

# Advanced Portfolio Optimization using Historical Data

**A COMPARATIVE ANALYSIS OF  
EQUAL VS. OPTIMIZED  
PORTFOLIO STRATEGIES IN  
THE PAKISTANI MARKET**

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## 1. Introduction

In the dynamic world of finance, investors constantly seek strategies to balance return and risk. Portfolio optimization, a key principle of Modern Portfolio Theory (MPT), enables investors to construct portfolios that maximize expected return for a given level of risk or minimize risk for a desired return. This project explores advanced portfolio optimization techniques using real historical data from Pakistani publicly listed stocks and gold, simulating real-world asset management decisions.

The objective of this project is to create a diversified portfolio using five stocks from different sectors of the Pakistan Stock Exchange (PSX) along with gold as a non-equity asset, compute relevant risk-return metrics, and optimize the portfolio using Excel tools. Emphasis is placed on key performance indicators like return, volatility, Sharpe Ratio, and maximum drawdown, as well as visual tools such as efficient frontier plots, pie charts, and correlation heatmaps to aid interpretation.

## 2. Methodology & Assumptions

### 2.1. Asset Selection & Data Collection

- Five stocks were selected from diverse sectors: Automobiles (**Indus Motor Co. Ltd. [INDUS]** ), Clothing (**Kohinoor Textile Mills Ltd. [KTML]** ), Containers/Packaging (**Packages Ltd. [PKGS]** ), Food Products (**Nestle Pakistan Ltd. [NESTLE]** ), and Beverages/Drinks (**Murree Brewery Co. Ltd. [MUREB]** ), along with Gold (PKR denominated) for diversification.

### • Table: Portfolio Securities Overview

Security	Sector/Type	Description
<b>INDUS</b>	Automobiles	Indus Motor Company Ltd. – Leading assembler and manufacturer of Toyota vehicles in Pakistan.
<b>KTML</b>	Clothing & Textiles	Kohinoor Textile Mills Ltd. – Major player in Pakistan’s textile and garment sector.
<b>PKGS</b>	Containers & Packaging	Packages Ltd. – Diversified company involved in packaging and consumer products.
<b>NESTLE</b>	Food Products	Nestlé Pakistan Ltd. – Subsidiary of Nestlé Global, a key player in food and nutrition.
<b>MUREB</b>	Beverages & Alcohol	Murree Brewery Co. Ltd. – One of Pakistan’s oldest and most recognized beverage companies.
<b>Gold (PKR)</b>	Commodity / Safe Haven Asset	Gold prices in PKR – included to diversify and hedge equity risk.

- Daily adjusted closing prices from the last five years (**01/Jan/2020 – 01/April/2025**) were collected via WSJ and manually cleaned in Excel, where we filled in missing values using 2 day average (above 2 days and below 2 days of the price).

## 2.2. Data Preparation and Return Calculation

- Daily returns for each security were computed using the formula:  

$$=(\text{Today's Price} - \text{Yesterday's Price}) / \text{Yesterday's Price}$$
- Annualized average returns and standard deviations were then calculated for each security using daily statistics:
  - $\text{Annual Return} = \text{Average Daily Return} \times 252$
  - $\text{Annual Std Dev} = \text{Daily Std Dev} \times \sqrt{252}$

## 2.3. Risk Metrics and Matrices

- Covariance and correlation matrices were constructed using Excel's built-in functions (COVARIANCE.P, CORREL) to assess asset relationships.
- A correlation heatmap was created using conditional formatting for visual interpretation.

## 2.4. Portfolio Performance (Equal Weights)

- An equally weighted portfolio was constructed as a baseline.
- Portfolio return was calculated using:
  - $=\text{SUMPRODUCT}(\text{Weights}, \text{Annual Returns})$
- Portfolio variance and volatility were calculated using:
  - $\text{Portfolio Variance} = \text{MMULT}(\text{MMULT}(\text{TRANSPOSE}(\text{Weights}), \text{Covariance Matrix}), \text{Weights} * 252)$
  - $\text{Portfolio Volatility} = \text{SQRT}(\text{Portfolio Variance})$

## 2.5. Portfolio Optimization Using Solver

- Excel Solver was used to maximize the Sharpe Ratio, defined as:  

$$(\text{Portfolio Return} - \text{Risk-Free Rate}) / \text{Portfolio Std Dev}$$
- Constraints included:
  - Total weights sum to 1
  - No short-selling (all weights  $\geq 0$ )
  - Weights had a minimum weight of 5% (You can't invest less than 5% on a stock/asset)

- Weights had a maximum weight of 25% (You can't invest more than 25% on a stock/asset)
- Risk-free rate assumed: **12.45%**, based on current government bond yield on [tradingeconomics.com/pakistan](http://tradingeconomics.com/pakistan)

## 2.6. Monte Carlo Simulation & Efficient Frontier

- 1000+ random portfolios were simulated using normally distributed returns (=NORM.INV(RAND(), Mean, Std Dev)).
- A scatterplot of portfolio returns vs. volatility was generated to visualize the efficient frontier.
- The optimized portfolio (highest Sharpe) was highlighted as a red dot on the graph.

