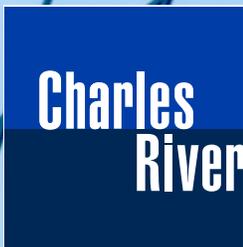
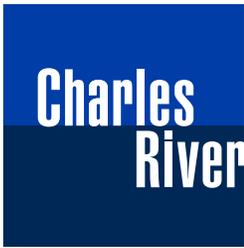


Charles River IMS

Fixed Income

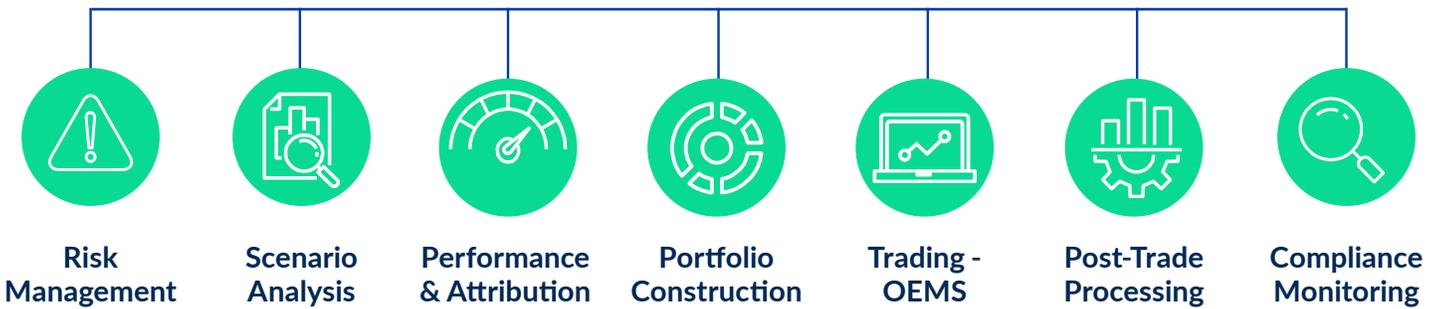


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The Charles River Fixed Income Investment Process



FOUNDATIONS

Position Management

Collateral Management

Analytics & Data

The Charles River Investment Management Solution

Charles River IMS combines all of the capabilities needed to effectively manage institutional fixed income portfolios, from portfolio risk analytics to trading, and position management to post trade processing. The front and middle office share a consistent view of positions, exposures and collateral.

Firms can implement their entire fixed income investment process on Charles River IMS for all products and strategies, including total return, smart beta, risk parity and liability driven products. A scalable, cloud-based platform provides traders and portfolio managers with the data, analytics and benchmarks required to support each desk and asset class, from rates to credits, and bank loans to structured products.

THIS ENABLES FIXED INCOME MANAGERS TO:

- Respond faster to market opportunities and make more informed allocation, targeting and hedging decisions
- Readily understand their portfolio's exposure to counterparty, credit, rate, geographic or sector risk
- Increase portfolio manager and analyst productivity by providing a complete set of capabilities across the investment process
- Eliminate disparate portfolio management, risk, performance, and middle-office platforms by managing all products and asset classes on Charles River IMS
- Leverage the latest capabilities, industry best-practices, and risk models with cloud-based deployment

Risk Management

MODEL, MEASURE AND MANAGE PORTFOLIO RISK

Fixed income managers, compliance teams, and risk analysts can calculate, manage, and monitor risk across the entire investment lifecycle on Charles River IMS. Assessments of portfolio, interest rate, and sector risk are calculated using a single, consistent set of data, limiting the potential for conflicting risk assessments. Managers can view portfolio exposures across multiple dimensions and custom classifications, propose trades to bring exposure to target levels, and see exposures adjust in real-time. Trades can then be generated and routed to the appropriate trading desk. Charles River IMS lets managers and analysts:

- Analyze sensitivities to rate, credit and inflation risk factors at portfolio and category levels
- Propose changes and analyze results of de-risking decisions pre-trade
- Model and hedge portfolios using the latest market data
- Optionally incorporate bespoke and 3rd party analytics
- Utilize industry-standard derivative valuation models

ASSESS FORWARD LOOKING RISK

Three ex-ante risk measures are supported to help managers assess forward looking risk and adjust their portfolios accordingly:



Value at Risk (VaR)

Uses historical simulation and Monte Carlo methodologies to calculate the worst case loss over a given time period that won't be exceeded with a given level of confidence.



