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Portfolio optimization using mean-variance model and single index model: Evidence from Indonesian and Malaysian capital markets

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ABSTRACT

This study explores the application of investment theories, explicitly focusing on portfolio optimization using the Mean-Variance Model by Markowitz and the Single Index Model by Sharpe in the Indonesian and Malaysian capital markets. Focused on the IDX30 and FTSE Bursa Malaysia KLCI indices, representing major stocks in Indonesia and Malaysia, the study underscores the complexities in portfolio formation due to market fluctuations, economic uncertainties, and regulatory changes. Historical data from the year 2010 to 2023 is utilized, employing both models to form optimal portfolios. Findings suggest that the mean-variance model provides more optimal results, with certain stocks dominating portfolio compositions, highlighting the importance of efficient asset selection over sheer quantity for effective diversification. The study concludes that the use of the Mean-Variance Model provides more optimal results compared to the Single Index Model in portfolio formation involving both the IDX30 index and the FTSE Bursa Malaysia KLCI index, with their fund proportions dominated by BBCA stocks for the IDX30 index and 4707 or Nestle (Malaysia) stocks for the FTSE Bursa Malaysia KLCI index. Therefore, the key to effective diversification lies not solely in the number of assets forming the portfolio but rather in the efficient selection of those portfolio assets.

Contribution/ Originality: In this study, we will investigate how to compare the diversification results applied to the Malaysian Stock Market with the Indonesian Stock Market by employing the mean-variance and single-index models.

1. INTRODUCTION

Investment theory states that a rational investor aims to maximize expected profits and minimize investment risks. To achieve this goal, investors face two main problems: first, the choice of shares to invest in, and second, the determination of how long the shares will be held. Diversification has been shown to reduce risk without diminishing the expected potential profit on the first issue. Regarding the second issue, the expected return can be enhanced by extending the duration of the investment. However, it should be noted that investment risks can also increase, and the extent to which such risks increase depends on the presence of serial correlations. Moreover, the benefits of diversification also depend on the correlation coefficients, which can be influenced by the duration of the investment (Tang, Kong, University, & Lee, n.d).

"Don't put all your eggs in one basket" is a famous saying in the context of a portfolio. This lesson is important because if one basket is broken, the whole egg will be destroyed, and an overall loss will occur. I mean, for those who want to invest, the selection should be done carefully. Diversification of investments becomes the primary objective in portfolio formation, although one part may undergo significant changes. However, different stock variations will occur to balance each other and reduce risk (Chen, Li, Hu, & Lu, 2023). This is because investment activities are always associated with stock price fluctuations that can significantly impact the level of risk and return. The relationship between risk and the desired return on investment reflects a positive correlation.

Optimum portfolio formation is a significant investment concern for investors and fund managers. One of the leading approaches in this regard is the Optimal Portfolio Theory developed by Markowitz (1952), known as the Mean-Variance Model. The Mean-variance approach uses several statistical parameters such as expected returns, standard deviations of securities and portfolios, as well as covariance between share returns. Risk can be minimized through diversification and integration of various investment instruments into a single portfolio (Markowitz, 1952). The Mean-variance model helps address the problem of how to distribute shares in a portfolio composition to provide the most efficient level of risk. This theory provides an investor with the ability to minimize the risk on portfolio investments at the expected rate of return or to achieve the expected maximum level of return at an acceptable level of risk (Liu, 2022).

Portfolio risk is calculated by assessing the asset risk and the risk of all stocks in the portfolio, along with the covariance between the stocks that comprise the portfolio. In Markowitz's theory, covariance, an absolute parameter that determines how likely the returns of two specific types of securities in a portfolio are to move simultaneously, employs a model that can be used to calculate returns and portfolio risk (Markowitz, 1952). However, to perform this calculation, the covariance must be determined by the amount of half of the forming stock surplus minus its forming share. The quantity of portfolio-forming shares generates increasing covariance. Mean-variance expected returns are derived by selecting the smallest risk from a variety of possible portfolio combinations. The method that can be employed for such purposes is that this optimization model utilizes calculated linear programming to maximize the average return and minimize risk (Tan, 2023).

Sharpe (1963) The Single Index Model is based on the idea that market price indices influence the prices of securities. This model simplifies a highly complex portfolio mean-variance risk analysis into a basic calculation and is a development of the Markowitz model (Sharpe, 1963). This model is used to create an optimal portfolio based on effective portfolio preferences. The Single Index Model theory facilitates the calculation of variables associated with the movement of stock returns and market indices.

In the Single Index Model, two main components are considered to estimate share returns: the component of return associated with the specific characteristics of the company, called alpha, and the component of return influenced by market movements, called beta. The term "beta" is a key concept in the Single Index Model and indicates the sensitivity of the share return to market changes: the higher the beta of the stock, the more sensitive it is to market changes. One of the advantages of the Single Index Model is its attempt to simplify the Markowitz model. The use of the Single Index Model can help in estimating the expected rate of profit for individual stocks (Mistry & Khatwani, 2023).

Forming an optimal portfolio is a challenging task due to various factors, such as market fluctuations, economic uncertainty, and changes in regulations in capital markets. The study focuses on the Indonesian and Malaysian capital markets, particularly the IDX30 index (Indonesia Stock Exchange 30) and FTSE Bursa Malaysia KLCI, which are key indicators of stock market performance in both countries. However, differences in stock market characteristics in both countries, such as stock liquidity and risk levels, make it challenging to implement the Markowitz Model and the Single Index Model effectively.

The IDX30 reflects the performance of 30 outstanding stocks; the IDX-30 can describe liquid stock capabilities with a large market capacity. The LQ45 stock index is considered excessive by some investment managers because it consists of 45 shares, so IDX30 is formed as an alternative. The IDX30 index consists of thirty stocks, giving a lighter portfolio composition. Moreover, the sum of the thirty is considered the ideal sum to reflect the diversity of assets in the portfolio. Stock exchanges occur twice a year, from February to July and August to January. Shares that do not meet the special requirements will be removed from the index and replaced by new shares that are equally eligible (Indonesia Stock Exchange, 2021).

In Malaysia, the KLCI index reflects the performance of 30 major stocks in the stock market. The FTSE Major Stock Market Index of Bursa Malaysia KLCI (Kuala Lumpur Composite Index) consists of the 30 largest and most liquid stocks listed on the Malaysia Stock Exchange. The calculation of this index is based on the stock market capitalization of the shares included in it, so shares with a larger market capitalization have a greater influence on the index. The change in the value of the index reflects changes in the stock prices of the constituents and gives a general picture of the direction of the Malaysian stock market. The FTSE Malaysia Stock Exchange KLCI is used as a key indicator by investors, financial analysts, and stock market participants to evaluate portfolio performance, identify market trends, and make investment decisions. These indices are also often the focus of technical and fundamental analysis to better understand the condition of the Malaysian stock market (Zakaria, Badrul Azhar, Mohamad Rawi, & Mohamed Yusof, 2020).

