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Evaluating Markowitz Portfolio Performance, CvaR, and Monte Carlo Simulation: Evidence from MSCI Indonesia

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ABSTRACT

This research analyzes the formation of an optimal portfolio, evaluates potential extreme risks, and measures the performance of stocks listed on the Morgan Stanley Capital International Indonesia index during the 2024-2026 period. The study addresses four primary objectives using the Markowitz model to establish optimal asset allocations. The methodology utilizes computational solver constraints to generate an efficient frontier without short selling, incorporating annualized daily expected returns and the Indonesia Government Yield Curve as the risk-free proxy. Extreme risk is assessed via the Conditional Value at Risk approach to capture maximum loss potential, followed by Monte Carlo simulation to project future investment outcomes under various market scenarios. Furthermore, portfolio performance is comprehensively evaluated using the Sharpe, Treynor, and Jensen Alpha ratios. The findings indicate the optimization process successfully identifies an asset combination maximizing expected returns relative to acceptable risk. Performance measurements and simulations reveal how the optimally constructed portfolio compares against market benchmarks in Indonesia, providing investors with a quantitative framework for mitigating equity investment risks.
Keywords*: Markowitz Model; Portfolio Performance; Tail Risk;Conditional Value at Risk; Optimal Portfolio.*

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INTRODUCTION

Portfolio investment has become one of the most widely used strategies for achieving financial returns while managing investment risk. However, investors face considerable challenges in selecting securities that can provide optimal returns without exposing portfolios to excessive risk. Since stock prices fluctuate due to macroeconomic conditions, market sentiment, and firm specific factors, investment decisions require a systematic approach to portfolio construction rather than relying solely on individual stock selection (Bodie et al., 2014; Keown et al., 2016).

One of the most established approaches to portfolio optimization is the Markowitz mean- variance model, which emphasizes diversification to achieve the most efficient balance between expected return and risk (Markowitz, 1952). According to Modern Portfolio Theory, portfolio risk depends not only on the characteristics of individual assets but also on the correlation among asset returns. By combining assets with imperfect correlations, investors can reduce overall portfolio risk without necessarily sacrificing expected returns. Consequently, the Markowitz model remains one of the most widely applied methods in portfolio optimization and continues to serve as a benchmark for investment research and practice (Feng, 2022; Muthohiroh et al., 2021). In Indonesia, the MSCI Indonesia Index has become an important benchmark for institutional and global investors because its constituents are selected based on market capitalization, liquidity, free-float adjustment, and investability criteria established by MSCI (MSCI, 2024).

Stocks included in the index generally represent companies with relatively strong market fundamentals and high trading activity, making them attractive candidates for portfolio construction. Furthermore, changes in the index composition through periodic rebalancing often influence capital flows and stock prices, particularly in emerging markets where international investors closely follow MSCI benchmarks (Escobar et al., 2021; Widyatmoko & Setiawan, 2023). The market volatility following the MSCI Indonesia rebalancing in early 2026 further highlighted the importance of constructing resilient portfolios capable of withstanding market uncertainty (Hunter, 2026).

Previous studies have demonstrated the effectiveness of the Markowitz model in constructing optimal portfolios. Feng (2022) reported that the model successfully improved portfolio efficiency by balancing expected return and risk. Similarly, Muthohiroh et al. (2021) applied the Markowitz approach to optimize Islamic stock portfolios using Expected Shortfall as an additional risk measure, while Nadia et al. (2026) confirmed the applicability of the model in the Indonesian stock market. In addition, Wu (2025) compared the Markowitz model with the Single Index Model under environmental, social, and governance (ESG) constraints and found that both models remain relevant under different investment objectives. These studies primarily focused on portfolio optimization and asset allocation.

