**Market Risk Analytics Project: Technical Design & Methodology Document**

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# 1. Introduction

This document provides a detailed technical overview of the Market Risk Analytics project, outlining the methodologies, algorithms, and assumptions employed in the calculation of various market risk metrics, scenario analysis, stress testing, and model backtesting. It is intended for technical stakeholders, including fellow quantitative analysts, model validators, and developers.

# 2. Project Architecture and Components

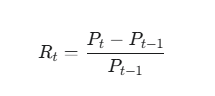
The project is structured as a Python script (market\_risk\_dashboard.py) that executes a sequential workflow:

1. **Configuration:** Defines key parameters such as data file paths, confidence levels, and simulation counts.
2. **Data Loading and Preparation:** Reads historical price data, calculates returns, and handles missing values.
3. **Portfolio Construction:** Defines portfolio weights and calculates aggregate portfolio returns.
4. **Market Risk Metrics Calculation:** Computes VaR and CVaR using Historical, Parametric, and Monte Carlo methods.
5. **VaR/CVaR Model Backtesting:** Evaluates the accuracy of the VaR and CVaR models against historical data.
6. **Scenario Analysis & Stress Testing:** Applies predefined stress scenarios to the current portfolio to assess potential losses.
7. **Regulatory Compliance Notes:** Provides conceptual insights into FRTB requirements and how the project's components relate.

# 3. Methodologies and Algorithms

## 3.1 Data Loading and Preparation

* **Input Data:** Historical daily closing prices for selected stocks (e.g., Cipla, TATACON, BEL) are loaded from an Excel file (Historical\_Portfolio.xlsx, sheet: portfolio). The 'Date' column is set as the DataFrame index.
* **Returns Calculation:** Daily percentage returns are calculated for each asset using the formula:

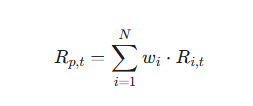


where Pt​ is the price at time t.

* **Missing Values:** The first row of returns (which will be NaN due to the pct\_change() operation) is dropped. Further NaN values, if any, are handled by dropping the corresponding rows, assuming sufficient historical data.

## 3.2 Portfolio Construction

* **Weights:** For simplicity, the project currently assumes an **equal weighting** scheme for all assets in the portfolio. If N is the number of assets, each asset has a weight of wi​=1/N.
* **Portfolio Returns:** Daily portfolio returns (Rp,t​) are calculated as the weighted sum of individual asset returns:



where Ri,t​ is the return of asset i at time t.

## 3.3 Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR) Calculation

The project calculates VaR and CVaR (Expected Shortfall) at a user-defined confidence level (e.g., 99%). Losses are represented as negative returns.

* **Confidence Level (**α**):** e.g., 0.99 for 99% VaR.
* **VaR Percentile:** The percentile corresponding to the VaR is 1−α (e.g., 0.01 for 99% VaR).

### 3.3.1 Historical VaR and CVaR

* **Methodology:** Non-parametric approach that directly uses the empirical distribution of historical portfolio returns.
* **VaR Calculation:** The Historical VaR is the (1−α)-th percentile of the sorted historical portfolio returns.



* **CVaR Calculation:** The Historical CVaR (Expected Shortfall) is the average of all historical portfolio returns that are worse than or equal to the Historical VaR.



### 3.3.2 Parametric (Delta-Normal) VaR and CVaR

* **Methodology:** Assumes portfolio returns are normally distributed.
* **Parameters:**
  + Mean Portfolio Return (μp​): portfolio\_returns.mean()
  + Standard Deviation of Portfolio Returns (σp​): portfolio\_returns.std()
* **VaR Calculation:**

​

where Z1−α​ is the (1−α)-th percentile (Z-score) of the standard normal distribution (e.g., norm.ppf(1-alpha) for a loss).

* **CVaR Calculation:**



where ϕ(Z1−α​) is the probability density function (PDF) of the standard normal distribution evaluated at Z1−α​.

### 3.3.3 Monte Carlo VaR and CVaR

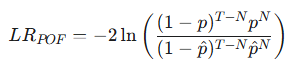
* **Methodology:** Simulates a large number of future portfolio returns based on statistical properties derived from historical data.
* **Simulation Process:** Future portfolio returns are simulated from a normal distribution with the historical μp​ and σp​ (i.e., np.random.normal(loc=mu\_p, scale=sigma\_p, size=num\_simulations)).
* **VaR Calculation:** The Monte Carlo VaR is the (1−α)-th percentile of the simulated portfolio returns.
* **CVaR Calculation:** The Monte Carlo CVaR is the average of all simulated portfolio returns that are worse than or equal to the Monte Carlo VaR.

# 4. VaR and CVaR Model Backtesting

Backtesting assesses the accuracy of the risk models by comparing forecasted risk measures with actual realized losses over a period.