## 2.7. Performance Evaluation

- Portfolio metrics such as Sharpe Ratio and Maximum Drawdown were calculated for both equal-weight and optimized portfolios.
- A dynamic drawdown analysis was implemented to interpret portfolio downside behavior.

## 2.8. Visualization Tools

- Pie charts compared asset allocation before and after optimization.
- Bar charts displayed individual asset returns and risks.
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## 2.9. Assumptions Made

- No transaction costs or taxes are considered.
- Market conditions are stable except for scenario simulations.
- Risk-free rate remains constant for Sharpe Ratio calculation.
- No short-selling is allowed (all weights are positive)

### 3. Performance Summary & Interpretations

#### 3.1. Individual Security/Asset Stats

<i>Security</i>	<i>Annual Return (%)</i>	<i>Annual Volatility (%)</i>
<b>KTML</b>	37.91	44.77
<b>Gold (PKR)</b>	28.12	23.24
<b>INDUS</b>	14.28	26.06
<b>PKGS</b>	11.43	32.92
<b>MUREB</b>	6.47	30.84
<b>NESTLE</b>	1.40	26.64

#### Key Insights:

- **Highest Return:**  
**KTML (Kohinoor Textile Mills)** has the highest annual return at **37.91%**, reflecting strong growth in the textile sector.
- **Best Risk-Adjusted Return:**  
**Gold (PKR)** provides a solid balance of high return (**28.12%**) with the **lowest volatility (23.24%)**, making it the most efficient asset in risk-adjusted terms.
- **Most Volatile Asset:**  
**KTML** is also the most volatile asset, with an annual standard deviation of **44.77%**, indicating significant price fluctuations despite high returns.
- **Most Stable Asset:**  
**Gold (PKR)** again stands out as the most stable investment, showing the **lowest annual volatility of 23.24%** while still offering attractive returns.
- **Lowest Return:**  
**Nestlé Pakistan** yielded the **lowest annual return at 1.40%**, highlighting its conservative growth despite moderate risk.
- **Moderate Performers:**  
**INDUS** and **PKGS** delivered decent returns of **14.28%** and **11.43%** respectively, with moderate volatilities of **26.06%** and **32.92%**, making them suitable for medium-risk portfolios.

### 3.2. Portfolio Optimization Results

#### Comparison between Portfolios

<i>Portfolio Metric</i>	<b>Equal-Weighted</b>	<b>Optimized</b>
<i>Portfolio Return (%)</i>	16.60	23.85
<i>Portfolio Risk (Volatility %)</i>	15.36	20.00
<i>Sharpe Ratio</i>	0.2703	0.57

#### Key Insights:

- **Higher Return, Higher Efficiency:** The optimized portfolio achieves **44% more return** than the equal-weighted portfolio.
- **Better Risk-Reward Trade-off:** Despite slightly higher volatility, the optimized portfolio delivers a **Sharpe Ratio over 2x higher**, meaning it compensates much better for each unit of risk.
- **Equal-Weighted as a Benchmark:** The equal-weighted approach serves as a good baseline but is clearly outperformed in both return and efficiency after optimization.
- **Optimization Success:** This result validates that using Solver for portfolio optimization leads to a significantly **more efficient asset allocation**, making the portfolio more suitable for investors aiming to maximize returns relative to risk.

### 3.3. Optimal Asset Allocation

<i>Securities</i>	<b>Weight</b>
<i>INDUS</i>	25.00%
<i>KTML</i>	25.00%
<i>MUREB</i>	18.51%
<i>NESTLE</i>	5.00%
<i>PKGS</i>	21.90%
<i>GOLD_PKR</i>	25.00%

### 3.4. Diversification Benefit Analysis

<i>Risk Metric</i>	<b>Value (%)</b>
<i>Average Volatility of Individual Securities</i>	30.75
<i>Optimized Portfolio Volatility</i>	20.00
<i>Diversification Benefit</i>	10.75

**Key Insights:**

**Diversification Benefit** quantifies the extent to which overall portfolio risk is reduced compared to holding the individual securities in isolation.

In this case, while the **average annual volatility** of individual assets is **30.75%**, the **optimized portfolio volatility** is only **20.00%**.

This **10.75% reduction in risk** is achieved through diversification — by combining assets that are not perfectly correlated, the overall risk of the portfolio decreases without necessarily sacrificing return.

This result supports **Modern Portfolio Theory (MPT)**, which states that an optimally diversified portfolio can achieve **higher risk-adjusted** returns by smoothing out unsystematic (asset-specific) risk.

### 3.5. Drawdown Analysis

The drawdown analysis models the portfolio’s performance over a 50-year horizon with consistent annual contributions of PKR 10,000, focusing on the potential magnitude of losses during adverse market periods. It is a critical risk assessment tool that extends beyond traditional volatility measures.

***Maximum Drawdown Results***

<b><i>Metric</i></b>	<b><i>Value</i></b>
<b><i>Maximum Drawdown</i></b>	<b>-30.5%</b>
<b><i>Annual Contribution</i></b>	<b>PKR 10,000</b>
<b><i>Simulation Period</i></b>	<b>50 years</b>

**Key Insights:**

A **maximum drawdown of 30.5%** indicates that the portfolio may experience notable declines during periods of market stress, although the extent of loss is moderate compared to more aggressive portfolios.

