**1998 Average**	Dec. 31, 1997
Interest rate	**$ 13**	**$16**	$23	**$75**	**$67**	$57
Foreign exchange	**7**	**8**	8	**3**	**17**	12
Equity	**5**	**7**	8	**15**	**9**	11
All other (primarily commodity)	**1**	**1**	–	**11**	**11**	11
Covariance adjustment	**(11)**	**(14)**	(14)	**(33)**	**(34)**	(30)
Total	**$ 15**	**$ 18**	$ 25	**$ 71**	**$ 70**	$ 61

	Citicorp		Salomon Smith Barney	
In Millions of Dollars	**High**	**Low**	**High**	**Low**
Interest rate	25	10	75	62
Foreign exchange	16	3	26	3
Equity	13	4	15	5
All other (primarily commodity)	5	1	2	9

Chase Manhattan: One-day 99% VaR vs. risk type

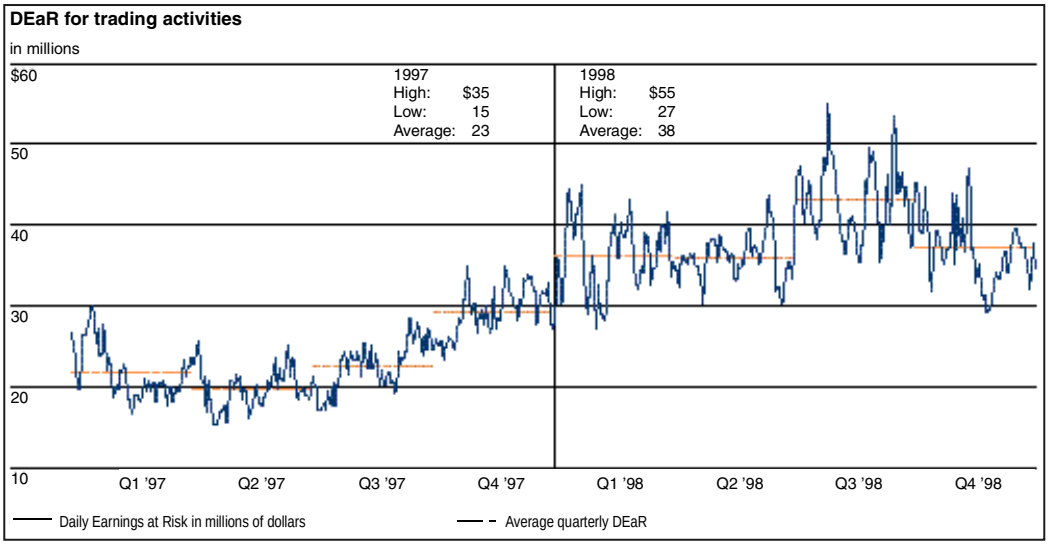
	Marked-to-Market Trading Portfolio			
Year Ended December 31, 1998 (in millions)	Average VaR	Minimum VaR	Maximum VaR	At December 31, 1998 V aR
Interest Rate VaR	**$ 22.8**	**$ 15.4**	**$ 36.8**	**$ 20.1**
Foreign Exchange VaR	**8.6**	**2.2**	**21.6**	**2.3**
Commodities VaR	**3.6**	**2.3**	**5.0**	**2.6**
Equities VaR	**3.8**	**1.9**	**9.4**	**4.6**
Less: Portfolio Diversification	**(13.1)**	**NM**	**NM**	**(8.9)**
Total VaR	**$ 25.7**	**$ 15.6**	**$ 44.9**	**$ 20.7**

(b) In addition to summary statistics, some firms, such as J.P. Morgan, provide a full history of aggregate daily portfolio VaR.

J.P. Morgan: Daily 95% VaR (or Daily-Earnings-at-Risk)

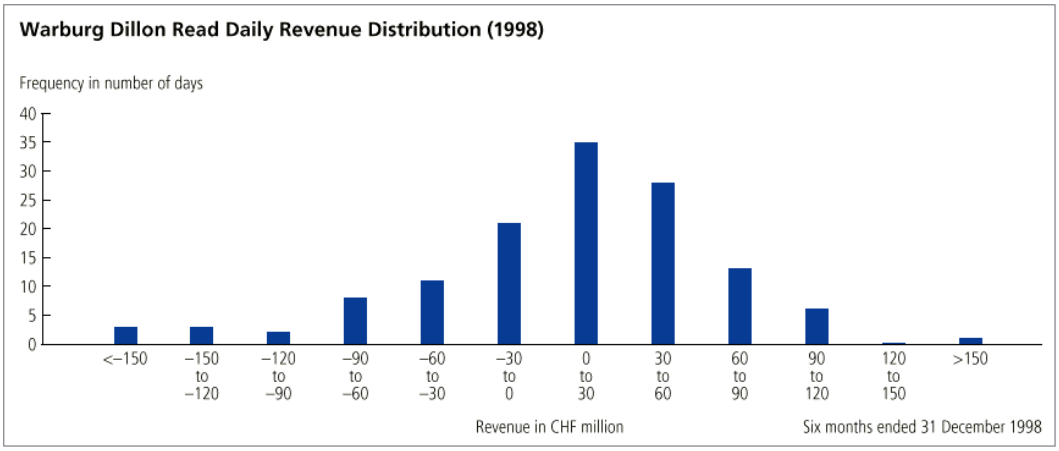
DEaR for trading activities

Average DEaR or trading activities increased 65% over the previous year to $38 million, reflecting growth in our market making activities as well as in extreme increases in volatility from August through October. Since we use DEaR primarily as a measure of expected volatility of short-term trading positions, our model weights recent patterns of market volatility and correlations most heavily. As a result our DEaR estimates changed rapidly in the August to October period of market turmoil.



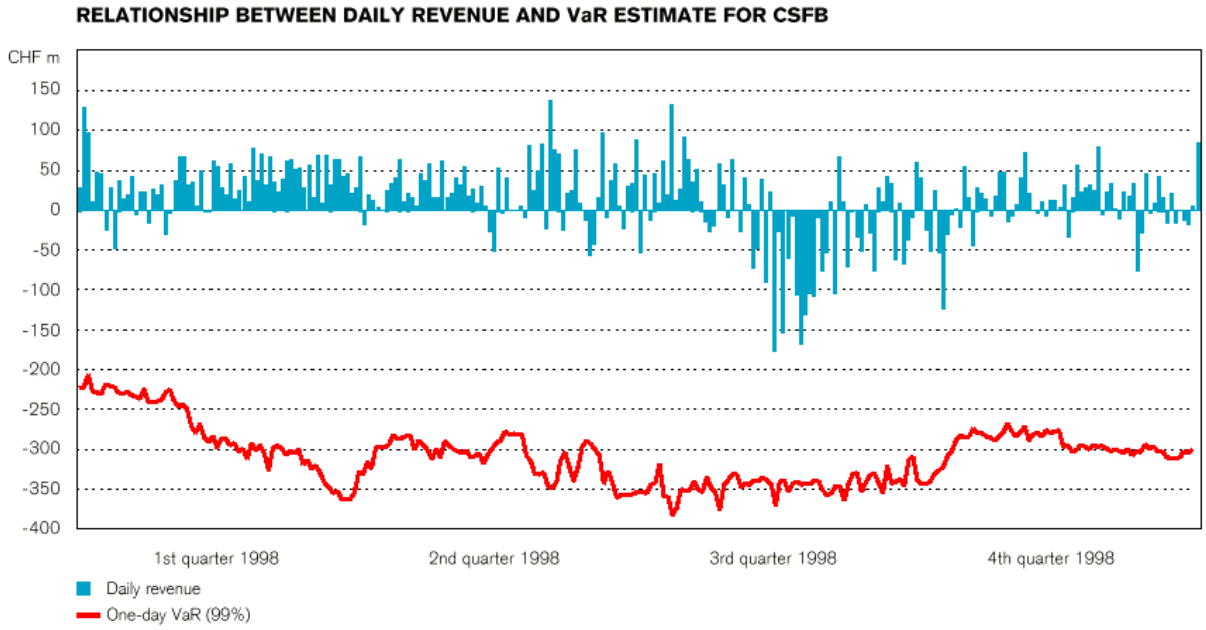
(c) Trading results are commonly released in the form of a histogram.

Warburg Dillon Read: Trading revenue distribution



(d) Some firms publish a history of daily revenues, with VaR bands, as required by the BIS for backtesting internal models for market risk.

Credit Suisse First Boston: Historical VaR vs. Revenue



RMG Comment: Credit Suisse First Boston's VaR vs. revenue band graph for 1998 shows an overly conservative VaR model. Revenues have a highly biased positive mean for the first two quarters of 1998, and even in the volatile 3rd quarter realized losses never come close to VaR estimates. At 99% confidence, CSFB should expect 2 to 3 daily downside exceptions per year (i.e., 1% of 252 trading days).

6.3 Voluntary risk disclosure for non-financial corporations

Increasingly, non-financial corporations provide the public with market risk disclosures. Voluntary disclosures are often perceived positively by the market place, because they demonstrate forward-looking financial management and a commitment to transparency. The ability to understand, measure, and manage market risk has become a competitive necessity for all global corporations.

Example 1: From Sony 1998 Annual Report

The financial instruments including financial assets and liabilities that Sony holds in the normal course of business are continuously exposed to fluctuations in markets, such as currency exchange rates, interest rates, and stock prices of investments.... Sony measures the effect of market fluctuations on the value of financial instruments and derivatives by using Value-at-Risk (herein referred to as "VaR") analysis. VaR measures a potential maximum amount of loss in fair value resulting from adverse market fluctuations, for a selected period of time and at a selected level of confidence. Sony uses the variance/co-variance model in calculation of VaR. The calculation includes financial instruments such as cash and cash equivalents, time deposits, marketable securities, non-lease short- and long-term borrowings and debt, investments and advances and all derivatives including transactions for risk hedging held by Sony Corporation and consolidated subsidiaries. Sony calculates VaR for one day from the portfolio of financial instruments and derivatives as of March 31, 1998, at a confidence level of 95%.

Based on this assumption, Sony's consolidated VaR at March 31, 1998 is calculated to be 6.9 billion yen ($52 million), which indicates the potential maximum loss in fair value resulting from market fluctuations in one day at a 95% confidence level. By item, the VaR of currency exchange rate risk is calculated to be 7.2 billion yen ($55 million) which mainly consists of risks arising from the volatility of the exchange rates between yen and U.S. dollars in which a relatively large amount of financial assets and liabilities and derivative transactions is maintained. VaR of interest rate risk and stock price risk are calculated to be 3.4 billion yen ($26 million) and 3.3 billion yen ($25 million), respectively. The net VaR for Sony's entire portfolio is smaller than the simple aggregate of VaR for each component of market risk. This is due to the fact that market risk factors such as currency exchange rates, interest rates, and stock prices are not completely independent, thus have the effect of offsetting a portion of overall profits and losses.

Example 2: From Proctor & Gamble 1998 Annual Report

The Company is exposed to market risk, including changes in interest rates, currency exchange rates and commodity prices. To manage the volatility relating to these exposures on a consolidated basis, the Company nets the exposures to take advantage of natural offsets and enters into various derivative transactions for the remaining exposures pursuant to the Company's policies in areas such as counterparty exposure and hedging practices. The financial impacts of these hedging instruments are offset by corresponding changes in the underlying exposures being hedged. The Company does not hold or issue derivative financial instruments for trading-purposes.

Derivative positions are monitored using techniques including market value, sensitivity analysis and a value at risk model. The tests for interest rate and currency rate exposures discussed below are based on a variance/co-variance value at risk model using a one-year horizon and a 95% confidence level. The model assumes that financial returns are normally distributed and approximates the financial return for options and other non-linear instruments. The model also reflects the impact of correlation and diversification from holding multiple currency and interest rate instruments. Estimates of volatility and correlations of market factors are drawn from the JP Morgan RiskMetrics™ dataset as of June 30,1998. In cases where data is unavailable in RiskMetrics™, a reasonable approximation is included. The effect of these estimates did not significantly change the total value at risk.

The Company's market risk exposures relative to interest and currency rates, as discussed below, have not changed materially versus the previous reporting period. In addition, the Company is not aware of any facts or circumstances that would significantly impact such exposures in the near-term

Interest Rate Exposure.... Based on the Company's overall interest rate exposure as of and during the year ended June 30, 1998, including derivative and other interest rate sensitive instruments, a near-term change in interest rates, within a 95% confidence level based on historical interest rate movements, would not materially affect the consolidated financial position, results of operations or cash flows.

Currency exposure.... Based on the Company's overall currency rate exposure as of and during the year ended June 30, 1998, including derivative and other foreign currency sensitive instruments, a near-term change in currency rates, within a 95% confidence level based on historical currency rate movements, would not materially affect the consolidated financial position, results of operations or cash flows.

Commodity Price Exposure.... Raw materials used by the Company are subject to price volatility caused by weather, supply conditions and other unpredictable factors. The Company uses futures and options contracts, primarily in food and beverage products, to manage the volatility related to certain of these exposures. Gains and losses relating to qualifying hedges of firm commitments or anticipated inventory transactions are deferred in prepaid expenses and are included in the basis of the underlying transactions. Commodity hedging activity is not material to the Company's consolidated financial position, results of operations or cash flows.

6.4 SEC disclosure requirements for derivatives

In 1997, the SEC recommended to its constituents to voluntarily report their derivative positions. As of June 1999, all members with a market cap of USD 2.5 billion or larger are required to report their derivative positions in one of three ways: (1) by listing their derivative positions in a tabular disclosure, (2) by providing sensitivity analyses, or (3) by reporting their exposures in VaR.[3] The companies are faced with the task of selecting one of the methods for reporting their market risk exposures.