Although previous studies have extensively examined portfolio optimization, relatively limited attention has given to evaluating the performance and tail risk of portfolios constructed using the Markowitz model, particularly for stocks included in the MSCI Indonesia Index. Most studies emphasize portfolio formation and the trade-off between expected return and variance, whereas the assessment of extreme downside risk receives less attention. Since variance measures overall return dispersion rather than the magnitude of losses under extreme market conditions, additional risk measures are needed to provide a more comprehensive evaluation of portfolio quality. Conditional Value at Risk (CVaR) estimates the average loss beyond the Value at Risk threshold and is therefore considered more informative for measuring tail risk (Rockafellar & Uryasev, 1999; Mozumder et al., 2024). Furthermore, Monte Carlo simulation enables future portfolio values to be projected under numerous possible market scenarios, allowing investors to evaluate portfolio resilience against adverse market movements (Indarwati & Kusumawati, 2021; Fabianová et al., 2023).

Based on these considerations, the urgency of this study is to offer practical insights for investors seeking resilient investment strategies amidst the highly volatile Indonesian capital market. This study evaluates the performance, tail risk, and projected outcomes of a portfolio constructed using the Markowitz mean-variance model based on constituents of the MSCI Indonesia Index during the period of April 2024 to May 2026. The novelty of this research, which distinguishes it from previous studies, lies in the integration of optimal portfolio construction with comprehensive performance evaluation measured using the Sharpe, Treynor, and Jensen's Alpha ratios tail-risk analysis utilizing Conditional Value at Risk (CVaR) at the 99% confidence level, and future projection using Monte Carlo simulation.

Based on the research objectives, this study addresses four primary research questions formulated as follows: (1) how is the optimal portfolio constructed using the Markowitz mean-variance model based on the MSCI Indonesia Index constituents during the 2024-2026 period, (2) what is the level of tail risk of the optimal portfolio as evaluated using Conditional Value at Risk (CVaR), (3) how does the optimal portfolio perform in terms of risk-adjusted performance when comprehensively evaluated against a risk-free benchmark using the Sharpe, Treynor, and Jensen's Alpha ratios, and (4) what are the projected investment outcomes of the optimal portfolio based on Monte Carlo simulation.

THEORETICAL BACKGROUND

Modern Portfolio Theory and Markowitz Model

Modern Portfolio Theory (MPT), introduced by Markowitz (1952), provides the theoretical foundation for portfolio optimization by emphasizing the trade-off between expected return and investment risk. Unlike traditional investment approaches that evaluate securities individually, MPT considers the relationship among asset returns and demonstrates that portfolio risk depends on the covariance between assets. By combining assets with imperfect correlations, investors can reduce unsystematic risk through diversification while maintaining expected returns (Markowitz, 1952; Bodie et al., 2014). The Markowitz mean- variance model identifies an optimal portfolio by allocating assets that maximize expected return for a given level of risk or minimize risk for a target return. Consequently, the model has remained one of the most widely applied portfolio optimization techniques in both academic research and investment practice (Feng, 2022; Muthohiroh et al., 2021).

Portfolio Performance

Evaluating an optimal portfolio requires not only considering expected returns but also assessing whether the returns adequately compensate investors for the risks undertaken. The Sharpe Ratio is one of the most widely used measures of risk-adjusted performance because it compares excess portfolio return with total portfolio risk measured by standard deviation (Sharpe, 1963). A higher Sharpe Ratio indicates more efficient portfolio performance and enables comparison among alternative investment strategies (Mumtazah & Permadhy, 2022).

Tail Risk Assessment

Although portfolio variance reflects the overall variability of returns, it does not adequately measure potential losses during extreme market conditions. Therefore, evaluating tail risk has become increasingly important in portfolio management. Conditional Value at Risk (CVaR) estimates the expected loss beyond the Value at Risk threshold and provides a more comprehensive assessment of downside risk than variance alone (Rockafellar & Uryasev, 1999).

