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MULTIOBJECTIVE FUZZY PORTFOLIO MODEL IN INDONESIAN SYARIAH STOCK MARKET

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ABSTRACT

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The current global financial instability has attracted investors in Indonesia to the Sharia capital market, which promises bright opportunities. This study emphasizes the importance of using a fuzzy approach in managing multi-objective portfolios to deal with uncertainty in the Sharia stock market. This approach allows investors to manage their portfolios more effectively by considering various investment objectives simultaneously, such as maximizing profits and minimizing risks, which are very important amidst the ever-changing market dynamics. The method in this study is a fuzzy portfolio approach using the Treynor and Sharpe ratios in evaluating investment performance. Data is processed using fuzzy trapezoids, and portfolios are used to minimize risk without using short sales so that it remains balanced between potential profits and risks. The results of the analysis show an expected rate of return of 0.00091 and a risk level of 0.000421. When the allocation is set with a proportion of 93.8% for ANTM shares and 6.17% for KLBF, the strategy can provide a return of 0.091% with minimized risk. This creates an optimal balance between profit opportunities and risk management.

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1. INTRODUCTION

The dynamism of the global market has played a role in significantly increasing the number of investors, including in Indonesia, investing in shares. After going through the COVID-19 pandemic period, the Indonesian stock market experienced positive growth overall [1]. This condition has good prospects, Indonesia can attract many investors to invest in stocks in Indonesia. The majority of the population is Muslim. The Islamic stock market in Indonesia can be a very relevant alternative for investment for investors [2]. Jakarta Islamic Index (JII) and Indonesia Sharia Stock Index (ISSI) in Indonesia are designed to measure the average performance of stock prices that comply with Sharia principles. Global Islamic Financial 2019 revealed that global Sharia financial assets reached 2.4 trillion US dollars in 2018. This data can be used as a benchmark to see the growth that occurs in Islamic finance at the global level. The last year period has shown significant growth in the Indonesian sharia market. Price stability is one of the key factors to ensure consistent performance and help investors navigate market fluctuations. [3], [4]. Fundamental performance, profitability ratios, leverage, and valuation are information that many investors pay attention to when investing in Sharia stocks [5]. One of the instruments that can be used as a reference when investing in the capital market is a portfolio.

A portfolio is a group of investment assets owned by an individual or an organization [6]–[8]. Portfolio management is essential before investing in the sharia capital market [8], [9]. A portfolio is vital for investors because it can reduce risk and optimize profits. However, in practice, many factors need to be considered, such as the number of shares, investor preferences, and other considerations [10], [11]. Price fluctuations and the amount of assets owned by investors are factors that can influence profits or losses in an investment [12]. The Sharia stock portfolio in Indonesia has promising valuation prospects, along with the significant growth that has occurred in the Sharia stock market in Indonesia. A portfolio is considered optimal if it generates the highest return for a given level of risk or minimizes risk to achieve a specified return [13]. Portfolios are designed to balance profit targets with the level of risk that investors can accept to create the most effective and efficient investment composition. To compile an optimal and efficient portfolio, investors need to conduct in-depth analysis. Multi-objective is one method that can be used.

The multi-objective portfolio approach integrates various aspects of investment, such as yield, risk level, and investor priorities, to achieve optimal results [14]–[20]. This method is different from conventional strategies, which generally only focus on one aspect, such as maximizing profits [21]. There is a need to study multi-objective portfolios to deal with the complexity and dynamics of the current Indonesian capital market. The rapid development of the capital market in Indonesia has made it a key element in driving national economic growth [22]. The progress and complexity of the Indonesian capital market make multi-objective portfolio strategies increasingly relevant, as they enable investors to manage various aspects of investment simultaneously [22]–[25]. The implementation of multi-objective portfolios in Indonesia can be observed from various aspects. The entry of more foreign investors increases the complexity and dynamics of the Indonesian capital market due to the diversity of their investment objectives. This diversity encourages the adoption of multi-objective portfolio strategies to accommodate various investor needs [23]. Tighter regulations on information disclosure and investor protection have reinforced the need for a multi-objective portfolio approach. Investors need an investment method that balances multiple objectives, including return, risk, and regulatory compliance [22], [26]. Financial technology and innovation facilitate the implementation of multi-objective portfolios in Indonesia. Multi-objective portfolio optimization models and algorithms have been widely developed and implemented by investment managers and capital market analysts in Indonesia. One important development is the application of fuzzy logic, which allows for more flexible handling of uncertainty and complexity in investment decision-making.