Below are actual examples of the three types of market risk reporting options.

Tabular disclosure

Example 1. Tabular listing of derivative positions

From Tenneco 1998 Annual Report:

In managing its foreign currency exposures, Tenneco identifies and aggregates naturally occurring offsetting positions and then hedges residual exposures through third party derivative contracts. The following table summarizes by major currency the notional amounts, weighted average settlement rates, and fair value for foreign currency forward purchase and sale contracts as of December 31, 1998. All contracts in the following table mature in 1999.

		Notional amount in foreign currency	Weighted average settlement rates	Fair value in U.S. dollars
Belgian Francs	Purchase	594	0.029	$17
	Sell	–644	0.029	–19
British Pounds	Purchase	98	1.660	163
	Sell	–152	1.660	–252
Canadian Dollars	Purchase	112	0.654	73
	Sell	–176	0.654	–115
Danish Krone	Purchase	79	0.157	12
	Sell	–	–	–
French Francs	Purchase	497	0.179	89
	Sell	–97	0.179	–17
German Marks	Purchase	3	0.599	2
	Sell	–56	0.599	–33
Portuguese Escudo	Purchase	1,947	0.006	11
	Sell	–30	0.006	–
Spanish Pesetas	Purchase	4,545	0.007	32
	Sell	–325	0.007	–2
U.S. Dollars	Purchase	105	1.000	105
	Sell	–33	1.000	–33
Other	Purchase	395	0.043	17
	Sell	–719	0.068	–49
Total				$1

[3] See http://www.sec.gov/rules/final/33-7386.txt.

Sensitivity analysis

Example 2. Sensitivity analysis of positions

From Texaco 1998 Annual Report:

Petroleum and Natural Gas Hedging

In 1998, the notional amount of open derivative contracts increased by $3,423 million, mostly related to natural gas hedging.

For commodity derivatives permitted to be settled in cash or another financial instrument, sensitivity effects are as follows. At year-end 1998,the aggregate effect of a hypothetical 25% change in natural gas prices, a 15% change in crude oil prices and 16–21% change in petroleum product prices (dependent on product and location) would not materially affect our consolidated financial position, net income or cash flows.

VaR disclosure

Example 3. VaR Disclosure

From Dell 1998 Annual Report:

Based on the Company's foreign exchange instruments outstanding at February 1, 1998, the Company estimates a maximum potential one-day loss in fair value of $12 million, using a Value-at-Risk ("VAR") model. The VAR model estimates were made assuming normal market conditions and a 95% confidence level. There are various types of modeling techniques that can be used in a VAR computation; the Company used a Monte Carlo simulation type model that valued its foreign currency instruments against a thousand randomly generated market price paths.

6.5 Summary

Increased regulatory scrutiny and public concern have stimulated a clear trend toward greater public disclosure of market risks, for both financial and non-financial corporations.

Several leading global financial firms have started voluntary disclosures of their market risk management methodology, including a range of VaR and trading results statistics, and sensitivity analysis. To avoid information overload, companies should limit disclosure to relevant information only. Relevant disclosure might include explanation of differences between reported accounting results and actual economic effects of hedges.

To encourage a broader range of institutions to disclose risks, BIS and IOSCO have jointly issued recommendations concerning voluntary global market risk disclosures. Regulatory agencies, in general, are also introducing mandatory disclosures.

In the United States, the SEC has required all non-bank members with a market capitalization of $2.5 billion or more to disclose derivative positions through tabular representation, sensitivity analysis or VaR. Other countries will surely follow, and risk disclosures are likely to become a standard for all major corporations.

If this trend of increased disclosure continues, it would be conceivable to one day find audited risk reports published in the annual or quarterly reports of all listed companies.

Chapter 7. Using risk information

7.1 Linking risk and return

Risk measurement is but an intellectual exercise unless it is used actively in managing businesses. Instead of focusing only on maximizing revenue, companies are increasingly considering return on risk in strategic planning and budgeting. Clearly, the risk taken should relate to both business performance evaluation and capital allocation. The link between risk and return should be established from the corporate level down to the individual trading desk.

7.2 Risk and performance

In deciding which risks to take on, investors weigh opportunities against the downside. One standard measure of return on risk is the Sharpe ratio, named after Nobel Laureate professor William F. Sharpe. Sharpe ratio analysis can be applied on different levels, from analyzing a single transaction to evaluating an entire business or asset class.

The general definition of the Sharpe ratio is

$$\textbf{Sharpe ratio} = \frac{\textbf{Annualized earnings}}{\textbf{Annualized standard deviation of earnings}}$$

Annualized earnings are net returns after funding costs. To annualize returns, you multiply linearly by time. For example, a monthly return of 1% converts to an annualized return of 12%.

Standard deviation of return is a measure of risk, or uncertainty, of return. To annualize standard deviation, multiply by the square root of time. For example, a monthly standard deviation of return of 1% converts to an annualized standard deviation of $1\% \times \sqrt{12} = 3.46\%$.

Note that the Sharpe ratio is also commonly expressed as

$$\textbf{Sharpe Ratio} = \frac{\textbf{Return} - \textbf{Risk-free rate}}{\textbf{Standard deviation of returns}}$$

Higher Sharpe ratios are better. You can improve Sharpe ratios either by increasing returns or by decreasing risk. Historical Sharpe ratios over long periods of time for most major asset classes have ranged from 0.3 to 2.

Using Sharpe ratios

Sharpe ratio benchmarks can be applied flexibly from the corporate to the trader level. In a business context, Sharpe ratios can be used for:

- Setting targets for results
- Evaluating performance after the fact
- Benchmarking

Risk performance reporting

Risk performance reporting gives a historical perspective of business risk-taking and performance and should include the following elements:

I. Business contribution (or net earnings after funding basis)
II. Risk measures (VaR)
III. Return on risk (Sharpe ratio)
IV. Histogram of realized P&L vs. estimated VaR
V. Historical revenue, risk, and excession statistics

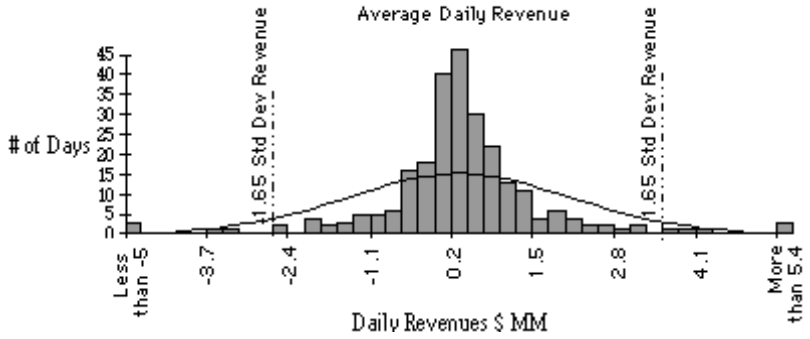
The sample quarterly risk performance report for Global Bank shows how the performance of the trading business could be monitored and evaluated.

Global Bank

Market Risk and Performance Report As of Jan 31, 1998

I. Contribution ($MM)	Last 3 Months	Last 12 Months		
Revenue	6.8	15.6		
Contribution	4.0	10.0		
II. Risk Measures ($MM)				
Volatility of Daily Revenues	2.7	1.8		
III. Return on Risk			Benchmark Value	Better Values
Sharpe ratio (mean contribution on volatility	0.4	0.3	0.7	higher

IV. Histogram for 12-month period ending Jan 31, 1998



V. VaR Excession Statistics

Period	Avg. Daily Revenue ($MM)	Revenue ($MM)	Avg VaR/1.65 ($MM)	Revenue	
				Upside Breaks	Downside Breaks
11/96–01/97	0.1	2.7	1.3	6%	11%
08/96–10/96	0.1	1.3	0.8	11%	13%
05/96–-07/96	0.0	0.9	0.9	5%	5%
02/96–-04/96	0.0	1.7	0.7	6%	6%

Comments
Reflecting a difficult market environment characterized by lower trading volume in Emerging Markets and decreasing spreads on derivatives due to increased competition, Global Bank failed to achieve its overall Sharpe ratio target of 0.7. However, it is too early to judge GB's performance without comparing it to the performance of industry peers. Global does show an increasing Sharpe ratio, going from 0.3 over the last 12 months to 0.4 over the last 3 months.

Performance evaluation cycle

Sharpe ratio measurement can be integrated into the overall business performance evaluation cycle, which consists of three elements:

1. Goal setting

- Defining business objectives
- Benchmarking

2. Monitoring

- Targeted reports
- Periodic reviews

3. Evaluation

- Feedback
- Compensation

Source: Managing Risk

7.3 Risk and capital

Companies must set aside equity capital as a cushion against anticipated worst-case losses from their business activities. Although methodologies for capital allocation are still hotly debated, clearly the level of risk taken should relate to capital: more risk = more capital. If a sensible link exists between risk and capital, companies can set minimum threshold return on capital targets, and optimize risk adjusted performance by maximizing return on capital.

The rest of this chapter first covers regulatory capital requirements, and then addresses economic capital allocation.

a. In recognizing the applicability of VaR for relating risk to capacity, the BIS gives international banks the option to use VaR to calculate required **regulatory capital** for market risk.

b. For determining **economic capital**, we recommend also taking into account stress test results on a judgemental basis, and realized revenue volatilities as an indication of business or franchise risk

A. Regulatory capital

Having recognized the importance of VaR measurement, the BIS has given certain international banks the option to set market risk capital requirements with internal VaR models. The criteria to qualify for this *Internal Models Approach* are described in the *Amendment to the Capital Accord to incorporate market risk*, January 1996, modified in September 1997. Many central banks have adopted BIS standards for minimum market risk capital.

Qualitative criteria

To satisfy the qualitative criteria, banks must have a sound conceptual approach to measuring risk, stress testing, backtesting, model reviews, risk-based limits, clear policies, use of risk measurement on a day-to-day basis, and several organizational factors such as active involvement of senior management, qualified staff, and an independent risk monitoring group.

Quantitative criteria

The main quantitative criteria are:

Frequency of calculation	VaR must be calculated on a daily basis.
Confidence level	99% confidence interval (one-tailed).
Time horizon	Assume a 10-day holding period (note that the legitimacy of square root of time scaling of daily VaR is currently debated).
Market data	A minimum of 1 year of evenly weighted historical market data, with at least quarterly updates of data (note: exponential weighting is not accepted).
Methodology for VaR	Flexibility in risk methodology: parametric, Monte Carlo and historical simulation. Methodology should take into account correlations within asset classes and non-linear risk characteristics of options.
Capital requirement	Banks must have sufficient capital for market risk every day, which is defined as the higher of (i) last day's VaR or (ii) the average VaR over the preceding 60 days times a multiplication factor.
VaR multiplication factor	The multiplication factor ranges from 3 to 4, depending on model accuracy as perceived by regulators. Banks start with a multiplication factor of 3, which regulators increase by adding a penalty factor from 0 to 1, depending on backtesting results (e.g., a penalty factor of 1 implies a net multiplication factor of 4).
Specific risk	There may be a specific risk charge for interest rate and equity instruments, depending on whether the bank's internal model appropriately takes into account specific risk.

In summary, we have the following formula for BIS market risk capital:

$$\text{Market Risk Capital} = \text{10-day, 99\% confidence VaR} \times (3 + \text{penalty factor})$$

For example, from information published in 1998 annual reports, we can estimate the minimum level of BIS market risk capital for the following companies (note that we assume no penalty factor or specific risk charge).

Company	1998 average daily VaR, $MM	99% confidence, 10-day VaR	Est. minimum BIS capital
Chase	64	202	606
Citicorp	18	57	171
Salomon	70	221	664
J.P. Morgan*	55	246	736

* J.P. Morgan uses 95% confidence level, while others in this list use 99%.

B. Economic capital

Firms must determine an efficient economic capital structure for their businesses. Too little equity capital puts a company at risk of defaulting because of business fluctuations. Setting aside a lot of equity capital is safer, but costly and inefficient. Generally, lenders and bond holders prefer high capitalization to protect against default, whereas equity investors prefer to minimize equity capital to earn a high return on investment. Finding an optimal capital struc-

ture involves finding the right balance between the need for safety and the desire for maximizing return on capital.

Capital allocation

In addition to setting aside a total amount of capital, a company must decide how much capital to allocate within its business and charge a cost of capital to each business unit. As a precious resource, capital should be allocated to projects offering the most promising return on capital. Again, the amount of capital allocated should be related to risk. However, stand-alone risk is less important than incremental risk. For example, a business with relatively large potential revenue fluctuations could in fact add very little incremental risk to a business if it has low or negative correlation to the overall business (i.e., it diversifies or even hedges the rest of the business).

Capital allocation follows a hierarchical structure which should reflect the organization of businesses and risk limits. For allocating capital properly, companies must have sensible categories for businesses. For example, a derivative desk which mitigates the risk of bond trading positions should not be looked at in isolation, but together with the bond trading book.

For capital allocation, companies may take into account daily MTM revenue fluctuations, in addition to VaR and stress testing. Beyond market risk, actualized revenue volatility includes franchise specific uncertainties, such as volumetric risk. Generally, companies use longer horizons, such as 1 year, for economic capital requirements.

VaRBaR

Capital and forecast horizon

A important issue for corporate risk managers is to determine an appropriate horizon for capital allocation, and whether to use one uniform or varying horizons depending on the type of business and financial instrument. If a firm applies a uniform horizon of say, 1 year, across all trading desks, traders of liquid investments may complain that 1 year is far too long a horizon to consider risk because their trading books turn around much more frequently, and that it is possible to get out of their positions in a matter of days. Clearly, there should be some advantage to trading liquid Eurobonds vs. illiquid loans. However, another argument holds that liquidity should not be the driving factor, but rather the concept of operating a going concern. If an Emerging markets bond trading business liquidates its positions and invest in US treasuries, it is no longer in the business it was paid to be in. Therefore, from the perspective of having a going concern, capital allocation should be part of longer term (e.g., annual) uniform planning horizon.