The Efficient Frontier is a chart formed from a portfolio with the minimum expected return at the same level of risk. Every investor will have an efficient portfolio and will always be close to the dominant portfolio. There are two efficient portfolios with $\mu1 \leq \mu2$ and $\sigma1 \pm \sigma2$. Investors with a higher risk will have a higher return, while those with a lower risk may have a larger takeover (Tian, 2023).

Through diversification, investors can reduce the unsystematic risks in their portfolios. However, the challenge is how to do this. By increasing the number of shares in a portfolio, an investor can reduce the total risk in the portfolio to the maximum level at which unsystematic risk can be eliminated. While unsystematic risks can be diversified, the question is how much diversification is needed to reduce such risks.

After conducting the analysis, by diversifying the investment, the portfolio will produce a variable expectation of return, and the standard deviation (SD) of that portfolio can change. When considering or ignoring risk-free assets, the expected return of the investment portfolio will vary relative to one asset. Although unpredictable, the investment portfolio's risk will spread gradually (Li, 2023).

Most of the previous research focused only on the diversification of the shares of one single country. Therefore, in this study, we will investigate how to compare the diversification results applied to the Malaysian Stock Market with the Indonesian Stock Market by employing the mean-variance and single index models. To limit the scope of the research, the samples taken in this study will analyze companies listed on the Indonesian Stock Exchange (IDX30) and the Malaysian Stock Exchange (FTSE Bursa Malaysia KLCI).

2. LITERATURE REVIEW

Investment is one of the activities in the capital market that involves investing in one or more ventures with the hope of making a profit in the future. Real investments and financial investments are different; real investments generate tangible assets, while financial investments generate dividends and capital gains (Assof, Primayudha, & Retha, 2022). The aim of investment is to make a profit in the future. Investors also engage in activities related to financial prosperity, such as improving the quality of life, reducing inflationary pressures, and attempting to lower taxes.

In Modern Portfolio Theory, Harry Markowitz established the foundational principles of mean-variance portfolio theory. This theory involves maximizing the expected return while maintaining a constant variance and minimizing the variance while maintaining a constant expected return. These two principles lead to the formation of the efficient frontier, from which investors can choose their desired portfolios based on their individual risk preferences and expected return levels (Buttell, 2010). The key message of this theory is that assets cannot be selected solely based on their characteristics. Instead, an investor must consider how each security moves in relation to all other portfolio securities. Moreover, taking into account these joint moves results in the ability to create portfolios that have the same return rates and lower risks than the portfolio created by ignoring the inter-security interaction. As a result, the current use of security interactions can be measured by asset correlation. Since then, asset allocation and diversification benefits have attracted academic interest. Stock market fluctuations will affect the level of correlation of assets. Asset correlations tend to rise in turbulent periods, which reduces the effectiveness of diversification, as well as in making risk management strategies. They also found that asset correlations and risk management models assume short-term stability of the covariance structure of the asset's earnings; however, in reality, covariance structures and correlational relationships are dramatically fluctuating.

Research carried out by Norsiman, Yakob, and McGowan (2019) investigates the impact of portfolio diversification on the Malaysian stock exchange. From the results, they assessed the extent to which the non-systematic risk component could be minimized through the application of mean-variance analysis. The stock price data used was taken randomly from Yahoo! Finance for five years, from January 2010 to March 2014. Robustness was tested using three sets of portfolios, each consisting of 55 stocks. The total sample used was 165 shares from various sectors listed on the Malaysia Stock Exchange. The results of the research showed that the increase in the number of shares in the sample portfolio resulted in a decrease in the standard deviation (unsystematic risk) of the investment portfolio, suggesting that each portfolio has been well diversified. The unique result of this study is the finding that the data frequency level significantly influences the change in the size of the stock portfolio required for optimal portfolio diversification. In the following year, Sharpe (1963) developed the Single Index Model, also known as the single index model. This model is a simplification of the mean-variance framework first introduced by Markowitz and explains the relationship between the output of a market index and the performance of each security. It provides a simpler approach to calculating portfolio variance compared to the method used in the calculation of Markowitz's model. The model can be used as a basis for solving problems related to portfolio management. In this Single Index model, the amount of calculations needed is less than that required in the approach developed by Markowitz to determine an efficient portfolio (Sharpe, 1963).

The Efficient Frontier describes a variety of optimal portfolios, while all of the portfolios below are considered less efficient. Portfolios are considered efficient if they have a similar level of risk and can increase profits or lower levels of risk with equivalent profits. However, an optimal portfolio is the choice of a set of efficient portfolios, which are then adjusted to investor preferences related to investment returns, including return, capital gains, and the level of risks they are willing to bear (Juszczuk, Kaliszewski, Miroforidis, & Podkopaev, 2023).

To plot a complete Efficient Frontier, the expected future returns and standard deviations of each portfolio asset, as well as the correlation coefficients between each portfolio asset pair, must be calculated. The Efficient Frontier chart (Figure 1) is a portfolio list that optimizes expected returns for different portfolio risk levels, from the lowest to the highest. The curve is in the form of an Efficient Frontier (Ling & Dasril, 2023).

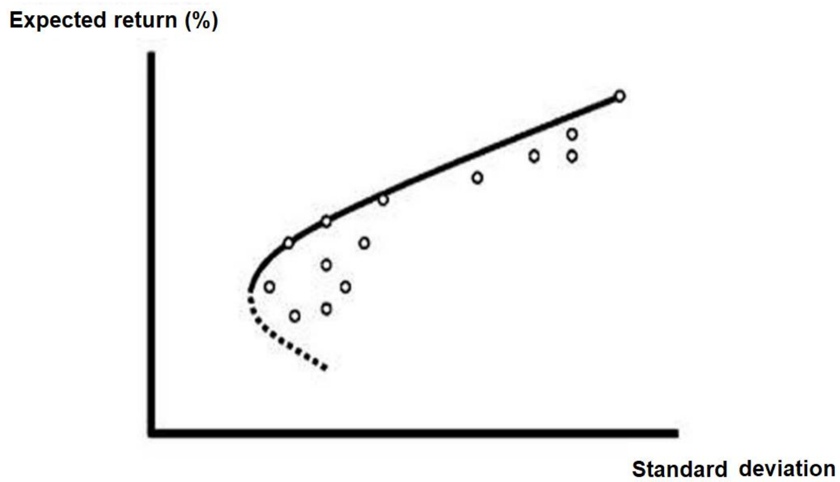

Figure 1. Efficient frontier curve.
Source: Ivanova and Dospatliev (2017)

The combination of assets with a certain level of risk in the portfolio described in the efficient frontier represents the lowest risk that can be obtained in the portfolio for the desired rate of return or the expectation of the best return for the acceptable rate of risk (Ivanova & Dospatliev, 2017).

3. RESEARCH METHOD

This research utilizes secondary data obtained through documentation methods and library research. The data will be collected using the stock prices of companies listed on the IDX30 Indonesia Stock Exchange and the FTSE Malaysia Stock Exchange KLCI. The stock price information will be obtained from the official websites of the Indonesia and Malaysia Stock Markets, which can be accessed through www.idx.co.id and www.bursamalaysia.com. For risk-free (Rf) parameters, the BI-7 Day Reverse Repo Rate (BI7DRR) and the overnight interest rate (OPR) will be used, and the data will be taken from the websites www.bi.go.id and www.bnm.gov.my. The market return calculation will use the Combined Stock Price Index (IHSG) and FTSE Malaysia KLCI (KLSE), with the shares' closing price data from the site id.investing.com.

