

# Portfolio Optimization: Efficient Frontier, CAL, & Monte Carlo Simulation

A Quantitative Analysis of Risk–Return Tradeoff using Modern Portfolio Theory

# Objective

The objective of this project is to construct and analyze an optimal equity portfolio using Modern Portfolio Theory by:

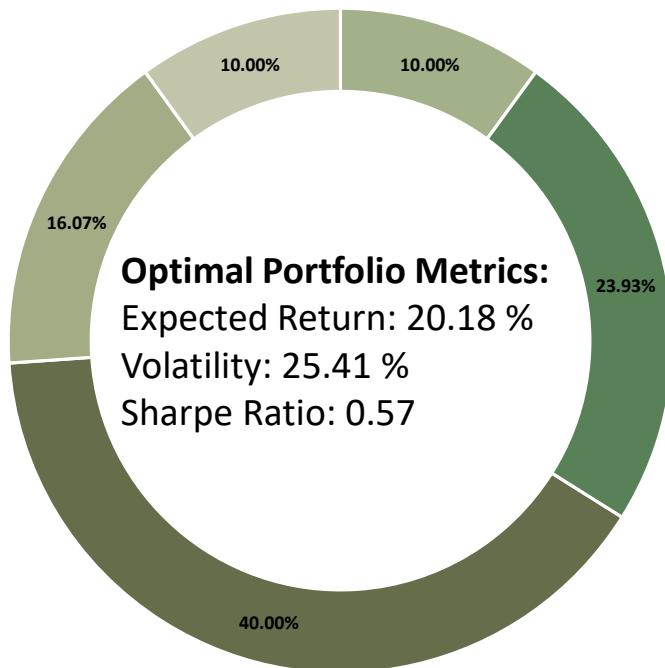
- Analyze five NSE-listed stocks using historical adjusted price data and compute annual returns & volatility.
- Construct an optimal portfolio under weight constraints (10%–40%) using mean-variance optimization.
- Develop the Efficient Frontier and Capital Allocation Line (CAL) to identify the optimal risky portfolio.
- Evaluate portfolio risk through Monte Carlo simulation and estimate 50-day Value at Risk (VaR).

The study aims to demonstrate how diversification and optimization techniques improve risk-adjusted returns.

## Data And Methodology

- Historical adjusted closing price data (2004–present) was extracted using Python (`yfinance` library).
- Logarithmic returns were computed to ensure time-additive and statistically stable return calculations.
- Annualized expected returns and standard deviations were derived from daily log returns.
- Portfolio optimization was performed under weight constraints (10%–40%) using mean-variance framework, followed by Efficient Frontier construction, CAL plotting, and Monte Carlo simulation for risk analysis.

# Portfolio Construction & Optimization



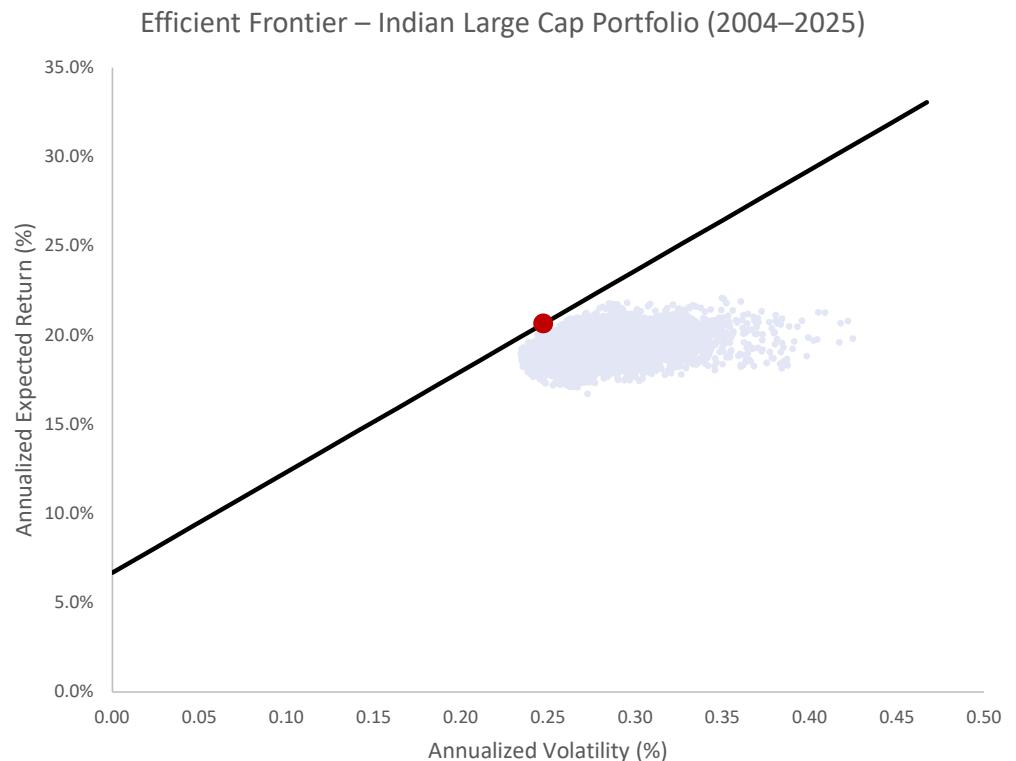
- Constructed a constrained five-asset portfolio (10%–40% allocation limits per security).
- Applied mean–variance optimization to identify the maximum Sharpe Ratio (optimal risky) portfolio.
- Derived optimal asset weights balancing expected return and portfolio volatility.
- Identified allocation concentration in HDFC Bank reflecting return-to-risk efficiency under constraints.