7.4 Summary

Companies should establish a linkage between risk and return to properly manage businesses. Two crucial areas for applying risk information are in evaluating business performance and allocating capital.

Risk performance reporting may include Sharpe ratio analysis to set performance targets or benchmarks, and to evaluate risk adjusted performance after the fact. Sharpe ratio measurement may be a part of the business performance evaluation cycle, which consists of goal setting, monitoring, and evaluation. Firms are beginning to link compensation of risk takers to their return on risk, as opposed to their absolute return. Sharpe ratios are calculated by analyzing the historical volatility of revenues (i.e., annualized return over the risk free rate divided by volatility of return).

Companies distinguish between regulatory minimum capital requirements and economic capital allocation. BIS has approved VaR for setting aside market risk capital of qualified international banks. For internal capital allocation, it may be useful to consider stress results on a judgmental basis, as well as the volatility and correlation of actualized revenues.

Chapter 8. Market data for risk reporting

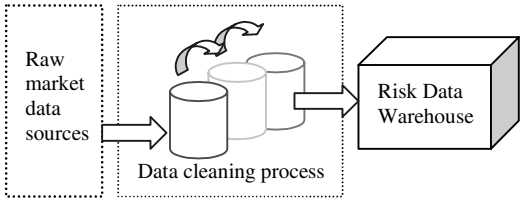
8.1 Type and quantity of market data

As mentioned in Chapter 4, to model potential changes in the value of financial instruments, market risk models must be supplied with daily updates of raw and derived data.

- Raw data includes time series of interest rates, foreign exchange rates, equity indices, commodities prices, and individual equity, bond, futures and options time series.
- Derived data includes **log returns**, **standard deviations**, **correlations**, **implied volatilities**, **credit spreads**, **constant maturity yields**, and **benchmark yield curves** and indices.

Data collection process

Raw market data is extracted from various sources (e.g., exchanges, data vendors), cleaned and processed in several stages, then stored in a risk database.



Risk managers have a voracious appetite for data. The more, the better. Specific data requirements, however, depend on the methodology used for predicting risk. Below, we provide some guidance on minimum data requirements, however, with the disclaimer that there is no universally correct answer to how much is enough.

Historical simulation

For historical simulation, at least 1 year of most recent daily market rates data should be available for 1-day VaR forecasts. Longer-horizon forecasts require more data. Historical data sets containing stress periods are especially valuable for stress testing. As discussed in Chapter 2, RiskMetrics research has compiled a number of relevant historical stress data sets, ranging from the 1997 stock market crash to the Russian devaluation.

Statistical VaR estimation

When using a statistical market risk forecasting approach (e.g., Monte Carlo simulation and parametric VaR), you need current market rates (e.g., interest rate and FX levels) as well as standard deviations and correlations derived from historical rates.[1]

Standard deviations and correlations are available from DataMetrics. They can also be derived on a case-by-case basis from statistical analysis of time series, as discussed in Chapter 5 of the *RiskMetrics Technical Document* and in Module 3 of the *Managing Risk* course. For example:

- Standard deviations can be forecasted by analyzing the magnitude of past market moves. Standard deviation, or volatility,[2] characterizes dispersion from the mean, or uncertainty.
- Correlations can be derived from observing statistical co-movement between different risk factors over time. Correlations, which range from –1 to 1, are the most important portfolio risk factors.

[1] Note that standard deviations and correlations can be derived from the same data set as historical simulations. By using only volatilities and correlations, you are discarding information about the actual distribution of returns. Note also that implied volatilities from option prices may also be used instead of historic volatilities, as discussed in the *RiskMetrics Technical Document*, Chapter 5.

[2] Within the RiskMetrics framework, volatility refers to the standard deviation of returns multiplied by 1.65.

BIS regulatory requirements for market risk call for historical volatility and correlation estimates based on at least 1 year of daily data, equally weighted. With a **decay factor** of 0.94, the last 75 trading days are the most important and account for 99% of 1-day volatility and correlation forecasts. A decay factor of 0.97 for 1-month volatility and correlation estimation implies that you need 150 days of data to achieve a 99% tolerance level.[3] More data, however, increases validity, and other statistical estimation techniques may require more data.

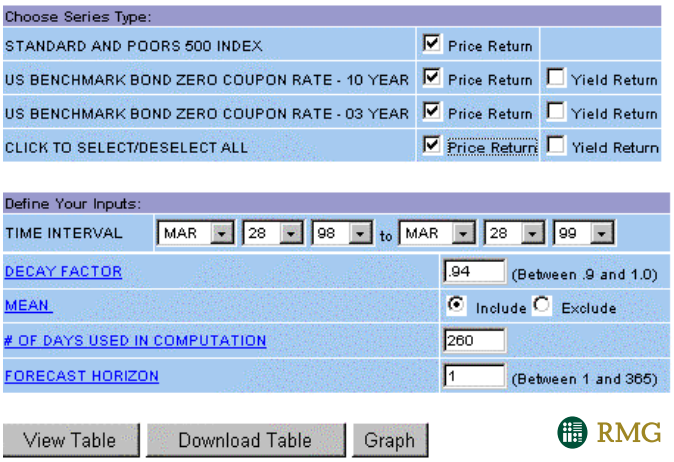
8.2 Deriving volatilities and correlations from raw historical data

The following DataMetrics demonstration[4] illustrates the process of deriving volatilities and correlations from raw price levels and is summarized in the three steps below.

a. Select desired time series and parameters

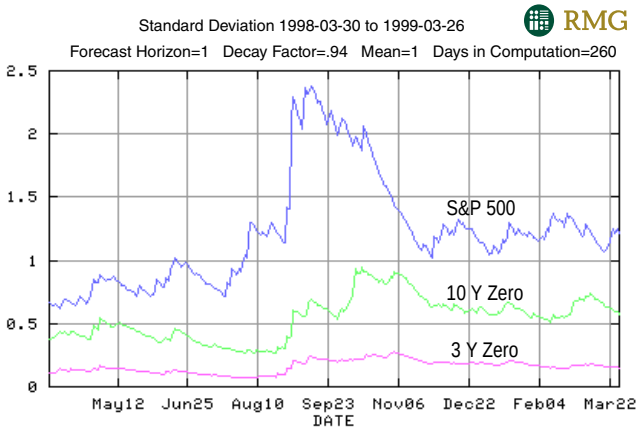
We choose the S&P 500 Equity Index, as well as the U.S. 10- and 3-year zero coupon rates. Note that we base risk calculations on price returns, as opposed to yield returns.

We choose an exponential decay factor of 0.94, as recommended by the *RiskMetrics Technical Document*, and select 1 year of history.



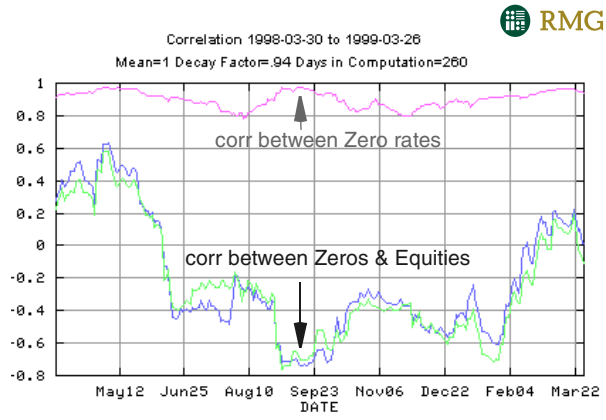
b. Derive volatilities

We can now choose to graph or download a table of DataMetrics-supplied volatilities. This first graph shows the volatility of the three time series we chose in Step a. As expected, the equity index is the most volatile, followed by the 10-year and 3-year zero coupons. Notice the volatility spike around September 1998 (during the Russian crisis and LTCM's near-death experience).



[3] See the R*iskMetrics Technical Document*, Table 5.9 (p. 100).
[4] See http://www.riskmetrics.com/data/index.cgi.

c. Derive correlations

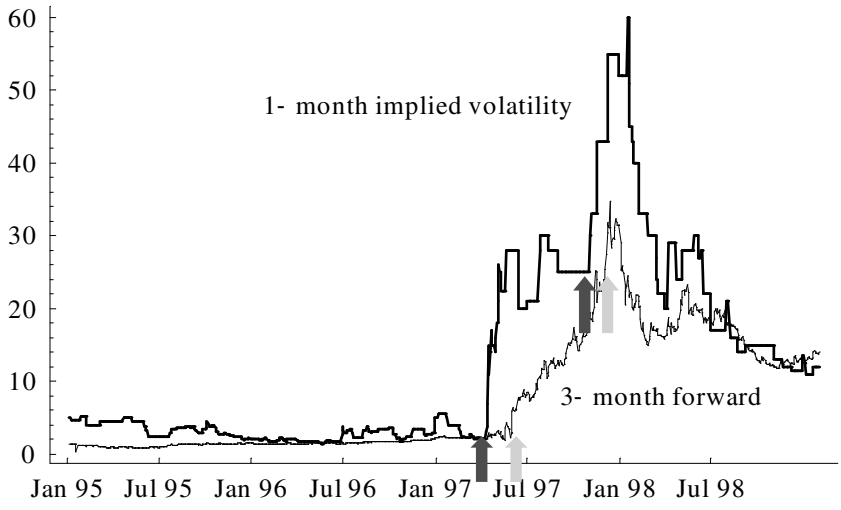


We can also view the dynamic nature of correlations. As expected, we see a consistently high correlation between the two zero rates (80% to 97%). More interesting is how the correlation of equities versus zero-price-changes drops from positive to negative in May '98, and becomes positive only in early '99. During normal market conditions, we expect to see a higher frequency of positive correlations between equities and bonds. Such shifts in correlations significantly impact portfolio risk, and can influence hedging and diversification strategies.

8.3 Use of historical versus implied volatilities

RiskMetrics volatility and correlation forecasts are currently based on historical price data. Volatility forecasts can also be derived from option prices. This allows risk forecasting based on the market's expectation of future volatility, instead of realized historical price volatility. In some instances, this approach is clearly compelling.

Implied volatilities lead forward rates in predicting crisis



Source: A. Malz, 1999, working paper, *Do implied volatilities predict crises?*

For example, in the case of a pegged currency (e.g., Hong Kong dollar, Argentine peso), implied volatilities contain valuable information about the market's perception of devaluation risk. In some cases, implied volatilities have been an early indicator of event risk. For example, implied volatilities started spiking upwards several days before the Thai baht devaluation in July 1997, as shown in the chart.

There are many practical and theoretical issues to consider regarding the use of implied forecasts. The most significant limitation of implied forecasts is the near impossibility of deriving implied correlation estimates (this is only possible with FX options and certain cross asset class options.) Several other concerns are discussed in the *RiskMetrics Technical Document*, Chapter 5.

8.4 Exponential weighting of time series

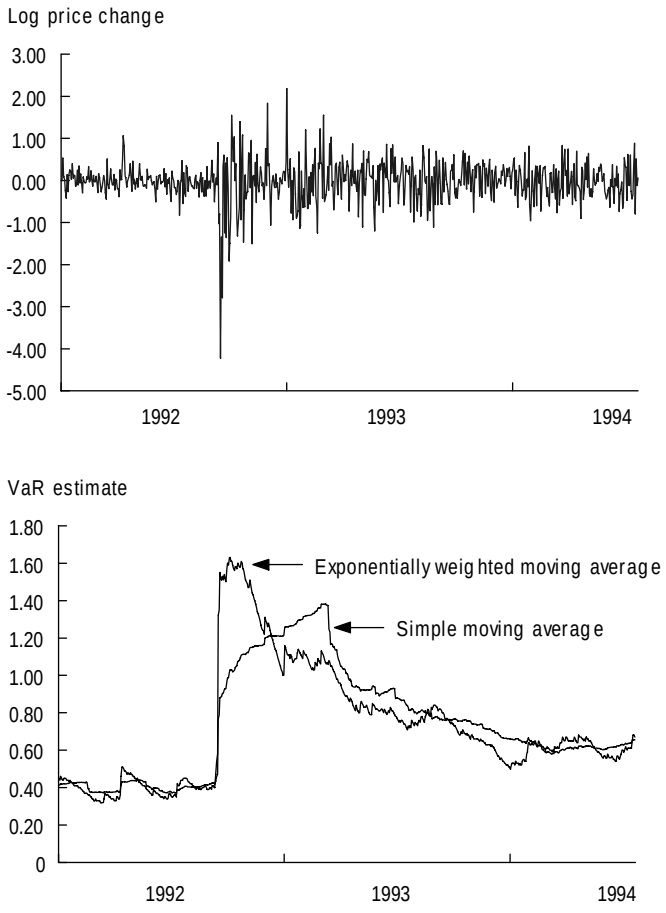
RiskMetrics recommends the use of the **exponentially weighted moving average (EWMA)** model to produce forecasts of variance and covariance, as discussed in Section 5.2 of the *RiskMetrics Technical Document.* Exponential weighting is more responsive to market shocks than equally weighted moving averages and is relatively simple to implement. The intuition behind EWMA is simple: volatility comes in clusters. If the markets move by a large amount today, chances are high that we will see some large shocks in the next few days. Exponential weighting means that you weight recent data points more heavily. The **decay factor**, or **lambda**, is the weight applied in the exponential moving average. It takes a value between 0 and 1.