The research data will be evaluated quantitatively. The Single Index and Mean-Variance model will be applied to analyze the data using Microsoft Excel to find the most optimal portfolio. In this study, a purposive sampling method was chosen to collect samples. The following parameters will be applied.

1. The company must have shares listed on the Indonesian Stock Exchange or the Malaysian Stock Exchange.
2. The stock data analyzed spans from 2010 to 2023, comprising stocks that meet the criteria of being consistently listed in the IDX30 and FTSE from 2017 to 2023. The selection of consistency serves solely to filter the stocks that have remained resilient in the index listings both before and after the COVID-19 pandemic.
3. The stocks registered in each of these indices must have complete data from 2010 to 2023. Expanding the timeframe from 2010 to 2023 offers the advantage of acquiring a richer historical dataset.
4. The stock must have a positive return value.

These criteria are applied to avoid research bias that may arise as unstable stocks enter the IDX30 and FTSE indices of the Malaysia Stock Exchange (KLCI). In addition, the criteria aim to maintain stock price stability during the observation period, ensure complete data availability, and prevent significant price fluctuations.

The study aims to identify and analyze the optimal portfolio by comparing the shares of IDX30 and FTSE Malaysia Bursa KLCI. The optimum portfolio will be formed using the Single Index and Mean-Variance Model, hoping to provide new insights into the development of investment strategies.

Modern portfolio analysis methodologies, including portfolio optimization techniques, risk analysis, and performance evaluation, will be used. Historical data on stock prices, rates of return, and volatility of both stock indices will be utilized to design and test portfolios. The research is expected to contribute positively to an understanding of optimum portfolio formation in Indonesian and Malaysian capital markets, as well as to serve as a practical guide for investors seeking diversification and optimal performance in their investments.

The following steps will be used for the optimal portfolio formation.

1) The Single Index Model is a model presented by Sharpe.

The model simplifies the relationship between securities and market indices. Portfolio analysis in Markowitz takes note of the covariance between portfolio formers, while in the Single Index, the stock model is linked to the capital market index (Sharpe, 1963). With other Sub variables, among others:

(1) Realized Return and Expected

Return Percentage of change in the price of the stock I from the month t, deducted by the share price i in the previous month t-1 and divided by the stock closing price in the preceding month t-1, known as realized return (R_i) (Akhter, Parvin, Mohammad, & Science, 2020).

$$R_i = \frac{P_t - P_{t-1}}{P_{t-1}} \qquad (1)$$

$$E(R_i) = \frac{\sum_{i=1}^{n} R_i}{n} \qquad (2)$$

Expected return E (R_i), is the standard percentage of receipt of share profit i. It can calculate the amount by dividing the receipt for share gain i by the number of periods (Verkino, Sinaga, & Andati, 2020).

(2) Share Beta (β_i) and Share Alpha (a_i)

The calculation of the return on the Single Index Model involves two fundamental factors, namely the return factor that is in series with the characteristics of the company represented by alpha (α) and the return factors that are in line with the market, represented by beta (β).

Since the beta indicates the level of sensitivity of the securities' returns to market return, it is the beta component that holds the important contribution in the single index model. By using the single index model, one can estimate the size of the expected return value for individual securities. By utilizing the single index model, capital investors can also include risk-free assets in their portfolios. The single index model can be formulated in the following way (Akhter et al., 2020).

Calculating stock beta and alpha stocks.

$$\beta_i = \frac{\sigma_{im}}{\sigma_m^2} \qquad (3)$$

$$\alpha_i = E(R_i) - (\beta_i . E(R_m)) \qquad (4)$$

Beta Stock (β_i) identifies the unique risk of the stock used in the Excess Return to Beta (ERB) calculation. A stock that holds $\beta i > 1$, is a stock whose profit growth is greater than the growth of market profit. Systematic risk correlates positively with the beta value.

Alpha Stock (α_i) scores the predictive value of a non-market-dependent securities return, so an alpha with a positive value can increase the predicted return independently of the market return (Verkino et al., 2020).

(3) Excess return to beta (ERB)

Calculate the Excess Return to Beta (ERB), which is an estimate of the relative surplus return for non-diversified hazard units calculated with beta (Verkino et al., 2020). where R_f is the risk-free asset return.

$$ERB = \frac{E(R_i) - R_f}{\beta_i} \qquad (5)$$

(4) Cut Off Rate (Ci)

Calculates the cut-off rate (Ci) block point that determines whether a stock is eligible to enter the portfolio. The value of Ci must be less than the ERB for the selected stock (Verkino et al., 2020).

$$C_i = \frac{\sigma_m^2 \sum_{j-1}^{i} \frac{[E(R_i) - R_f]\beta_i}{\sigma_{ei}^2}}{1 + \sigma_m^2 \sum_{j-i}^{i} \frac{\beta_i^2}{\sigma_{ei}^2}} \qquad (6)$$

(5) Proportion of funds

Calculating the ratio of each share (W_i), the stock that holds a value of Ci greater or equal to the cut-off point to be selected in the optimal portfolio. Calculates the size of the capital ratio carried out after the portfolio was formed, calculated by the formula.

$$W_i = \frac{Z_i}{\sum_{j=1}^{i} Z_j} \qquad (7)$$

Zi is counted using the following formula.

$$Z_i = \frac{\beta_i}{\sigma_{ei}^2} . (ERB - C^*) \qquad (8)$$

(6) Expected Return Portfolio

The expected return of the portfolio is the weighted average of the individual earnings on the shares that comprise the portfolio. The calculation method used is as follows (Verkino et al., 2020).

$$E(R_P) = \alpha_p + \beta_p . E(R_m) \quad (9)$$

The stock beta portfolio describes the relative rate of fluctuation of the individual securities portfolio as a whole, measured by the individual stock beta of the securities that constitute it (Akhter et al., 2020).

(7) Portfolio risk

Portfolio risk is obtained by estimating the variances of the portfolio (Verkino et al., 2020).

$$\sigma_p^2 = \beta_p^2 . \sigma_m^2 + (\sum_{i=1}^{n} W_i . \sigma_{ei})^2 \quad (10)$$

2) Mean-Variance

According to research by Lin, Xu, and Xu (2023) portfolio investment theory plays a crucial role in the global financial market. However, the specific effects of the combination are influenced by various factors, such as the selection of weights and assets. Based on the Markowitz model, we apply a more reasonable method for weight selection in forming an asset portfolio.

The mean-variance model approach involves analyzing the relationship between risk and expected return. Risk is measured by standard deviation or variance, while expected return is determined by the average return. The mean-variance model illustrates the proportional differences between the average return estimates of assets and the return variations representing the diversified stocks in the portfolio (Ivanova & Dospatliev, 2017).

Optimal portfolio formation can be achieved by following the steps of the Mean-Variance model, using the Solver tool in Excel. The Solver program helps in finding the optimal weights for each stock, allowing us to determine the most optimal proportions in the portfolio. Here is how to construct an optimal portfolio using the Mean-Variance model (Xie, 2021).

