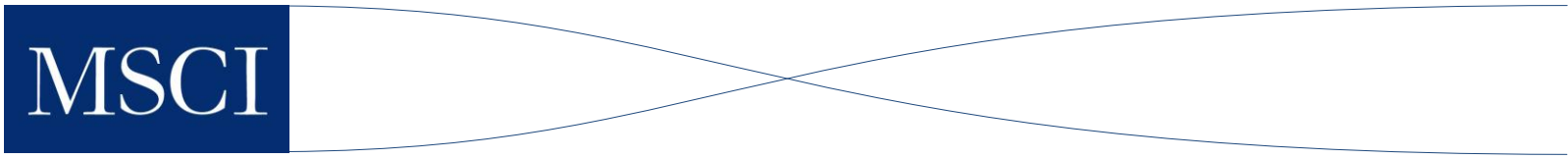

Selecting a Market Risk System: A Holistic Approach

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Selecting a Market Risk System

Of the many lessons learned from the 2008 global financial crisis, perhaps one of the most important is that no single approach can provide a complete picture of market risk. Since risk is used to drive fundamental investment decisions, the selection of an appropriate risk system is critical to the success of an asset management firm.

This paper touches on some of the key elements for consideration when evaluating market risk systems. Understanding the holistic set of components that drive a successful risk system is essential for selecting the solution that best fits your needs. The following sections walk you through some of the key criteria that should be considered; these will help you to ask the right questions, to create a check-list of how to begin, and to find the solution that bests suits your firm's particular need.

Foundations

Four essential components of any risk system are data, risk models, accessibility, and the support infrastructure.

Data

The lifeblood of any risk system is data; essential to develop risk models, and to compute the risk of portfolios and instruments against these models. Risk system vendors should demonstrate rigor in their data processes, use high-quality market data across asset classes, and have access to a broad set of historical data for model-building and research. They should be able to deliver high-volumes of data from global markets and across asset classes on a dependable, daily basis.

Data Coverage

Risk management systems need to provide reconciled market data on a daily basis, from global markets, and across the asset class spectrum. This data includes instrument terms and conditions (T&Cs), currency exchange rates, market spread, interest rates, and prices.

Daily data feeds provide the essential information needed to price positions and to analyze risk factors. It is imperative that the data be delivered systematically on at least a daily frequency. Since client-side automation often depends on updated market data, the systematic and consistent on-time delivery of data updates is critical.

Terms and Conditions Data

Risk systems should provide a security master database with T&Cs for global instruments. This allows clients to avoid sourcing T&C data from multiple internal and external sources, having to format it, and load it into the risk system. Comprehensive risk systems allow clients to add positions by supplying only a standard, public identifier (i.e. CUSIP, ISIN).

Benchmark Data

Relative risk, active risk, and tracking error are all synonymous terms for the risk relative to a benchmark. Regardless of the name used, benchmark data is required. This data comes in two flavors – a time series of benchmark returns, and constituent-level holdings (where the benchmark is represented by constituents in a portfolio, weighted according to the benchmark provider's definition).

Risk systems should be able to deliver benchmarks from each of the major index vendors. Major providers include MSCI, Russell, S&P, FTSE, Dow-Jones, Bank of America Merrill Lynch, Citibank,

Barclays, and JP Morgan as well as more specialized ones such as Nomura, Euronext, and iBoxx. Constituent-level benchmarks are preferred as they support more flexible and granular risk analytics. Risk systems should allow clients to easily create custom benchmarks based on user-defined sets of index-provider and bespoke portfolios – this is required for clients managing to blended benchmarks.

Dedicated Data Team

Risk system vendors may employ large data teams to maintain and monitor production data feeds, data load processes, and derived data construction. To ensure the data quality assurance process is effective, these teams should utilize processes to flag and remediate exceptions (such as static or missing values, unusual jumps, and inconsistency across tenors and sectors). Sophisticated data processes help ensure that data is delivered on a consistent, systematic basis by allowing the risk system vendor to efficiently manage large volumes of heterogeneous global market and instrument data.