8.5 Log price change of GBP/DEM and 95% VaR estimates

EWMA: responds better to shocks

The charts highlight an important difference between equally and exponentially weighted volatility forecasts by using as an example the GBP/DEM exchange rate in the fall of 1992.

In late August of that year, the foreign exchange markets went into a turmoil that led a number of Europe's currencies to leave the ERM and be devalued. The standard deviation estimate using an exponential moving average rapidly reflected this state of events, but also incorporated the decline in volatility over subsequent months. The simple 6-month moving average estimate of volatility took longer to register the shock to the market and remained higher in spite of the fact that the foreign exchange markets calmed down over the rest of the year.[5]



8.6 What is good market data

As mentioned earlier, compiling a good risk database is a challenge for all participants in the financial markets. Often data must be obtained from different vendors and extensively evaluated and cleaned.

[5] *RiskMetrics Technical Document*, Sec. 5.2, p. 79.

Current

Market data should be updated on a daily basis to reflect current market conditions. Having timely data is crucial for dynamic risk estimation in turbulent market conditions.[6]

Comprehensive

Market data should be comprehensive in country and asset class coverage. Often, proxies or benchmark risk factors can be used to model instrument risk. For example, selected points of a fitted interest rate curve can be used to model interest rate sensitivities for loans, bonds, swaps, futures, forwards, swaptions, caps, and floors.[7] Similarly, credit curves by country, industry, and credit rating may be used to calculate credit spread sensitivity for corporate debt issues.

Clean

Data must be clean, consistent, and complete. When extracting data, risk managers often encounter pricing inconsistencies from different sources, unrealistic illiquid prices, missing data points, and human error. Data errors must be cleansed in a rigorous quality control process.

Consistent

Whenever possible, market time series should be consistently **snapped** at the same time of day. If data is captured at different times, correlations are underestimated. Note that synchronous snaps may not be achieved in markets that trade in non-overlapping time zones, such as the U.S. and Japan.

8.7 The task of the risk data analyst

Large financial institutions often have dedicated data analysts to ensure that required risk data is available for risk measurement. Responsibilities include procuring new time series, diagnosing, cleaning, organizing, analyzing, and distributing data.

Diagnosing and cleaning

The DataMetric*s* team defines a rigorous process for diagnosing and cleaning data:

> The first procedure diagnoses data for **outliers**. DataMetrics defines an outlier as a data point that is either the **same** as the previous day's data point (i.e., the data is "static"), or **missing**, or that has **changed substantially** from the previous day's value.
>
> In addition to evaluating each time series individually, we have implemented a diagnostic procedure to compare the same time series from different contributors. For instance, we might compare a 2-year USD interest rate swap rate from Broker A to the same 2-year swap rate from three other brokers. This **multi-contributor comparison** is useful in identifying potentially spurious values.
>
> The remaining procedures diagnose
>
> - the **basis point shifts** from one day to the next for each vertex of a curve,
> - the **slope** from one vertex to another for a single curve, and the
> - the **change in standard deviation and correlation from one day to the next**.To test the validity of data, analysts may engage in the time-consuming task of checking alternate data sources or news stories related to a particular financial market.

[6] During crisis events, such as the '94 Mexican peso crisis, banks discovered that updating market risk factors on a daily basis was essential. For example, monthly risk factor updates resulted in constant excessions of risk limits until the event was included in the data set. Unfortunately, after the event was included, risk was drastically overestimated for the next month because market conditions had calmed down.

[7] See the *RiskMetrics Technical Document*, Chapter 6.

Deriving data

Once raw data is diagnosed and cleansed, the next step is to derive risk data:

> After all "raw" data have been deemed correct, data processing continues with the creation of what we call **derived data**. Often, time series values within DataMetrics are not observable in a market or traded on an exchange, but are created (derived) from other data. Typically, we derive data to
>
> 1. create a series that represents the behavior of a "constant maturity" instrument, and to
> 2. "smooth out" the effects of contract expiration.

Data analysts ensure that this cycle of collecting, cleansing, organizing, and processing market data works smoothly every day.

8.8 Where to get market risk data

Risk managers have traditionally derived data from many different sources, including data vendors, broker screens, and a firm's own prices. However, to assure independence, risk managers should not rely on internal traders' quotes, and always have a reliable external source (at least for verification). Before raw data becomes useful for risk management, it must be processed, cleaned, and verified extensively. Transforming raw market data into usable risk data requires a significant investment in time, technology, and people.

DataMetrics is the first complete risk data solution specifically tailored for risk managers. As a single source, it is the word's most extensive public market risk database, with new time series added continuously. Due to significant infrastructure investment and economies of scale, DataMetrics can offer a high-quality and economical data solution to risk managers everywhere. You can visit the DataMetrics web site for a demonstration of the service.

8.9 Summary

In this market-based information age, accurate and timely data is crucial. To accurately reflect current market conditions, data should be updated on a daily basis. Risk managers use both raw data (e.g, interest and foreign exchange rates) and derived data (e.g., volatilities and benchmark yield curves).

Specific data needs vary, depending on risk methodology and time horizon. Generally, risk managers should have access to a minimum of 6 months of daily market data to make reliable forecasts. Historical data sets during market crises are valuable for stress testing.

The most common derived data for portfolio risk estimation are historical volatilities and correlations. RiskMetrics research recommends the use of EWMA to forecast historical volatilities and correlations. EWMA responds quickly to market shocks, which tend to come in clusters. The DataMetrics web site allows users to quickly derive, visualize, and download historical volatilities and correlations. The evolution of volatilities and correlations gives valuable insights into market behavior.

Implied volatilities can also provide important insights into market risk. Often, implied volatilities have been an early indicator of event risks, such as the devaluation of the Thai Baht in July '97, which precipitated the Asian crisis. The use of implied volatilities, however, has many practical and theoretical constraints, the most important of which are limited market coverage and the infeasibility of deriving implied correlations.

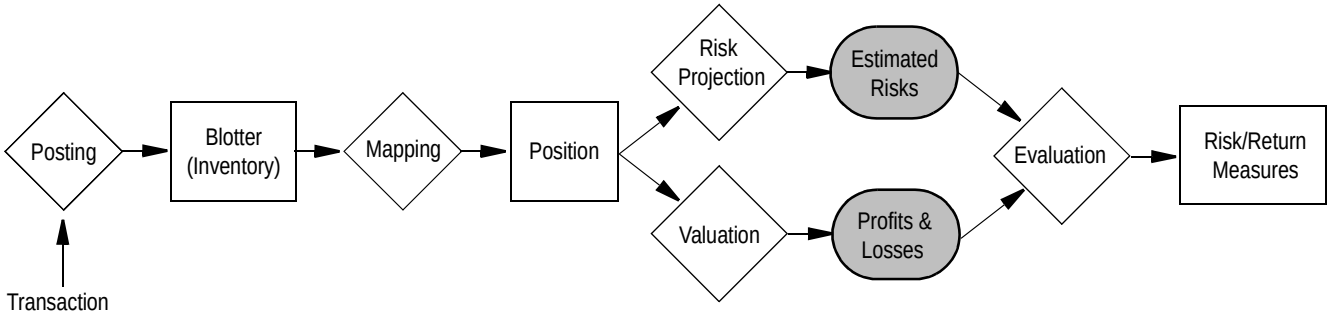
Companies have traditionally allocated significant resources to developing an in-house process to efficiently gather, clean, and verify data. Risk managers now have the option of outsourcing this entire process. Through DataMetrics, risk managers have access to a single comprehensive source of reliable risk data, captured in a clear and fully documented format.

Chapter 9. Position data for risk mapping

9.1 The data collection process

On a typical day, major financial institutions engage in thousands of individual transactions involving every conceivable financial instrument.

This flow chart shows the generic transaction cycle, from inception to evaluation of risks and calculation of P&Ls.



Companies have the formidable task of collecting, cleansing, organizing, and aggregating timely position information to get an accurate risk profile. It is not unusual for firms to allocate up to 80% of their risk management budget and time to developing their position data infrastructure. Some banks, such as CIBC, have set up elaborate firmwide position data warehouses for enterprise-wide risk management and regulatory risk monitoring and compliance.

The following considerations can simplify the data collection process considerably: (a) only **net** position information is required,[1] and (b) not every financial instrument must be treated uniquely.

Net position information

Risk measurement systems require only **net** position information, as opposed to individual transaction data. We define net position as the sum of all purchases and sales of a particular instrument. We are either net long or net short in a particular position: for example, long $1 and short $2 IBM stock means that we are net short $1 IBM stock. Netting implies that significant data aggregation can occur before position data is actually fed into the risk system. For example, in FX and interest rate management, all cash flows with the same date, currency, and credit quality can be netted.[2]

Instrument mapping

Mapping is part of the data collection process that can improve risk calculation performance significantly. Mapping refers to the process of translating the cash flow of actual positions into standardized position vertices. The advantage of not treating every financial instrument uniquely is that it enables aggregation of many different types of transactions into a reduced number of risk categories. For example, we can decompose linear fixed income instruments into their cash flows. Cashflow sensitivities can then be mapped to standardized yield curve vertices.

---

1 For credit risk, transaction level information by counterparty may be required.

2 Note that for counterparty credit exposure measurement (e.g., VaR by counterparty), net position information by counterparty is required.

9.2 What type of position information is required

The two main levels of position information are

- instrument description, and
- cashflow description.

Instrument description

At the instrument description level, we select the instrument type and provide instrument-specific information. The position may be tagged to identify the risk taker or account. For credit exposure measurement (e.g., VaR by counterparty), counterparty information is required.

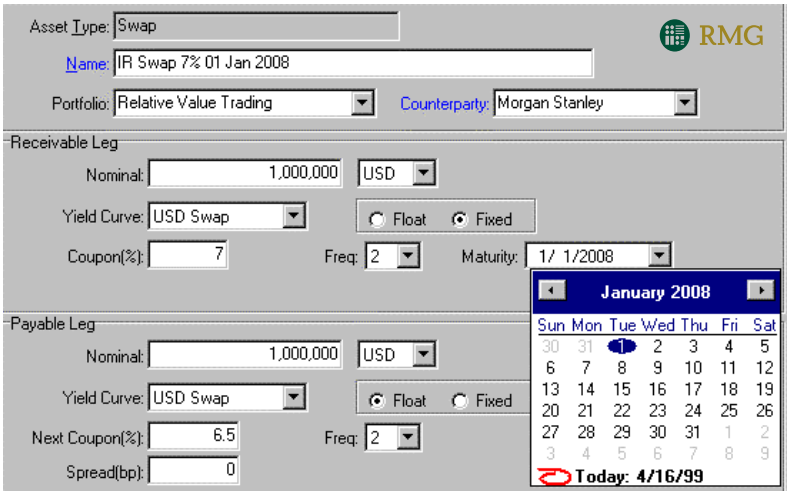
Instrument description	Examples
Instrument type	Bond, IR swap, FX forward, equity swap, put option, swaption
Instrument-specific information	Strike price, reset dates, reference rates
Account or risk taker	Frankfurt Treasury, NY Bond Arbitrage, Singapore Swaps
Counterparty	Citibank (only necessary for credit exposure calculations)

Cashflow description

At the cashflow description level, currency, cashflow amounts and timing, and credit quality should be specified.

Cashflow description	Examples
Currency	USD, JPY, EUR, THB
Trade date	Jan 1 1999
Cashflow dates and amounts	$5 MM annually 1/1/2000 to1/1/2008, $100 MM 1.1.11
Credit quality	Gov't, Swap, AAA, AA, A, BBB, BB, B yield curve

For example, below is an input screen for a USD/EUR Currency swap, from the RiskMetrics RiskManager market risk application.



- The *instrument description,* at the top third of the screen is: IR swap, risk taker (Portfolio) is Relative Value Trading, counterparty is Morgan Stanley.
- The basic *cashflow description,* in the remainder of the screen is: receive 7% semiannually fixed, pay semiannually floating, on $1,000,000 notional maturing January 1, 2008. For credit quality of the cash flows, the swap yield curve is used.

Fortunately for risk managers, position information need not be entered manually. Risk managers should work with IT staff to assemble position feeds from front-, middle- or back-office systems. Building a clean position collection process and database is a tedious, but important task. The most sophisticated analytics are useless if position data is incomplete.

Once this position information is stored in a database, it can be imported into the risk application. For detailed information required for specific financial instruments, refer to the *RiskMetrics RiskManager Import File Specifications* document.[3]

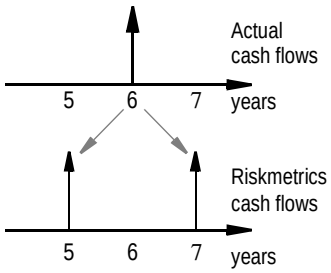
VaRBaR

Implementing a new risk measurement system

The first milestone for RMG analysts was to produce a one-time snapshot of their clients' firmwide market risks. Analysts took position information from whatever reports they could get their hands on—front office position reports, trader spreadsheets, Asset Liability Management (ALM) Gap reports, and accounting systems. Next, the analysts manually entered the position information into RMG's market risk software and sourced the necessary market data to calculate an initial rough snapshot of market risk by business unit. RMG advisors then designed a one-page firmwide market risk report and presented the results to senior management. Even if this risk report wasn't 100% complete, it gave the client a solid deliverable and a clear understanding of what information was required. The client's internal risk management team was now prepared to integrate RMG's risk software and data with internal position feeds. Its task was to produce clean and reliable daily risk reports on a regular basis—at first on a weekly basis, and eventually on a same-day basis.

9.3 Principles of cashflow mapping for interest rate risk

Cashflow mapping was designed to simplify risk calculations for parametric risk estimation, but it can be efficient for simulations also, especially if many cash flows occur on similar dates. Instead of treating all transactions individually, future cash flows of thousands of different transactions and instrument types can be mapped onto defined yield curve vertices.