# Efficient Frontier & Capital Allocation Line (CAL)

- Generated multiple portfolio combinations to construct the Efficient Frontier (risk vs return space).
- Identified the maximum Sharpe Ratio portfolio (highlighted point).
- Plotted the Capital Allocation Line (CAL) from the risk-free rate to illustrate optimal risk-adjusted allocation.

**Optimal Portfolio Sharpe Ratio: 0.57**

Risk-Free Rate Assumed: 6.68 % as 10-year Government Security Yield (approx.)



# Monte Carlo Simulation (Scenario VaR)

- Generated 10,000 simulated portfolio return scenarios using historical log return distribution.
- Projected portfolio value over a 50-day horizon under simulated market conditions.
- Estimated 95% Value at Risk (VaR) from the lower tail of the simulated distribution.

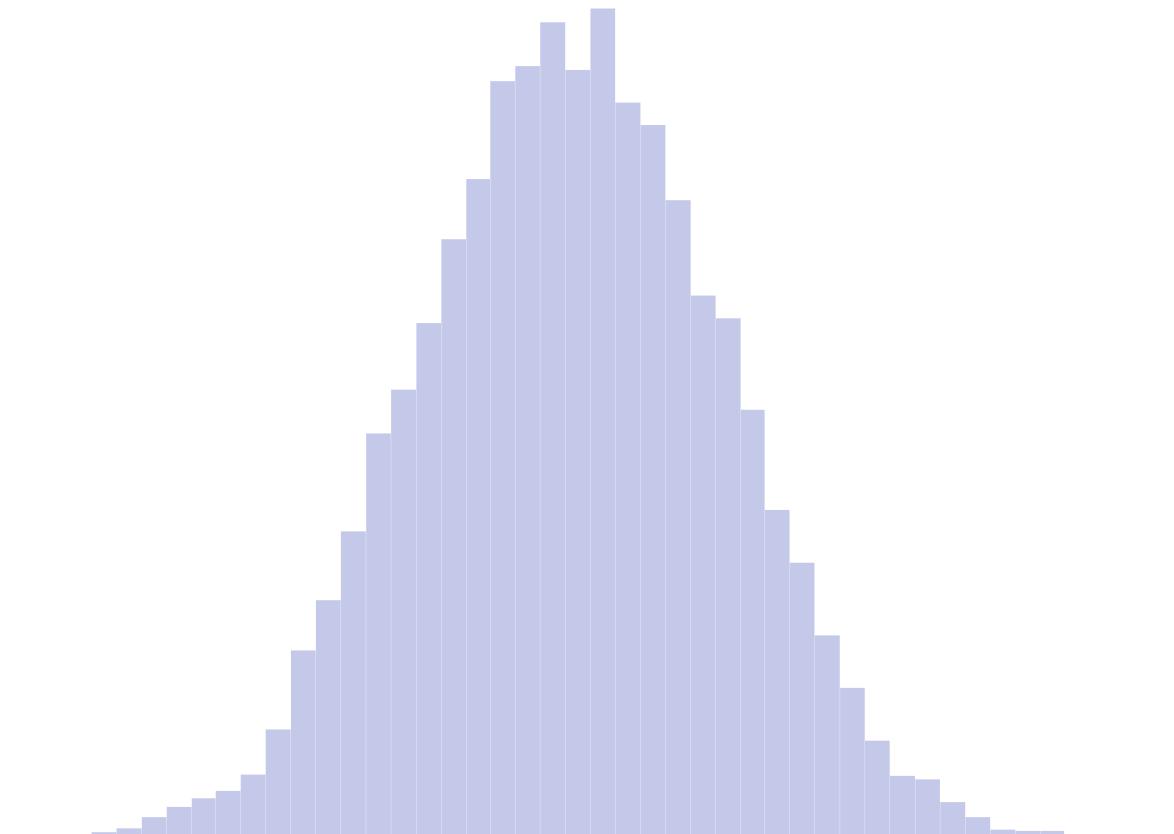
## **Simulation Summary:**

Initial Portfolio Value: ₹1,00,00,000

Horizon: 50 Days

Simulations: 10,000

Confidence Level: 95%



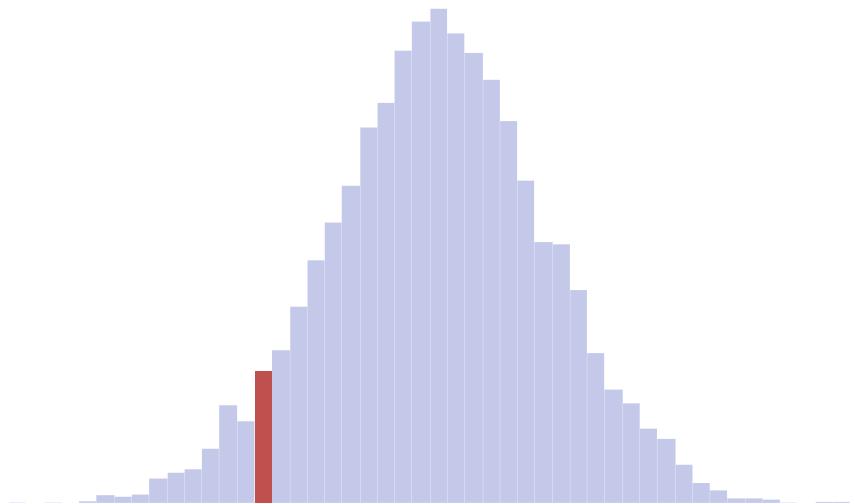
# Value at Risk (VaR) — 50 Day Horizon

## **Key Risk Metrics:**

Portfolio Value: ₹1,00,00,000  
Confidence Level: 95%  
Time Horizon: 50 Days

## **Estimated Downside Risk:**

Scenario VaR: ₹ 26,36,406  
Monte Carlo VaR: ₹ 36,80,601



At the 95% confidence level, the estimated 50-day downside risk is approximately ₹36.8 lakh based on 10,000 simulated scenarios.

# Conclusion & Key Takeaways

- A constrained mean–variance optimization (10%–40% bounds) resulted in an optimal portfolio with:
  - Expected Return: 20.18%
  - Volatility: 25.41%
  - Sharpe Ratio: 0.57
  - Risk-free rate assumed: 6.68% (10Y G-Sec)
- HDFC Bank reached the upper allocation bound (40%), indicating superior risk-adjusted return efficiency relative to other securities.
- Despite concentration tendencies, portfolio-level volatility remained lower than several individual stocks, demonstrating effective diversification benefits under constraint conditions.
- Monte Carlo simulation (10,000 scenarios, 50-day horizon) estimated a 95% Value at Risk of ₹37.38 lakh, meaning: There is a 5% probability that losses may exceed this amount under simulated market stress.
- The study demonstrates practical application of Modern Portfolio Theory under real-world constraints and highlights the importance of optimization, risk measurement, and scenario-based stress testing in equity portfolio construction.

# Technical Framework & Skills Demonstrated

## **Quantitative Methods**

- Mean–Variance Optimization
- Sharpe Ratio Maximization
- Efficient Frontier & Capital Allocation Line
- Parametric & Monte Carlo VaR

## **Tools & Implementation**

- Advanced Excel (Solver, Data Tables, Statistical Functions)
- Covariance Matrix Construction
- Scenario Simulation (10,000 iterations)
- Percentile-Based Risk Estimation

## **Core Competencies**

- Risk Modeling
- Portfolio Analytics
- Data-Driven Decision Making
- Financial Modeling