Risk Models

Risk systems should support a broad variety of risk methods and investment horizons. Typical risk methodologies and measures include Value at Risk (VaR) and common factor models. Each method has strengths, weaknesses, and a level of suitability given different asset classes, horizon, and needs. The methodologies support functionality such as stress testing, counterparty credit exposure, liquidity risk, and credit risk.

As financial regimes change, risk system vendor research groups should update models and analytics on a regular basis. These updates span the spectrum from the timely introduction of new analytics to modeling new instruments as they are created by the industry, to updating prepayment models as behaviors and expectations change due to secular changes in the macro environment. As the market changes, risk models need to incorporate new data and methodologies.

Accessibility

Risk analytics or models should be easily accessible through a variety of methods. A software interface should offer ease of use and rich tools to engender analysis of portfolios and strategies along several dimensions. Accessibility should be on an anywhere, anytime basis. The interface should provide simplicity in accessing data, flexibility in creating reports, and be able to handle complex strategies such as levered, long-short, and multi-asset class portfolios.

One common use of an interface is to perform what-if analyses that evaluate the potential impact of trades on portfolios or strategies. A typical what-if interface allows users to experiment with hedging strategies, assess the potential impact of modifying portfolio constituents, or applying an overlay or completion strategy. After modifying the investment mix, the interface should allow you to view the pre- and post- impact of the investment decisions being considered.

The risk system should also be accessible via programming interfaces that provide direct access to processing functions, reports, and data exports. These programming interfaces can support large-scale automation of risk reporting and distribution, obviating the need for users to log in and manually load positions or create reports.

In addition, the risk system should be available using alternative user interfaces such as Microsoft® Excel. This allows risk measures to be brought directly into user workflows.

Support and Research

Given the complexity inherent in markets today, setting up an effective risk management system may require a significant financial investment as well as considerable analytical and technical expertise. Therefore, risk system vendors should provide a support infrastructure to maximize their system's utility and value.

Since risk is a driver of investment decisions, risk system vendors should maintain a staff capable of explaining risk model output and how clients can apply it to their investment process. Such staff normally combines quantitative expertise with an understanding of the investment process. They should also be experts fluent in the multiple measures of risk, and how risk can be used by managers to drive investment and allocation decisions.

The support infrastructure should also include systems integration experts and automation tools to link the risk system with source data systems (for example, portfolio accounting systems or custodial systems); analytics experts to model complex instruments or set up views of risk most appropriate to the fund; and on-call staff to assist with training and day-to-day usage questions.

Research Strength

Risk system vendors should maintain a strong research department. Researchers play a key role in product development by creating new analytics and updating analytics for pricing models and statistics. Research departments can also provide valuable input into the vendor's product development agenda.

Typically, risk system vendor research departments publish research papers which provide insight into how the company's risk models and financial instruments are developed. Some vendors also provide clients with specially prepared documents and stress tests created by their research departments. Research departments may also analyze major market, investment, risk management, and regulatory trends, and help map the risk system vendor's product development agenda.

