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Constructing Optimal Portfolios Using the Single Index Model and Markowitz Model: A Study on Cryptocurrencies

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Abstract

This study analyzes the formation of optimal portfolios on cryptocurrency assets using the single index model and the Harry Markowitz model. This study covers 79 cryptocurrencies with the largest market capitalization during the period June 2023–June 2024. We calculate the optimal portfolio using the single index model and Markowitz, and evaluate its performance using the Sharpe Ratio. The results show that the Harry Markowitz model produces better portfolio performance compared to the single index model. The Markowitz portfolio produces a positive Sharpe ratio (1.8496), a portfolio return rate of 7.678%, and lower risk (0.0415). Conversely, the single index model portfolio shows a negative Sharpe ratio (-2.0971), indicating lower returns than risk-free assets. In addition, the Markowitz model offers more efficient diversification than the single index model. However, in general, both the Single Index Model and the Markowitz Model have a significant effect on the formation of optimal portfolios, with the Sharpe Index proving to be a significant mediator in the relationship between the two models and the optimal portfolio. The R-squared value shows that the SIM variables, Markowitz Model, and Sharpe Index explain 48.4% of the variation in the optimal portfolio. This study recommends the use of the Harry Markowitz model for cryptocurrency investment because it can provide higher returns with more controlled risks. This study provides important insights for investors on the strategy of diversifying cryptocurrency asset portfolios.

Keywords: *Cryptocurrency, Optimal Portfolio, Single Index Model, Markowitz Model, Risk Management*

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INTRODUCTION

The Investment is the investment of capital in a type of business with the hope of making a profit from the activity (Yunita, 2023). The purpose of investing is to make the money we have work to get more value or profit from the effort, there are several options for investing such as in traditional assets (stocks, bonds, mutual funds, and shares) but with the changing financial industry comes one of the new investment alternatives, namely investing in crypto-currencies (Li et al., 2021). Cryptocurrency is a digital asset created as a digital medium of exchange that operates independently of an organization or central bank (Akadur & Senkardes, 2021). It employs cryptographic technology and is based on blockchain technology (Dong et al., 2023).

Blockchain technology is a digital ledger that records transactions in a transparent and immutable manner. These transactions are publicly accessible, and the technology's development has been accelerated by the advent of Industry 4.0. Blockchain technology is beginning to be utilized extensively in the financial sector, particularly in the domain of decentralized finance (DeFi). Apart from DeFi, numerous applications of blockchain technology can be observed in the financial industry, including the field of cryptocurrency (Sharma et al., 2021; Yuhanitha & Robiyanto, 2021).

As posited by (Brauneis, A., & Mestel, 2018), cryptocurrency represents a virtual currency generated and traded via a cryptographic process utilizing blockchain technology. According to data from STATISTA in the verified annual Cryptoasset user report, the number of users has increased exponentially, from 5 million in 2016 to 516 million in 2023. This illustrates the growing prominence of cryptocurrency as a viable investment option. Meanwhile, in Indonesia itself, the Commodity Futures Trading Supervisory Agency (BAPPEPTI) reports that 18.61 million individuals are registered as cryptocurrency investors, with the number of transactions in January–April 2024 reaching Rp. 211 trillion. This indicates that cryptocurrencies are a prominent investment option in Indonesia. This is corroborated by the Commodity Futures Trading Supervisory Agency Regulation Number 8 of 2021, which outlines guidelines for the physical market trading of cryptocurrencies (Cryptoasset) on futures exchanges (Letho et al., 2022; Putri et al., 2023).

Numerous researchers have investigated the potential for utilizing cryptocurrencies as alternative investments or a means of portfolio diversification. Abdelmalek, 2023; Ahmadi, 2023; Bartolucci & Kirilenko, 2020; Castro et al., 2020; Ichsani & Pamungkas, 2022; Lumbantobing & Sadalia, 2021; Ma et al., 2020; Moreno et al., 2022; Yahya, 2022 are among the scholars that have explored this subject. The growing number of investments in cryptocurrency in Indonesia indicates a rising interest and awareness among the Indonesian public in investing in this asset class. Consequently, investors must conduct a comprehensive portfolio analysis to maximize returns and minimize risk (Hrytsiuk et al., 2019; Meiryani et al., 2023; Yanida et al., 2023).

Cryptocurrency, as a digital asset that uses cryptography and blockchain technology to ensure transaction security, has grown rapidly in recent years and is increasingly attracting attention as an alternative investment (Akadur & Senkardes, 2021). Blockchain technology enables the creation of a transparent and immutable digital ledger, which has a major impact on the financial sector, especially in decentralized finance (DeFi) (Dong et al., 2023). In Indonesia, cryptocurrency is increasingly popular, with BAPPEPTI data showing more than 18 million crypto investors in 2024, indicating the importance of cryptocurrency as a rapidly growing investment instrument. In this context, the modern portfolio theory introduced by Harry Markowitz is an important foundation in forming an optimal portfolio (Yuliana & Robiyanto, 2022). The

Markowitz model prioritizes diversification to minimize risk and maximize returns, taking into account correlations between assets (Stiawan, 2022). Alternatively, the Single Index Model, developed by William Sharpe, simplifies this approach by using a market index as a single reference variable to calculate asset returns (Sasmita Rahma et al., 2022).

One way to evaluate portfolio performance is to use the Sharpe ratio, which measures how much return is generated compared to the risk taken. A high Sharpe ratio indicates that the portfolio provides good returns for a given level of risk, while a negative Sharpe ratio indicates that the return generated is lower than a risk-free investment, so the portfolio is considered inefficient (Sharpe, 1994). In addition, this study also uses Markowitz's theory, a theory that explains that investors can reduce the overall risk of a portfolio by choosing a combination of assets that are not fully correlated with each other. In this case, the risk in question is systematic risk that can be reduced through diversification. One of the main concepts in MPT is the efficient frontier, which is a graph that shows the combination of portfolios that produce the highest returns for a given level of risk or the lowest risk for a given level of return. Markowitz also emphasized the importance of choosing a portfolio that optimizes the relationship between risk and return, using the standard deviation measurement for risk. This theory teaches that by choosing assets that have a low correlation with each other, investors can reduce the overall volatility of the portfolio (Maf'ula et al., 2018).

The objective of this study is to construct an optimal portfolio using the single index model and the Harry Markowitz Model with 100 cryptocurrencies included in the 100 largest market caps recorded from June 2023 to June 2024. Following the construction of the optimal portfolio, the performance of the portfolio will be evaluated using the Sharpe Ratio to determine which method produces the most favorable results. In accordance with the theoretical framework and methodological approach employed, this research utilizes quantitative methods. The sample for this study comprises 79 cryptocurrencies, representing 79% of the total population of 100 cryptocurrencies. In addition, this study employs the monthly closing price of each cryptocurrency, the closing price of the JCI as a market index, and the Bank Indonesia interest rate as a risk-free interest rate.