Conditional VaR

Or expected shortfall, quantifies the potential loss once the VaR threshold has been exceeded.



Component VaR

Lets portfolio managers quickly visualize how much a particular sector, category or security adds or subtracts to their overall VaR so they can reduce or hedge those exposures.

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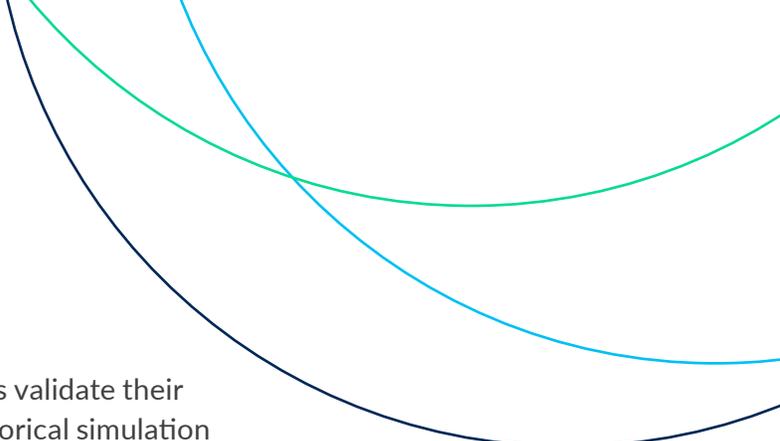
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COMPONENT VaR

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(Risk Management continued)

Adjustments are immediately visible, helping managers validate their decisions and understand portfolio-level impacts. Historical simulation is a robust, non-parametric method for calculating VaR that makes no assumptions about the underlying distribution of risk factors or returns. VaR calculations can incorporate either exponential decay to weigh recent data more heavily, or stressed conditions to produce realistic worst-case forecasts. Replacement securities can be utilized to account for missing data.

Risk forecasts based on factor models, including projected volatility, tracking error, and beta are also supported. Firms can utilize Charles River's proprietary factor model based on Principal Components Analysis (PCA), or incorporate in-house and third-party models. Volatility and tracking error can be decomposed into systemic and idiosyncratic risk. Managers and analysts can then view and analyze the decomposition of systemic risk into factors.

UNDERSTAND RISK IN A HISTORICAL CONTEXT

Portfolio managers can monitor changes in historical VaR and ex-post risk metrics over time and analyze the evolution of their portfolio using trend analysis. This provides insight into whether changes to risk levels were anticipated and desired, or whether they were a result of increased risk exposures that should have been managed and reduced. The displays are also interactive, so de-risking activities can be carried out and reflected in real time.

Scenario Analysis

SCENARIO ANALYSIS, STRESS TESTING AND TREND ANALYSIS

Fixed income managers and risk analysts apply Scenario Analysis to model portfolio impacts of one or more stress factors, including interest rate and FX shifts, credit spread changes, inflation shocks, volatility shifts, and prepayment shifts. Alternatively, fixed income managers can use factor model-based scenarios to understand how a change in one of the risk factors (e.g., oil price) will impact the remaining factors (e.g., interest rates). This allows the manager to more accurately assess the full impact of a particular stress event on the portfolio.



STRESS TESTING

Applies scenarios mandated by regulatory authorities to model potential outcomes and gauge worst-case portfolio drawdown.