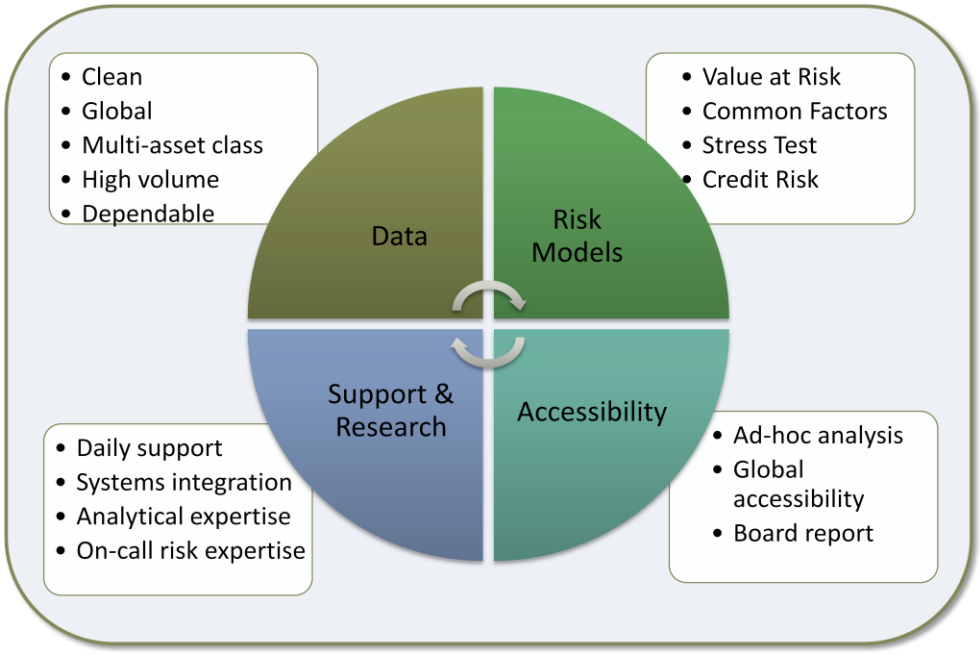

Figure 1: Risk System Foundations

Client Support Services

In evaluating the products and services offered by a risk system vendor, client support is a critical component of the vetting process. Some client support professionals have deep market knowledge and extensive domain expertise that can be leveraged for the benefit of the client.

In addition to providing value-added industry perspectives, vendors should also be able to provide comprehensive service offerings that meet clients' existing and future needs. These are sometimes included with the system or can be procured separately a la carte, but include:

- Risk system implementation services
- On-site training and skill enhancement workshops
- Frequent model upgrades
- Functionality enhancements
- Periodic updates provided through webinars and industry events
- New research completed by the vendor's internal research department

Defining Your Needs

The risk solution you select must be aligned with your needs, and should be flexible enough to grow as your needs grow. Basic questions to ask are:

- What is your investment horizon?
- Do you require flexibility and ad-hoc reporting capabilities, or periodic (daily, monthly or quarterly), predefined reports?
- Will you need to access the risk analytics via programming interfaces?
- Is automated, batch processing required?
- What is your capacity or desire to manage the process on a daily basis?
- How will you access the system?

Regardless of your specific needs, it is always wise to plan for the future. A good idea is to seek out systems that can adapt to additional asset classes, can support large volumes of throughput, and have a proven track record of keeping up with new instruments and improvements in risk methodologies. As your requirements grow, you will want your risk system vendor to support your needs. The following sections provide an overview of some of the features in risk systems that can meet those needs.

Investment Horizon

Your risk system should be aligned with your investment strategy's horizon. High turnover strategies benefit from shorter-horizon risk metrics, while lower-turnover strategies benefit from longer-horizon forecasts.

Typical portfolio grouping analytics such as country or sector exposure breakdowns are by definition historical in nature and offer little in the way of predictive capability. Sensitivity metrics such as duration

offer a view into the valuation of a fixed income portfolio given immediate changes in market conditions.

Stress testing also provides a shorter horizon forecast of risk because it is based on portfolio revaluations. Some risk systems can lengthen the horizon of stress tests by applying the market shock over a given period of time; however, this method usually only impacts the discounting of dividends and portfolio cash flows, and therefore offers limited utility for non-fixed income portfolios or fixed income portfolios with shorter durations.

Simulation-based models such as Value at Risk and Expected Shortfall offer customization in model inputs that provide longer risk forecast horizons, usually one to ten days. For longer horizon risk forecasts, multi-factor models provide a structured factor overlay to valuation models and can therefore provide forecasts up to one year out.

Reporting Services and Flexibility

Risk systems should be capable of producing a full range of risk reports. Reports should break risk down to the position level as well as by sector, country, and risk factors. Risk system vendors can also provide reports that can help clients with respect to regulatory requirements. For instance, some vendors provide reporting services that can be used by institutional investors to help address UCITS, Form PF (Private Fund assets), or Solvency II requirements.