RiskMetrics has defined specific yield curve vertices onto which all cash flows are mapped. Actual cash flows falling in between these vertices are split and re-distributed onto the two adjacent vertices, as shown in the illustration.

Note that cashflow mapping may limit drill-down capability by instrument, because position information is aggregated.

This cashflow mapping approach is fully described in the *RiskMetrics Technical Document*, Chapter 6 (pages 107 to 147),[4] which also mentions two alternate approaches to mapping interest rate positions: *duration* and *principal* mapping.

Cashflow mapping can be applied to virtually all fixed income securities: bonds, Floating Rate Notes (FRN), Interest Rate Swaps, Currency Swaps, IR Forwards, Futures, FX forwards, and FX spot. Note, however, that complications may arise when cashflow streams are uncertain, as with callable or puttable bonds. Several illustrative cashflow mapping examples are provided in the *RiskMetrics Technical Document*.[5]

[3] See www.riskmetrics.com/rmgr/pubs/index.cgi.

[4] Recently, RiskMetrics research has published an improved cashflow mapping methodology as a working paper (*Improved Cash Flow Map*) at www.riskmetrics.com/research/working/index.cgi

[5] See the *RiskMetrics Technical Document,* Chapter 6.3, pp. 131–133 and pp. 146–148.

9.4 Mapping commodities

Similar to interest rates, commodities have a spot and future cashflow component. Physical commodities can be mapped to relevant spot prices, and futures or swaps can be mapped onto the term structure of commodities prices.

Commodities spot indices are published by several leading firms, including J.P. Morgan, Goldman Sachs, Merrill Lynch, and Bankers Trust.

J.P. Morgan's JPMCI consists of the following:

Base metals	22%	Energy	55%	Precious metals	23%
Aluminum	9	WTI crude	33	Gold	15
Copper	8	Heating oil	10	Silver	5
Nickel	2	Natural gas	7	Platinum	3
Zinc	3	Unleaded gas	5		

Commodities term structures can be derived from futures contracts.

The *RiskMetrics Technical Document* shows an example of how to map a WTI futures contract (see Section 6.4, Example 6.8, page 145).

9.5 Mapping equities

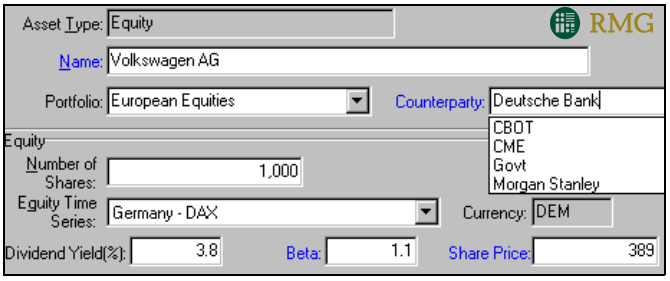
Equities should be expressed as spot positions in home currency equivalents, and foreign equities are subject to FX risk in addition to equity risk. Several approaches can be taken for measuring the risk of equities. The most accurate and straightforward approach is to treat every stock as an individual instrument. This approach, however, can become overwhelming for large portfolios because individual time series for every single stock are required. Common approaches for simplifying equity risk calculations are (a) country mapping, (b) sub-index mapping, or (c) factor analysis.

A. Country index mapping approach

The most efficient approach for large portfolios is to map equities onto a country index (e.g., Ford would be mapped onto the S&P 500 Index, while Volkswagen would be mapped to the DAX index). For country mapping, all we need is a securities **beta** against the index. Betas are published by major brokerage houses and data vendors and are available on the Internet via search engines or electronic brokerages. While the country mapping approach works well with highly diversified portfolios, it may not be appropriate for concentrated portfolios, as firm- and industry-specific risk is not taken into account (note that firm- and industry-specific risk diversifies away for large portfolios).

Note that it is possible to adjust VaR estimates from country mapping upwards to reflect expected firm-specific risk. This methodology is discussed in "Estimating Tracking Errors for Equities" in the *RiskMetrics Monitor*, Q2 '98. The key variables used in this methodology are (a) average volatility of stocks, (b) index volatility, and (c) number of stocks in the portfolio.

Country mapping example
In this example, we mapped Volkswagen AG (VW) to the German DAX Index, with a beta of 1.1. This means that on average, we expect VW to rise (fall) 1.1% for every 1% rise (fall) in the DAX Index.



While this approach will underestimate the risk of the individual stock, it will estimate the incremental systematic risk that the stock contributes to the diversified portfolio.

B. Industry sub-index mapping approach

For more concentrated portfolios, equities could be mapped into industry sub-indices within each country. This is a more efficient approach and is significantly less data intensive than getting instrument-specific information. However, complications may arise when companies need to be mapped to several indices.[6] Furthermore, not all firm-specific risk is taken into account, so sub-index mapping may not be accurate enough for concentrated portfolios.

C. Factor analysis

Another methodology for mapping equities is to use **factor analysis**, which would map equities to multiple factors such as country, size, industry, interest rate sensitivity, and oil price sensitivity. Factor analysis will allow risk managers to take into account higher order interrelationships between stocks. For example, we could find that an equity portfolio is unusually exposed to interest rate risk, because it has a concentration of companies with high-interest sensitivity loadings (e.g., banks, insurance companies, and utilities). Factor analysis is another way to simplify the raw amount of data needed for large portfolios; however, it does requires a continuous update of factors and re-estimation of factor loadings.

9.6 Choosing a methodology

In choosing an approach, risk managers should weigh accuracy against efficiency. Treating each stock individually is recommended for highly concentrated portfolios (i.e., more than 5% in any single equity) or specialized portfolios (e.g., hi-technology fund). Industry sub-index mapping or factor analysis would be appropriate for moderately diversified portfolios, and country index mapping should only be used to calculate systemic risk of highly diversified global portfolios.

[6] In this case, sufficient information must be available to allocate percentage mapping to different indices.

A comparison of different equity position mapping approaches shows the following:

Approach	Advantages	Disadvantages
Individual equities	• Most accurate	• Most data intensive
Country Index	• Least data required	• Least accurate, does not capture any firm-specific risk
Industry sub-index	• Moderate data required • Captures some firm-specific risk	• Fails to capture all firm-specific risk
Factor analysis	• Moderate data required • Captures some firm-specific risk	• Needs re-estimation of factors and loadings • Fails to capture all firm-specific risk

9.7 Summary

Collecting position information is often the most excruciating implementation issue for risk managers. Accurate and timely position data must be sourced and cleaned on a daily basis, often from different front- or back-office systems, including antiquated legacy systems.

Two considerations make data processing more efficient: netting and mapping of comparable transactions. For interest rate and FX transactions, all cash flows of comparable credit quality occurring on the same date can be netted. Furthermore, interest rate positions can be mapped onto standardized yield curve points. Similarly, commodities transactions can be netted and mapped to a futures price curve. Equities can be treated as individual instruments, or mapped to traded indices or derived factors.

Chapter 10. Evaluating a risk software vendor

10.1 How to choose a risk solution

Gone are the pioneering days when VaR models were cobbled together on spreadsheets by recent college graduates on their first rotation at a financial institution. As companies have begun looking externally for risk solutions, an entire software industry has developed (…now VaR models are built by recent college grads in software startups). Risk managers have an ever-expanding palate of software to choose from. Below is some advice on how to go about the process of selecting the right risk solution for your company.

There are three important steps:

Step 1: Define your objectives
Step 2: Specify your requirements
Step 3: Consider evaluation criteria

Step 1: Define your objectives

Risk management is about getting the right information to the right people at the right time. Therefore, risk measurement objectives can be defined in terms of what information is required, who uses it, and when.

(a) What information is required?

Information	Comment
❑ VaR	Firmwide or desk level? Marginal and Relative VaR?
❑ Stress testing	Hypothetical scenarios, historical scenarios, tweaking?
❑ Credit exposure	Credit exposure for market-driven instruments (e.g., swaps)
❑ Cash flows	Cashflow Maps, Duration Maps, Present Value Reports
❑ Instrument valuation	Analytics for valuing cash and derivative instruments

(b) Who uses the information?

Internal reporting	External reporting
❑ Corporate office	Regulators (BIS, Fed, SEC, etc.)
❑ Risk monitors	Shareholders (annual report)
❑ Business managers	Auditors
❑ Traders	Credit analysts

(c) When is the information required?

❑ Real time	❑ Same day	❑ Next day
❑ Weekly	❑ Monthly	❑ Quarterly

Step 2: Specify your requirements

Once your objectives are clear, you can specify requirements for your risk solution. You can then summarize them in a Request for Proposal (RFP) and send it to vendors to fill out and return.

A. Scope of software

When making a purchasing decision, begin narrowing down the potential software candidates by specifying the scope of software you're looking for. Narrowing the scope will also help in allocating an appropriate budget for a risk system. Risk-related software ranges from small add-ins to gigantic enterprise-wide systems.

- Even if you are developing a proprietary risk measurement system, it may make sense to purchase a standardized VaR engine with an analytics library. There's no need to re-invent standard tools.
- Firms upgrading their enterprise trading systems may wish to examine the suitability of risk modules offered by large systems vendors.
- Most risk managers prefer a stand-alone risk system that fits their specific risk analysis and reporting needs.

B. Financial instruments

A risk system needs to handle the relevant instruments in a company's portfolio. Risk managers should indicate the required accuracy for valuing instruments. There is a difference between accuracy needed for pricing instruments vs. risk assessment. The incremental effort for accurate instrument valuation for risk assessment is often not feasible or worth the investment. For example, one may implement efficient parametric approximations for certain exotic options instead of using computer-intensive simulation-based pricing.

Group	Instrument
Interest Rates	Money Market, Bond, Bond Future, Bond Option, FRA, FRN, Cap, Floor, Interest Rate Future, Option on Bond Future, Option on Interest Rate Future, Swap, Swaption, Zero Coupon Bond, etc.
Foreign Exchange	Cash, FX Forward, FX Option, Currency Swap, etc.
Equity	Equity, Equity Future, Equity Option, Equity Swap, etc.
Commodity	Commodity, Commodity Future, Commodity Option, Commodity Swap, etc.
Exotic Options	Barrier (knock-in, knock-out) options, Asian options, Bermuda options, Digital options, Binary options, etc.

C. Flexibility and customization

Most users demand a fair amount of flexibility in their risk software, particularly in designing reports, choosing among different methodologies, creating stress scenarios, and importing time series. Some high-end users want to customize risk and pricing analytics. Customization, however, is a two-edged sword. It only makes sense if the end-user has the resources to develop, test, and support analytics customization (i.e., have a dedicated group of financial engineers and programmers).

Risk software may offer customization of the following categories:

Category	Allows users to …
Reporting	tailor reports with different information and detail
Data	introduce new time series
VaR analytics	choose among VaR methodologies; add/modify analytics
Stress analytics and scenarios	personalize stress scenarios; add/modify analytics
Instrument analytics	add/modify instruments and pricing algorithms

Step 3: Consider evaluation criteria

If a system meets objectives, risk managers can weigh priorities for making an investment decision. Important dimensions to consider are as follows:

Speed of integration	All software vendors can show flashy demonstrations. The more important determinant is what it takes to get their systems up and running in real life. Integration issues may concern (a) interfacing with position feeds, (b) availability of risk data, and (c) the need to customize analytics and reporting.
Ease of use	Risk systems should be easy to learn and use. Any risk taker, risk monitor, and senior manager should be able to perform risk analysis without extensive training.
Transparency of methodology	Risk software should not be a black box. The methodologies and algorithms used to map positions and forecast risk should be clear and accessible. Furthermore, a variety of risk methodologies should be available to the user (i.e., parametric, Monte Carlo, and historical simulation).
Support and training	Support staff should be responsive, experienced, and knowledgeable. High-quality training should be available to all users (management and staff).
Cost	Direct cost for the software may be a combination of an up-front fee and an annual maintenance contract. A large up-front investment should be avoided, because it locks clients into its system and gives the vendor minimal incentive to improve its product and service. Pay-as-you go annual contracts are more sensible. Indirect cost for the software—in the form of integration and data needs—should also be considered.
Innovation	Risk measurement is a quickly evolving field, which requires vendors to continually upgrade systems to stay current. Does the vendor have the commitment and capability to stay on the leading edge and incorporate the latest research into its products?

10.2 Summary

Investing in a risk measurement system is a must for participants in the financial markets. Choosing the right system can be a challenging task in a rapidly developing market for risk solutions, where financial institutions, data vendors, software companies, and consultants are hawking their wares. The flip side of the coin is that it's a buyer's market: premium risk management solutions are now within reach for all types of institutions, not just top-tier global banks. In choosing systems, companies should be careful to define their objectives and requirements. It's essential to be an educated consumer.

10.3 Conclusion

This *Guide* addresses some of the common issues faced by risk managers around the globe: producing risk reports, stress testing, and designing a risk information infrastructure. In an evolving field fueled by advances in research, technology, and financial instruments, the *Guide* is a starting point for further exploration.

Risk reporting is one of the most important responsibilities of the risk manager. Managers need to understand the dynamic nature of market risks arising within all their businesses in order to act effectively in crisis situations. Macro risk measurement allows companies to target more stable risk taking over time, which translates to fewer avoidable surprises for management, shareholders, lender, and regulators. Steve Thieke, the former head of J.P. Morgan's Corporate Risk Management Group, often said that risk managers "are like the glue that binds an organization together." To create organizational cohesiveness, risk managers must foster a common language for communicating about risk and put the appropriate framework and tools in place for measuring risk.