To calculate the Expected Return of the Portfolio $E(R_P)$, which is the weighted average calculation of the expected returns for each stock in the portfolio.

$$E(R_P) = \sum_{i=1}^{n} W_i . E(R_i) \quad (11)$$

Calculating Portfolio Risk (σ_p), To calculate the portfolio risk, the formula used involves the matrix multiplication between the covariance matrix and the weight matrix of each stock.

$$\sigma_P^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} W_i \, W_j \sigma_{ij} \quad (12)$$

Investors can determine the expected rate of return in advance, and through the given formula, they can ascertain the proportion of their investments in each project, such as stocks, to minimize the total investment risk. In other words, the formula allows investors to identify the optimal capital allocation for each project (Jin, Li, & Yuan, 2021).

From all the diversified portfolios formed using the Single Index Model and Mean-Variance, the Coefficient of Variation (CV) value is then calculated.

3) Efficient Frontier

The efficient frontier is a collection of portfolios that offers the maximum expected return for a given level of risk or the minimum risk for a given level of return. A portfolio is considered efficient if no other portfolio dominates it. Every investor will choose an efficient portfolio, typically gravitating towards the dominant one. However, different investors will select different portfolios on the same efficient frontier based on their individual needs.

There are two efficient portfolios with $\mu 1 \leq \mu 2$ and $\sigma 1 \leq \sigma 2$. A very cautious investor will opt for a lower risk even if it means a smaller return. Meanwhile, another investor might choose a higher risk with the expectation of a greater return, driven by the belief that higher returns usually come with higher risks.

In particular, an efficient portfolio has the highest expected return compared to other portfolios with the same level of risk (standard deviation) and the lowest risk compared to other portfolios with a similar return. Therefore, the efficient frontier must be part of the minimum variance line.

4) Coefficient of Variation (CV)

$$CV = \frac{\sigma_p}{E(R_p)} \quad (13)$$

In calculating the Coefficient of Variation, the factors considered are the expected return of the portfolio and the portfolio's level of risk. The smaller the Coefficient of Variation, the lower the portfolio's risk and the higher the expected return from the portfolio. Therefore, an optimal portfolio has the lowest Coefficient of Variation (Ren, Allenmark, Müller, & Shi, 2021).

4. RESULTS AND DISCUSSION

The results and analysis of the model applied to stocks in the IDX30 and FTSE Bursa Malaysia KLCI are presented. Each index consists of a total of 30 stocks. By considering the established criteria for sample selection, we successfully filtered the stocks that met the requirements. Consequently, 13 out of the 30 IDX30 stocks were selected, while 18 out of the 30 FTSE Bursa Malaysia KLCI stocks were chosen by purposive sampling criterion number 2, which states: "The shares must be listed in IDX30 and FTSE Bursa Malaysia KLCI consistently from 2017 to 2023." Table 1 shows the list of chosen stocks.

Table 1. Purposive sampling of IDX30 and FTSE Bursa Malaysia KLCI.

No	Malaysia		Indonesia	
	CODE	Constituent name	CODE	Constituent name
1	1023	CIMB Group Holdings	ADRO	PT. Adaro Energy Indonesia Tbk
2	1066	RHB BANK	ANTM	PT. Aneka Tambang Tbk
3	1082	Hong Leong Financial	ASII	PT Astra International Tbk
4	1155	Malayan Banking	BBCA	PT. Bank Central Asia Tbk
5	1295	Public Bank Bhd	BBNI	PT. Bank Negara Indonesia (Persero) Tbk
6	1961	IOI Corporation Bhd	BBRI	PT. Bank Rakyat Indonesia (Persero) Tbk
7	2445	Kuala Lumpur Kepong	BMRI	PT. Bank Mandiri (Persero) Tbk
8	3182	Genting	INDF	Indofood Sukses Makmur Tbk
9	3816	MISC Bhd	KLBF	PT Kalbe Farma Tbk
10	4065	PPB Group	PGAS	PT. Perusahaan Gas Negara Tbk
11	4197	Sime Darby	SMGR	PT. Semen Indonesia (Persero) Tbk
12	4707	Nestle (Malaysia)	TLKM	PT. Telkom Indonesia (Persero) Tbk
13	4715	Genting Malaysia Bhd	UNTR	PT. United Tractors Tbk
14	5347	Tenaga Nasional	UNVR	PT. Unilever Indonesia Tbk
15	5681	Petronas Dagangan		
16	5819	Hong Leong Bank		
17	6012	Maxis Bhd		
18	6033	Petronas Gas		
19	6888	Axiata Group Bhd		
20	7277	Dialog Group		
21	8869	Press Metal Aluminium Holdings		

Source: *www.idx.co.id* and *www.bursamalaysia.com* which is processed.

Considering the established criteria for sample selection, we successfully filtered the stocks that met the requirements. Out of the 14 IDX30 stocks, one stock, PGAS (0.000530), did not qualify as a portfolio candidate due to its negative return.

For the FTSE Bursa Malaysia KLCI stocks, 18 out of 21 stocks were selected based on criteria 3 and 4 of purposive sampling: the company must be registered in both indices and have complete data from 2010 to 2023, and the stock must have a positive return value. The FTSE Bursa Malaysia KLCI stocks that did not yield positive returns were IOI Corporation Bhd (0.000073), Genting (0.000031), and Maxis Bhd (0.000423). Table 2 shows the return value of the stocks chosen.

Table 2. Purposive sampling of IDX30 and FTSE Bursa Malaysia KLCI stocks with positive return values.

NO	Malaysia		INDONESIA	
	CODE	$E(R_i)$	CODE	$E(R_i)$
1	1023	0.001	ADRO	0.010
2	1066	0.002	ANTM	0.007
3	1082	0.006	ASII	0.007
4	1155	0.002	BBCA	0.016
5	1295	0.005	BBNI	0.015
6	1961	(0.000073)	BBRI	0.016
7	2445	0.003	BMRI	0.014
8	3182	(0.000031)	INDF	0.007
9	3816	0.001	KLBF	0.015
10	4065	0.002	PGAS	(0.000530)
11	4197	0.000008	SMGR	0.005
12	4707	0.008	TLKM	0.008
13	4715	0.003	UNTR	0.008
14	5347	0.004	UNVR	0.007
15	5681	0.008		
16	5819	0.006		
17	6012	(0.0004)		
18	6033	0.005		
19	6888	0.001		
20	7277	0.012		
21	8869	0.028		

Source: *www.yahoo.finance.com* which is processed.

4.1. Single Index Model

Expected return and company risk data, including the IDX30 and FTSE Bursa Malaysia KLCI indices, were obtained through research activities covering stock exchange data from Indonesia and Malaysia. Historical data were extracted from the Yahoo Finance website and subsequently processed using data analysis tools and Excel's Solver function. Table 3 shows the expected return standard deviation, risk, and covariances of the stocks chosen from the Indonesia Stock Exchange. From Table 3, it is evident that PT. Perusahaan Gas Negara Tbk is not included in the portfolio candidates due to having a negative expected return value of 0.000530, which does not meet the purposive sampling criteria.