HYPOTHETICAL SCENARIO ANALYSIS

Allows managers to construct and apply a plausible scenario based on their portfolio's risk exposures, reflecting the full impact of underlying instruments, including derivatives, and taking into account all portfolio and cash events.



SEARCH SPREADSHEET

Applies shifts and then displays portfolio performance over a horizon term ranging from days to years, based on a reinvestment rate for any cash flows received, including coupon payments, maturities, and callable/puttable bonds that would be called/put within that term.

Performance & Attribution

PERFORMANCE MEASUREMENT AND ATTRIBUTION

Fixed income managers can view historical portfolio performance across any timeframe and understand the portfolio construction and asset selection decisions responsible for that performance. Users can change performance or attribution settings on the fly and run different analyses for the same account across asset types, down to the individual security level. Performance results can be converted to any currency and custom benchmarks can be created by importing and blending category- or constituent-level indices.



Managers and analysts can:

- Measure performance using either true time-weighted or modified Dietz methodologies, configurable at the account level
- Attribute performance using van Breukelen and Tim Lord-styled breakdowns (income, roll, duration, convexity, spread allocation and selection, currency)
- Calculate multiple return types, including capital, income, base, local, currency, gross and net
- Roll up performance to any level, including multiple nested classifications, total portfolio/benchmark, account groups and composites



Attribution methodologies and major capabilities include:

- Select daily attribution by asset style, including currency, fixed income roll, duration, convexity and spread effects
- Choose the attribution methodology that best supports their business needs, and configure the methodology at global system, account, or report levels
- Roll up attributions to multiple classification levels for each security, including domicile (region, country, currency) and sector (industry or sub-sector) country, currency) and sector (industry or sub-sector)

Charles River offers an advanced fixed income attribution methodology with a more granular return decomposition and can closely align with a portfolio manager's investment strategy and decision-making process. These factors include: curve positioning bets by utilizing key rate durations, sector bets by using the spreads of underlying securities, inflation, currency management, and investment in interest-bearing securities.

Charles River also supports attribution analysis based on third-party factor models. Firms can assess the contribution impact in their portfolios from active exposure to each factor. The factor-level analysis can be combined with return-based analysis to provide a comprehensive view of the sources of a portfolio's active return.

Portfolio Construction

PORTFOLIO CONSTRUCTION, OPTIMIZATION AND ANALYSIS

Centralized portfolio management capabilities provide flexible views of exposures and holdings, allowing fixed income managers to:

- See the impact of asset allocation and de-risking decisions across mandates. Managers can drilldown into specific portfolios to take action while maintaining a view of desk-wide positioning
- Construct portfolios that align with investment mandates, while deconstructing exposure and risk analytic contributions on an absolute or relative basis
- Understand even the most complex compliance and risk guidelines and readily adjust proposed allocations



Visualization: Portfolio managers can access standard landing page views to highlight high-level portfolio positioning information such as duration, top 10 issuers/holdings, active orders, cash flow data, and compliance violations to take action where necessary. The dashboard can also be used to decompose portfolio information and drilldown into detailed breakdowns of holdings and analytics. For mobility and reporting, reports can be printed or exported on an ad-hoc or scheduled basis.



Portfolio Optimization: Portfolio attributes such as turnover level, tracking error ranges and number of transactions can be optimized directly. Portfolios can be tilted toward specific targets for any number of user-defined variables or security groupings. Hard constraints can be applied in absolute terms, relative to a benchmark, or relative to the initial position. Both market neutral and uneven long/short strategies can be optimized as a single problem to help eliminate the need to perform separate optimizations. The optimizer can use factors derived from both Charles River's standard models and third-party models.



Historical Analysis: Portfolio managers can view history across key dates in terms of holdings and perform trend analysis. For example, a fixed income manager may wish to see how they were positioned actively against a benchmark in terms of exposure and duration across the last four quarters versus today; this analysis can be performed via the historical views and charted for visual effect.