The figure 1 is a conceptual framework in this study where the independent variables are the single index model and the Harry Markowitz Model with the mediator variable Sharpe index, and the dependent variable is the optimal portfolio.

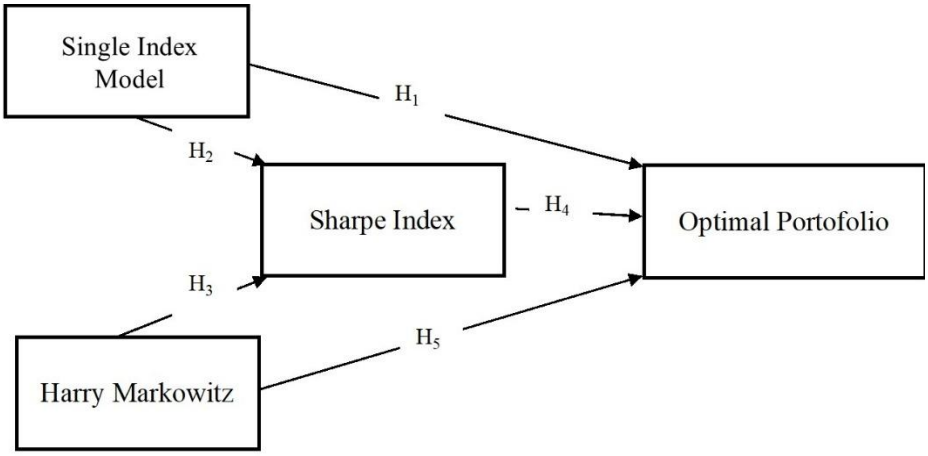

Figure 1. Conceptual Framework
Source: Processed data, 2024

As defined by (Hardani, 2020) a hypothesis is a provisional explanation that guides a study. It is, therefore, an essential component of any study. In this study, the author presents the following hypothesis:

H_1 : The single index model affects the creation of the optimal portfolio.

H_2: The single index model is subject to influence from the Sharpe index regarding the creation of an optimal portfolio.

H_3: The Harry Markowitz model is influenced by the Sharpe index with respect to the creation of an optimal portfolio.

H_4: The Sharpe Index affects the creation of the optimal portfolio.

H_5: The Harry Markowitz model affects the creation of an optimal portfolio.

RESEARCH METHOD

Quantitative Method

Single Index Model

The single index model is a statistical model that calculates the return of a stock by dividing the effect on the return of the market index. The model was developed by William Sharpe because of simplifying the mean-variance model with the aim of overcoming the complexity inherent in the preparation of an optimal portfolio (Sasmita Rahma et al., 2022). The single index model can be calculated as follows:

1. Calculate the Total Return of each type of cryptocurrency using the formula:
   $Total\ Return\ = \frac{P_t - P_{t-1}}{P_{t-1}}$

   In this study, we used the monthly closing of each cryptocurrency.

2. Calculating Expected Return for each stock
   $Expected\ Return\ = \frac{\sum_{i-1}^{n} R_i}{P_{t-1}}$

3. Calculating excess return to beta (ERB) using the formula:
   $ERB_i = \frac{E(R_i) - R_{BR}}{\beta_i}$

4. Calculate the cut-off point (Ci) using the formula:
   $$C_i = \frac{\sigma M^2 \sum_{j=i}^{i} A_i}{1 + \sigma M^2 \sum_{j=i}^{i} B_i}$$

5. Calculate the proportion of each cryptocurrency using the formula:
   $W_i = \frac{Z_i}{\sum_{j=i}^{k} Z_j}$ with $Z_i = (ERB - C*)\frac{\beta_i}{\sigma ei^2}$

In making the optimal portfolio using the single index model, the ERB value must be greater than the C* value, the C* value is obtained from the highest Ci value (Solin et al., 2019).

Model Harry Markowitz

Modern portfolio theory was developed by Henry Markowitz as a means of enabling investors to mitigate risk while constructing a diversified portfolio, thereby maximizing returns while managing risk within acceptable limits. Stiawan, (2022) to perform Markowitz calculations, you can do:

1. Calculating the return of each cryptocurrency using the formula:
   $$\frac{Pt - Pt - 1}{Pt - 1}$$
2. Calculating Expected Return on each cryptocurrency using the formula:
   $$E(R) = \sum_{I=1}^{N} R_i Pr_i$$
3. Calculating the Risk

   To ascertain the risk (variance and standard deviation) of an investment in each asset, it is essential to measure the risk to establish the probability that the obtained value will deviate from the expected value. The following formula may be employed for this purpose:

   Variance *return* $= \sigma^2 = \sum [R_i - E(R)]^2 \, Pr_i$

   Standard Deviation = $\sigma = (\sigma^2)^{\frac{1}{2}}$

   In measuring the risk of securities, it is also necessary to calculate the risk per unit of expected return. The relative risk measure that can be used is the variation coefficient. With the formula:

   Coefficient = $\frac{Standard\ deviation\ return}{Expected\ Return}$

4. Calculating the covariance between stocks in a portfolio, the formula used to calculate the covariance is as follows:
   $$\rho\sigma_{AZ} = \sum_{i=1}^{m} [R_{A,i} - E(R_A)] \ldots [R_{Z,i} - E(R_Z)] \, Pr_i$$

   Formula:

   $$\rho = \frac{n \sum XY = (\sum X)(\sum Y)}{\sqrt{(n \sum X^2)} \, (\sum X)^2 \sqrt{(n \sum Y^2)} \, (\sum Y)^2}$$

   a) Determining the proportions of candidate portfolio assets.
   b) Calculating the expected return of a portfolio can be calculated using the formula:
   $$E(R_p) = \sum_{i=1}^{n} W_i E(R_i)$$

5. Calculate the risk (Variance and Standard Deviation) of the portfolio as follows:
   $$\sigma_p = [W_A^2 \sigma_A^2 + W_B^2 \sigma_B^2 + 2(W_A)(W_B)(\rho_{AB})\sigma_A \sigma_B]^{\frac{1}{2}}$$

Sharpe

Sharpe performance is a method used to assess Sharpe performance, measured by comparing the risk premium during the sample period with the portfolio risk expressed as a standard deviation using the following formula.

$$S_i = \frac{R_i - RFR}{\sigma_i}$$

Optimal Portfolio

As posited by (Zhang, 2022), a portfolio represents an investment approach that combines a variety of assets into a unified portfolio with the objective of reducing investment risk. Consequently, this research is centered on the identification of an optimal portfolio of crypto assets. The objective of the research is to identify an optimal portfolio of crypto assets that offers the highest possible return with a correspondingly low level of risk.