Table 3. Expected return($E(R_i)$), standard deviation(σ_i), Risk (σ_i^2) and stock market covariance (σ_{im}) IDX30 stocks from the Indonesia stock exchange.

CODE	$E(R_i)$	σ_i	σ_i^2	σ_{im}
ADRO	0.010	0.116	0.013	0.002
ANTM	0.007	0.141	0.020	0.003
ASII	0.007	0.077	0.006	0.002
BBCA	0.014	0.055	0.003	0.002
BBNI	0.015	0.097	0.009	0.003
BBRI	0.016	0.078	0.006	0.002
BMRI	0.014	0.074	0.006	0.002
INDF	0.007	0.066	0.004	0.001
KLBF	0.015	0.070	0.005	0.001
PGAS	(0.000530)	0.119	0.014	0.003
SMGR	0.005	0.092	0.008	0.002
TLKM	0.008	0.060	0.004	0.001
UNTR	0.008	0.088	0.008	0.001
UNVR	0.007	0.067	0.004	0.000460

Source: *www.yahoo.finance.com* which is processed.

Table 4 shows the expected return, standard deviation, risk, and covariances of the stocks chosen from Bursa Malaysia. From Table 4, it is observed that stocks with codes 1961 (IOI Corporation Bhd), 3182 (Genting), and 6012 (Maxis Bhd) are not included in the portfolio candidates because they do not meet the criteria for purposive sampling, as they yield negative expected returns.

Table 4. Expected return($E(R_i)$), standard deviation(σ_i), Risk (σ_i^2) and stock market covariance (σ_{im}) The FTSE Bursa Malaysia KLCI stocks are from the Bursa Malaysia exchange.

CODE	$E(R_i)$	σ_i	σ_i^2	σ_{im}
1023	0.002	0.062	0.004	0.001
1066	0.002	0.051	0.003	0.001
1082	0.007	0.046	0.002	0.001
1155	0.002	0.035	0.001	0.001
1295	0.005	0.040	0.002	0.001
1961	(0.000073)	0.051	0.003	0.001
2445	0.003	0.048	0.002	0.001
3182	(0.000031)	0.072	0.005	0.001
3816	0.001	0.063	0.004	0.001
4065	0.002	0.044	0.002	0.001
4197	0.000008	0.060	0.004	0.001
4707	0.008	0.037	0.0014	0.000366
4715	0.003	0.071	0.005	0.001
5347	0.004	0.048	0.002	0.001
5681	0.008	0.061	0.004	0.001
5819	0.006	0.042	0.002	0.001
6012	(0.000423)	0.042	0.002	0.000527
6033	0.005	0.044	0.002	0.001
6888	0.001	0.066	0.004	0.001
7277	0.012	0.068	0.005	0.001
8869	0.028	0.112	0.0126	0.001

Source: *www.yahoo.finance.com* which is processed.

The Single Index Model is valuable for investors and aids fund managers in harnessing the benefits of securities to create portfolios with adequate diversification. Selecting stocks appropriate for the optimal portfolio category can be done under the condition ERB > Ci (Rout & Panda, 2020). Based on Table 4, only three stocks have ERB values exceeding Ci and are included in the optimal portfolio: KLBF, BBCA, and BBRI. The value of C* or Cut-Off Point is represented by the Ci value of BBRI (0.007008). Table 5 and Table 6 show the results of the Single Index Model for IDX30 and FTSE Bursa Malaysia KLCI, respectively.

Table 5. Results of the single index model for IDX30.

DATE	ERB		Ci
KLBF	0.013	>	0.003
BBCA	0.011	>	0.007
BBRI	0.008	>	0.007
UNVR	0.007	<	0.007
BMRI	0.006	<	0.007
BBNI	0.006	<	0.007
ADRO	0.005	<	0.007
TLKM	0.004	<	0.006
UNTR	0.004	<	0.006
INDF	0.003	<	0.006
ASII	0.002	<	0.006
ANTM	0.001	<	0.006
SMGR	(0.000022)	<	0.005

Source: *www.yahoo.finance.com* which is processed.

Table 6. Results of the single index model for FTSE Bursa Malaysia KLCI.

Date	ERB		Ci
4707	0.014	>	0.002
8869	0.014	>	0.005
7277	0.009	>	0.006
5681	0.006	<	0.006
5819	0.005	<	0.007
1082	0.005	<	0.007
1295	0.004	<	0.007
6033	0.003	<	0.007
5347	0.002	<	0.006
2445	0.000981	<	0.006
4715	0.000437	<	0.006
1155	0.000192	<	0.005
1066	0.000149	<	0.005
4065	(0.000448)	<	0.005
1023	(0.000451)	<	0.004
6888	(0.000753)	<	0.004
3816	(0.000973)	<	0.004
4197	(0.002)	<	0.004

Source: *www.yahoo.finance.com* which is processed.

Based on Table 6, three stocks with ERB > Ci are included in the optimal portfolio, namely stocks 4707 (Nestlé (Malaysia)), 8869 (Press Metal Aluminium Holdings), and 7277 (Dialog Group). The value of C* or Cut-Off Point is located at the Ci value of 7277 (0.005943).

Findings from the research conducted by Akhter et al. (2020) indicate that the Single Index Model is the simplest and most commonly used method for calculating the optimal portfolio. This method requires fewer variables than the mean-variance method. In portfolio construction, only one index is required; hence, it is known as the Single Index Model. There are only three steps in the Single Index Sharpe Model: ranking stocks, determining the cutoff rate, and finding the appropriate investment proportions.

In modern portfolio theory, the Markowitz model, known as the mean-variance model, is the core of the theory. This model elaborately explains the process of calculating the optimal portfolio solution and its principles. Additionally, it depicts various portfolio situations using the horizontal axis for variance and the vertical axis for mean. The Markowitz model emphasizes the use of variance as a representation of portfolio risk and means as a representation of portfolio return expectations (Dai, 2023).

Table 7. Comparison of portfolio optimization results for IDX30 index using mean-variance model and single index model.

CODE	Mean-variance					Single index model
	MV-1	MV-2	MV-3	MV-4	MV-5	
ADRO	5%	5%	4%	3%		
ANTM	1%					
ASII	5%					
BBCA	20%	33%	46%	53%	69%	61%
BBNI		2%	4%	5%		
BBRI	2%	5%	7%	9%	14%	10%
BMRI	7%	11%	13%	14%	3%	
INDF	10%	5%				
KLBF	2%	6%	9%	11%	14%	29%
SMGR	6%	2%				
TLKM	10%	5%				
UNTR	12%	11%	11%	5%		
UNVR	20%	15%	6%	1%		
$E(R_p)$	0.010	0.012	0.014	0.015	0.016	0.016
σ_p	0.032	0.034	0.039	0.043	0.049	0.049
σ_p^2	0.001	0.001	0.002	0.002	0.002	0.002

Source: *www.yahoo.finance.com* which is processed.