Exception Based Workflows: The portfolio management workspace helps makes it easier to identify specific portfolios and positions requiring attention. The workspace also helps managers focus on sector, issuer and rate curve bets, and identify potential opportunities to enhance portfolio returns with derivative overlays.

Liability Driven Investing

CONSTRUCT AND MANAGE LDI DRIVEN STRATEGIES

Liability-Driven Investment (LDI) strategies help insurers and pensions manage assets based on the cash flows required to fund future liabilities. These strategies may include matching the cash flows of assets with the cash flows of liabilities, or matching the risk sensitivities of both assets and liabilities, so that assets can still fund liabilities if market conditions change. These capabilities help asset managers minimize a portfolio's liquidation risk by ensuring asset sales, interest, and dividend payments correspond with expected payments to beneficiaries.

The Charles River Investment Management Solutions (Charles River IMS) uses a "Liability Instrument" to streamline modeling of cash flows.

The following capabilities support LDI workflows:



Liability Benchmarks

Users assign a liability benchmark to their respective funds. These benchmarks contain the liabilities that correspond to the fund.



Liability Mapping

Users can define liabilities to be either nominal or inflation-adjusted. Inflation adjusted liabilities can be modeled based on an imported set of real and/or inflation adjusted cash flows.



Flexible Analytics

Liability valuations can be produced relative to a set of actuarial cash flows discounted relative to the appropriate curve (e.g., IRS curve) and spread. Users can specify tenor set sensitivities for the asset portfolio and the liabilities.

The sets feature:

- Flexible tenor definitions
- Ability to generate interest rate and inflation sensitivities per tenor
- Ability to link interest rate to inflation sets

(Liability Driven Investing continued)



Portfolio Management

The Charles River Manager Workbench enables users to efficiently manage a portfolio of assets and liabilities. Portfolio managers can display liability securities, calculate and show funding ratios, and generate a range of analytics by tenor, including PV01, DV01 and IE01. This supports standard hedging and targeting workflows, for example, hedging a position and determining funding ratio impact.



Scenario Analysis

Charles River Scenario Analysis supports the ability to shift the market factors that are relevant to liabilities (e.g., interest rates, inflation and spreads). User-specified shifts are applied to all relevant curves, liability, and asset attributes in order to obtain a scenario specific set of valuations, analytics and cash flows.



From a fund management perspective this allows a portfolio manager to:

- View funding and hedge ratios subject to various economic environments
- Perform cash ladder analysis relative to their liabilities
- Analyze changes in valuations and sensitivities subject to regime changes

For stress testing, liabilities can be proxied or used in factor scenarios if factor exposures are available.



Compliance Monitoring

Compliance rules can be based on portfolio level analytics, tenors, and funding ratio.

Trading – OEMS

MULTI-ASSET ORDER AND EXECUTION MANAGEMENT

The Order and Execution Management System (OEMS) provides connectivity to all venues and dealers, and aggregates quote and inventory data on a centralized platform. A single, consistent user interface that is applicable across multiple trading models helps ensure that buy-side traders need to learn only one interface, and delivers a transparent and broad view of inventory and liquidity. Charles River's FIX team builds and maintains FIX interfaces to electronic execution venues and continually adds new venues to the OEMS.



INVENTORY AGGREGATION

Vendor-supported interfaces let dealers send inventory and indicative pricing directly to the OEMS trading blotter. Buy-side firms can save on integration and support costs, and benefit from more efficient workflows, greater market transparency, and detailed audit trails. By helping traders break up large orders to reach all available market liquidity, the OEMS supports the industry trend towards smaller trade sizes.



PRE-TRADE DECISION SUPPORT

The OEMS displays inventory, quotes and streaming executable prices. It also incorporates streaming time and sales data from TRACE and MSRB. The latter feeds are used to enrich order and trade history prior to archiving in the OEMS database and provide traders with increasingly critical visibility into market structure and trade activity at the point of execution.