To complement this analysis, Monte Carlo simulation projects future portfolio values under numerous possible market scenarios, enabling investors to estimate the probability and magnitude of extreme losses that may occur in the future (Indarwati & Kusumawati, 2021; Fabianová et al., 2023). Based on these theoretical perspectives, this study evaluates the performance of the optimal portfolio constructed using the Markowitz model through the Sharpe Ratio and assesses its tail risk using CVaR and Monte Carlo simulation. The combination of these approaches provides a more comprehensive evaluation of portfolio quality by considering both risk-adjusted performance and exposure to extreme losses.

RESEARCH METHOD

The observation period from April 2024 to May 2026 was selected because it captures several MSCI index rebalancing cycles (February, May, August, and November), which are often associated with portfolio reallocation by institutional investors, changes in capital flows, and increased market volatility. Furthermore, the period includes the market turbulence surrounding the MSCI Indonesia rebalancing in early 2026, providing a relevant setting for evaluating both portfolio performance and tail risk. The data utilized are secondary, consisting of daily historical stock prices, market index data, and the Indonesia Government Yield Curve (IGYSC) as the proxy for the risk-free asset.

The MSCI Indonesia Index was selected because it represents large and mid-cap companies that satisfy MSCI's investability criteria, including market capitalization, liquidity, and free-float requirements (MSCI, 2024). The study utilized secondary data consisting of daily closing stock prices obtained from Yahoo Finance. Information regarding the MSCI Indonesia Index constituents was collected from MSCI, while the risk-free rate was based on the Indonesia Government Securities Yield Curve (IGYSC) with a 10-year maturity. The sample consisted of companies that consistently remained constituents of the MSCI Indonesia Index throughout the observation period. Subsequently, a screening process was conducted by selecting stocks with positive expected returns before portfolio optimization.

The data analysis technique began with calculating the annualized expected return of individual assets by multiplying the daily mean return by 252 active trading days. Subsequently, the optimal portfolio was constructed using the Markowitz mean-variance model facilitated by Microsoft Excel Solver. To accurately generate the efficient frontier, two primary constraints were applied within the solver: a full-investment constraint where the total weight of the portfolio must equal one hundred percent, and a no-short-selling constraint meaning no asset weight could be negative. The expected portfolio return was calculated as:

$$E(R_p) = \sum_{i=1}^{n} \omega_i E(R_i)$$

Source: Markowitz, 1952

where w_i denotes the weight of asset i, while $E(R_i)$represents the expected return of asset i. Portfolio risk was measured using portfolio standard deviation derived from the variance-covariance matrix. The resulting optimal portfolio was subsequently evaluated using the Sharpe Ratio to measure risk-adjusted performance:

$$Sharpe = \frac{R_p - R_f}{\sigma_p}$$

Source: Sharpe, 1963

where R_p is the portfolio return, R_f is the risk-free rate, and σ_p is the portfolio standard deviation. Tail risk was assessed using Conditional Value at Risk (CVaR) at the 99% confidence level, which estimates the expected loss beyond the Value at Risk threshold:

$$CVaR_\alpha = E(X \mid X \leq VaR_\alpha)$$

Source: Rockafellar & Uryasev, 1999

Finally, Monte Carlo simulation was employed to project future portfolio values under numerous possible market scenarios based on the historical return distribution of the optimal portfolio. The simulation results were analysed using the 1st percentile of the simulated portfolio value distribution to evaluate potential extreme losses. The overall analytical framework therefore consisted of portfolio construction using the Markowitz model, performance evaluation using the Sharpe Ratio, and tail-risk assessment using CVaR and Monte Carlo simulation.

RESULT AND DISCUSSION

RESULT

Portfolio Construction Using the Markowitz Model

Table 1 presents the descriptive statistics of the 10 (ten) MSCI Indonesia Constituent stocks included in this study. The expected returns and standard deviation varied across the sample, reflecting differences in return potential and risk.