In this study, stablecoins were excluded from the analysis for several reasons. First, stablecoins do not meet the required data criteria, such as the volatility required in forming an optimal portfolio. In addition, the research objectives that focus on the analysis of returns and risks become less relevant if stablecoins, which have low volatility because their values are pegged to certain assets such as the US dollar, are included. By excluding stablecoins, this study avoids potential bias in the results, especially in affecting the average portfolio return, which tends to be lower.

The data preprocessing process in this study was carried out in several stages. First, of the 100 cryptocurrencies with the largest market capitalization, only 79 assets were used after stablecoins were excluded. The data collected included the monthly closing price of each cryptocurrency, the closing price of the JCI as the market index, and the Bank Indonesia interest rate as the risk-free rate. This closing price data was then processed to calculate total returns, expected returns, risk (variance and standard deviation), and relationships between assets using the Single Index Model and Markowitz Model methods.

Furthermore, data that did not meet the criteria or had discrepancies in the calculations were removed from the dataset. To ensure consistency of calculations, data is processed using mathematical formulas such as Excess Return to Beta (ERB), systematic risk, and unsystematic risk. Data validity is tested using several parameters, namely outer loading (>0.7), average variance extracted (AVE, >0.5), and composite reliability (>0.7). This preprocessing stage is designed to ensure that the data used is qualified and relevant for optimal portfolio analysis in the context of cryptocurrency.

RESULTS AND DISCUSSION

Results

The following Table 1 is the calculation result for optimal portfolio construction using single index model.

Table 1. Single Index Model Calculation

Cryptocurrency	α	B	unsystematic risk	ERB	Ci	C*	Decision
GALA	0,0776	-0,2292	0,1572	1,8380	0,0004	0,0420	OPTIMAL
XTZ	0,0067	-0,9007	0,0302	0,5430	0,0084	0,0420	OPTIMAL

Cryptocurrency	α	B	unsystematic risk	ERB	Ci	C*	Decision
FLOW	0,0422	-0,8785	0,0726	0,5163	0,0032	0,0420	OPTIMAL
SAND	0,0106	-0,9847	0,0661	0,4923	0,0042	0,0420	OPTIMAL
ATOM	-0,0171	-1,0583	0,0279	0,4838	0,0111	0,0420	OPTIMAL
AXS	0,0250	-1,0317	0,0556	0,4557	0,0051	0,0420	OPTIMAL
PENDLE	0,2125	-0,7651	0,1551	0,3710	0,0008	0,0420	OPTIMAL
INJ	0,1440	-1,1093	0,1377	0,3162	0,0016	0,0420	OPTIMAL
XRP	-0,0296	-1,6826	0,0193	0,3100	0,0245	0,0420	OPTIMAL
LDO	0,0075	-1,7038	0,0456	0,2843	0,0102	0,0420	OPTIMAL
CHZ	0,0237	-1,7333	0,0592	0,2701	0,0078	0,0420	OPTIMAL
PEPE	0,3941	-0,4470	0,7842	0,2322	0,0000	0,0420	OPTIMAL
THETA	0,1108	-1,7003	0,1369	0,2241	0,0027	0,0420	OPTIMAL
BEAM	0,0626	-1,9379	0,1967	0,2209	0,0024	0,0420	OPTIMAL
FET	0,2645	-1,0747	0,3140	0,2144	0,0005	0,0420	OPTIMAL
ETC	0,0236	-2,1768	0,0258	0,2141	0,0208	0,0420	OPTIMAL
OKB	-0,0048	-2,4359	0,0193	0,2025	0,0308	0,0420	OPTIMAL
XLM	-0,0437	-2,6621	0,0204	0,1995	0,0337	0,0420	OPTIMAL
MATIC	-0,0092	-2,7173	0,0426	0,1826	0,0168	0,0420	OPTIMAL
ETH	0,0550	-2,3875	0,0304	0,1816	0,0180	0,0420	OPTIMAL
LEO	0,0242	-2,5978	0,0128	0,1784	0,0420	0,0420	OPTIMAL
BTC	0,0667	-2,4679	0,0296	0,1708	0,0184	0,0420	OPTIMAL
BGB	0,0752	-2,6007	0,0394	0,1586	0,0145	0,0420	OPTIMAL
GRT	0,0974	-2,5063	0,1134	0,1559	0,0049	0,0420	OPTIMAL
LTC	-0,0182	-3,3180	0,0335	0,1514	0,0245	0,0420	OPTIMAL
ADA	0,0339	-3,0151	0,0630	0,1498	0,0117	0,0420	OPTIMAL
KCS	0,0460	-3,1011	0,0701	0,1416	0,0105	0,0420	OPTIMAL
VET	0,0497	-3,2128	0,0878	0,1354	0,0087	0,0420	OPTIMAL
NEXO	0,0512	-3,3138	0,0439	0,1307	0,0167	0,0420	OPTIMAL
STX	0,1378	-2,7759	0,2023	0,1257	0,0027	0,0420	OPTIMAL
ROSE	0,0881	-3,1660	0,1116	0,1254	0,0063	0,0420	OPTIMAL
DOT	0,0212	-4,0276	0,0571	0,1141	0,0163	0,0420	OPTIMAL
HBAR	0,0395	-4,0456	0,0694	0,1091	0,0132	0,0420	OPTIMAL
OP	0,0418	-4,5476	0,1625	0,0960	0,0067	0,0420	OPTIMAL
IMX	0,1081	-4,3519	0,1682	0,0853	0,0053	0,0420	OPTIMAL
MKR	0,0728	-4,7514	0,0924	0,0852	0,0107	0,0420	OPTIMAL
BNB	0,0683	-4,8994	0,0505	0,0834	0,0182	0,0420	OPTIMAL
ENS	0,1140	-4,7011	0,1232	0,0774	0,0074	0,0420	OPTIMAL
FIL	0,0242	-5,9398	0,1203	0,0754	0,0110	0,0420	OPTIMAL
AVAX	0,1083	-4,9563	0,1586	0,0743	0,0062	0,0420	OPTIMAL
RNDR	0,1607	-4,4019	0,1188	0,0723	0,0063	0,0420	OPTIMAL