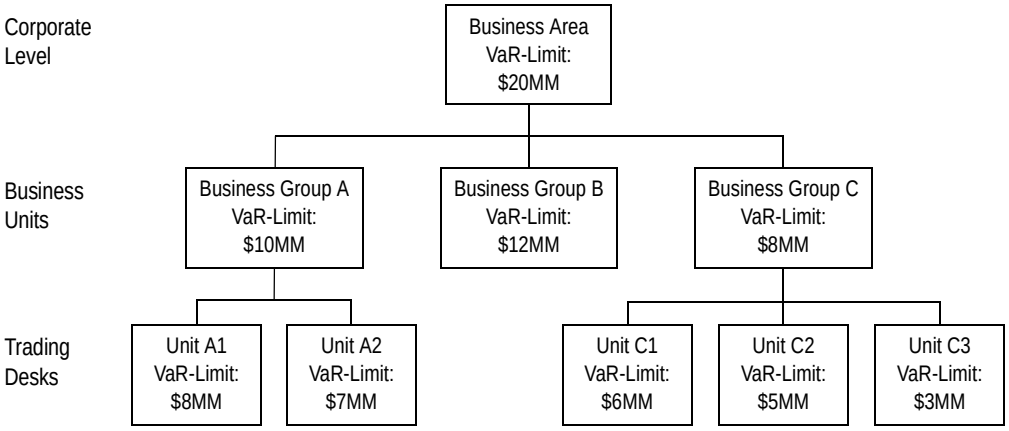
If you would like to discuss any issues addressed in this *Guide*, we invite you to call or e-mail RMG at education@riskmetrics.com.

Appendices

Appendix A. Risk-based limits

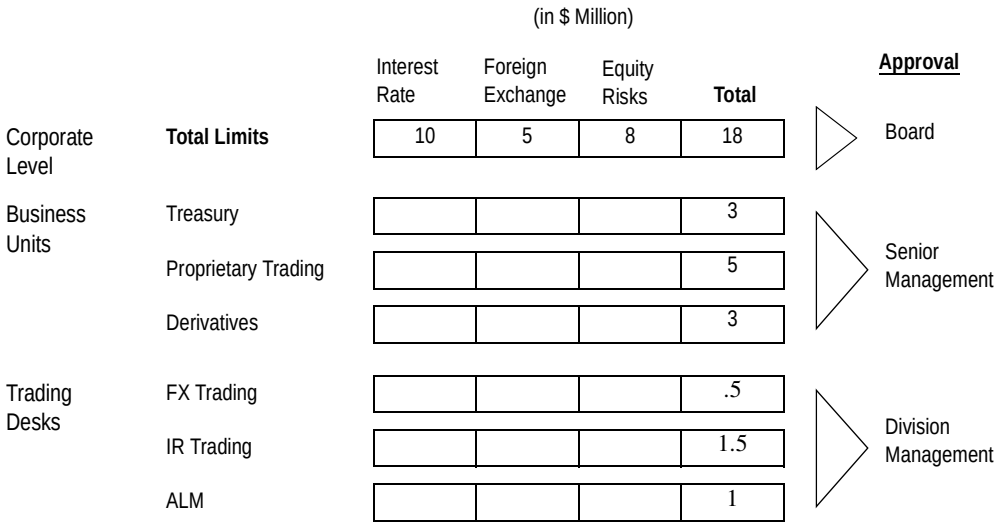
VaR measurement allows companies to implement risk-based limits structures, instead of relying on traditional notional measures.

Risk limits should follow a firm's hierarchical organizational structure and set expectations for risk taking and profitability. Risk-based limits empower managers to allocate risk capital dynamically to areas that offer the best opportunities, or in which the firm's expertise is greatest. When close to or exceeding limits, risk takers should discuss risks and opportunities with risk monitors and management.



Because VaR-based limits incorporate diversification effects between different risk types and risk taking activities, the sum of individual VaRs adds up to more than the aggregate total.

Companies commonly set risk limits by risk type and business group. This concept is illustrated in the sample limit structure for a bank.



Furthermore, aggregate risk limits may be set by risk type and region. For example:

Numbers in $ MMs	IR	FX	Equity	*Total*
Total	***20***	***4***	***6***	***25***
Europe & Japan	3	1	2	***5***
North America	3	1	2	***5***
Emerging Markets				
Asia	3	1	1.5	***4***
Eastern Europe	2	0.5	1	***3***
Latin America	15	1	2	***16***
Africa	0.5	0.2	0.2	***0.7***

VaRBaR

Other risk limits

In addition to VaR limits, other types of management limits may be applied. For example, see the following excerpt from Chase Manhattan's 1998 *Annual Report*:

> ***Evaluation of Risk Appetite:*** *Chase utilizes a comprehensive limit structure as part of its market risk management process. In addition to establishing VAR limits on market risk activities at the aggregate and business unit levels, Chase maintains non-statistical risk limits to mitigate risk in those instances where statistical assumptions break down. Nonstatistical measures include net open positions, basis point values, position concentrations and position turnover. Criteria for risk limits include, among other factors, relevant market analysis, market liquidity, prior track record, business strategy and management experience and depth. Risk limits are reviewed regularly to maintain consistency with trading strategies and material developments in market conditions, and are updated at least twice a year. Chase also uses stop-loss advisories to inform senior management when losses of a certain threshold are sustained from a trading activity. Chase believes the use of non-statistical measures and stop-loss advisories in tandem with VAR limits reduces the likelihood that potential trading losses will reach the daily VAR limit.*

Appendix B. Credit exposure of market-driven instruments

Credit exposures from market-driven transactions such as swaps, forwards and purchased options are an issue for all participants in the OTC derivatives markets. Credit or market risk can result from fluctuations in market rates. Below, we first show how credit exposure and market risk are interrelated and then discuss how to analyze credit exposure for market driven instruments. An authoritative resource for counterparty risk management is *Improving Counterparty Risk Management Practices*, which was published by the Counterparty Risk Management Policy Group (CRMPG) in June 1999. CRMPG was formed by a group of 12 global banks in the aftermath of the 1998 market turmoil to promote better industry-wide counterparty market and credit risk practices.

Swap example

The interrelationship of credit and market risk can be illustrated in a simple example of an interest rate swap. Global Bank (GB) engages in an interest rate swap with Global Hedge Fund (GHF), paying 5-year fixed rate and receiving 3-month LIBOR.

If 5-year rates go down, GB incurs a market loss because it agreed to pay GHF an above-market interest rate. On the other hand, if 10-year rates fall, the swap is in-the-money for GB. However, this MTM gain on the swap is now a credit exposure to GHF: if GHF defaults, GB forsakes the MTM gain on the swap.

Therefore, *a company has credit exposure whenever rates fluctuate in its favor.* A company has potential credit exposure from the time a contract is initiated up to final settlement.

Managing Credit

Note that it is much more straightforward to reduce market risk than credit risk. To reduce the market risk in our example, GB can purchase a 10-year government bond or futures contract, or enter into an opposite swap transaction with another counterparty. Credit risk presents a more complex problem. For example, taking an offsetting swap with another counterparty to reduce market risk actually increases credit risk (one counterparty will always end up owing you the NPV of the swap). Solutions to the credit problem are available, however. GB could arrange a credit enhancement structure with GHF, such as structuring a collateral or MTM agreement (e.g., GHF agrees to post collateral or pay the MTM of a swap on a periodic basis, or if a certain threshold is reached). Furthermore, a credit derivative could be written by a third party to insure the swap contract.

Four exposure measures

There are four relevant exposure measures: **current exposure**, **maximum exposure**, **expected exposure**, and **standard deviation of exposure**.

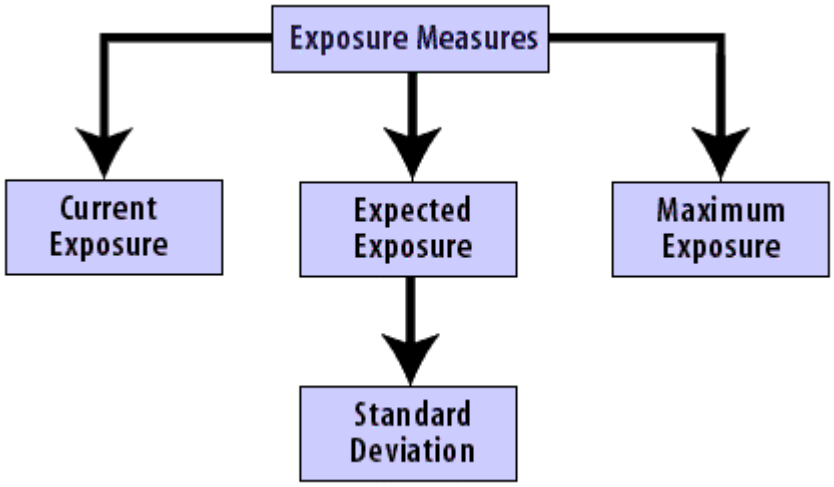
Current exposure is the mark-to-market value of a contract and the amount of money we would lose if our counterparty defaulted. If the mark-to-market value is positive, we have credit exposure. If the mark-to-market value is negative or zero, we don't have credit exposure.

Maximum exposure measures potential future exposure with a specified confidence level if rates fluctuate in our favor. If we project maximum exposure with 95% confidence, there is a 5% chance that our actual future exposure will exceed our projected maximum exposure amount. We calculate maximum exposure by generating a 95% confidence worst-case scenario of rates fluctuating in our favor and revaluing the instrument at a different point in the future.

Expected exposure is our probability weighted exposure at a point in time.

Standard deviation of exposure measures the volatility of exposure, or the deviation from the expected exposure.

The chart below illustrates these exposure measures:



Source: *Managing Risk*

Swap example

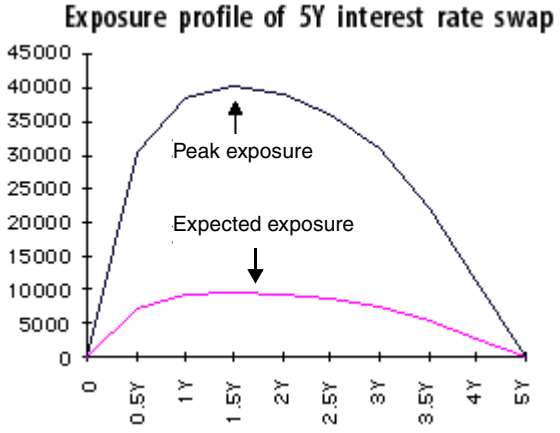
The following example illustrates the use of these exposure measures in our swap example.

GB engages in a $1MM USD 5-year swap with GHF, in which it agrees to pay 5-year fixed rates in exchange for LIBOR.

Results

GB calculates its maximum exposure by time band by projecting 95% worst-case interest rate movements in its favor; expected exposure is the probability-weighted exposure.

The inverse U-shaped exposure profile is typical for an interest rate swap. Current exposure is zero because the transaction was initiated at market rates. Maximum and expected exposure increase, peak at 18 months, then fall back to zero as cash flows are exchanged and the transaction matures. The inverse U-shape can be explained by two counteracting forces: increasing interest rate volatility and decreasing duration with time.



Source: *Managing Risk*

Below is a report that summarizes the entire swap exposure:

Portfolio: One Swap
GHF Credit Exposure Time Profile in USD

Analysis date: 18 June 1998; Based on RiskMetrics Data for: 3 June 1998
Confidence Level: 95%; Horizon = 1D; Valuation method: Yield curve

Sampling Time	Maximum Exposure	Expected Exposure	Std. Deviation
0 Days			
6 M	30,447	7,240	10,813
1 Y	38,360	9,262	13,616
18 M	40,291	9,592	14,308
2 Y	39,079	9,245	13,881
30 M	35,982	8,579	12,778
3 Y	31,115	7,620	11,039
42 M	22,253	5,391	7,898
4 Y	11,234	2,637	3,991
54 M			
5 Y			
Average Exposure		5,553	

Source: Managing Risk

Exposure profiles

Below are some points describing the exposure characteristics of options, swaps, and forwards.

Options

Only purchasers of **options** have credit exposure to their counterparts. If the option is in-the-money and your counterparty defaults, you're in trouble.

For example, Global Bank has potential credit exposure when it buys a put option on the S&P 500 Index to insure an equity portfolio. If the equity market falls and Global's counterparty defaults on its obligation to honor the put option, Global would incur a credit loss (for example, the insurer of its equity portfolio did not fulfill its obligation). Sellers of options don't have credit exposure. After you sell an option and collect the premium, you are not exposed to your counterparty (for example, it won't owe you anything, but you will potentially owe it something). As a seller of options, you incur only market risk (i.e., the risk that market rates move out of your favor).

The projected credit exposure of options increases with time, with the peak exposure expected just before final settlement.

Swaps and forwards

Counterparties engaging in swaps and forwards incur credit exposure to each other. Swaps and forwards are generally initiated at-the-money. That is, at the beginning of a contract, neither counterparty owes the other anything. However, as rates change, the mark-to-market value of the contract changes and one counterparty will always owe another counterparty money (the amount owed will be the mark-to-market value).

As illustrated in the previous example, the projected credit exposure of interest rate swaps resembles an inverse U-shape. Projected exposure of **currency swaps**, however, increases with time and peaks just before settlement. Currency swaps have a larger, and continually upward sloping exposure profile due to the FX risk of the principal amounts, which is only exchanged

at final settlement. Projected credit exposure of **forwards** also slopes continually upward, as there is no exchange of payments before settlement.

VaR by Counterparty

As a simple measure of credit exposure, VaR by counterparty can be calculated. Note, however, that many aspects of credit exposure reporting, such as netting and credit enhancement structures, are not reflected in VaR-by-counterparty reports. More importantly, VaR by counterparty does not reveal longer-term projections of potential credit exposure (i.e., months or years).

