# Mortgage-Backed Securities (MBS) Pricing Model Development Document

# Executive Summary

The objective of this validation is to independently evaluate and challenge the assumptions, theoretical underpinnings, data integrity, and computational framework of the **Mortgage-Backed Securities (MBS) Pricing Model** for the review period **June 2022 to June 2023**. The validation also examines the adequacy of the implementation environment, performance monitoring practices, and governance framework within which the model operates.

The **MBS Pricing Model** (“the Model”) is designed to manage pipeline risk, forecast interest rate movements, optimize trading decisions, and achieve best execution in the pricing and hedging of mortgage-backed securities. The model enables the Bank to assess and manage the value of its mortgage pipeline and corresponding hedge instruments, ensuring consistency with internal risk management policies and regulatory expectations.

As part of the Model Risk Management (MRM) process, the validation assessment covers the following four key areas:

* **Conceptual Soundness** – Evaluation of the model’s theoretical basis, methodology, segmentation, assumptions, and data used for development and calibration.
* **Outcome Analysis** – Review of model outputs, reasonableness checks, back-testing, and benchmarking to ensure the model behaves as expected under different market conditions.
* **Model Implementation and Use** – Verification of implementation accuracy, system controls, and model usage practices to ensure the model operates as intended in production.
* **Model Monitoring and Governance** – Assessment of ongoing monitoring, reporting practices, and compliance with the Bank’s model governance policies.

## Model Theory

This section provides a detailed assessment of the conceptual soundness of the **MBS Pricing Model**, focusing on its purpose, structure, and methodological integrity. The objective is to ensure that the model’s theoretical framework, data inputs, assumptions, and calibration procedures are conceptually justified, transparent, and aligned with the intended business use.

Each component of the model—covering interest rate modeling, mortgage rate projections, and pipeline valuation—is evaluated to confirm that the methodologies are grounded in sound quantitative theory and reflect industry best practices. The review also examines the coherence between model components, ensuring that their interdependencies contribute to consistent and accurate pricing of mortgage-backed securities under various market scenarios.

## Model Purpose

The **MBS Pricing Model** serves as a comprehensive analytical framework used by the Bank to **value, hedge, and manage risks associated with mortgage-backed securities and related mortgage pipeline positions**. The model integrates multiple components, including the **Interest Rate Model**, **Mortgage Rate Model**, and **Pipeline & Warehouse Valuation Module**, to derive market-consistent valuations and support hedging and trading strategies.

The primary objectives of the model are to:

* Estimate the **fair market value** of mortgage-backed securities and pipeline positions across different interest rate environments.
* Support **daily risk management** by quantifying exposure to changes in interest rates, basis risk, and pipeline fallout.
* Facilitate **hedge optimization** through the valuation of To-Be-Announced (TBA) securities and other derivative instruments.
* Provide inputs for **accounting and financial reporting**, ensuring that valuations and P&L impacts are aligned with fair value principles.
* Enable **benchmarking and scenario testing**, including TBA pricing comparisons and interest rate stress scenarios.

The actively hedged pipeline and warehouse portfolios, primarily managed through TBA positions, are continuously monitored to mitigate valuation volatility resulting from rate movements. Daily runs of the CompassPoint model incorporate data from the Bank’s internal systems, market rate feeds, and pricing sources to ensure accurate and timely valuation updates.

Overall, the MBS Pricing Model provides a robust, data-driven approach for managing mortgage pipeline exposure and achieving best execution in the secondary mortgage market. It not only supports trading and hedging operations but also enhances transparency, governance, and control over the valuation process within the Bank’s risk management framework.

**2.2 Methodology & Model Theory**

This section outlines the methodological foundation and theoretical framework of the **Mortgage-Backed Securities (MBS) Pricing Model**. The model integrates several interlinked components — interest rate simulation, prepayment modelling, cashflow generation, discount factor bootstrapping, and net present value computation — to determine the fair value of MBS instruments under varying market scenarios.

The workflow, as depicted in the model pipeline, begins with the estimation of Hull–White parameters, followed by interest rate simulation, computation of conditional prepayment rates, single-month mortality (SMM) estimation, generation of scheduled and simulated cashflows, and culminates in discounted valuation and simulation reporting.

The methodology combines stochastic interest rate modeling with prepayment and cashflow analytics to replicate the behavior of mortgage pools and associated pass-through securities. Each component of the model is explained below.

**2.2.1 Interest Rate Model**

The **Interest Rate Model** serves as the cornerstone of the MBS Pricing framework. It employs the **Hull–White single-factor model**, a short-rate stochastic process designed to capture the mean-reverting nature of interest rates. The model specification is as follows:

where

* = instantaneous short rate
* = mean reversion speed
* = long-term mean rate
* = volatility of the short rate
* = Wiener process

The Hull–White parameters are estimated using the current term structure of interest rates and observed market volatility (swaption volatility surface). Once calibrated, the model simulates thousands of future interest rate paths, each consistent with current market conditions.