Many risk systems also allow clients to create their own custom reports, enabling them to select financial statistics, change risk setting, and integrate stress test results within standard VaR reports. Clients should be able to create reports using standard risk and financial statistics such as VaR, duration, standard deviation, present value, Greek sensitivities, and other measures.

Most systems allow users to create and assign custom “tags” to financial positions. The tags allow reports to be aggregated into different tagged dimensions, such as position type by currencies by positions, currency by position types, manager by position types, and other custom groupings.

Some risk systems also provide data visualization modules which provide graphical analysis of complex data and trends. Most also allow users to “slice and dice” data into interactive dashboards and high level senior management reports.

Web Services

When analyzing your own risk reporting needs, you may decide that it’s essential that your company integrate its internal financial reporting systems with a risk system vendor’s. If so, you’ll want to select a risk system vendor that provides services that allow you to directly connect your own risk applications to the vendor’s analytics engine over the Internet – a common name for these capabilities is “web services”.

Using such web services, your company may be able to use C++, Perl, R, Java or Visual Basic scripts to trigger queries from your own applications to the risk system vendor’s. The risk system vendor’s analytics engine would then respond to the query with results (such Value at Risk numbers, exposures, or other financial statistics. Web services queries should also be able to access the risk system vendor’s stress tests, liquidity or counterparty credit exposure analytics.

Batch Processing

Many risk systems also allow batch processing which automates the process of loading portfolios and running reports—usually on a regular basis. Some vendors allow the entire batch process to be set up in the risk system itself. Once set up, the system automatically could execute the following tasks on a daily basis: download market data, import market data, import portfolios, run analyses, export and print reports and charts.

Managed Services

If you are concerned that your company does not have the internal resources to load positions into a risk system or produce reports; you may want to seek a vendor that provides "managed" risk services. Typically, clients that need to process very large portfolios that require a large amount of processing power use their risk system vendor's managed services to supplement their staffing and capabilities

Risk system vendors that offer managed services usually handle the entire process of loading, mapping and modeling portfolios and producing professional, presentation-quality risk reports. The risk system vendor assumes the responsibility and overhead of day-to-day risk management operational tasks—tasks that a client would normally need to perform. For many clients this can be a cost effective method of handling both mundane and complex risk operations.

Risk System Delivery Options

Most risk systems are either locally installed, or accessible through internet-based tools such as web browsers and direct connections to hosted analytics servers. Systems that are accessed through internet-based tools are also called Software as a Service, or SaaS. Whereas early risk systems were usually locally installed, many institutional investors today prefer a SaaS system due to the latter's operational and cost advantages.

Locally Installed Systems

In a local install system, the analytics engine and front-end interface are installed at the client location. Although some clients prefer keeping all data and operations in-house, a locally installed system may place a heavy system maintenance burden on IT staff; for example, large amounts of market data should be updated daily and as new instrument types are developed by financial markets, continuous updates to analytics libraries are required to keep current. Installed systems can also require a sizeable investment in hardware and backup infrastructure. As needs grow, and the risk system vendor enhances workflows and risk analytics, local install clients may also be required to install on-site software updates and purchase new hardware.

Web-Based Systems

In a SaaS system, the analytics libraries, risk application, and market data servers are hosted by the risk system vendor at large-scale, secure data centers. The system is accessed by users using a secure internet connection or by calling the analytics libraries directly through secure internet protocols. Many risk clients prefer a SaaS solution because it usually requires little more than a Web Browser to access the risk system, and most vendor updates (whether data, analytics, or workflow/reporting) appear automatically as soon as users log in. This allows vendors to deliver new analytics and coverage for new asset types much more nimbly that having to apply local installs. Due to the ease in accessibility, SaaS systems also allow rapid and comprehensive adoption of risk management practices across an organization.

SaaS systems usually require little or no hardware purchases which reduce the total cost of ownership; they also free up a client's IT staff from having to maintain the system, or deal with back up issues or disaster recovery.