VaR by Counterparty Report **April 27, 1999**

95% VaR (10 days)	Aggregate	IR Swap	Cap	Floor	Swaption	FX Forward	FX Option	FX Swap	Equity Option	Option on Equity Future
Aggregate	5,802,900	2,917,103	35,506	200,446	106	505,151	456,494	534,377	1,737,042	1,357,897
ABB	11,343							11,343		
ABN Amro	2,168,901	2,168,901								
Bangkok Bank	51,514	51,514								
Bank of America	608,404					360,129		251,056		
Bank of Ayudhya	360,523				57					360,541
Barclays Global	1,754,971								1,766,096	
Chase Manhattan	63,897								33,745	11,131
Citibank	4,680	2,244						1,719	3,450	
Credit Suisse	394,591		35,657	85,611	64	269,886	38,811	286,943		
Ford	69,608							97,556		
GM	481,882	369,237				24,346				426,648
Goldman Sachs	581,957	558,165								
Home Savings Bank	98,530									98,530
HP	11,713	2,257				9,445		102		142
HSBC	870,774									870,774
Intel Corp	583									583
J.P. Morgan	406,618							406,618		
Krung Thai Bank	268							268		
Lehman Br.	522,405	313,032						200,600		
Merrill Lynch	110,393	9,725						102,559		
Microsoft	31,140							31,140		
Motorola	187,842			187,842						
Paribas	99,069					7,997		9,168		99,882
Quantum Fund	73									
Salomon	460,405								25,133	
Sun Microsystems	392,030	367,583				89,070		83,921		
Thai Farmers Bank	326,385	380,566						132,731		171,035
UBS Group	6,931							6,931		
UOB	1,652,727	112,699	455	1,962		166,867	427,911		7,783	668,166

Comments

- Note high concentration to financials, which are the major derivatives counterparties. Largest exposure is to ABN Amro from Swaps dealing, and second largest is to Barclays due to a bought option.
- Aggregate VaR by counterparty assumes that ISDA cross product netting agreement is in place.

VaRBaR

CRMPG recommendations

CRMPG's *Improving Counterparty Risk Management Practices* reviews the major issues surrounding counterparty risk management and provides recommendations for improving market practices. Two central themes are management of credit enhancement structures (e.g., collateral, marking to market) and the treatment of leverage and liquidity in a way that is integrated with market risk. The main recommendations the report makes are to improve counterparty risk management in banks (credit providers), and to improve the risk disclosure of hedge funds (credit users) to banks.

For banks, the crucial issue is the monitoring of counterparty exposures. The key recommendation is that banks be able to monitor their counterparties by four statistics:

1. Current exposure (e.g., the value of all obligations of the counterparty, or the replacement cost of all obligations of the counterparty) based on mark to market using prevailing market rates, not including any credit mitigation (collateral, etc.)

2. Current exposure based on prevailing rates, including collateral adjustments

3. Current exposure accounting for liquidity problems in liquidating (or replacing) the counterparty exposures

4. Potential future exposure, accounting for all future credit mitigation, such as collateral, marking to market, and other credit enhancement structures

Other issues raised include stress testing, credit practices, and internal valuation issues. The stress testing section encourages banks to use stress testing for more than just regulatory compliance and to pay special attention to stress test results on larger and more illiquid positions. The credit practices section promotes the use of more up front collateral. The valuation section stresses consistency in banks' own valuation of positions, emphasizing credit charges, illiquidity concerns, and hedge costs, among other factors.

Source: C. Finger, unpublished review, RMG

Appendix C. The independent risk oversight function

Independent risk monitors

Most financial firms have formed independent corporate risk monitoring functions that are responsible for the design and implementation of the firm's overall risk management framework and system.

Primary objective

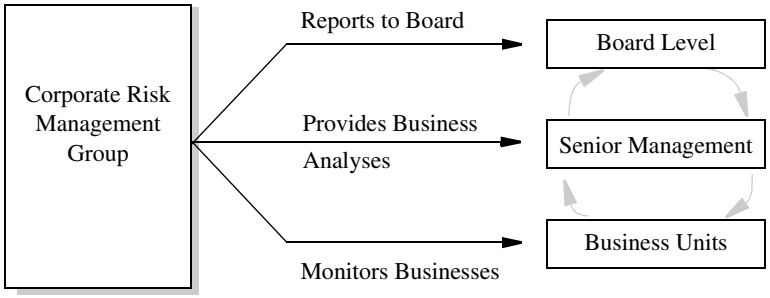
A Corporate Risk Management Group (CRMG) develops, communicates, and implements an institutional view of and process for managing risks across a firm's product lines. It also supports the business communication process.

Scope of mandate

While the specific mandates vary, responsibilities generally include the following:

- Risk management policies
- Risk management analytics
- Business risk monitoring
- Risk information standards
- Risk management training
- Risk resource allocation

The chart below illustrates how the corporate risk management group interacts with three levels of the organization.



At the business group level, CRMG monitors the risk profile of businesses. At the senior management level, CRMG often analyzes business risk performance. At the board level, the senior manager of CRMG keeps the board informed about the overall risk profile of the firm, generally on a quarterly basis.

For firmwide risk management to be effective, CRMG should be independent of business groups and headed by a senior member of the firm with a direct link to the corporate office.

The following graphic illustrates how CRMG could be organized into three functions.

Group	Function
Research and Analysis	This group is responsible for developing the overall methodological framework for risk management, which involves analytical modeling and ongoing methodology development across all business groups.
Business Risk Monitoring	Business Risk Monitors (BRMs) are liaisons between the business group and senior management. BRMs should be in close touch with a business and be aware of its strategy, risk profile, large positions, and concentrations.
Risk Management Information	The Risk Management Information group should be responsible for determining information technology architecture and investments and ensuring that appropriate market and position data are available.

Glossary of terms

absolute return. Measure of net economic return. Takes into account all costs (for example, cost of funding, balance sheet charges, administrative expenses).

ARCH. *See* **Autoregressive Conditional Heteroskedascticity**.

at-the-money. When the strike price of an option is the same as the price of the underlying.

at-the-money forward. When the strike price of an option is the same as the forward price of the underlying.

autocorrelation (serial correlation). When observations on the same time series are correlated over time. In mathematical terms, the covariance between data recorded sequentially on the same series is non-zero.

Autoregressive Conditional Heteroskedascticity (ARCH). A time series process which models volatility as dependent on past returns.

BIS. ***See*** **Bank for International Settlement.**

back-office. Clerical operations at trading institutions that include confirmation and settlement of trades, record keeping, and regulatory compliance.

backtesting. A method of testing the validity of VaR models, usually performed by comparing risk forecasts with actual or hypothetical trading results.

Bank for International Settlement. An agency headquartered in Basle, Switzerland, which serves as an international forum for monetary cooperation and banking regulation.

base currency. Currency in which operating gains and losses are measured.Typically this is the reporting currency of a company.

basis risk. The potential loss due to small pricing differences between equivalent instruments, such as futures, bonds and swaps. Hedges are often subject to basis risk.

Basle regulatory market risk capital requirements. Minimum requirements for capital that international banks must carry to cushion against adverse market movements.

benchmark. A custom or published index of a predetermined set of securities used to compare performance and risk. Asset managers' performance is often gauged against a benchmark of published market indices.

benchmark yield curves. Derived yield curves that correspond to a country, industry, or credit rating category, typically generated through a yield curve fitting algorithm.

beta. A volatility measure relating the rate of return on a security with the return of its market over time. It is defined as the covariance between a security's return and the return on the market portfolio divided by the variance of the return of the market portfolio.

Black-Scholes. A model invented by Fischer Black and Myron Scholes for pricing call options based on arbitrage arguments. Key variables are current asset price, exercise price, risk-free rate, time to expiry, and expected standard deviation of the asset.

bonds. Debt instruments issues with a maturity greater than 1 year. A purchase of a bond is comparable to giving a loan.

call option. The right, but not the obligation, to buy an asset at a prespecified price on, or before, a prespecified date in the future.

CAPM. *See* **Capital Asset Pricing Model**.

Capital Asset Pricing Model (CAPM). A model which relates the expected return on an asset to the expected return on the market portfolio.

caps and floors. Interest rate options. Caps are an upper limit on interest rates (if you buy a cap, you make money if interest rates move above cap strike level). Floors are a lower limit on interest rates (if you buy a floor, you make money if interest rates move below floor strike level).

cashflow map. A report that shows net cash flows of foreign exchange and interest rate related cash flows (typically grouped by maturity, country, or credit rating).

Cash-Flow-at-Risk. Estimated potential cashflow loss (through reduction in revenues or increase in outgoings) due to adverse market movements (for example, unfavorable movements in interest rates, exchange rates, commodity prices, and other markets) within a specific time horizon and subject to a given confidence level.

change return. *See* **log return**.

confidence bands. Projected upper and lower boundaries for portfolio returns (e.g., 5% band breaks are associated with a 95% confidence band).

confidence level. A specified level of certainty for a statistical prediction (e.g., 95% confidence worst-case loss).

confidence level scaling factor. A multiplier to scale standard deviation to a specified confidence level, assuming normality (e.g., 1.65 is the confidence level scaling factor to arrive at a 95% one-tailed confidence level).

convertible bond. A bond with an imbedded option that allows the holder to convert the bond to common stock.

core positions. Net firm-wide position representing a directional view on the market.

correlation. A linear statistical measure of the co-movement between two random variables. A correlation (Greek letter ρ, pronounced “rho”) ranges from +1.0 to −1.0. Observing clumps of firms defaulting together by industry or geographically is an example of positive correlation of default events.

counterparty. The partner in a credit facility or transaction in which each side takes broadly comparable credit risk. When a bank lends a company money, the borrower (not Counterparty)

has no meaningful credit risk to the bank. When the same two agree on an at-the-money forward exchange contract or swap, the company is at risk if the bank fails, just as much as the bank is at risk if the counterparty fails (although for the opposite movement in exchange or interest rates). After inception, swap positions often move in/out-of-the-money and the relative credit risk changes accordingly.

credit exposure. The amount subject to changes in value upon a change in credit quality through either a market-based revaluation in the event of an up(down)grade or the application of a recovery fraction in the event of default.

credit quality. Generally refers to an obligor's relative chance of default, usually expressed in alphabetic terms (e.g., Aaa, Aa, A, etc.).

credit spreads. A spread over government rates to compensate investors for credit risk, typically expressed in basis points (one hundredths of a percent).

current exposure. For market-driven instruments, the amount it would cost to replace a transaction today should a counterparty default. If there is an enforceable netting agreement with the counterparty, then the current exposure would be the net replacement cost; otherwise, it would be the gross amount.

decay factor. *See* **lambda**.

delta. The change in a derivative's price given an incremental change in the underlying asset. For example, a delta of –0.5 would imply –1/2% change in the derivative's price given a 1% increase in the underlying asset.

derivatives. Securities, such as options, futures, and swaps, whose value is derived in part from the value and characteristics of another underlying security.

diffusion process. Assumes continuous (as opposed to discrete) price changes of asset prices.

diversification. The process of risk reduction achieved by assembling a portfolio of securities with low correlations (less than 1).

duration (Macaulay). *See* **Macaulay duration**.

Earnings-at-Risk. Similar to Cash-Flow-at-Risk, except for necessary adjustments due to accounting treatments of cash flows when determining earnings. Typical adjustments include deferral of cash flows that are subject to deferral accounting treatment, advance treatment of cash flows that are accrual accounted, and inclusion of operating cash flow that are hedged.

economic capital. Economic capital is defined as an equity reserve or cushion for unexpected losses. It ensures that a company remains solvent and stays in business even under extreme conditions. It is important to recognize that economic capital is distinct from regulatory capital, which focuses on market and credit risk. Conceptually, economic capital is comprehensive and covers all significant risks.

economic exposures. Also called strategic exposures. Market exposures that consider how changes in foreign exchange rates, interest rates, or commodity can affect the overall operating environment of a firm (for example, level of demand for products and services).

EWMA. Equally Weighted Moving Average (of volatility). Applying equal weights to a set of data points.

excess returns. Returns above the funding rate.

excessions. Confidence level band breaks (i.e., observed exceptions, or outliers).

exponential moving average. Applying weights to a set of data points with the weights declining exponentially over time. In a time series context, this results in weighting recent data more than data from the distant past.

fat tails. *See* **leptokurtosis**.

fixed income. Refers to interest rate instruments (e.g., bonds, zero coupon bonds, floating rate notes).

futures. A term used to designate contracts covering the sale of financial instruments or physical commodities for future delivery on an exchange.

FX risk. Foreign exchange risk; risk of loss due to movements in foreign exchange rates.

gamma. The ratio of an option's change in delta relative to an incremental change in the price of underlying asset.

hedge. Reduce the risk of a position by taking an offsetting position.

hedge fund. A fund targeted to sophisticated investors that may use a wide range of strategies to earn returns, such as taking long and short positions based on statistical models.

hedges. Transactions that are designed to reduce the risk of a position. Hedges are good at eliminating market risk, but often result in basis risk.

historical simulation. A nonparametric method of using past data to make inferences about the future. One application of this technique is to take today's portfolio and revalue it using past historical price and rates data.

Hot Spots. A measure of contribution to portfolio risk, highlighting significant risk concentrations. A trademark of Goldman Sachs.

implied volatility. Implied volatilities are obtained from observable prices for traded options, and capture the market's current expectations for the future distribution of market prices.

incremental VaR. A measure of a position's impact on VaR as the position size is increased.

independent. Implies no correlation or relationship between variables.