Table 1. Descriptive Statistics of MSCI Indonesia Stocks

Stock	Annualized Expected Return	Standard Deviation
TLKM	3,15%	36,60%
ASII	12,37%	34,51%
UNTR	11,02%	35,09%
BRPT	90,28%	74,69%
BBCA	-18,90%	27,53%
BBRI	-16,85%	33,29%
BMRI	-17,84%	35,31%
BBNI	-9,22%	35,39%
GOTO	-0,31%	48,79%
CPIN	-3,06%	34,63%

Source: Data by the Author, 2026

Figure 1 illustrates the distribution of the sample stocks based on their expected returns and standard deviations. Four stocks, namely TLKM, ASII, UNTR, and BRPT, generated positive expected returns and were therefore selected for portfolio optimization.

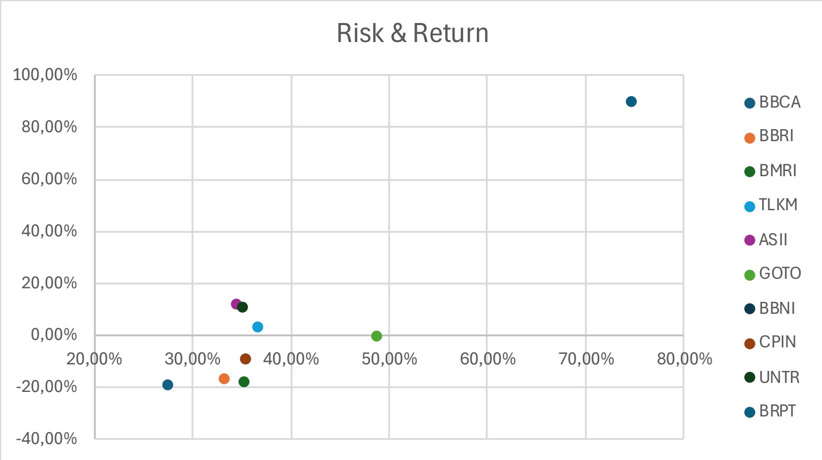

Figure 1. Risk-Return Distribution of Sample Stocks
Source: Data by the Author, 2026

Figure 2 presents the efficient frontier generated using the Markowitz mean-variance model. The optimization produced several efficient portfolios with different combinations of expected return and risk. The portfolio with a target return of 14,00% was selected for further evaluation.

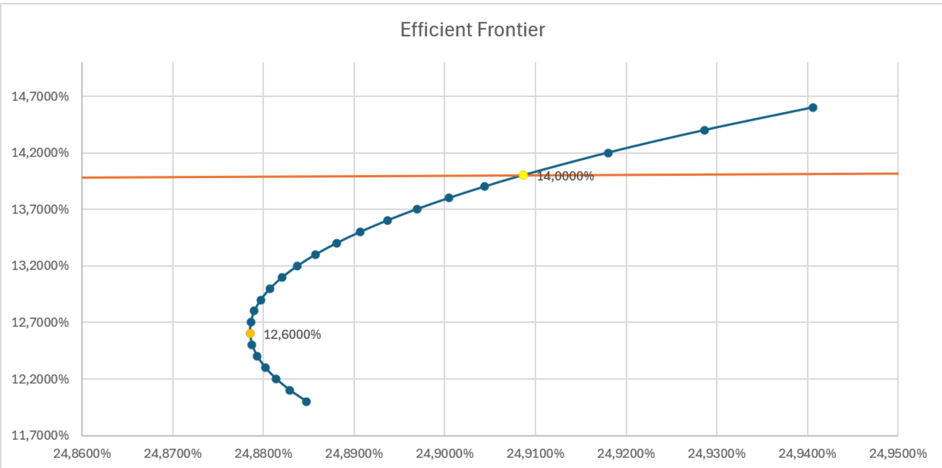

Figure 2. Efficient Frontier
Source: Data by the Author, 2026

The selected portfolio consist of four stocks with different allocation weights. The optimal portfolio weights are presented in Table 2.