System Performance and Disaster Recovery

As you consider a risk system vendor's analytics and client service, it is important to evaluate the actual performance of the risk system. If your portfolios are large and consist of complex instruments that require simulations and complex pricing, you will need to be assured that the risk system can process your required analytics in a timely manner, on a consistent basis. Risk systems should have a track record of robust performance, and vendors should be able to provide service-level agreements.

In addition, risk system vendors should also be able to provide descriptions of data center security and disaster recovery procedures, as well as independent operational audits such as those complying with the SSAE-16 standards. All data centers should be highly secure and production systems should be redundant and backed up on a systematic basis.

Risk Management Analytics

Most risk systems are anchored by specific methodologies for analyzing risk. It is important to understand the fundamental concepts of these of approaches and decide which is most appropriate for your strategies, investment horizon, and risk management use case. Common methodologies of risk are full revaluation and simulations.

Pricing Models and Asset Coverage

Regardless of the methodology, pricing models for financial instrument valuation are at the core of any risk system. Pricing models enable the calculation of sensitivities to market conditions and exposures to risk factors; these provide the starting point for instrument and portfolio valuation. Pricing models are particularly important in derivative and structured product valuation, where market prices may not be readily available and instrument behavior is non-linear.

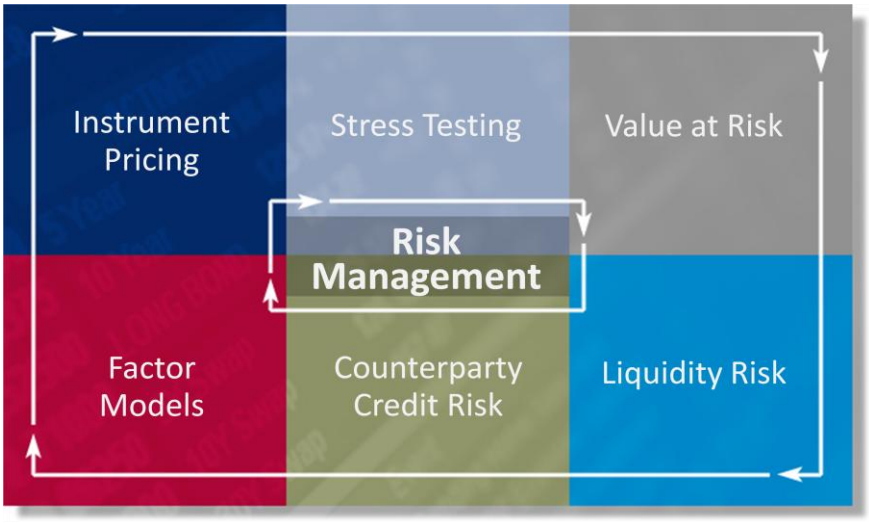

Figure 2: Risk management analytics

Common pricing models utilized by risk applications include Black-Scholes (option pricing), Barone-Adesi and Whaley analytic approximation (Options), Monte Carlo – Geometric Brownian Motion-based approach, Hull-White (future interest rates), and trinomial trees (convertible bonds).

Versatile risk systems allow users to change inputs and parameters to the pricing models. This provides

flexibility in pricing instruments under different scenarios, weighting schemes, and distribution assumptions. The greater flexibility offered in pricing models, the more precise an instrument's valuation can be represented in a risk system.

The combination of pricing models, data, and instrument risk factors allow risk systems to model, or cover, financial instruments. Multi-asset class risk systems can model simple and complex securities across all asset classes, including equities, bonds (rate, credit, and mortgage products), derivatives and swaps, commodities, currencies, and alternative asset classes such a private equity and private real estate.

Fixed income is an especially challenging asset class to cover. Risk systems should be able to properly model instruments that range from fixed coupon bonds to mortgage backed securities impacted by prepayments and cash flow waterfall rules; inflation protected bonds, and bonds with complex coupon payment structures. Pricing models should account for cash flows derived from terms and conditions to arrive at a fair value price for the instrument.