EXECUTION ANALYSIS

Traders can make more informed order routing decisions based on broad and deep execution analysis metrics generated by the OEMS. This data helps traders understand when to trade electronically versus manually, and provides visibility into the full trade lifecycle for all orders, not merely a portion of the orders that most vendors and venues are limited to.

Post-Trade Processing

CENTRALIZED CONFIRMATION, TRADE MATCHING AND SETTLEMENT

By automating the post trade process and providing centralized confirmation, trade matching and settlement instruction workflows, the Charles River IMS reduces clearing-related risk. For each transaction, dealers and traders, portfolio managers, compliance, and operations personnel have the same real-time view of all post-trade processing activity and data. The resulting low-touch settlement process minimizes manual steps and enables fixed income managers to:

- Expedite settlement by routing individual trades and allocations in real time to facilitate same-day matching and confirmation
- Reduce failed trades and boost operational efficiency with automated matching and confirmation of blocks and allocations
- Automate the trade confirmation process across multiple asset classes with Omgeo Central Trade Manager (Omgeo CTM) for central matching of cross-border and domestic transactions
- Support local trade matching with standing settlement instructions and configurable, rule-based tolerance matching
- Manage “by exception” with personalized views and alerts that save time and speed up corrective intervention
- Satisfy regulatory mandates with OTC clearing workflows and audit trails
- Consolidate post-execution operations by centralizing all reference data and settlement instructions

Compliance Monitoring

FULL TRADE LIFE-CYCLE COMPLIANCE MONITORING AND MANAGEMENT

Firms can meet regulatory demands for more stringent risk management with centralized compliance monitoring and management capabilities, and advisory services that utilize a comprehensive library of built-in rules for worldwide regulatory requirements and mandates. Charles River IMS automates the compliance workflow and provides advanced compliance rule building, testing and maintenance, customizable reporting and a complete audit history, including the ability to:

- Reduce intra-day risk by validating compliance at any stage of the trade lifecycle:
- Pre-trade, in-trade, post-execution, end-of-day and portfolio level
- Expedite portfolio management workflows by incorporating compliance rules into “what-if” analysis
- Optimize compliance monitoring by prioritizing and filtering alerts
- Trace violations and perform forensic historical trend analysis through “As of” compliance reporting

Position Management

REAL-TIME, CONSOLIDATED POSITIONS AND CASH

The Investment Book of Record (IBOR) automates position management across all asset classes. This provides the front office with accurate real-time positions and lets the middle office retrieve and reconstruct historic positions to support compliance inquiries. As an independent source of start-of-day positions, IBOR decouples the front office from the back office and enables consistent management of position data on a single platform. Downstream reporting, performance, and risk systems can utilize IBOR's accurate real-time positions. By establishing a "single and current version of the truth", IBOR instills greater confidence in investment decisions.

IBOR feeds the Charles River IMS with beginning-of-day positions and can distribute position keeping data to ancillary front and middle office systems. By eliminating dependency on daily feeds from back-office systems for investment operations and consolidating multiple sources of position-related data onto one platform, clients can eliminate position errors, streamline operations, and reduce costs.

For fixed income securities, IBOR performs several instrument-specific operations via end-of-day processing:



PAY-DOWNS

IBOR can process cash flow payments, including asset- and mortgage-backed security pay-downs and swap cash flows. Cash flow payment processing can be run internally, or by importing values generated externally. For mortgage-backed securities, IBOR generates transactions to account for principal, accrued interest as well as cost adjustments for paydowns.



AMORTIZED COST BASIS

Several attributes are calculated daily for fixed income positions, including book value, market value, fair value, exposure, accrued interest, and unrealized gain/loss. IBOR supports the amortization of premium/discount through the effective yield method, as well as the adjustment of cost basis from mortgage-backed security pay-downs. The adjusted and non-adjusted cost basis can be used to maintain each day's unrealized gain/loss.



MATURITY AND COUPONS

Maturing bonds and expiring futures and options are closed to prepare IBOR's beginning-of-day positions. Appropriate transactions are generated to close the positions and generate any related cash transactions.