A portfolio with a multi-objective fuzzy approach is an innovation in portfolio management that aims to overcome high levels of uncertainty and complexity in the investment decision-making process [27], [28]. This concept integrates fuzzy theory, which can manage vague information, with a multi-objective approach to portfolio optimization. In a multi-objective fuzzy portfolio, investors can consider multiple objectives, such as maximizing returns, minimizing risks, and maintaining liquidity, using a fuzzy membership function model to represent uncertain preferences and constraints. This approach continues to grow in line with the increasing need for flexible and adaptive methods of portfolio management, especially in dynamic markets. Thus, multi-objective fuzzy portfolios offer the tools needed by investors to make more precise and wiser investment decisions, especially in the face of dynamic markets. The advantage of the multi-objective fuzzy portfolio model lies in the use of historical data. The data used involves four components, namely the open, closed, highest, and lowest prices. This makes the estimation process more complete in reading the data records owned by the stock. In addition, involving four important data components also makes the resulting portfolio more accurate.

The novelty of multi-objective fuzzy portfolios lies in their ability to simultaneously integrate uncertainty in risk and return assessments and consider multiple competing investment objectives. In this context, the use of fuzzy theory allows for a more realistic representation of investor preferences that are not always linear or fixed. However, although this approach has made significant contributions to portfolio optimization, there is a research gap that needs to be explored further, especially in terms of developing more efficient models that can handle highly dynamic and large-scale market data. In addition, limitations in empirical validation and practical application in various market conditions are also areas that require further research. Therefore, our research focuses on developing a more adaptive and robust multi-objective fuzzy portfolio model, taking into account dynamic factors and the complexity of the global market. We also explore new optimization methods that can improve portfolio performance while maintaining flexibility and resilience in the face of market uncertainty.

2. RESEARCH METHODS

This section discusses the supporting theories for compiling fuzzy portfolios using the Treynor ratio and the Sharpe ratio.

2.1 Fuzzy Portfolio

R is a set of real numbers. Nonlinear adaptive fuzzy numbers $A(x), x \in R$ has a membership function:

$$\mu\big(A(x)\big) = \begin{cases} f(x), if\ x \in [p,q] \\ 1\ \ , if\ x \in [q,r] \\ g(x), if\ x \in [r,s] \\ 0\ \ , if\ x\ Other \end{cases} \tag{1}$$

Characteristics $f(x)$ has a real value function, increases, and continues to the right. While the function $g(x)$ has real value, decreases, and continues to the left. The value p,q,r,s is a real number with the characteristic $p < q < r < s$. Fuzzy numbers $A(x)$ which contains functions$f(x)$ and $g(x)$, defined as:

$$f(x) = \left(\frac{x-p}{q-p}\right)^n, \tag{2}$$

$$g(x) = \left(\frac{s-x}{s-r}\right)^n, \tag{3}$$

where $n > 0$, then it is symbolized by $A = (p,q,r,s)_n$ as a class of adaptive non-linear fuzzy numbers. If $n = 1$, The special form is a general trapezoidal fuzzy number with $A = (p,q,r,s)$. If the case $n = 1, n$ expected value and variance of trapezoidal fuzzy numbers $A = (p,q,r,s)$, that is:

$$E(A) = \frac{p+2q+2r+s}{6} \tag{4}$$

and

$$Var(A) = \frac{(p+2q-2r-s)^2}{36} + \frac{(p-q+r-s)}{72}, \tag{5}$$

2.2 Adaptive Fuzzy Number Formation

The fuzzy number formation is built using the opening, closing, highest, and lowest prices of the assets traded each day. The formation consists of:

Opening price $\{P_{it}^{open}, t = 1,2,3, \dots, T, i = 1,2, \dots, n.\}$,
Closing price $\{P_{it}^{close}, t = 1,2,3, \dots, T, i = 1,2, \dots, n.\}$,
Highest price $\{P_{it}^{high}, t = 1,2,3, \dots, T, i = 1,2, \dots, n.\}$,

Lowest price $\{P_{it}^{low}, t = 1,2,3, \dots, T, i = 1,2, \dots, n.\}$.
Daily asset return $to - i$ and time $to - t$ expressed in trapezoidal fuzzy numbers as follows:

$$r_{it} = \left(r_{it}^{min}, r_{it}^{av1}, r_{it}^{av2}, r_{it}^{max}\right). \tag{6}$$

α-cut r_{it} which can be described as follows:

$$[r_{it}]_\alpha = \left[r_{it}^{min} + \alpha\left(r_{it}^{av1} - r_{it}^{min}\right), r_{it}^{max} - \alpha\left(r_{it}^{max} - r_{it}^{av2}\right)\right]. \tag{7}$$