The optimal fund proportion for stocks in the IDX30 index, using the mean-variance model, is dominated by more than 30% of BBCA shares. Meanwhile, using the Single Index Model, it is also dominated by BBCA shares by more than 50%. This is shown in Table 7.

Both individual returns and portfolio returns and risks are the same. However, the Markowitz model appears to be easier to calculate individual returns and portfolio returns. On the other hand, the Sharpe Single Index model simplifies the process of calculating portfolio risk by avoiding the time-consuming covariance calculations in the Mean-Variance model. As the number of stocks increases, calculating covariances between all companies becomes difficult in the Mean-Variance model. This research was conducted on specific stocks and shows that both models provide almost the same value for both individual returns and risks, as well as portfolio returns and risks. It can be concluded that the Single Index Model is more suitable for calculating portfolio risk because the Mean-Variance model requires covariance calculations between stocks to identify portfolio risk, which becomes increasingly difficult as the number of stocks increases. Therefore, this limitation encourages the use of the Single Index Model in calculating portfolio risk.

The optimal allocation of funds to stocks in the FTSE Bursa Malaysia KLCI index varies depending on the method used, whether it's mean-variance dominated by stock 4707 by more than 20% or the Single Index Model dominated by stock 4707 by more than 50%. This is because stock 4707, or Nestlé (Malaysia), has the lowest level of risk measured by a standard deviation of 0.037137. This is shown in Table 8.

Table 8. Comparison of portfolio optimization results for the FTSE Bursa Malaysia KLCI index using mean-variance model and single index model.

CODE	Mean-variance							Single index model
	MV-1	MV-2	MV-3	MV-4	MV-5	MV-6	MV-7	
1023	0%	0%	0%	0%	0%	0%	0%	-
1066	0%	0%	0%	0%	0%	0%	0%	-
1082	5%	7%	8%	9%	7%	0%	0%	-
1155	15%	12%	5%	1%	0%	0%	0%	-
1295	9%	9%	9%	9%	3%	0%	0%	-
2445	7%	5%	3%	1%	0%	0%	0%	-
3816	4%	3%	1%	0%	0%	0%	0%	-
4065	9%	6%	2%	0%	0%	0%	0%	-
4197	3%	1%	0%	0%	0%	0%	0%	-
4707	20%	24%	30%	33%	37%	35%	39%	53%
4715	1%	0%	0%	0%	0%	0%	0%	-
5347	7%	6%	4%	2%	0%	0%	0%	-
5681	3%	4%	7%	8%	9%	9%	8%	-
5819	7%	8%	10%	11%	10%	2%	0%	-
6033	9%	10%	10%	10%	6%	0%	0%	-
6888	1%	0%	0%	0%	0%	0%	0%	-
7277	1%	3%	6%	8%	12%	20%	21%	19%
8869	0%	2%	6%	8%	15%	33%	32%	28%
$E(R_p)$	0.005	0.006	0.008	0.009	0.011	0.015	0.015	0.014
σ_p	0.020	0.021	0.023	0.025	0.029	0.044	0.044	0.045
σ_p^2	0.000420	0.000438	0.000530	0.000606	0.000849	0.002	0.002	0.002

Source: *www.yahoo.finance.com* which is processed.

Based on research conducted by Dai (2023), the findings from this study can provide insights for financial investors. After calculations and observations of the performance of the Mean-Variance and Single Index Models, this paper highlights several key findings. First, it was found that the results generated by both models are very similar. Second, the results achieved using the Single Index Model are slightly higher compared to those using the Mean-Variance Model. In most conditions, the performance of the Single Index Model on selected stocks appears to be better than that of the Mean-Variance Model. Thus, out of the 10 stocks analyzed from these three sectors, all show satisfactory performance and are worth considering for investment.

These research findings show different results from previous studies. According to this research, the mean-variance model produces better results compared to the Single Index Model. This is because when they both have the same risk, the return generated by the mean-variance model is higher than that of the Single Index Model.

This optimally constructed portfolio set aligns with the concept known as the "efficient frontier" according to Markowitz's theory. This frontier is a hyperbolic line showing optimal portfolios considering rational investor preferences. The efficient frontier is a graph depicting the expected return on the y-axis and risk on the x-axis. The most efficient portfolios are those that provide the highest return at a certain risk level. Points above the efficient frontier line are unattainable, while portfolios below the frontier line are considered inefficient and require asset allocation adjustments to approach this efficient line, as explained (Huni & Sibindi, 2020).

Figure 2 illustrates the mean-variance efficient frontier, where the portfolios on the upper part of the curve are superior to those on the lower part. This is because the upper portion indicates a higher portfolio return for a given portfolio variance. Therefore, the upper boundary is the efficient frontier (Tan, 2023). Figure 2 shows that the efficient frontier produced by IDX30 using the Single Index Model is inefficient, as it lies below the efficient frontier line. The portfolio points generated by the Single Index Model are below the efficient frontier line, indicating that the Single Index Model yields the same risk but a lower return compared to the mean-variance approach.

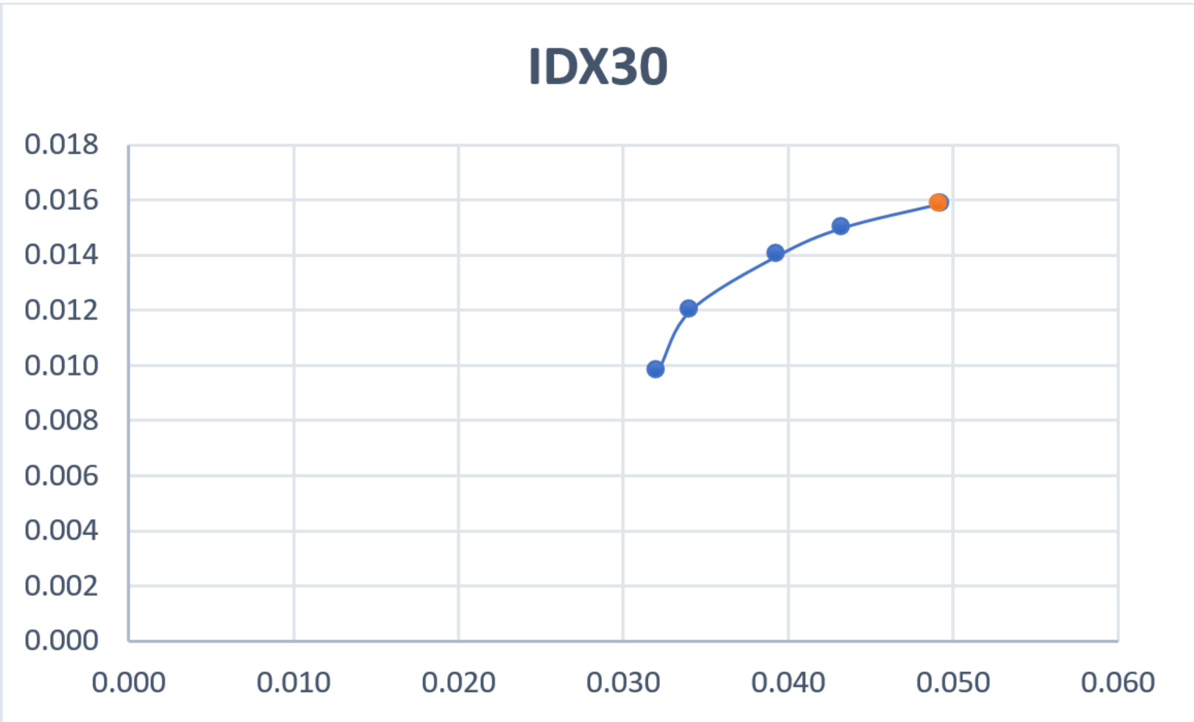

Figure 2. Efficient frontier IDX30.