Collateral Management

COLLATERAL MANAGEMENT AND MARGIN TRACKING

Collateral and Margin Management capabilities help fixed income managers comply with new regulatory requirements and industry best practices. An increasing number of firms must post collateral for bilateral (uncleared) swaps, to settle collateral on T+1, and to maintain separate legal documentation arrangements for initial and cleared variation margin.

Several front office and middle office capabilities support new margin requirements, from pre-trade decision support through to management of margin calls and collateral posting. Managers gain visibility into the initial margin estimate based on regulatory guidelines and can readily establish whether required collateral agreements are in place. Real-time updates of the trading book eliminate over/under pledging. Charles River IMS facilitates recording, reconciliation, identification of eligible collateral, and selection and tracking tasks. Additionally the status of margin instructions and linked collateral is displayed.

Analytics & Data

GLOBAL MULTI-ASSET COVERAGE

The Charles River Data Service provides managed reference and pricing data to support broad and deep global coverage across all asset classes. Frequent updates ensure that new instruments are made available to asset managers on a timely basis.

FIXED INCOME, CURRENCIES AND COMMODITIES (FICC)

- Global Government: Over 100 jurisdictions/sovereigns
- Securitized Products: MBS, ABS, CMBS and CMOs
- Treasury and Swap curve-based analytics, swap curves in 14 currencies
- Corporate: Global Investment Grade, High Yield, and Bank Loans
- Structured Products: Fixed Rate, Floating Rate, Fixed-to-Float, Stepped, PIK, Callable
- Municipals: Comprehensive state coverage
- Inflation Linked: Over 20 countries
- Convertible bonds
- Currencies: Spot and Forwards for 174 base currencies
- Futures for over 3200 commodities

CONSISTENT AND ACCURATE ASSET VALUATIONS

A highly performant analytics engine; managed reference, benchmark and pricing data; extensive global instrument coverage; and industry standard computational models help ensure accurate, real-time valuations of all instruments. Firms can store and compare multiple reference, analytics, and pricing suppliers and sources to meet the particular valuation requirements of their investment process and product mix. Charles River's global team of data analysts maintains always-current mappings for 1000+ data elements to support over 120 types of bonds globally. Continuous validation helps ensure that accrued interest and critical analytics are calculated correctly.

DERIVATIVES

Exchange Traded:

Bond Futures, Interest Rate Futures, Currency Futures, Equity Index Futures, Options on Futures, Equity Options and Equity Index Options

OTC Rate and Credit:

Interest Rate Swaps, Inflation Swaps, Asset Swaps, FRAs, Caps/ Floors, Swaptions, CDS, CDX/iTraxx, TRS- Bond, CDS/CDX Swaptions

OTC Other:

TRS- Equity, Variance/Volatility Swaps, FX Forwards, FX Options, Commodity Swaps

EQUITIES

- Common Stock, Closed-End Funds, ETFs, ADRs, REITs, Convertible Bonds
- Developed and Emerging Markets in 160 countries and 72 currencies

(Analytics & Data continued)



PRIVATE CLOUD-BASED DELIVERY

Regular, managed upgrades help ensure firms are accessing the latest front and middle office capabilities and workflows. Application specialists manage the Charles River IMS according to best practices, and provide application and integration expertise that is difficult for firms to build and maintain in-house. This helps ensure optimal application performance and reliability.



INTEGRATED DATA SERVICES

The Charles River Data Service and Data Management Service alleviate many of the challenges, complexities and costs of data management by integrating multiple data sources to provide complete, accurate and timely data to the Charles River IMS.



FIX CONNECTIVITY

A certified global FIX network is administered by an internal support team that manages, tests and certifies broker connectivity, helping to ensure seamless, reliable electronic trading.

RAPID, FLEXIBLE DEPLOYMENT AND MANAGED DATA

Charles River IMS is deployed via the cloud. This is designed to simplify client operations, improve data quality and investment professional productivity, control risk, and lower technology costs.