The simulated interest rates feed directly into downstream modules — influencing prepayment speed estimation, discount factor generation, and ultimately, the valuation of MBS cashflows. The **Simulation Calibration Report** is generated to validate parameter convergence, volatility alignment, and path stability.

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## Simulated Interest Rate

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**2.2.2 Mortgage Rate and Prepayment Model**

The **Mortgage Rate and Prepayment Model** links borrower behavior to the projected interest rate paths. The model uses the **Conditional Prepayment Rate (CPR)** framework to estimate early repayments driven by refinancing incentives, housing turnover, and burnout effects.

For each simulated interest rate path:

* The **conditional prepayment rate (CPR)** is computed as a function of the spread between the current mortgage rate and simulated market rate.
* The **Single-Month Mortality (SMM)** rate is derived as:
* The **SMM** determines the proportion of principal prepaid each month.

This behavioral modeling ensures that cashflows respond dynamically to market rate shifts — higher prepayments under falling rate environments and slower prepayments when rates rise.

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**2.2.3 Discounting and Cashflow Generation**

The cashflow generation process combines scheduled principal and interest payments with stochastic prepayment adjustments derived from the SMM. Two parallel modules — **Scheduled Cashflow** and **Simulated Cashflows** — are used to calculate the total cashflows across simulation paths.

To discount these cashflows, the **Discount Factor Bootstrapping** module constructs the term structure of discount factors from the simulated interest rate paths. This ensures consistency between simulated rate dynamics and present value computation.

Each monthly cashflow (scheduled and prepaid) is discounted using the appropriate factor, generating a **Simulated NPV** for each path. The aggregation of NPVs across simulations provides the model’s expected fair value estimate for the MBS tranche or pass-through security.

**2.2.4 Simulation and Reporting Framework**

The **Simulation Summary** consolidates outcomes from all paths to produce:

* Expected MBS price (mean simulated NPV)
* Price volatility and duration measures
* Sensitivity of MBS value to parallel and non-parallel rate shifts (±100 bps, ±400 bps)
* Scenario-based valuation shocks and yield curve impacts

The results are presented through the **Simulation Calibration Report**, ensuring that pricing, prepayment dynamics, and duration metrics align with observed market benchmarks.

This modular and transparent simulation architecture allows for easy recalibration, scenario testing, and governance traceability. Each component — from Hull–White calibration to NPV aggregation — is validated individually and as part of the integrated system, ensuring conceptual soundness, numerical stability, and regulatory compliance in MBS valuation and risk management.

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**2.3 Model Inputs and Data**

**2.3.1 Input Data Sources**

The MBS Pricing Model integrates multiple data sources to ensure robust valuation and alignment with prevailing market conditions. The inputs are grouped into **market**, **loan-level**, and **assumption-based** categories:

|  |  |  |  |
| --- | --- | --- | --- |
| **Data Type** | **Description** | **Source** | **Frequency** |
| Yield Curves | Treasury and Swap Curves for discounting and Hull-White calibration | Bloomberg / Reuters / Internal Market Feeds | Daily |
| Swaption Volatility Surface | Used for Hull-White parameter estimation (α, σ) | Bloomberg / Market Data Vendor | Weekly |
| Mortgage Pool Characteristics | Loan balance, WAC, WAM, remaining term | Internal Loan Servicing System | Daily |
| Prepayment Model Parameters | Historical CPR/SMM data, refinance elasticity, burnout factor | Vendor (e.g., AD&Co or internal analytics) | Monthly |
| Credit Spread Curve | Applied to discount cashflows to account for liquidity and credit risk | Market Implied / Trader Input | Daily |
| TBA Prices | Benchmark MBS tradeable prices | Market Feeds | Intraday |

All data feeds are validated against control thresholds for completeness, continuity, and reasonableness before ingestion. Any missing or anomalous data triggers alerts and requires manual approval before model execution.

**2.3.2 Assumptions and Parameters**

Key model parameters are calibrated periodically and stored within a version-controlled configuration repository. Examples include:

* **Mean Reversion Speed (α):** Typically ranges between 0.03–0.08; estimated via maximum likelihood from swaption data.
* **Volatility (σ):** Derived from historical rate volatility; capped to maintain numerical stability.
* **Prepayment Elasticity:** Defines sensitivity of CPR to interest rate differentials.
* **Discount Margin:** Reflects credit and liquidity spreads specific to MBS pools.

Assumptions are reviewed quarterly and recalibrated whenever significant market regime shifts occur (e.g., yield curve inversion, rapid volatility expansion).