Full Valuation and Simulations

The full valuation methodology is based on representing each security in terms of its granular pricing components. Once the drivers of price are identified, a security can be priced under existing, simulated, and historical market conditions to compute a distribution of prices under different market conditions. For example, for a 10-year treasury bond, the pricing components are points on the corresponding treasury curve up to 10 years out. For an equity option, the components are the equity price, the discount curve; and, if specified, the implied volatility. These components are the "risk factors" used to compute the risk of each position.

This distribution of prices, obtained by fully revaluing each security, supports risk measures such as VaR and Expected Shortfall (ES). VaR and ES are two of the most widely used statistics to measure potential economic losses. VaR measures the expected loss over a specified time period and confidence level, and ES measures the average loss when the VaR amount is breached.

VaR answers the question, "What is the amount we expect losses to exceed with a certain percent probability over a set horizon?" For instance, a VaR of $10 M at a 95% confidence level and a 1-day horizon means that in 1 day in 20, you could expect to lose at least $10 M due to market movements (losses less than $10 M would occur on 19 out of 20 days, or 95% of the time). Expected Shortfall allows you to estimate the amount of losses exceeding $10 M, when a VaR break occurs. VaR and ES are cornerstone measures of risk, applicable across asset classes and investment strategies.

VaR and ES are typically computed using three methodologies:

- Parametric (also referred to as variance-covariance, closed form, or delta normal): This methodology assumes statistical price distributions. Volatilities and correlations are calculated directly from time series data which can be based upon user-specified start and end dates. Users may be able to specify an optional data decay factor to fine tune the weight given to more recent market observations. The parametric method is generally considered accurate for linear assets, but less accurate for options and other non-linear derivatives.
- Monte Carlo: Full-valuation re-pricing simulation based on randomly generated market moves, assuming statistical price distributions. Like Parametric VaR, volatilities and correlations are calculated directly from time series data based upon specified start and end dates. Users may

also be able to specify an optional decay factor, as well as the number of simulations to perform.

- Historical: Full-valuation repricing simulation based on historical time series according to start and end dates, and an optional decay factor.

Note also that some risk systems allow modifying simulation based settings to also allow alternate statistical distributions for fat tail analysis.

Stress Testing

Stress testing is a full valuation methodology related to VaR and ES. While VaR and ES are computed from distribution of multiple revaluations, stress testing is the result of a single, usually bespoke, revaluation of market conditions.[1]

Stress tests allow users to determine potential losses due to "event risk" – which might not be captured by standard analyses. Stress tests can be designed to reprice current positions as well as probe for portfolio-specific weaknesses and vulnerabilities. They can also provide sensitivity analysis by identifying a portfolio's sensitivity to specific risk factors such as a rise in interest rates or changes in implied volatility.

Most vendors provide *historical* stress tests, which represent historically observed market movements. Historical stress tests allow users to investigate how an adverse financial event (similar to a past financial crisis) might affect a portfolio. For instance, the risk system vendor's application might provide historical stress tests that analyze how events like the 1998 Russian Crisis or the 2001 terrorist attacks might impact portfolios.

Many vendors also provide basic risk factor stress tests, allowing users to customize their own stress test by changing the value of risk factors (interest rates, FX levels, commodity curves, CDS Spread Curves, etc.). The portfolio is revalued using the new risk factors.

More sophisticated are *predictive* stress tests which will revalue not only the variables being stressed, but also all of the other factors in the portfolio. For instance, a user could stress oil prices 10% and see the impact on a portfolio, even though it doesn't include any positions in oil. This technique is based on the structural relationship of the assets determined by their volatilities and correlations.

Common Factor Risk Models

As with VaR, ES, and Stress Testing, common factor models also use full revaluation of instruments. Factor models complement VaR models: where VaR uses full revaluation to build a distribution of prices across multiple simulations, common factor models use full revaluation to compute asset exposures to a less granular, but common, set of risk factors.