Table 2. Optimal Portfolio Weights

Stocks	Weight
TLKM	31,79%
ASII	29,62%
UNTR	32,17%
BRPT	6,41%

Source: Data by the Author, 2026

The optimization generated a diversified portfolio consisting of four stocks with different allocation weights. The resulting portfolio represents the combination of assets that provides the most efficient trade-off between expected return and portfolio risk based on the historical data used in this study.

Portfolio Performance Evaluation

Following the portfolio optimization process, the performance of the optimal portfolio was evaluated using expected portfolio return, portfolio standard deviation, and the Sharpe Ratio. These indicators provide an assessment of the portfolio's return, overall risk, and risk-adjusted performance.

Table 3. Portfolio Performance of the Optimal Markowitz Portfolio

Indicator	Value (%)
Expected Portfolio Return	14,00%
Risk-free Rate (IGYSC)	6,86%
Portfolio Standard Deviation	24,91%
Sharpe Ratio	28,68%

Source: Data by the Author, 2026

As presented in Table 3, the optimal Markowitz portfolio generated an expected annual return of 14,00% with a portfolio standard deviation of 24,91%, indicating that investors may expect a 14,00% return while bearing a corresponding level of portfolio risk. Using the 10-year Indonesia Government Securities Yield Curve (IGYSC) as the risk-free rate of 6,86%, the portfolio achieved a Sharpe Ratio of 28,68%. This result indicates that the portfolio provides a favorable level of risk-adjusted performance, suggesting that the return generated is relatively high compared to the total risk undertaken.

Conditional Value at Risk (CVaR)

To evaluate downside risk, this study employed Conditional Value at Risk (CVaR) at the 99% confidence level. CVaR estimates the expected loss that may occur beyond the Value at Risk threshold under extreme market conditions.

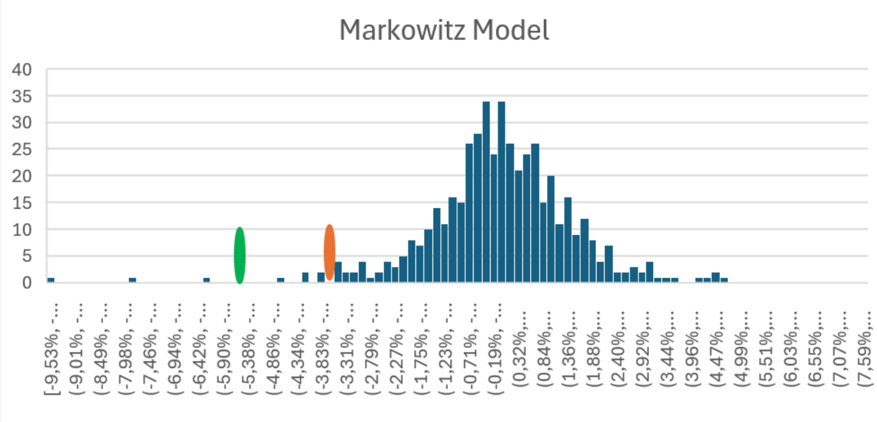

Figure 3. VaR and CvaR Markowitz
Source: Data by the Author, 2026

Table 4. Tail Risk Measurement

Indicator	Value (%)
VaR (99%)	-3,61%
CVaR (99%)	-5,46%

Source: Data by the Author, 2026

Table 4 shows that the estimated VaR at the 99% confidence level is -3.61%, indicating that under normal market conditions there is only a one percent probability that portfolio losses will exceed 3.61% in a single period. Furthermore, the estimated CVaR of -5,46% indicates that if losses exceed the VaR threshold, the average loss is expected to reach approximately 5,46%. These findings suggest that although the portfolio performs well under normal market conditions, investors remain exposed to substantial losses during extreme market events.

Monte Carlo Simulation

Monte Carlo simulation was conducted to estimate the future value of the optimal portfolio under numerous randomly generated market scenarios. The simulation provides a probability distribution of possible investment outcomes and enables the assessment of potential extreme losses.