Cryptocurrency	α	B	unsystematic risk	ERB	Ci	C*	Decision
GNO	0,0787	-6,2951	0,1200	0,0622	0,0101	0,0420	OPTIMAL
UNI	0,0731	-6,4786	0,1450	0,0612	0,0089	0,0420	OPTIMAL
AGIX	0,1476	-5,4526	0,3106	0,0599	0,0032	0,0420	OPTIMAL
FLR	0,0485	-7,1603	0,1378	0,0583	0,0104	0,0420	OPTIMAL
SOL	0,1986	-4,9684	0,1485	0,0559	0,0050	0,0420	OPTIMAL
ORDI	0,4465	-0,9373	1,3345	0,0523	0,0000	0,0420	OPTIMAL
DOGE	0,0466	-8,4345	0,1480	0,0490	0,0108	0,0420	OPTIMAL
ICP	0,1171	-7,6376	0,3712	0,0454	0,0038	0,0420	OPTIMAL
BCH	0,0461	-9,6705	0,2098	0,0422	0,0087	0,0420	OPTIMAL
NEAR	0,1411	-8,4018	0,1959	0,0380	0,0066	0,0420	-
SHIB	0,0733	-12,3172	0,2741	0,0299	0,0073	0,0420	-
JASMY	0,2650	-16,5723	0,9534	0,0094	0,0014	0,0420	-
SUI	0,4709	-57,0543	9,8394	-0,0042	-0,0007	0,0420	-
FLOKI	0,4535	13,4237	1,2163	-0,0082	-0,0007	0,0420	-
CORE	0,4210	13,7834	1,2766	-0,0105	-0,0008	0,0420	-
ARB	0,3470	7,5677	1,6813	-0,0250	-0,0005	0,0420	-
AR	0,3164	8,0446	0,4316	-0,0276	-0,0022	0,0420	-
TON	0,2255	6,9038	0,1437	-0,0445	-0,0072	0,0420	-
RUNE	0,2288	5,5218	0,2209	-0,0539	-0,0040	0,0420	-
FTM	0,1470	5,9374	0,1985	-0,0642	-0,0060	0,0420	-
GT	0,1062	4,6249	0,1145	-0,0899	-0,0089	0,0420	-
AKT	0,2326	2,7385	0,1071	-0,1024	-0,0040	0,0420	-
KAS	0,2306	2,6732	0,2433	-0,1055	-0,0018	0,0420	-
BSV	0,0818	3,5886	0,1651	-0,1213	-0,0053	0,0420	-
CFX	0,0503	2,4422	0,1192	-0,1889	-0,0054	0,0420	-
JUP	0,0333	2,0364	0,3713	-0,2339	-0,0015	0,0420	-
LINK	0,0925	1,5695	0,0625	-0,2644	-0,0060	0,0420	-
QNT	-0,0061	1,5362	0,0326	-0,3342	-0,0136	0,0420	-
XMR	0,0179	1,2208	0,0139	-0,3997	-0,0236	0,0420	-
ALGO	0,0598	0,9587	0,0766	-0,4639	-0,0032	0,0420	-
TRX	0,0489	0,9734	0,0099	-0,4682	-0,0249	0,0420	-
APT	0,0392	0,7168	0,0707	-0,6477	-0,0027	0,0420	-
EOS	0,0030	0,5834	0,0396	-0,8566	-0,0043	0,0420	-
EGLD	0,0193	0,3456	0,0709	-1,3957	-0,0014	0,0420	-
NEO	0,0340	0,1967	0,0379	-2,3743	-0,0014	0,0420	-
CRO	0,0640	0,1370	0,0511	-3,1867	-0,0007	0,0420	-
RONIN	0,1525	0,0859	0,1886	-4,0515	-0,0001	0,0420	-
AAVE	0,0457	0,0715	0,0403	-6,3588	-0,0005	0,0420	-

Source: Processed data, 2024

The average interest rate of the Indonesian bank for the June 2023-June 2024 period is 0.50 with an expected market return of -0.0047. From the table1, out of 100 cryptocurrencies that entered the calculation, only 79 cryptocurrencies were included in the calculation because in this study stable coins were excluded from the calculation by deleting several coins because the available data did not enter the criteria. Of the 79 cryptocurrencies included in the portfolio, only 50 cryptocurrencies are included in the optimal portfolio, for the calculation of the proportion for each type of cryptocurrency included in the single index model (Table 2).

Table 2. Single Index Model Optimal Portfolio

No	Cryptocurrency	Weight	No	Cryptocurrency	Weight
1	LEO	9,6230%	26	GRT	0,8777%
2	XRP	8,1469%	27	ROSE	0,8246%
3	XLM	7,1481%	28	THETA	0,7887%
4	OKB	7,0450%	29	MKR	0,7736%
5	ATOM	5,8359%	30	INJ	0,7703%
6	XTZ	5,2000%	31	BEAM	0,6145%
7	ETC	5,0590%	32	FIL	0,5743%
8	ETH	3,8213%	33	PENDLE	0,5660%
9	LTC	3,7831%	34	OP	0,5271%
10	BTC	3,7462%	35	ENS	0,4705%
11	LDO	3,1557%	36	STX	0,4005%
12	MATIC	3,1243%	37	RNDR	0,3920%
13	BGB	2,6801%	38	IMX	0,3908%
14	AXS	2,6775%	39	GNO	0,3692%
15	SAND	2,3401%	40	AVAX	0,3520%
16	NEXO	2,3353%	41	UNI	0,2985%
17	CHZ	2,3271%	42	FLR	0,2958%
18	FLOW	2,0015%	43	FET	0,2057%
19	ADA	1,7997%	44	SOL	0,1624%
20	DOT	1,7733%	45	DOGE	0,1395%
21	KCS	1,5362%	46	AGIX	0,1095%
22	BNB	1,4005%	47	PEPE	0,0378%
23	HBAR	1,3634%	48	ICP	0,0244%
24	VET	1,1923%	49	BCH	0,0032%
25	GALA	0,9133%	50	ORDI	0,0025%

Source: Processed data, 2024

From the Table 2 there are 50 cryptocurrencies that have different weights, the largest weight is held by LEO of 9.623% and the smallest proportion is ORDI of 0.003%. After making the proportion, the next step is to calculate the risk and expected return of the portfolio with the results (Table 3).

Table 3. Expected return market and expected return portfolio

E(rm)	Variance Market	Standard Deviation Market	Expected Return Portfolio	Variance Portfolio	Standard Deviation Portfolio
-0,0047	0,0006	0,0241	0,0327	0,2635	0,5133

Source: Processed data, 2024

From the results of the Table 3, the portfolio using the single index model is generating an Expected Return of 0.0327 or 3.27% greater than the expected return market of -0.0047 or -0.4747%, this shows that the performance of cryptocurrencies is more favorable than market conditions.