**2.4 Model Outputs and Usage**

**2.4.1 Primary Outputs**

The MBS Pricing Model produces a suite of quantitative metrics used across risk, accounting, and trading functions. Key outputs include:

|  |  |  |
| --- | --- | --- |
| **Output** | **Description** | **Utilization** |
| **Fair Value / NPV** | Expected present value of future MBS cashflows across simulated paths | Balance Sheet Valuation |
| **Duration and Convexity** | Measures price sensitivity to yield curve shifts | Interest Rate Risk Reporting |
| **OAS (Option Adjusted Spread)** | Spread that equates discounted cashflows to market price | Trading / Hedging Decisions |
| **Scenario Sensitivities** | Value change under +/−100, +/−400 bps shifts | Stress Testing / ALCO Reporting |
| **Prepayment Distribution** | Expected vs realized CPRs across rate paths | Model Monitoring |

**2.4.2 Model Usage and Governance**

The model serves multiple user groups within the Bank:

* **Treasury:** Uses the model for daily MBS portfolio valuation and hedge ratio determination.
* **Risk Management:** Monitors duration gap, OAS movements, and prepayment volatility.
* **Accounting:** Applies fair value estimates under IFRS 13 and hedge accounting documentation.
* **Model Risk Management (MRM):** Performs periodic validation, performance testing, and documentation review.

Access to the model is controlled through role-based authentication within the Bank’s Quantitative Analytics Environment (QAE). Execution logs, parameter files, and simulation results are stored in the **Model Evidence Repository (MER)** for auditability.

**2.5 Outcome Analysis**

Outcome analysis evaluates whether the model behaves as expected under both base and stressed market conditions.

**2.5.1 Back-Testing**

Back-testing compares historical realized MBS prices and spreads with model-predicted values using the same input data. The following checks are performed quarterly:

* **Directional Accuracy:** Price increases under falling yield scenarios.
* **Magnitude Accuracy:** Model-predicted OAS within ±5 bps of observed market levels.
* **Prepayment Fit:** Realized vs simulated CPR differences within 10% tolerance.
* **Duration Accuracy:** Model duration within ±0.2 years of benchmark index.

**2.5.2 Benchmarking**

The model outputs are benchmarked against external vendor models (e.g., PolyPaths, Yield Book) to ensure valuation alignment. Deviations beyond tolerance levels are analyzed for input discrepancies, assumption drift, or calibration error.

**2.6 Model Monitoring and Governance**

Ongoing monitoring ensures that model performance remains stable and assumptions remain valid over time.

**2.6.1 Monitoring Plan**

|  |  |  |
| --- | --- | --- |
| **Frequency** | **Test** | **Objective** |
| **Daily** | Parameter stability check | Detect abrupt changes in α, σ, or OAS spreads |
| **Weekly** | Sensitivity test (+/−100 bps) | Ensure consistent price response to rate shifts |
| **Monthly** | Back-test of predicted vs observed OAS | Validate fair value accuracy |
| **Quarterly** | Full recalibration | Align parameters with latest market data |
| **Annually** | Independent Validation | Ensure compliance with SR 11-7 and internal MRM standards |

**2.6.2 Governance Structure**

* **Model Owner:** Treasury Quantitative Analytics
* **Model Developer:** Quantitative Research and Valuation Team
* **Model Validator:** Model Risk Management (MRM)
* **Data Owner:** Market Risk Data Office
* **Users:** Treasury, Risk, Accounting

All model documentation, version logs, and validation findings are reviewed by the **Model Risk Committee (MRC)** for approval prior to production deployment.

**2.7 Limitations and Recommendations**

**2.7.1 Limitations**

* Reliance on vendor data for volatility and CPR assumptions may introduce model dependency risk.
* The Hull–White model assumes log-normal rate dynamics, which may understate tail risk during extreme market conditions.
* Prepayment response functions are linearized approximations, which may not fully capture behavioral shifts.
* Limited liquidity in secondary MBS markets during stress events may cause deviation from fair value estimates.

**2.7.2 Recommendations**

* Introduce multi-factor term structure extensions (e.g., G2++ model) for improved rate curve fitting.
* Develop internal prepayment model calibrated to proprietary borrower data.
* Enhance OAS stress framework by incorporating macroeconomic drivers (GDP, unemployment, inflation).
* Implement real-time market validation dashboard within the MRM Vault or Nimbus Uno governance suite.

**2.8 Conclusion**

The MBS Pricing Model provides a robust, theoretically grounded, and operationally sound framework for the valuation and risk management of mortgage-backed securities. It integrates stochastic rate modeling, dynamic prepayment analytics, and scenario-based valuation into a cohesive system aligned with market standards and regulatory expectations.

While the model performs well across most scenarios, improvements in documentation, behavioral calibration, and scenario governance would further enhance transparency, traceability, and long-term maintainability.