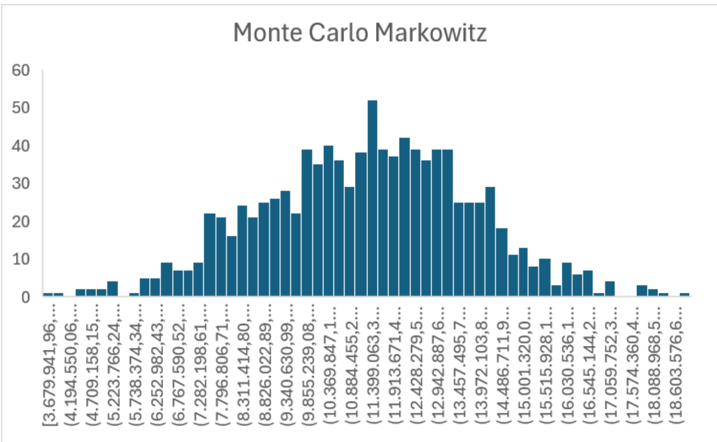

Figure 4. Distribution of Simulated Portfolio Values
Source: Data by the Author, 2026

Figure 4 show the simulation results indicate the distribution of projected portfolio values generated from repeated simulations. The simulation results illustrate the distribution of projected portfolio values over a one-year investment horizon.

Table 5. Summary of Monte Carlo Simulation Results

Indicator	Value
Initial Investment	Rp 10.000.000
Mean Portfolio Value	Rp 11.419.049
Median Portfolio	Rp 11.511.685
Percentile 1%	Rp 5.345.229

Source: Data by the Author, 2026

As presented in Table 5, an initial investment of Rp 10.000.000 is projected to grow to a mean portfolio value of Rp 11.419.049, while the median projected value reaches Rp 11.511.685. The higher median than mean indicates that a small number of unfavourable simulation outcomes reduce the average portfolio value. Furthermore, the 1st percentile of Rp 5.345.229 suggests that under extreme market conditions, portfolio value may decline substantially, highlighting the importance of considering tail risk alongside expected portfolio performance.

DISCUSSION

The findings indicate that the Markowitz model successfully constructed a diversified portfolio from the selected MSCI Indonesia constituent stocks. The optimized portfolio allocated investment across four stocks with positive expected returns, achieving a balance between expected return and portfolio risk in accordance with the principles of Modern Portfolio Theory (Markowitz, 1952). Rather than concentrating investment in a single asset, the portfolio demonstrates the importance of diversification in reducing unsystematic risk while maintaining favorable return potential. This finding is consistent with Feng (2022), who reported that the Markowitz model remains effective in improving portfolio efficiency through optimal asset allocation.

The portfolio performance evaluation further demonstrates that the optimized portfolio generated a positive Sharpe Ratio, indicating that the portfolio produced returns exceeding the risk-free rate after accounting for total portfolio risk. This suggests that the optimization process successfully generated returns that adequately compensated investors for the level of risk undertaken. The findings support the fundamental concept of Modern Portfolio Theory, which emphasizes that investment decisions should be based on the trade-off between expected return and overall portfolio risk rather than expected return alone (Bodie et al., 2014; Keown et al., 2016). The results are also consistent with Nadia et al. (2026), who found that the Markowitz model provides an effective framework for constructing efficient portfolios in the Indonesian stock market.

While the portfolio exhibited favorable risk-adjusted performance, the tail-risk analysis indicates that investors remain exposed to potential losses under extreme market conditions. The CVaR results at the 99% confidence level estimate the average loss beyond the Value at Risk threshold, illustrating that adverse market movements may still generate substantial portfolio losses despite the benefits of diversification. These findings reinforce the argument of Rockafellar and Uryasev (1999) that variance alone is insufficient to measure downside risk because it treats positive and negative deviations equally. Consequently, CVaR provides a more comprehensive measure of extreme downside risk by focusing specifically on losses in the tail of the return distribution. The Monte Carlo simulation complements the historical risk analysis by projecting portfolio values over a one-year investment horizon under numerous possible market scenarios. The simulated distribution indicates that although the portfolio is expected to generate positive growth under normal market conditions.