Harry Markowitz

After conducting the correlation coefficient in the study using Microsoft excel software with the solve model for the formation of weight, risk and sharpe ratio with several results (Table 4).

Table 4. Sharpe Ratio Max

Cryptocurrency	Weight
TRX	34,553%
XMR	23,803%
UNI	15,031%
LINK	9,570%
AR	7,616%
MKR	5,610%
KAS	3,812%
SHIB	0,006%

Source: Processed data, 2024

Table 4 shows the proportion of each cryptocurrency by maximizing the sharpe value, with the above weights having a sharpe ratio value of 1.849 with a risk level of 0.4151. As for the Table 5 shows for modeling that emphasizes risk, the largest weighting is in the JCI asset type with a proportion of 75.91%, the risk selection model with minimal risk has a sharpe ratio value of 0.536 with a risk of 0.0134. From Tables 3 dan Table 4, an investor can choose based on the investor's tolerance level by adjusting the sharpe ratio and risk, because in Markowitz modeling investors can choose a portfolio according to the investor's risk profile.

Ratio Sharpe

The sharpe ratio is a method used to assess the work of a portfolio, the sharpe ratio is measured by measuring the performance of a portfolio by considering its risk, the sharpe ratio calculates whether the returns obtained are commensurate with the risks taken in this study (Table 6).

Table 5. Minimum RISK

Asset	Weight
IHSG	75,91%
LEO	6,84%
XMR	6,15%
OKB	3,90%
HBAR	2,53%
UNI	2,35%
ENS	1,02%
MKR	0,56%
AR	0,48%
JUP	0,26%
SHIB	0,01%

Source: Processed data, 2024

From Table 6 shows the value of the sharpe ratio of each portfolio, the single index model has a negative value indicating that the single index model produces a smaller rate of return compared to risk-free assets, it can be concluded that the single index model not only has a lower return compared to investing in risk-free assets but also has a greater risk compared to risk-free assets. While the sharpe ratio results on the Markowitz model have a sharpe value of 1.8496, this shows that using the Markowitz model produces a high rate of return compared to risk-free assets and investors are advised to choose a portfolio generated by Markowitz compared to portfolio results using a single index model.

Table 6. Ratio Sharpe

	SIM	Markowitz Sharpe Max	Markowitz Minimum Risk
σ	0,2228	0,0415	0,0134
Sharpe	-2,0971	1,8496	0,5356

Source: Processed data, 2024

Then a negative Sharpe ratio indicates that the portfolio generates a lower rate of return compared to the rate of return of the risk-free asset. In this study, the portfolio generated by the single index model has a Sharpe ratio of -2.0971, indicating that investors using this model not only receive lower returns than risk-free investments but also take additional risks that do not provide commensurate compensation. This indicates that the portfolio is inefficient in managing risk and return, so it is not worthy of being an investment choice. As an implication, investors should allocate their funds to risk-free assets such as government bonds or fixed-interest savings, because a portfolio with a negative Sharpe ratio does not provide additional benefits compared to the risk taken.

For investors, a negative Sharpe ratio provides important insight into the lack of portfolio efficiency and the need to avoid risks that are not commensurate with returns. Portfolios that have negative Sharpe ratios also emphasize the importance of re-evaluating the investment methods

used. In this study, the portfolio generated by the Harry Markowitz model has a positive Sharpe ratio of 1.8496, indicating that this model is better able to manage risk and generate better returns. Therefore, investors are advised to choose a portfolio generated by the Markowitz model. In addition, a negative Sharpe ratio also provides a warning for conservative investors or those who focus on capital protection to avoid such underperforming portfolios. Additional diversification can also be a strategy to improve portfolio performance. Thus, a negative Sharpe ratio is a signal for investors to be more selective in choosing an investment model that is able to provide returns that are in accordance with the level of risk taken.

Optimal Portfolio

The optimal portfolio that has been formed will be evaluated using the sharpe ratio with the following results (Table 7).

Table 7. Optimal Portfolio

	SIM	Markowitz Sharpe Max	Markowitz Minimum Risk
σ	0,2228	0,0415	0,0134
Sharpe	-2,0971	1,8496	0,5356

Source: Processed data, 2024

Table 7 shows the calculation of the sharpe ratio show that the portfolio formed using Markowitz has a better value than the portfolio formed using a single index model, according to the sharpe ratio can provide return compensation for each total risk of 1.8496.

Validity Test

Based on the outer loading validity test Figure 2, it is known that all outer loading values are > 0.7, which means that they have met the validity requirements based on the outer loading value. Furthermore, Table 8 shows validity testing is carried out based on the average variance extracted (AVE) value.

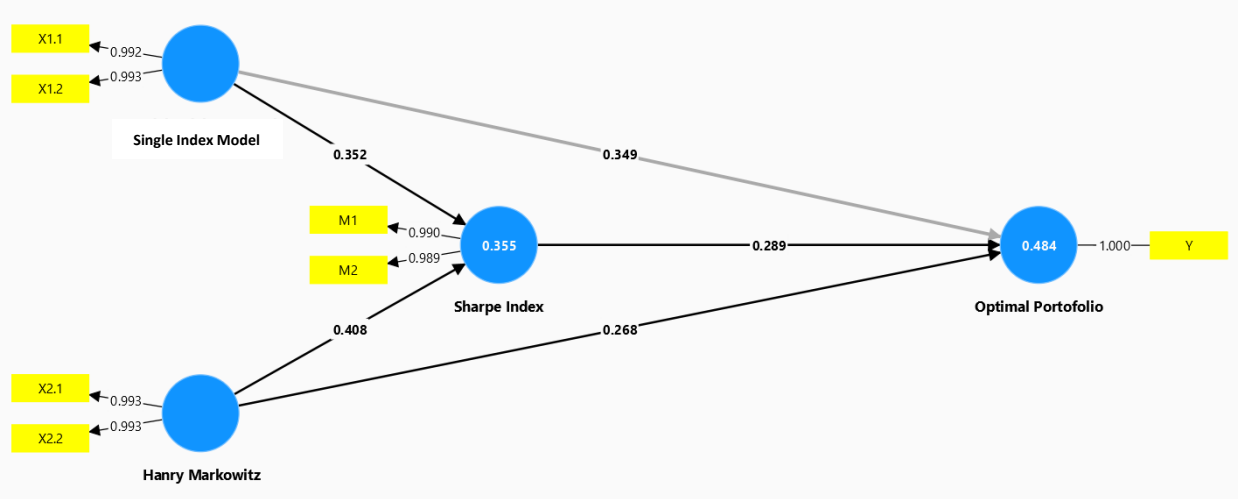

Figure 2. Based on Outer Loading

Source: Processed data, 2024

Table 8. Validity Test Use Average Variance Extracted

	Average variance extracted (AVE)
Harry Markowitz	0.986
Single Index Model	0.985
Sharpe Index	0.979

Source: Processed data, 2024

Average Variance Extracted (AVE)

The recommended AVE value (Table 8) is more than 0.5. It is known that all AVE values are> 0.5, which means that they have met the validity requirements based on AVE. Furthermore, reliability testing is carried out based on the composite reliability (CR) value.