Institutional Swap Dealers Association (ISDA). A committee sponsored by this organization was instrumental in drafting an industry standard under which securities dealers would trade swaps. Included in this was a draft of a master agreement by which institutions outlined their rights to net multiple offsetting exposures which they might have to a counterparty at the time of a default.

instrument summary report. A report that summarizes instrument statistics, such as net present value, duration, convexity, and maturity.

International Organization of Securities Commissions (IOSCO). A committee of supervisory authorities for securities firms in major industrialized countries.

interest rate swap. A binding agreement between counterparties to exchange periodic interest payments on a predetermined notional principal amount. For example, one party will pay fixed and receive variable interest rate on a USD 100 million notional principal amount.

internal models approach. A proposal by the Basle Committee that permits banks to use approved risk models to calculate market risk capital.

in-the-money. When an option has positive intrinsic value (that is, for a call option, when the price is above the strike, and for a put option, when the price is below the strike).

investment manager. A manager of a portfolio of investments.

IOSCO. *See* **International Organization of Securities Commissions.**

ISDA. *See* **Institutional Swap Dealers Association.**

kurtosis. Characterizes relative peakedness or flatness of a given distribution compared to a normal distribution. It is the fourth moment of a distribution. *See* **leptokurtosis**.

lambda (decay factor). The weight applied in the exponential moving average. It takes a value between 0 and 1. In the RiskMetrics lambda is 0.94 in the calculation of volatilities and correlations for a 1-day horizons and 0.97 for 1-month horizon.

leptokurtosis. Often called “fat tails.” The situation where there are more occurrences far from the mean than predicted by a standard normal distribution.

leptokurtosis. The property of a statistical distribution to have more occurrences far away from the mean than would be predicted by a normal distribution.

linear derivatives. Derivative security whose value changes proportionally with changes in underlying rates. Examples of common linear derivatives are futures, forwards, and swaps. Examples of nonlinear derivatives are options, whose prices change non-linearly with changes in the underlying.

linear risk (nonlinear). For a given portfolio, when the underlying prices/rates change, the incremental change in the payoff of the portfolio remains constant for all values of the underlying prices/rates. When the payoff of the portfolio is not constant, the risk is said to be nonlinear.

liquidity. There are two definitions: At the enterprise level, the ability to meet current liabilities as they fall due; often measured as the ratio of current assets to current liabilities. At the security level, the ability to trade in volume without directly moving the market price; often measured as bid/ask spread and daily turnover.

long. If you buy an asset, you are long the asset. You will benefit if the price goes up.

long position. Opposite of short position; a bet that prices will rise. For example, you have a long position when you buy a stock, and will benefit from prices rising.

Long Term Capital Management (LTCM) . A famous hedge fund that was rescued by a consortium of banks after extreme market volatility in August ’98 wiped out most of its equity capital.

Macaulay duration. The weighted average term of a security’s cash flow.

macro hedges. Portfolio hedges that reduce the risk of a collection of transactions (a large position).

mapping. The process of translating the cash flow of actual positions into standardized positions (vertices): duration, principal, and cash flow.

marginal statistic. A statistic that describes how an asset affects a portfolio; the statistic is obtained by taking the difference between the value of the statistic for the entire portfolio and the value of the statistic for the portfolio without the asset.

marginal VaR. Impact of a given position on the total portfolio VaR. *See also* **marginal statistic**.

market exposure. For market-driven instruments, there is an amount at risk to default only when the contract is in-the-money (i.e., when the replacement cost of the contract exceeds the original value). This exposure/uncertainty is captured by calculating the netted mean and standard deviation of exposure(s).

market making. Refers to a trading style where dealers publish bid and offer prices at which they are prepared to trade. The long-term goal of market makers is to earning a consistent bid-ask spread on transactions, as opposed to making profits on directional betting. Market making differs from proprietary trading, which takes directional views.

market neutral. A trading strategy that eliminates broad market risk (equity, interest rate, foreign exchange, or commodity), leaving only residual risk. For example, a hedge fund manager can hedge the market risk of a U.S. stock portfolio by shorting S&P 500 Index futures, leaving only firm-specific residual risk.

market rates. Refers to interest rates, equity prices, commodities prices, foreign exchange rates, credit spreads, futures prices, and other market related prices or levels.

market risk capital requirements. The minimum amount of capital needed to support market risk positions, as required by banking regulatory authorities.

market risk. The risk that the value of on- or off-balance-sheet positions will be adversely affected by movements in equity and interest rate markets, currency exchange rates and commodity prices.

market-driven instruments. Derivative instruments that are subject to counterparty default (e.g., swaps, forwards, options, etc.). The distinguishing feature of these types of credit exposures is that their amount is only the net replacement cost—the amount the position is in-the-money—rather than a full notional amount.

mark-to-market (MTM). "Mark-to-market approach" means that, unlike traditional accrual accounting, positions are valued on a replacement cost basis by marking to the current traded market price.

mean reversion. When short rates will tend over time to return to a long-run value.

mean reversion. The statistical tendency in a time series to gravitate back towards a long-term historical level. This is on a much longer scale than another similar measure, called autocorrelation; mean reversion and autocorrelation are mathematically independent of one another.

mean. A statistical measure of central tendency. Sum of observation values divided by the number of observations. It is the first moment of a distribution.

modified duration. An indication of price sensitivity. It is equal to a security's Macaulay duration divided by one plus the yield.

moments (of a statistical distribution). Statistical distributions show the frequency at which events might occur across a range of values. The most familiar distribution is a normal bell-shaped curve. In general, the shape of any distribution can be described by its (infinitely many) moments. The first moment is the mean, which indicates the central tendency.The second moment is the variance, which indicates the width. The third moment is the skewness, which indicates any asymmetric leaning either left or right. The fourth moment is the kurtosis, which indicates the degree of central peakedness or, equivalently, the fatness of the outer tails.

Monte Carlo simulation. A methodology for solving a problem through generation of a large number of scenarios and analysis of the collective result, which is generally a probability distribution of possible outcomes.

MTM. *See* **mark-to-market**.

netting. There are at least three types of netting: **(*i*)** Close-out netting: In the event of counterparty bankruptcy, all transactions or all of a given type are netted at market value. The alternative would allow the liquidator to choose which contracts to enforce and which not to (and thus potentially "cherry pick"). There are international jurisdictions where the enforceability of netting in bankruptcy has not been legally tested. **(*ii*)** Netting by novation: The legal obligation of the parties to make required payments under one or more series of related transactions are canceled and a new obligation to make only the net payment is created. **(*iii*)** Settlement or payment netting: For cash settled trades, this can be applied either bilaterally or multilaterally and on related or unrelated transactions.

nonparametric. When potential market movements are described by assumed scenarios, not by statistical parameters.

notional amount. The face amount of a transaction typically used as the basis for interest payment calculations. For swaps, this amount is not itself a cash flow. Credit exposure arises not against the notional, but against the present value (market replacement cost) of in-the-money future terminal payment(s).

outliers. Sudden, unexpectedly large rate or price returns; also called excessions.

P&L Report. A Profit and Loss report, which shows MTM gains or losses for traders

parametric. When a functional form for the distribution a set of data points is assumed. For example, when the normal distribution is used to characterize a set of returns.

peak exposure. For market-driven instruments, the maximum (perhaps netted) exposure expected with 95% confidence for the remaining life of a transaction.

percent marginal. VaR expression in percent terms of the impact of a given position on the total portfolio VaR.

percentile level. A measure of risk describing a worst-case loss at a specified level of confidence, e.g., the probability that the portfolio market falls below the first percentile level (99% confidence level) is 1%.

portfolio. A collection of investments; these can be long (purchased) or short (sold) positions.

portfolio aggregation. A methodology for estimating portfolio VaR without using volatilities and correlations. A subset of historical simulation which involves statistical fitting of hypothetical portfolio returns generated from historical market rates.

position. The buyer of an asset is said to have a long position and the seller of an asset is said to have a short position.

put option. The right, but not the obligation, to sell an asset at a pre-specified price on or before a pre-specified date in the future.

regulatory capital. Capital that banks are required to set aside to cover potential losses due to market or credit risk.

relative market risk. Risk measured relative to an index or benchmark.

relative return. Measures performance relative to a reference or benchmark return.

residual risks. Defined by the RiskMetrics Group as non-systemic, market driven risks, which includes spread risk, basis risk specific risk, and volatility risk. Residual risk is often defined as issuer-specific risk.

risk-based limits. Limits for market or credit risk taking that are defined in risk as opposed to notional terms. Risk-based limits have become a necessity for institutions trading a broad range of financial instruments, where the same notional exposure can imply a very different risk (for example, a $1MM notional USD interest rate swap position vs. a $1MM equity swap).

RMVI. RiskMetrics Volatility Index. An index of global market volatility created by RMG and published at www.riskmetrics.com.

S&P 500 Index. The Standard and Poor's 500 Index is a market-capitalization weighted equity index of 500 U.S. stocks.

sector loadings. For correlation analysis, a firm or industry group is said to be dependent upon underlying economic factors or sectors such as: ***(i)*** the market as a whole, ***(ii)*** interest rates, ***(iii)*** oil prices, etc. As two industries "load" (are influenced by) common factors, they become better correlated.

serial correlation. *See* **autocorrelation**.

Sharpe ratio. A return on risk ratio named after Nobel laureate and Stanford University professor William F. Sharpe. The Sharpe ratio is defined as annual return minus risk free rate divided by standard deviation of return.

short. If you sell an asset short, you are short the asset. You will benefit if the price falls.

short position. Opposite of long position; a bet that prices will fall. For example, a short position in a stock will benefit from the stock price falling.

skewness. Characterizes the degree of asymmetry of a distribution around its mean. Positive skewness indicates leaning toward positive values (right-hand side); negative skewness indicates leaning toward negative values (left-hand side).

snapped. When RMG collects data, we say we "snap" the data (as in taking a snapshot).

specific risk. Refers to issuer specific risk, e.g., the risk of holding Yahoo! stock vs. an S&P 500 futures contract. According to the Capital Asset Pricing Model (CAPM), specific risk is entirely diversifiable.

spread risk. The potential loss due to changes in spreads between two instruments. For example, there is a credit spread risk between corporate bonds and government bonds.

square root of time scaling. A simple volatility scaling methodology that forecasts long-horizon volatility by multiplying volatility by the square root of time (e.g., 10-day volatility = 1-day volatility times the square root of 10).

stand-alone standard deviation. Standard deviation of value for an asset computed without regard for the other instruments in the portfolio.

standard deviation. A statistical measure which indicates the width of a distribution around the mean. A standard deviation (Greek letter σ, pronounced "sigma") is the square root of the second moment (variance) of a distribution.

stochastic. Involving a random element (variable).

stress testing. The process of determining how much the value of a portfolio can fall under abnormal market conditions. Stress testing consists of generating worst-case stress scenarios (e.g., stock market crash) and revaluing a portfolio under those stress scenarios.

strike price. The stated price for which an underlying asset may be purchased (in the case of a call) or sold (in the case of a put) by the option holder upon exercise of the option contract.

substitute securities. Securities that are identical or comparable to assets you are trying to hedge; for example, government bonds, interest rate swaps, and interest rate futures may be used as substitute securities for hedging purposes.

swaps. Derivative contracts whereby two companies agree to exchange cash flows based on different underlying reference assets. The most common swaps are interest rate swaps, where fixed coupon cash flows are exchanged for floating-rate cash flows. Total return swaps can be

structured on just about any underlying reference asset or index, for example S&P 500 Equity Index vs. J.P. Morgan EMBI+ Index.

swaptions. Options on swaps (e.g., the right, but not the obligation, to buy or sell swaps at pre-defined strike rates).

tail risk. Risk of loss due to extreme market movements (e.g., market changes that fall into the tail of the probability distribution).

theta. Refers to time decay of options positions.

tracking error. In an indexing strategy, the difference between the performance of the benchmark and the replicating portfolio.

transactions. An individual agreement to buy or sell a specific financial instrument (e.g., a purchase of $1 MM of Yahoo! stock).

underlying. An asset that may be bought or sold is referred to as the underlying.

unwinding positions. Reversing positions. If you own a security (are long), sell the security (go short). If you have a short position, buy the security back.

Value-at-Risk (VaR). A measure of the maximum potential change in the value of a portfolio of financial instruments with a given probability over a preset horizon.

variance. A statistical measure which indicates the width of a distribution around the mean. It is the second moment of a distribution. A related measure is the standard deviation, which is the square root of the variance.

vega. Change in an option's price relative to change in volatility.

volatility risk. Potential loss due to fluctuations in implied option volatilities; often referred to as vega risk. Short option positions generally lose money when volatility spikes upward.

zero coupon. A bond with no periodic coupon payments, redeemed at par value (100% of face value) at maturity.

Resources

Risk associations

- Global Association of Risk Professionals (GARP): www.garp.com
- International Association of Financial Engineers (IAFE): www.iafe.org/
- International Finance & Commodities Institute (IFCI): http://risk.ifci.ch/

Regulators

- IOSCO: www.iosco.org
- BIS: www.bis.org
- SEC: www.sec.gov
- Federal Reserve: www.ny.frb.org

RMG on-line risk education

- *Managing Risk*: www.riskmetrics.com/edu/index.cgi
- *Exploring Risk*: www.riskmetrics.com/edu/index.cgi
- RiskTalk: www.riskmetrics.com/support/risktalk/index.cgi
- Research: www.riskmetrics.com/research/index.cgi
- Book Club: www.riskmetrics.com/research/bookclub/index.cgi
- VaR Calculator: www.riskmetrics.com/rm/cde/index_varcalc.cgi

RMG risk data

- Data Directory: www.riskmetrics.com/data/view/index.cgi
- Risk Indices: www.riskmetrics.com/index/index.cgi
- LongRun Forecasts: www.riskmetrics.com/corp/longrun/forecasts/index.cgi

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