Unfavorable scenarios remain possible, as reflected by the lower percentile of the simulated portfolio value distribution. The 1st percentile represents the lower tail of the simulated outcomes and provides additional insight into the portfolio's exposure to extreme downside events. Unlike historical CVaR, which is estimated from observed return data, Monte Carlo simulation offers a forward-looking assessment by evaluating potential portfolio performance across a wide range of hypothetical market conditions (Indarwati & Kusumawati, 2021; Fabianová et al., 2023).

Unlike previous studies that primarily evaluated portfolio performance using traditional risk-return measures, this study integrates the Markowitz model with both historical tail-risk measurement (CVaR) and forward-looking scenario analysis through Monte Carlo simulation, providing a more comprehensive assessment of portfolio performance under both normal and extreme market conditions. Overall, the results suggest that evaluating portfolio performance solely through traditional risk-adjusted measures may not provide a complete assessment of investment risk. Integrating the Sharpe Ratio with CVaR and Monte Carlo simulation enables investors to evaluate both portfolio efficiency and exposure to extreme losses. Therefore, this study extends the application of the Markowitz model by demonstrating that portfolio optimization should be accompanied by tail-risk assessment to support more informed investment decisions, particularly in emerging markets such as Indonesia where market volatility remains relatively high.

CONCLUSION

This study evaluated the performance and tail risk of an optimal portfolio constructed using the Markowitz mean-variance model based on selected constituents of the MSCI Indonesia Index during April 2024-May 2026. The findings demonstrate that the Markowitz model successfully generated a diversified portfolio with favorable risk-adjusted performance, as indicated by a positive Sharpe Ratio. These results suggest that the optimized portfolio was able to generate returns exceeding the risk-free rate relative to the level of risk undertaken.

Although the optimized portfolio achieved an efficient balance between return and risk, the CVaR analysis and Monte Carlo simulation revealed that investors remain exposed to potential losses under extreme market conditions. These findings indicate that evaluating portfolio performance solely through traditional risk measures, such as variance or standard deviation, may not adequately capture downside exposure. Therefore, integrating the Sharpe Ratio with CVaR and Monte Carlo simulation provides a more comprehensive assessment of portfolio performance and tail risk, supporting more informed investment decision-making.

This study contributes to the portfolio management literature by demonstrating that traditional portfolio optimization can be strengthened through the integration of historical tail-risk measurement and forward-looking risk simulation. By combining the Markowitz model with CVaR and Monte Carlo simulation, the study provides a more comprehensive framework for evaluating portfolio performance under both normal and extreme market conditions in the Indonesian capital market. Future research may extend this analysis by incorporating alternative portfolio optimization models, comparing different tail-risk measures, using longer observation periods, or examining other market indices to evaluate portfolio performance across different market conditions.

REFERENCE

Aufa, G., & Mahadewi, L. (2024). Portfolio optimization for green sharia stocks: Unlocking Indonesia sustainable islamic finance potential. *In Proceeding of International Conferences: The 5th Asia-Pacific Management Research Conference (APMRC) 2024: Adapting Sustainability Strategies in Business and Management,* 342-351. Sciendo. https://doi.org/10.2478/9788367405850-030

Bodie, Z., Kane, A., & Marcus, A. J. (2014). *Investments* (10th ed.). McGraw-Hill Education.

Escobar, M., Pandolfi, L., Pedraza, A., & Williams, T. (2021). *The anatomy of index rebalancings: Evidence from transaction data* (Working Paper No. 621). Centre for Studies in Economics and Finance.