Table 9. Validity Test Use Composite Reliability (CR)

	Composite reliability (rho_c)
Harry Markowitz	0.993
Single Index Model	0.993
Sharpe Index	0.990

Source: Processed data, 2024

Composite Reliability (CR)

The recommended CR value (Table 9) is more than 0.7. It is known that all CR values > 0.7, which means that they have met the reliability requirements based on CR. Furthermore, reliability testing was carried out based on the Cronbach's alpha (CA) value.

Table 10. Validity Test Use Croncbach Alpa

	Cronbach's alpha
Harry Markowitz	0.986
Model Indeks Tunggal	0.985
Sharpe Index	0.979

Source: Processed data, 2024

Cronbach's Alpha (CA)

The recommended CA value (Table 10) is more than 0.7. It is known that all CA values are > 0.7, which means that they have met the reliability requirements based on Cronbach's alpha. Furthermore, discriminant validity testing was carried out with the Fornell-Larcker approach. Table 10. presents the results of discriminant validity testing.

Significance Test of Effect

Based on the test results in Table 11, it was found that Harry Markowitz has a significant effect on the Optimal Portfolio, with a T-Statistic of 5.100, which is greater than 1.96, and a P-Value of 0.000, which is less than 0.05. This supports the acceptance of the hypothesis stating this influence. Furthermore, Harry Markowitz also significantly affects the Sharpe Index, as evidenced by a T-Statistic of 10.394, which exceeds 1.96, and a P-value of 0.000. Therefore, this hypothesis is accepted as well. In addition, the Single Index Model demonstrates a significant effect on the

Optimal Portfolio, with a T-statistic of 8.360, which is greater than 1.96, and a P-value of 0.000, supporting the hypothesis's acceptance. The Single Index Model also has a significant effect on the Sharpe Index, as indicated by a T-statistic of 9.361, which exceeds 1.96, and a P-value of 0.000. Thus, this hypothesis is also accepted.

Table 11. Significance Test of Effect

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Hanry Markowitz -> Optimal Portfolio	0.268	0.264	0.053	5.100	0.000
Hanry Markowitz -> Sharpe Index	0.408	0.412	0.039	10.394	0.000
Single Index Model -> Optimal Portfolio	0.349	0.352	0.042	8.360	0.000
Single Index Model -> Sharpe Index	0.352	0.350	0.038	9.361	0.000
Sharpe Index -> Optimal Portfolio	0.289	0.289	0.056	5.153	0.000
Hanry Markowitz -> Sharpe Index -> Optimal Portfolio	0.118	0.119	0.027	4.407	0.000
Single Index Model -> Sharpe Index -> Optimal Portfolio	0.102	0.101	0.023	4.470	0.000

Source: Processed data, 2024

Table 11 shows that Sharpe Index is proven to have a significant effect on the Optimal Portfolio, with a T-Statistic of 5.153, which is greater than 1.96, and a P-Value of 0.000, which is less than 0.05. This supports the acceptance of the hypothesis. Moreover, the Sharpe Index plays a significant mediating role in the relationship between Harry Markowitz and the Optimal Portfolio, as evidenced by a T-Statistic of 4.407 and a P-Value of 0.000. Consequently, the mediation hypothesis is accepted. Similarly, in the relationship between the Single Index Model and the Optimal Portfolio, the Sharpe Index shows a significant mediating role, with a T-Statistic of 4.470, which exceeds 1.96, and a P-Value of 0.000. Therefore, this mediation hypothesis is also accepted.

Table 11. R Square

	R-square
Optimal Portfolio	0.484
Sharpe Index	0.355

Source: Processed data, 2024

The R-Square value of the Optimal Portfolio is 0.484, which means the Single Index Model, Harry Markowitz, Sharpe Index can explain or influence the Optimal Portfolio by 48.4%, the remaining 51.6% is influenced by other factors. The R-Square value of the Sharpe Index is 0.355, which means the Single Index Model, Harry Markowitz can explain or influence the Sharpe Index by 35.5%, the remaining 64.5% is influenced by other factors.

Discussion

In previous research that has been done by previous researchers, it shows different things in previous researchers who produced optimal portfolios using the single index model. As for the results of this study are the same as the results of research (Aljinović et al., 2021) In this study, cryptocurrency is also suitable to be used as a diversified portfolio in accordance with the results of research from the Harry Markowitz Model (Colombo et al., 2019).

By conducting an analysis of cryptocurrencies in cryptocurrency assets that are in the 100 largest market capitalizations for the period June 2023 - June 2024 which are included in the optimal portfolio using a single index model, only 50 cryptocurrencies. Using a single index model has an expected portfolio return of 3.266% which is greater than investing in the JCI market, for the JCI expectation value of -0.475, this shows that the optimal portfolio using the single index model has better performance than the general market conditions. But with a high level of expectation there is a greater risk compared to the JCI, the single index model portfolio risk is at 4.97% more this decision is returned to investors.

By conducting an analysis of cryptocurrencies in cryptocurrency assets that are in the 100 largest market capitalizations for the period June 2023 - June 2024 which are included in the optimal portfolio using the Harry Markowitz model, there are only 8 cryptocurrencies for the maximum sharpe ratio option and 11 cryptocurrencies for the lower risk option with the following proportions: TRX 34.553%, XMR 23.803%, UNI 15.031%, LINK 9.570%, AR 7.616%, MKR 5.610%, KAS 3.812%, and SHIB 0.006% with a risk level of 0.0415 and has a portfolio return expectation value of 7.678% (Sahu et al., 2024). Meanwhile, the least risk has a proportion of: JCI 75.91%, LEO 6.84%, XMR 6.15%, OKB 3.90%, HBAR 2.53%, UNI 2.35%, ENS 1.02%, MKR 0.56%, AR 0.48%, JUP 0.26% and SHIB 0.01% with a portfolio risk level of 0.0134 and a portfolio return expectation of 0.72% this is still better than the market return level of -0.475.