Although the efficient frontier points of the Single Index Model and Mean-Variance 5 (MV-5) for IDX30 are nearly the same, it can be seen that at the same risk level, the expected return from the mean-variance approach is higher than that from the Single Index Model.

Figure 3 shows that the efficient frontier generated by the FTSE Bursa Malaysia KLCI using the Single Index Model is inefficient, as it lies below the efficient frontier line. The portfolio point produced by the Single Index Model is below the efficient frontier line, indicating that while the Single Index Model generates the same level of risk as the mean-variance model, it yields a lower return than the mean-variance model.

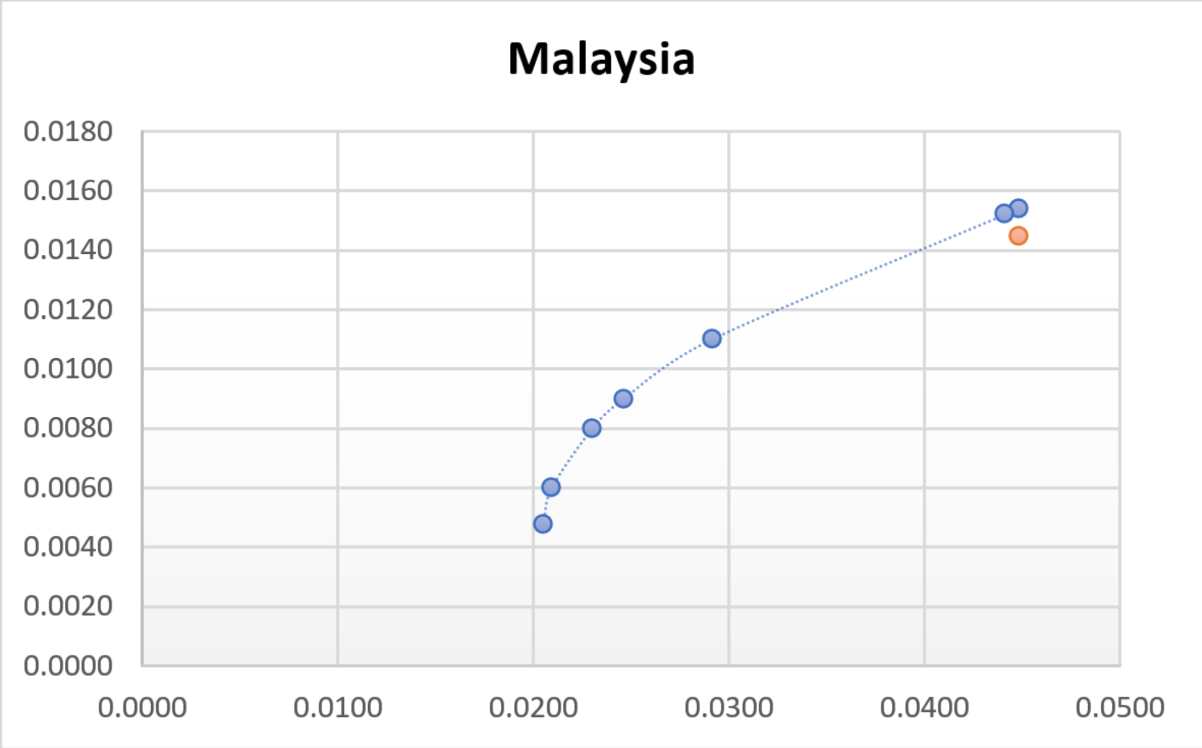

Figure 3. Efficient frontier IDX30.

According to research by Tan (2023), the efficient frontier points with higher portfolio weights have an advantage over those with lower weights, as the upper portfolio points indicate higher returns for a given portfolio variance. Therefore, the upper bound is considered the efficient boundary, and optimized portfolios will lie on this efficient boundary (Tan, 2023).

The Single Index Model ignores the cross-sectional covariance components, which can provide valuable information for managing portfolio risk. As a result, the solutions produced by the Single Index Model differ not only in the selection of stocks included in the portfolio but also in the number of stocks selected. Additionally, the tendency of the Single Index Model to over-diversify is not consistently related to the degree of freedom. However, it is more influenced by the methodology used to estimate residual variance statistics (Hammer & Phillips, 1992).

The smaller the Coefficient of Variation (CV), the lower the portfolio risk and the higher the expected return. Therefore, the optimal portfolio is considered to be the one with the lowest CV (Ren et al., 2021). According to research Deveci Kocakoç and Köymen Keser (2023), the CV is a highly useful descriptive statistic, especially when comparing the variability of more than two groups of curves. This holds true even when the variability results in significant differences in the mean curves. The CV, the ratio of the mean to the standard deviation, has a particular property that explicitly shows greater acceleration than the standard deviation function.

From Table 9, it is evident that when using the Markowitz Model to consider the smallest portfolio risk, the CV for the IDX30 index is 3.11, and for the FTSE Bursa Malaysia, the KLCI index is 3.10. However, when using the mean-variance model, the CV for the FTSE Bursa Malaysia KLCI index at the same risk level (MV-6) is 2.91, and the IDX30 index at the same risk level is 3.10.

Based on these calculations, one could conclude that the Mean-Variance model provides more optimal results for both the IDX30 and FTSE Bursa Malaysia KLCI indices, resulting in a smaller CV compared to the Single Index Model.

Table 9. Coefficient of variation of the Indonesia stock exchange and Bursa Malaysia.

Coefficient of variation	Mean-variance							Single index model
	MV-1	MV-2	MV-3	MV-4	MV-5	MV-6	MV-7	
IDX30	3.28	2.84	2.82	2.89	3.10			3.11
FTSE Bursa Malaysia KLCI	4.30	3.49	2.88	2.74	2.65	2.91	2.89	3.10

Source: *www.yahoo.finance.com* which is processed.

5. CONCLUSION

The Efficient Frontier line depicts a series of efficient portfolios with the lowest risk for each target level of return, as illustrated in Figures 2 and 3. Once the efficient frontier line is established, the task for investors is to select an appropriate portfolio from the points on the graph based on their risk preferences. Investors with low-risk tolerance tend to choose portfolios with a combination of risk and return located to the left of the frontier line. Conversely, those who are more willing to take on higher risks for greater gains are inclined towards portfolios on the right side of the frontier line.