The fuzzy average return of assets i calculated as a trapezoidal fuzzy number as follows:

$$r_i = \frac{1}{T}\sum_{t=i}^{T} r_{it}\,. \tag{8}$$

Portfolio weight is expressed by the set $w_1 = (w_1, \dots, w_n)$, and portfolio returns are presented with trapezoidal fuzzy numbers as follows:

$$r_P(w) = \sum_{t=i}^{n} w_i r_i\,. \tag{9}$$

The fuzzy covariance of assets i and assets j calculated as a trapezoidal fuzzy number as follows:

$$s_{ij} = \frac{1}{T}\sum_{t=i}^{T}(r_{it} - r_i)(r_{jt} - r_i), \tag{10}$$

Portfolio variance is expressed by trapezoidal fuzzy numbers as follows:

$$r_P(w) = \sum_{t=i}^{n} w_i r_i\,. \tag{11}$$

Arithmetic operations of trapezoidal fuzzy numbers calculate $r_i, r_P(w), s_{ij}$ and $s_{P(w)}$. The expected portfolio return and portfolio variance are each defined as the mean. $r_{P(w)}$ and mean $s_{P(w)}$ presented as follows:

$$\mu_P(w) = E[r_P(w)], \tag{12}$$

$$\sigma_P^2(w) = E[s_P(w)]. \tag{13}$$

Construction of portfolio with minimum variance and tangency This portfolio is without any short sales. Simulation of stock data is done without considering short sales. Short-selling often requires large credit qualifications [29], [30]. The minimum fuzzy variance portfolio is defined as follows:

$$\{\sigma_P^2(w) | l'w = 1, w \geq 0\} \tag{14}$$

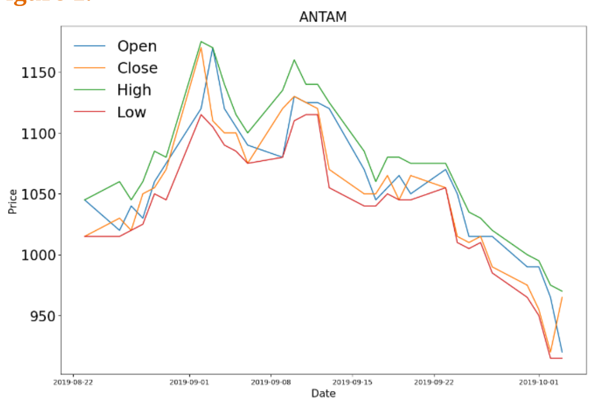
3. RESULTS AND DISCUSSION

The data used in the study is time series data of Sharia stock prices listed on the Indonesian Sharia Stock Index (ISSI). The data used was taken from the last five-year period, starting from August 2019 to August 2024, with a total of 1,214 trading data, including opening prices, closing prices, highest prices, and lowest prices. Sharia stocks were selected based on several types of sectors, and the information is presented in **Table 1**. In the stock selection process used in the research, there are several stock characteristics representing different sectors. The selected stocks have high liquidity criteria, stocks have high market capitalization, and stocks comply with sharia. The number five was chosen because five stocks are representative enough to simplify the analysis and focus on model development while maintaining accuracy in the research results.

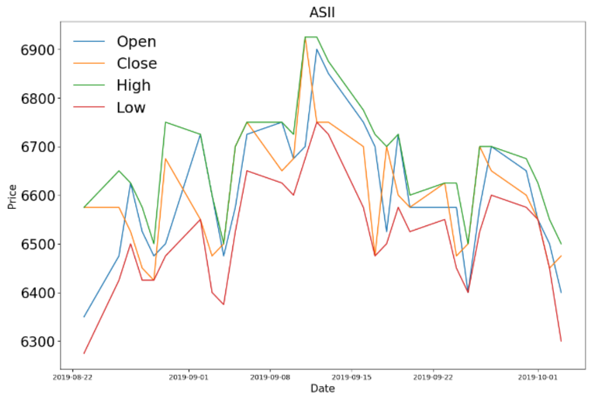
Table 1. Stock Types and Sectors

Stock	Sectors
ANTM	Mining and metals
ASII	Automotive, agribusiness, infrastructure
KLBF	Health, pharmacy, and nutrition
PTBA	Coal mining and energy
UNVR	Consumer goods

Detecting stock patterns and movements is possible to analyze through the opening, closing, lowest, and highest prices which are then used as references in research. The stock data is represented visually in Figure 1.