According to the results of the calculation of the optimal portfolio evaluation that has good performance is the optimal portfolio creation using the Harry Markowitz model because it has a positive sharpe ratio value, this is inversely proportional to the results of the calculation of the single index model which has a negative ratio. The evaluation of the optimal portfolio highlights that the Harry Markowitz model demonstrates better performance compared to the Single Index Model. This is due to the positive Sharpe ratio produced by the Harry Markowitz model, indicating superior risk-adjusted returns, while the Single Index Model yields a negative Sharpe ratio. The analysis also reveals that the Harry Markowitz model and the Single Index Model significantly influence the construction of optimal portfolios and the Sharpe Index. Moreover, the Sharpe Index plays a crucial role in connecting both models to the optimal portfolio, acting as a significant mediating variable. These findings suggest that the Harry Markowitz model is more effective in creating an optimal portfolio, offering better returns relative to risk, and reinforcing its practical application in portfolio management. The mediating role of the Sharpe Index further emphasizes its importance in assessing and improving portfolio performance.

CONCLUSION

This study evaluates the construction of optimal portfolios using the single index model and the Harry Markowitz model in the context of cryptocurrency investment. The results show that the Harry Markowitz model outperforms the single index model in forming optimal portfolios. The portfolios consist of cryptocurrencies with various types of cryptocurrencies, excluding stablecoins, and consider factors such as average interest rates and expected market returns. The

Sharpe Index is used to evaluate portfolio performance, with certain cryptocurrencies identified as optimal in the constructed portfolios.

Validity and hypothesis tests show that the single index model and the Harry Markowitz model have a significant effect on the formation of optimal portfolios. The research findings, the use of the Harry Markowitz model is recommended for cryptocurrency investors because it is able to offer higher returns with more controlled risks. This study provides important insights for investors to utilize cryptocurrency assets as a portfolio diversification tool with a more sophisticated quantitative approach.

This study contributes to the understanding of portfolio optimization in the cryptocurrency market, highlighting the importance of utilizing sophisticated models such as the Harry Markowitz model to improve the risk-return trade-off. By analyzing cryptocurrency performance using these models, investors can make informed decisions to maximize returns while effectively managing risk. The findings suggest that the Harry Markowitz model is a valuable tool for constructing optimal portfolios in the dynamic and volatile cryptocurrency market, offering insights for investors looking to navigate this asset class efficiently.

This study has several limitations, including that this study only focuses on cryptocurrencies with the largest market capitalization, so it does not reflect the potential for diversification or returns from small-cap cryptocurrencies. This study uses a single index model and the Harry Markowitz model, which have certain theoretical assumptions such as the normal distribution of asset returns and investor rationality, although the reality of the cryptocurrency market often deviates from these assumptions. In addition, external factors such as regulation, market sentiment, and adoption of blockchain technology are not directly analyzed, even though these factors can significantly affect cryptocurrency performance.

Furthermore, to extend the analysis period to capture more comprehensive market dynamics, including bullish and bearish cycles. Further research also needs to include small-cap cryptocurrencies to explore the potential for diversification and broader returns. In addition, considering external factors such as monetary policy, government regulation, and adoption of blockchain technology can provide more relevant and contextual results. Modern approaches, such as machine learning or artificial neural networks, can also be used to predict returns and risks with higher accuracy. Market sentiment analysis through social media or news data can also be a valuable addition in understanding the influence of sentiment on cryptocurrency performance. Finally, testing portfolio performance under various market conditions, such as high volatility, economic crises, or growth periods, will help generate more adaptive recommendations for investors. Thus, future research can provide deeper and more applicable insights in the context of cryptocurrency investment

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List of Abbreviations

There are no additional abbreviations that need to be explained for this document.

Authors' Contribution

Eko Sanjaya Nurhakim was responsible for the research design, data analysis, and manuscript writing. Abdul Mukti Soma and Irni Yunita provided methodological guidance, research supervision, and contributions to manuscript revision and further analysis.

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Conflicts of Interest

The authors declare no conflict of interest in this research

Availability of Data and Materials

The data used in this study are available and can be accessed upon request through correspondence with the lead author.

REFERENCES

Abdelmalek, W. (2023). Cryptocurrencies and portfolio diversification before and during COVID-19. EuroMed Journal of Business, July. https://doi.org/10.1108/EMJB-10-2022-0182

Ahmadi, H. (2023). Is Cryptocurrency Risky as An Investment Instrument? Analysis of Return and Risk with A Comparison of Sharia Stocks. International Journal of Islamic Business Ethics, 8(1), 40. https://doi.org/10.30659/ijibe.8.1.40-53

Akadur, O., & Senkardes, C. G. (2021). A research on the factors affecting cryptocurrency investments within the gender context. Pressacademia, 10(4), 178–189. https://doi.org/10.17261/pressacademia.2021.1463

Aljinović, Z., Marasović, B., & Šestanović, T. (2021). Cryptocurrency portfolio selection—a multicriteria approach. Mathematics, 9(14). https://doi.org/10.3390/math9141677

Bartolucci, S., & Kirilenko, A. (2020). A model of the optimal selection of crypto assets. Royal Society Open Science, 7(8). https://doi.org/10.1098/rsos.191863

Brauneis, A., & Mestel, R. (2019). Cryptocurrency-portfolios in a mean-variance framework. Finance Research Letters, 28, 259-264. https://ssrn.com/abstract=3124832 or http://dx.doi.org/10.2139/ssrn.3124832

Castro, J. G., Tito, E. A. H., Brandão, L. E. T., & Gomes, L. L. (2020). Crypto-assets portfolio optimization under the omega measure. Engineering Economist, 65(2), 114–134. https://doi.org/10.1080/0013791X.2019.1668098

Colombo, J. A., Cruz, F. I., Cortes, R. X., & Paese, L. H. (2019). Are cryptocurrencies suitable for portfolio diversification? Cross-country evidence. Anpec. Org. Br, 0-19. https://www.anpec.org.br/encontro/2019/submissao/files_I/i8-a2719c2b29132625fa99c7f2b5ed47c3.pdf

Dong, S., Abbas, K., Li, M., & Kamruzzaman, J. (2023). Blockchain technology and application: an overview. PeerJ Computer Science, 9(November). https://doi.org/10.7717/peerj-cs.1705

Hardani, E. al. (2020). Metode Penelitian Kualitatif & Kuantitatif. CV. Pustaka Ilmu Group.