MORTGAGE PASS-THROUGH SECURITIES AND TBAS

Trade-time analytics and mortgage duration and convexity are calculated natively. Charles River provides a Public Securities Association (PSA) pre-payment model based on an absolute, constant pre-payment rate. Alternately, externally calculated cash flows can be imported to model pre-payments. Additionally, Charles River offers its own proprietary dynamic prepayment model for US Fixed Rate Agency Pools.

ASSET-BACKED SECURITIES

Instrument coverage includes RMBS and CMBS, agency and non-agency CMOs, fixed and adjustable rate mortgages, TBAs and other asset-backed securities. More sophisticated pre-payment models are supported in the Charles River IMS via the integrated Yield Book analytics. For example, the Citi Mortgage Prepayment model incorporates over 12 factors, including average credit score, turnover effects, refinancing, and loan-to-value. Supported interest rate models include LIBOR-Market, 2-factor skew and 1-factor single volatility.

(Analytics & Data continued)

NATIVE AND BESPOKE ANALYTICS

The Charles River IMS supports both natively calculated and third-party analytics for bonds, derivatives, mortgages, and asset-backed securities. Natively calculated analytics are compatible with major index analytics across all asset types such that comparisons to benchmarks can be performed accurately. This helps eliminate the need for external index-provider analytics systems. However, external analytics (and other data) can be imported and selectively mixed and validated.

Native analytics calculated using the embedded analytics engine.

Category	Analytic(s)
Trade-level	Price, yield, accrued interest, projected cash flows, factor, spread to benchmark
Sensitivities	Duration, modified duration, convexity, DV01, mortgage-specific sensitivities
Derivative-related	Option greeks, credit DV01, inflation DV01, par swap rate
Advanced	Option adjusted spreads, I-spread, Z-spread, fair value, spread duration, spread convexity, key rate durations

Users also have the capability to recalculate analytics for specific components of their portfolios should underlying market activity dictate. Analytics are calculated using industry standard methodologies, and new methods (e.g., dual-curve stripping) are added when industry best practices change.

Representative methodologies utilized to calculate analytics.

Instrument Type	Methodology
Bonds	1-factor Hull-White model, Black Karasinski with configurable volatility and mean reversion parameters
Options	Black Scholes or binomial tree for European options, Binomial tree for American or Bermudan options, Dividend yield or projected discrete dividends
CDS Basket	1-factor Gaussian copula for homogeneous baskets, Normal copula for non-homogeneous baskets
CDS Index Tranche	Monte Carlo, Fast Fourier Transform, Recursion method
Swaptions	Black model with lognormal volatility
Inflation Swaps	Accruing on inflation swap curves, discounting on LIBOR/Swap or OIS
Interest Rate Swaps	Discounted cash flows with different principal exchange conventions, Supporting different accrual (forward) and discount curves – e.g., accrual on LIBOR/Swap and discount on OIS
Variance & Volatility Swaps	Discounted cash flows, Heston, and Options Portfolio Replicating methods

Charles River Development, A State Street Company

Investment firms, asset owners, wealth managers, hedge funds and insurers in more than 30 countries rely on Charles River's front and middle office investment management platform to manage more than US\$30 Trillion in assets. Together with State Street's middle and back office capabilities, Charles River's cloud-deployed software technology forms the foundation of State Street AlphaSM. The Charles River Investment Management Solution (Charles River IMS) is designed to automate and simplify the institutional investment process across asset classes, from portfolio management and risk analytics through trading and post-trade settlement, with integrated compliance and managed data throughout. Charles River's growing partner ecosystem enables clients to seamlessly access external data and analytics, applications and liquidity venues that support the demands of their product and asset class mix. Headquartered in Burlington, Massachusetts, we serve clients globally with more than 1,000 employees in 11 regional offices.

(Statistics as of February 2021)

Learn more at [crd.com](https://www.crd.com)

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