## 4.1 VaR Backtesting: Kupiec's Proportion of Failures (POF) Test

* **Purpose:** To test if the observed frequency of VaR exceptions (losses exceeding VaR) is consistent with the expected frequency.
* **Hypotheses:**
  + H0​: The model is accurate, i.e., the observed proportion of exceptions equals the expected proportion (p=1−α).
  + H1​: The model is inaccurate, i.e., p=1−α.
* **Test Statistic (**LRPOF​**):**



Where:

* + T: Total number of observations (daily returns).
  + N: Observed number of exceptions (times actual loss was worse than VaR).
  + p: Expected probability of an exception (1−α).
  + p^​: Observed proportion of exceptions (N/T).
* **Decision Rule:** LRPOF​ follows a χ2 distribution with 1 degree of freedom. If LRPOF​ exceeds the critical value (e.g., 3.841 for a 95% confidence level), we reject H0​, indicating the model is inaccurate.
* **Implementation Note:** For simplicity, the historical\_var calculated over the entire dataset is used for backtesting against the same dataset. In a real-world scenario, a rolling window approach would be used, where VaR is re-estimated daily/periodically based on past data.

## 4.2 CVaR Backtesting: Average Exceedance Test

* **Purpose:** To assess if the average magnitude of losses on VaR breach days is consistent with the predicted CVaR.
* **Methodology:**
  1. Identify all instances where the actual portfolio return was worse than the calculated VaR (VaR violations).
  2. Calculate the average of these actual losses during the VaR violation days.
  3. Compare this "Average Actual Loss on VaR Violation Days" to the predicted CVaR value.
* **Interpretation:**
  1. If the average actual loss is significantly worse (more negative) than the predicted CVaR, the model might be underestimating tail risk.
  2. If the average actual loss is significantly better (less negative) than the predicted CVaR, the model might be overestimating tail risk.
* **Limitations:** This is a qualitative comparison. More advanced statistical tests for CVaR backtesting (e.g., those based on tick losses or conditional coverage) exist but are beyond the scope of this project's basic implementation.

# 5. Scenario Analysis and Stress Testing

* **Purpose:** To assess potential portfolio losses under extreme, predefined hypothetical market conditions that may not be captured by historical data or statistical models alone.
* **Methodology:**
  1. Obtain the most recent (last) closing prices of the portfolio assets.
  2. Assume an initial total portfolio value and derive the number of shares held for each asset (assuming equal initial investment per asset).
  3. Define a set of stress scenarios, each specifying a percentage shock for individual assets (e.g., -15% market downturn, -25% sector-specific shock, historical crisis scenarios).
  4. Apply these shocks to the current prices to derive "stressed prices."
  5. Recalculate the total portfolio value using the stressed prices and the shares held.
  6. Compute the absolute loss and percentage loss from the current portfolio value to the stressed portfolio value.
* **Scenarios Implemented:** Includes general market downturns, sector-specific shocks, and approximate historical crisis scenarios (2008 GFC, COVID-19 decline).

# 6. Assumptions and Limitations

* **Data Quality:** Assumes clean, accurate, and sufficient historical price data.
* **Returns Distribution:** Parametric and Monte Carlo VaR/CVaR currently assume normally distributed returns. This is a simplification; actual financial returns exhibit fat tails and skewness.
* **Static Portfolio:** Assumes a fixed portfolio composition (shares held) and weights during the analysis period.
* **VaR/CVaR Horizon:** Calculations are typically for a 1-day horizon based on daily returns.
* **Backtesting Window:** Simplified backtesting uses the full historical data, not a rolling window, which is standard in practice.
* **FRTB Simplification:** The FRTB integration is conceptual. Full FRTB capital charge calculation requires highly detailed risk factor mapping, non-modellable risk factor treatment, and specific P&L attribution tests not implemented here.
* **No Derivatives/Complex Products:** The project focuses solely on equity spot positions. Integrating derivatives would require specific pricing models and sensitivity (Greeks) calculations.
* **Correlation:** Assumes historical correlations are stable for parametric/MC. Stress testing implies specific correlation changes but doesn't model dynamic correlation.

# 7. Technical Details

* **Programming Language:** Python 3.x
* **Key Libraries:**
  + pandas: For data manipulation and time-series operations.
  + numpy: For numerical computations, array operations, and statistical functions.
  + scipy.stats: For statistical distributions (e.g., norm for normal distribution percentiles/PDF, chi2 for chi-squared distribution for Kupiec's test).
  + openpyxl: (Implicitly used by pandas) for reading .xlsx files.

# 8. Future Enhancements

* **Interactive Visualizations:** Incorporate matplotlib, seaborn, or plotly for graphical representation of results.
* **Custom Portfolio Weighting:** Allow user input for portfolio weights.
* **Advanced Backtesting:** Implement Christoffersen's conditional coverage test and more formal CVaR backtests.
* **Alternative Risk Measures:** Explore other measures like Expected Shortfall (ES) at different confidence levels or extreme value theory (EVT).
* **Inclusion of Derivatives:** Implement basic pricing models for options/futures and integrate their sensitivities.
* **Dynamic Rolling Window:** Implement rolling window for VaR/CVaR calculations for more realistic backtesting and current risk assessment.
* **Factor-Based Risk Models:** Develop models that link portfolio returns to macroeconomic or market-specific factors.
* **Database Integration:** Replace Excel input with database connectivity.

This document should provide a solid technical foundation for discussing your project's inner workings during your interview.