Hrytsiuk, P., Babych, T., & Bachyshyna, L. (2019). Cryptocurrency portfolio optimization using Value-at-Risk measure. Advances in Economics, Business and Management Research, 95(Smtesm), 385–389. https://doi.org/10.2991/smtesm-19.2019.75

Ichsani, S., & Pamungkas, A. (2022). Analisis perbandingan kinerja aset kripto, ihsg dan emas sebagai alternatif investasi periode 2017-2021. JIIP-Jurnal Ilmiah Ilmu Pendidikan, 5(6), 2025-2034. https://doi.org/10.54371/jiip.v5i6.674

Letho, L., Chelwa, G., & Alhassan, A. L. (2022). Cryptocurrencies and Portfolio Diversification in an Emerging Market. China Finance Review International, 12(1), 20–50. https://doi.org/10.1108/CFRI-06-2021-0123

Li, J. P., Naqvi, B., Rizvi, S. K. A., & Chang, H. L. (2021). Bitcoin: The biggest financial innovation of fourth industrial revolution and a portfolio's efficiency booster. Technological Forecasting and Social Change, 162(September 2020), 120383. https://doi.org/10.1016/j.techfore.2020.120383

Lumbantobing, C., & Sadalia, I. (2021). Analisis Perbandingan Kinerja Cryptocurrency Bitcoin, Saham, dan Emas sebagai Alternatif Investasi. Studi Ilmu Manajemen Dan Organisasi, 2(1), 33–45. https://doi.org/10.35912/simo.v2i1.393

Ma, Y., Ahmad, F., Liu, M., & Wang, Z. (2020). Portfolio optimization in the era of digital financialization using cryptocurrencies. Technological Forecasting and Social Change, 161(August), 120265. https://doi.org/10.1016/j.techfore.2020.120265

Maf'ula, Z., Handayani, S. R., & Z.A, Z. (2018). Portofolio Optimal dengan Penerapan Model Markowitz sebagai Dasar Keputusan Investasi (Studi pada Perusahaan yang Tergabung dalam Indeks LQ-45 Tahun 2014). Jurnal Administrasi Bisnis, 63(1), 1–7. https://administrasibisnis.studentjournal.ub.ac.id/index.php/jab/article/view/2695

Meiryani, Marco, Albert, & Ayuanda, N. (2023). Investment decisions: Comparative analysis of the performance of cryptocurrencies Bitcoin, Gold and Stocks. E3S Web of Conferences, 426. https://doi.org/10.1051/e3sconf/202342601108

Moreno, D., Antoli, M., & Quintana, D. (2022). Benefits of investing in cryptocurrencies when liquidity is a factor. Research in International Business and Finance, 63, 101751. https://doi.org/10.1016/j.ribaf.2022.101751

Putri, A. P., Yusnita, R. R., & Mochtar, R. A. F. (2023). Pemilihan Portofolio Cryptocurrency: (Bitcoin, Yearn.Finance, Dogecoin, Binance Coin, Cardano, Dan Monero). Bisnis-Net Jurnal Ekonomi Dan Bisnis, 6(1), 127–141. https://doi.org/10.46576/bn.v6i1.3249

Rahma, A. S., Saifi, M., & Nuzula, N. F. (2022). Optimal Portfolio Using Single Index Model and Alpha Jensen for Best Investment Alternative (Study on IDX30, BISNIS27, and INVESTOR33 Stocks on the Indonesia Stock Exchange 2017-2019 Period). *Indonesian Journal of Social & Humanity Study/Wacana: Jurnal Sosial dan Humaniora*, *25*(3). https://doi.org/10.21776/ub.wacana.2022.025.03.03

Sahu, S., Ochoa Vázquez, J. H., Ramírez, A. F., & Kim, J. M. (2024). Analyzing Portfolio Optimization in Cryptocurrency Markets: A Comparative Study of Short-Term Investment Strategies Using Hourly Data Approach. Journal of Risk and Financial Management, 17(3). https://doi.org/10.3390/jrfm17030125

Sharma, D., Verma, R., & Sam, S. (2021). Adoption of cryptocurrency: an international perspective. International Journal of Technology Transfer and Commercialisation, 18(3), 247. https://doi.org/10.1504/ijttc.2021.118863

Sharpe, W. F. (1994). The Sharpe Ratio. Streetwise: The Best of The Journal of Portfolio Management, 169–178. https://doi.org/doi:10.1515/9781400829408-022

Solin, M. M., Alamsyah, A., Rikumahu, B., & Saputra, M. A. A. (2019). Forecasting portfolio optimization using artificial neural network and genetic algorithm. 2019 7th International Conference on Information and Communication Technology, ICoICT 2019, 1–7. https://doi.org/10.1109/ICoICT.2019.8835344

Stiawan, E. (2022). Manajemen Inavestasi, Portofolio, dan Pasar Modal (A. S. Putra (ed.); Volume 1). CV. Sinar Jaya Berseri.

Yahya, J. (2022). Problematika Pembelajaran Pendidikan Agama Islam Di Sekolah Menengah Pertama (SMP) Islam Muqorrobin Singosari. In Science (Vol. 7, Issue 1).

Yanida, P., Pratiwi, L. N., & Nugrahani, W. P. (2023). Comparative Evaluation of Portfolio Performance: A Study of Cryptocurrency, Stock, and Foreign Exchange Investments. Jurnal Ilmu Keuangan Dan Perbankan (JIKA), 13(1), 45–62. https://doi.org/10.34010/jika.v13i1.10314

Yuhanitha, N. ., & Robiyanto, R. (2021). Cryptocurrencies as a Hedge and Safe Haven Instruments during Covid-19 Pandemic. JASF: Journal of Accounting and Strategic Finance, 4(1), 13–30. https://doi.org/10.33005/jasf.v4i1.129

Yuliana, A. F. ., & Robiyanto, R. (2022). Revisit the Dynamic Portfolio Formation between Gold and Stocks in Indonesia in the Period Before and During the COVID-19 Pandemic. JASF: Journal of Accounting and Strategic Finance, 5(1), 1–21. https://doi.org/10.33005/jasf.v5i1.161

Yunita, I. (2023). Evaluasi Kinerja Investasi Saham Syariah menggunakan Indeks Sharpe, Treynor dan Jensen Periode 2021-2022. Jurnal Ilmiah Ekonomi Islam, 9(1), 435–442. http://dx.doi.org/10.29040/jiei.v9i1.7348

Zhang, Z. (2022). The Optical Portfolio of the Markowitz Model and the Index Model. Proceedings of the 2022 7th International Conference on Financial Innovation and Economic Development (ICFIED 2022). https://doi.org/10.2991/aebmr.k.220307.248