Fabianová, J., Janeková, J., Fedorko, G., & Molnár, V. (2023). A Comprehensive Methodology for Investment Project Assessment Based on Monte Carlo Simulation. *Applied Sciences,* 13(10), 6103. https://doi.org/10.3390/app13106103

Feng, Q. (2022). Optimal portfolio construction based on Markowitz model. *BCP Business & Management, 35*, 273-280. https://doi.org/10.54691/bcpbm.v35i.3303

Hunter, G. (2026, January 29). Explainer: What is MSCI and what has it done to Indonesia's stock market? *Reuters.* https://www.reuters.com/world/asia-pacific/what-is-msci-what-has-it-done-indonesias-stock-market-2026-01-29/

Indarwati, E., & Kusumawati, R. (2021). Estimation of the portfolio risk from conditional value at risk using Monte Carlo simulation. *Jurnal Matematika, Statistika dan Komputasi, 17*(3), 370-380. https://doi.org/10.20956/j.v17i3.11340

Keown, A. J., Martin, J. D., & Petty, J. W. (2016). *Financial management: Principles and applications* (12th global ed.). Pearson Education.

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance, 7*(1), 77. https://doi.org/10.2307/2975974

Mozumder, S., Hassan, M. K., & Kabir, M. H. (2024). An evaluation of the adequacy of Lévy and extreme value tail risk estimates. *Financial Innovation, 10*(1). https://doi.org/10.1186/s40854-024-00614-6

MSCI. (2024). *MSCI Global Investable Market Indexes Methodology*. https://www.msci.com/indexes/documents/methodology/1_MSCI_Global_Investable_Market_Indexes_Methodology_20240812.pdf

MSCI. (2025, May). *MSCI global investable market indexes methodology: Index construction objectives, guiding principles and methodology for the MSCI global investable market indexes.* https://www.msci.com/documents/10199/ab796822-b8bf-9122-5e67-cfb93af723c9

MSCI. (2025, November). *MSCI Indonesia Index (USD)* [Index Factsheet]. https://www.msci.com/documents/10199/255599/msci-indonesia-index-price-usd.pdf

Mumtazah, G. I., & Permadhy, Y. T. (2022). Analisis kinerja reksa dana saham dengan metode Sharpe, Treynor, dan Jensen selama masa pandemi. *Jurnal Riset Manajemen Sains Indonesia, 13*(01), 53-75. https://doi.org/10.21009/jrmsi.013.1.04

Muthohiroh, U., Rahmawati, R., & Ispriyanti, D. (2021). Pendekatan metode Markowitz untuk optimalisasi portofolio dengan risiko Expected Shortfall (ES) pada saham syariah dilengkapi GUI Matlab. *Jurnal Gaussian, 10*(4), 508-517. https://doi.org/10.14710/j.gauss.v10i4.33098

Nadia, F., Batubara, T. K., Saragih, B. R., Hamidah, N., Pratama, D., Annisa, T., Sari, D. A., & Harahap, M. I. (2026). Analisis Kinerja Portofolio Optimal Menggunakan Model Markowitz pada Instrumen Saham di Bursa Efek Indonesia. *Journal of International Entrepreneurship and Management (JIEM), 4*(1), 1338-1355. https://doi.org/10.61722/jiem.v4i1.8626

Rockafellar, R. T., & Uryasev, S. (1999). *Optimization of conditional value-at-risk* [Research Report No. 99-2]. Department of Industrial and Systems Engineering, University of Florida. https://sites.math.washington.edu/~rtr/papers/rtr179-CVaR1.pdf

Sharpe, W. F. (1963). A simplified model for portfolio analysis. *Management Science, 9*(2), 277-293. https://doi.org/10.1287/mnsc.9.2.277

Widyatmoko, A. S., & Setiawan, D. (2023). Reaksi pasar pada peristiwa rebalancing indeks MSCI di negara ASEAN-5. *Jurnal Kajian Akuntansi, 7*(1), 35-55. https://doi.org/10.33603/jka.v7i1.7217

Wu, M. (2025). Portfolio Optimization under ESG Constraints: Markowitz Model vs. Index Model. *SHS Web of Conferences, 218*, Article 02002. https://doi.org/10.1051/shsconf/202521802002