Based on the research findings, it can be concluded that the use of Mean-Variance provides more optimal results compared to the Single Index Model in portfolio formation involving both the IDX30 index and the FTSE Bursa Malaysia KLCI index, with their fund proportions dominated by BBCA stocks for the IDX30 index and 4707 or Nestlé (Malaysia) stocks for the FTSE Bursa Malaysia KLCI index. It is evident that the calculation of an optimal portfolio, aided by data analysis tools and Excel's Solver, is primarily dominated by only a few stocks. Therefore, the key to effective diversification lies not solely in the number of assets forming the portfolio but rather in the efficient selection of those portfolio assets.

Future research should explore alternative optimization methods like Black-Litterman or machine learning, assess the impact of international diversification, examine the efficacy of sector diversification, analyze portfolio stability across different economic periods, and incorporate ESG factors in stock selection. Further research in these areas can provide additional valuable insights and aid in developing more comprehensive and adaptive investment strategies.

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REFERENCES

Akhter, A., Parvin, S., Mohammad, H., & Science, D. (2020). Optimal portfolio construction using sharpe's single index model: Evidence from Dhaka stock exchange in Bangladesh. *Journal of Science and Technology, 18*, 69–77.

Assof, M. S., Primayudha, R., & Retha, H. M. A. (2022). Portfolio management using the markowitz method to provide optimum investment weighting decisions. *Jurnal Kajian Ekonomi Dan Kebijakan Publik*, 7(1), 11-19.

Buttell, A. E. (2010). Harry M. Markowitz on modern portfolio theory, the efficient frontier, and his life's work. *Journal of Financial Planning, 18*(10), 54–61.

Chen, Y., Li, C., Hu, Y., & Lu, Z. (2023). A parallel non-convex approximation framework for risk parity portfolio design. *Parallel Computing, 116*, 102999. https://doi.org/10.1016/j.parco.2023.102999

Dai, L. (2023). Portfolio optimization using the Markowitz model and index model: A study on 10 selected stocks. *Highlights in Business, Economics and Management, 10*, 264–269. https://doi.org/10.54097/hbem.v10i.8050

Deveci Kocakoç, I., & Köymen Keser, I. (2023). Outlier detection based on the functional coefficient of variation. *Statistics in Transition New Series, 24*(2), 1-16. https://doi.org/10.59170/stattrans-2023-017

Hammer, J. A., & Phillips, H. E. (1992). The single-index model: Cross-sectional residual covariances and superfluous diversification. *International Review of Financial Analysis, 1*(1), 39-50. https://doi.org/10.1016/1057-5219(92)90013-T

Huni, S., & Sibindi, A. B. (2020). An application of the Markowitz's mean-variance framework in constructing optimal portfolios using the Johannesburg securities exchange tradeable indices. *The Journal of Accounting and Management, 10*(2), 41–57.

Indonesia Stock Exchange. (2021). *IDX stock index handbook V1.2. IDX Stock Index Handbook V1.2, 52.* Retrieved from https://www.idx.co.id/media/9816/idx-stock-index-handbook-v12-_-januari-2021.pdf

Ivanova, M., & Dospatliev, L. (2017). Application of Markowitz portfolio optimization on Bulgarian stock market from 2013 to 2016. *International Journal of Pure and Applied Mathematics, 117*(2), 291-307. https://doi.org/10.12732/ijpam.v117i2.5

Jin, M., Li, Z., & Yuan, S. (2021). *Research and analysis on Markowitz model and index model of portfolio selection.* Paper presented at the 2021 3rd International Conference on Economic Management and Cultural Industry (ICEMCI 2021), Guangzhou, China.

Juszczuk, P., Kaliszewski, I., Miroforidis, J., & Podkopaev, D. (2023). Expected mean return—standard deviation efficient frontier approximation with low-cardinality portfolios in the presence of the risk-free asset. *International Transactions in Operational Research, 30*(5), 2395-2414. https://doi.org/10.1111/itor.13121

Li, J. (2023). Application research of portfolio related theory--based on Hong Kong stock data. *Advances in Economics, Management and Political Sciences, 4*, 68-74. https://doi.org/10.54254/2754-1169/4/20221024

Lin, X., Xu, X., & Xu, Y. (2023). *Investment portfolio establishment based on markowitz model and highest sharpe ratio.* In Proceedings of the 4th International Conference on Economic Management and Model Engineering (ICEMME 2022, November 18-20, 2022, Nanjing, China). EAI.

Ling, L. P., & Dasril, Y. (2023). Portfolio selection strategies in bursa malaysia based on quadratic programming. *Journal of Information System Exploration and Research, 1*(2), 93-102. https://doi.org/10.52465/joiser.v1i2.178

Liu, Y. (2022). Barriers of good corporate governance practices: Evidence from emerging economy. *International Journal of Business and Management, 1*(1), 87-108.

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance, 7*(1), 77–91. https://doi.org/10.1111/j.1540-6261.1952.tb01525.x

Mistry, J., & Khatwani, R. A. (2023). Examining the superiority of the Sharpe single-index model of portfolio selection: A study of the Indian mid-cap sector. *Humanities and Social Sciences Communications, 10*(1), 1-9. https://doi.org/10.1057/s41599-023-01686-y

Norsiman, N. N. M., Yakob, N. Z., & Mcgowan, J. C. B. (2019). The effect of portfolio diversification for the Bursa Malaysia. *Accounting and Finance Research, 8*(4), 1-76. https://doi.org/10.5430/afr.v8n4p76

Ren, Y., Allenmark, F., Müller, H. J., & Shi, Z. (2021). Variation in the "coefficient of variation": Rethinking the violation of the scalar property in time-duration judgments. *Acta Psychologica, 214*, 103263. https://doi.org/10.1016/j.actpsy.2021.103263

Rout, S., & Panda, S. (2020). Optimal portfolio formation using the Single Index Model: Evidence from Indian stock market. *International Journal of Advanced Science and Technology, 29*(6), 10893–10906.

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

Tan, H. (2023). An empirical study on the Markowitz portfolio. *BCP Business & Management, 44*, 503–511. https://doi.org/10.54691/bcpbm.v44i.4861

Tang, G. Y. N., Kong, H., University, B., & Lee, R. S. K. (n.d.). Composition of mean-variance efficient portfolio: Taiwan and Malaysia.

Tian, Y. (2023). A simple study of the applicability of the Markowitz model in the current stock market. *BCP Business & Management, 44*, 527–536. https://doi.org/10.54691/bcpbm.v44i.4882

Verkino, B., Sinaga, B. M., & Andati, T. (2020). Optimal stock investment portfolio from 6 sectors in the LQ45 index for the 2015-2018 period. *Jurnal Aplikasi Bisnis Dan Manajemen, 6*(2), 389-402. https://doi.org/10.17358/jabm.6.2.389

Xie, D. (2021). Empirical study of Markovitz portfolio theory and model in the selection of optimal portfolio in Shanghai stock exchange of China. *Journal of Economics, Business and Management, 9*(4), 87-92. https://doi.org/10.18178/joebm.2021.9.4.661

Zakaria, S., Badrul Azhar, B. N. Y., Mohamad Rawi, I. N. A. M., & Mohamed Yusof, N. (2020). Performance of Kuala Lumpur composite index stock market. *Malaysian Journal of Computing, 5*(2), 553-562.