RISK FORECASTING USING MONTE CARLO SIMULATION FOR LONG-TERM MUTUAL FUND INVESTMENTS

1. Project Background

A mid-sized wealth advisory firm managing client portfolios worth over $200 million approached me with a recurring challenge: **Clients were unable to grasp the long-term uncertainty** in their mutual fund returns using static CAGR estimates and standard deviation figures. The firm needed a **more intuitive, visual, and data-backed way to demonstrate investment outcomes and risk exposure**—tailored for investors of varying risk appetites.

Their goal was to offer clients **personalized return distributions** and better confidence in how portfolios might behave under various market conditions—especially across 10–15 year timeframes.

2. Objectives

The objective of this project was to:

- Simulate multiple investment paths based on historical return behavior for a 15-year horizon
- Quantify probabilities of gain and loss, including best-case and worst-case scenarios
- Integrate **market volatility, interest rate shifts, inflation**, and rebalancing logic
- Produce **visually intuitive outputs** that financial advisors could use in meetings
- Reduce reliance on one-size-fits-all projections by making the model dynamic and scenario-based

3. Tools & Technologies Used

- **Language & Platform:** Python
- **Libraries:** NumPy, Pandas, Matplotlib, Seaborn, SciPy
- **Scenario Engine:** Monte Carlo random walk with log-normal return generation
- **Visualization:** Custom charts built with Matplotlib, along with formatted Excel summaries
- **Reporting:** PDF report generated with Jupyter Notebook and LaTeX exports

4. Data Sources

- **Mutual Fund NAVs:** 15 years of historical monthly data across 3 fund types (Equity, Hybrid, Debt)
- **Macroeconomic Inputs:** RBI repo rate trends, inflation index (CPI) history
- **Asset Allocation Strategy:**
    - Moderate profile: 50% Equity, 30% Debt, 20% Hybrid
    - Rebalanced yearly

5. Methodology and Workflow

a. Data Preprocessing

- Cleaned and interpolated missing NAVs
- Converted NAVs into monthly return series
- Calculated **mean, standard deviation, and correlation matrix** for each fund
- Adjusted historical volatility for **macro events** (COVID crash, 2013 taper tantrum)

b. Simulation Model Design

- Simulated 10,000 investment paths using **geometric Brownian motion (GBM)**
- Incorporated **annual portfolio rebalancing** logic to maintain target allocations
- Modeled **inflation adjustment** to project **real returns** instead of nominal only
- Applied **compound return logic** with rolling cumulative returns for each simulation

c. Sensitivity and Risk Metrics

- Computed **Value-at-Risk (VaR)** and **Conditional VaR (CVaR)** at multiple confidence levels
- Analyzed sensitivity to equity proportion: 40%, 50%, 60% exposure
- Measured downside deviation instead of just standard deviation
- Estimated **time-to-recovery** from market crashes in simulation paths

6. Deliverables

Component	Description
Python Simulation Script	Fully commented code with adjustable parameters for allocation, horizon, and rebalancing frequency
Risk Visualizations	- Distribution curves (PDF and CDF) - Box plots of cumulative returns - Heatmap of downside risks vs. equity exposure
Client-Facing Report	Professionally designed PDF with:

- 3-page executive summary
- Simulation charts
- Forecast tables
- Strategy-specific recommendations | | Excel Summary Tool | Easy-to-use Excel file with embedded simulation results for custom asset allocations | | Training Session | Conducted a 1-hour internal workshop for client advisors on how to interpret and present results |

7. Key Insights

- **95% of 15-year simulations showed positive returns**, validating SIP strategy
- **Median expected return (CAGR):** 8.4%
- **Downside risk:** Only 1.7% of simulations resulted in capital loss after 15 years
- **Optimal Allocation Adjustment:** Increasing hybrid exposure by 10% reduced drawdowns by 22% with only a 0.4% drop in median CAGR
- Provided **custom scenarios** for 3 client profiles: conservative, moderate, aggressive

8. Stakeholder Benefit

- Helped the firm convert **abstract return discussions into data-driven visual forecasts**
- Advisors reported improved **client retention and confidence**, especially among HNIs
- The model was later reused for **ULIP and NPS product comparisons**
- Reduced reliance on Excel templates, increasing operational efficiency

9. Client Testimonial

“This simulation model changed how we communicate investment risk. It’s the first time clients are understanding the difference between volatility and long-term uncertainty in a way that makes them stay invested.”