By using a less granular set of factors, users can decompose portfolio risk into common and intuitive investment themes that can be used for portfolio construction. These themes have been proven to explain security returns over time. For equities, industry factors are one common theme, as are fundamental ratios (e.g. Earnings to Price, Leverage) and technical indicators (e.g. return momentum). Fixed income factors typically include interest rate and credit spread movements. These models extend

[1] Note that a single revaluation of market condition does not imply that only one pricing factor is simulated. Rather, a single revaluation refers to one or (typically) multiple pricing factors or market conditions being simulated at once.

well known market models such as the Capital Asset Pricing Model (CAPM) or the Fama-French three factor model.

Factor analysis is an effective way of describing a security. Each security can be thought of having exposure to a number of factors that are common across the asset class (industry, growth or value, large cap or small cap, dividend paying or non-dividend paying, etc.). For example, Exxon Mobil is a large company with significant exposure to the energy industry. It therefore is categorized as having positive exposure to the Size and Energy factors. The use of a factor model also enables us to determine whether or not Exxon Mobil has positive or negative exposure to all the other factors in the factor model.

A factor model should include factors that are appropriate for the asset class and market. The factors should be relevant in explaining asset returns, familiar to users, and applicable to all assets. A good risk system vendor will update their factors periodically, or in response to significant changes in the market.

The factors in a factor model illustrate the intended and unintended bets within a portfolio, and quantify potential impacts from changes to the portfolio. Understanding these bets is a critical part of portfolio construction. A factor model approach also provides a solid basis for risk reporting, portfolio optimization, performance attribution and stress testing.

Counterparty Credit and Liquidity Risk

As the economy unraveled after the 2008 financial crisis and regulators began to investigate root causes, the need to include counterparty credit exposure and liquidity analytics in risk systems became essential. The recent MF Global collapse certainly reinforces that exposure to trading counterparties represents a risk that needs to be measured and managed.

Counterparty risk relies on modeling sophisticated netting and collateral agreements across multiple trades with a single counterparty.

Counterparty Credit Exposures

Counterparty credit risk is the risk of loss that is incurred by an institution in the event of default of its counterparty. Counterparty risk arises if the counterparty fails to honor the contractual payments to the institution. In case of default, the surviving party has to close out its position and usually seeks to replace the trade in order to maintain its market position. The cost associated with replacing a position with a defaulted counterparty is the counterparty exposure. The price of the counterparty credit risk is called Credit Valuation Adjustment (CVA). It is by definition the difference between the risk-free portfolio/trade value and the true portfolio/trade value that takes into account the counterparty's default.

Calculation of counterparty exposure requires a powerful Monte Carlo simulation and pricing framework coupled with the ability to account for complex netting, margining and closeout rules. The system must be able to compute a variety of exposure measures, including current exposure, potential future exposure, expected exposure, effective exposure, and others. Calculation of CVA adds the need to estimate a counterparty's probability of default, perform Risk-Neutral simulations, and take into account wrong-way risk. The system must allow users to define and monitor limits on any of the exposure measures, or on CVA.

Liquidity Analytics

There are two sides to liquidity risk: market (or asset) liquidity risk, and funding liquidity risk. The liquidity risk of a portfolio not only stems from how liquid the portfolio's assets are, but also from a number of specific portfolio characteristics inherent in the investment rationale. These characteristics include projected future cash flows, commitments to clients' redemptions/withdrawals, the need and ability to resort to funding sources, regulatory framework constraints, restrictions from investment policies, and so on.

While systems that combine market and funding liquidity analysis are scarce, significant strides have been made in the development of market liquidity analytics. A full-fledged market liquidity analytics system must be capable of estimating transaction costs for multi-asset class portfolios taking into account market impact of trading under different market and redemption scenarios, and different trading horizons. The system must be capable of imposing and monitoring liquidity limits, computing optimal liquidation strategies, and providing a framework for scenario analysis.

A Final Note

As you complete the process of evaluating risk systems and risk system vendors, you should be certain that you fully understand the features, performance, support model, and the drawbacks of the system and services you finally select. If you do, this should help lead to a mutually beneficial relationship with your risk system vendor that will last for many years.

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