Key interpretations include:

1. **Moderate Risk Exposure:** While not extreme, a 30.5% drawdown still reflects a significant temporary loss potential, highlighting the need for careful risk consideration.
2. **Long-Term Commitment Required:** The portfolio is most appropriate for investors with a long investment horizon (10+ years), who can tolerate short- to medium-term drawdowns.
3. **Investor Suitability:** This level of drawdown may be acceptable for moderately aggressive investors seeking long-term returns but may be too volatile for highly risk-averse individuals.
4. **Recovery Expectations:** Investors should be prepared for potentially extended recovery periods before regaining peak portfolio value following drawdowns.



This analysis enhances traditional risk metrics by quantifying downside potential in real-world terms, offering a more holistic view of portfolio behavior under adverse conditions.

### 3.6. Scenario Analysis

The scenario analysis explores how the portfolio might perform under distinct economic conditions. By simulating specific market events, this approach provides insight into the portfolio’s potential resilience, vulnerabilities, and behavior across different environments.

*Scenario Outcomes*

<i>Scenario</i>	<i>Impact</i>	<i>Portfolio Value (PKR)</i>	<i>Description</i>
<i>Tech Boom</i>	<b>+20%</b>	15671.18	<b>Strong performance driven by rapid growth in the tech sector and innovation.</b>
<i>Normal Market</i>	<b>0%</b>	13059.31	<b>Market remained stable with balanced growth and no major economic surprises.</b>
<i>Interest Rate Hike</i>	<b>-20%</b>	10882.76	<b>Markets declined due to aggressive monetary tightening and economic slowdown.</b>

*Key Insights*

- Positive Tech Exposure:** The portfolio shows strong upside potential in innovation-driven markets, benefiting significantly during tech sector expansions.
- Macroeconomic Sensitivity:** A 20% drop in the interest rate hike scenario highlights the portfolio’s susceptibility to macroeconomic shocks, particularly rising rates and tightening financial conditions.
- Stability in Neutral Conditions:** The relatively stable value under normal market conditions suggests the portfolio maintains a balanced profile in the absence of strong external forces.
- Real-World Relevance:** This analysis translates abstract financial metrics into real-world performance expectations, helping investors better prepare for diverse economic climates.

These scenario simulations are a valuable planning tool, allowing for better anticipation of potential risks and opportunities, and guiding informed investment decisions amid changing economic landscapes.

### 4. Recommendations for Different Investor Profiles

Different investors have varying risk tolerances and investment goals. Based on the optimized portfolio's risk-return characteristics, here's how it aligns with distinct investor profiles:

#### 4.1 Risk-Averse Investors (Conservative)

- **Characteristics:** Prioritize capital preservation over high returns; uncomfortable with large fluctuations.
- **Recommendation:**
  - Consider increasing allocation to low-volatility assets like Gold (PKR) and NESTLE, which showed lower historical volatility.
  - Reduce exposure to high-risk, high-return assets like KTML.
  - Alternatively, adopt a hybrid strategy using a mix of the optimized portfolio and a fixed-income component.
  - May prefer the equal-weighted portfolio for a more balanced, less concentrated approach.

#### 4.2 Moderately Aggressive Investors

- **Characteristics:** Willing to accept some volatility for higher long-term returns.
- **Recommendation:**
  - The optimized portfolio is well-suited for this group, offering a strong Sharpe Ratio (0.57) and diversified sector exposure.
  - Portfolio drawdown of -30.5% is acceptable for investors with a 7–10+ year investment horizon.
  - Sector allocation spreads risk across cyclical and defensive sectors, maintaining a good risk-return tradeoff.

#### 4.3 Aggressive Investors (Growth-Oriented)

- **Characteristics:** High risk tolerance, seek substantial long-term gains, willing to withstand volatility and drawdowns.
- **Recommendation:**

- Increase allocation to high-growth stocks like KTML, INDUS, and PKGS to further capitalize on sectoral momentum.
- May consider loosening optimization constraints (e.g., increase maximum weight from 25% to 30%) for higher conviction plays.
- Could supplement the portfolio with small-cap or emerging tech stocks to chase alpha.

## **5. Conclusion**

This project successfully demonstrates the application of Modern Portfolio Theory using historical data from PSX-listed equities and gold, delivering a structured approach to building and optimizing a diversified investment portfolio.

### **Key Outcomes:**

- The optimized portfolio outperforms the equal-weighted baseline in both return (23.85% vs. 16.60%) and risk-adjusted terms (Sharpe Ratio of 0.57 vs. 0.27).
- Optimization with Solver and real constraints (min/max weights, no short selling) delivers a realistic, implementable strategy for Pakistani investors.
- The portfolio benefits from diversification, reducing average risk by 10.75% compared to holding individual assets.
- Scenario and drawdown analysis provide crucial insights into the portfolio's behavior in both normal and adverse market conditions.
- Tailored recommendations allow investors to align their strategy with individual risk appetites and investment horizons.