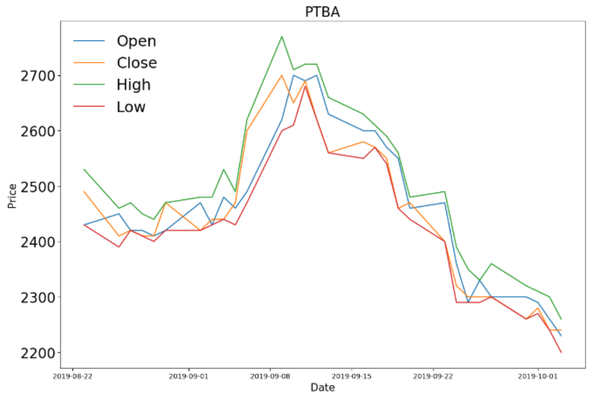


(a)

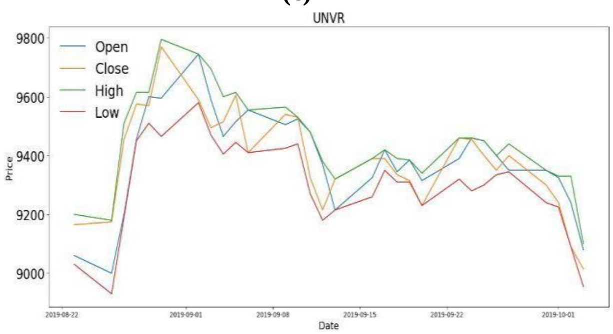


(b)

(c)



(d)



(e)

Figure 1. Visualization of Stock Price Trends (2019-2024) for (a) ANTM, (b) ASII, (c) KLBF, (d) PTBA, and (e) UNVR Based on Opening, Closing, High, and Low Prices Over the Analyzed Period

3.1 Determining the Value r_{it} , $r_p(w)$ and $s_p(w)$

To find the expected portfolio return and portfolio variance, it is necessary to determine r_{it}, $r_p(w)$, and $s_p(w)$ according to the fuzzy method. Determination r_{it} done using a formula $r_{it} = (r_{it}^{min}, r_{it}^{av1}, r_{it}^{av2}, r_{it}^{max})$ which represents the value of minimum return, average value, and maximum value. The values obtained are used to define parameters in the fuzzy portfolio model. The calculation of the r_{it} value shows the interval for all assets. Rows are used to describe each asset being observed (r_1 *to* r_5), while in the columns where $a(min), b(av1), c(av2), d(max)$ are used to describe the value of $(r_{it}^{min}, r_{it}^{av1}, r_{it}^{av2}, r_{it}^{max})$. The results obtained are presented in **Table 2**.

Table 2. Return Value (r_{it}) Assets Based on the Fuzzy Method

r_i	a(min)	b(av1)	c(av2)	d(max)
r_1	−0.03551909	−0.01843868	0.01643326	0.03746333
r_2	−0.02591934	−0.01421090	0.01288688	0.02682805
r_3	−0.02868648	−0.01565489	0.01504654	0.02995334
r_4	−0.02898465	−0.01483295	0.01374839	0.03021291
r_5	−0.02504700	−0.01383858	0.01210850,	0.02599338

Where:
a(Minimum return), b and c (Average between returns), and d (Maximum return)

After r_{it} obtained, the next stage determines the value of $s_p(w)$ by using the specified formula:

$$r_p\,(w) = \sum_{i=1}^{n} w_i r_i = r_p(w) = w_1 r_1 + w_2 r_2 + w_3 r_3 + w_4 r_4 + w_5 r_5$$

w_i Is the weight used to represent each asset and r_i Is the return value of the asset. The formula is used to find the value of $r_p\,(w)$, where $r_p\,(w)$, is the portfolio return calculated based on the weight of each asset. The calculation shows the combination of weight (w_i) and return (r_i) of each asset. The obtained value data is presented in **Table 3**.

Table 3. Portfolio Return Data $r_p(w)$

	a(min)	b(av1)	c(av2)	d (max)
$w_1 r_1$	$-0.03551909w_1$	$-0.01843868w_1$	$0.01643326w_1$	$0.03746333w_1$
$w_2\,r$	$-0.02591934w_2$	$-0.01421090w_2$	$0.01288688w_2$	$0.02682805w_2$
$w_3 r_3$	$-0.02868648w_3$	$-0.01565489w_3$	$0.01504654w_3$	$0.02995334w_3$
$w_4\,r_4$	$-0.02898465w_4$	$-0.01483295w_4$	$0.01374839w_4$	$0.03021291w_4$
$w_5\,r_5$	$-0.02504700w_5$	$-0.01383858w_5$	$0.01210850w_5$	$0.02599338w_5$

Where:

a, b, c, d (Portfolio return value interval), w_i (Weight of Asset$-i$), and r_i (Return of Asset$-i$)

The next stage searching for value $s_p(w)$ Using a predetermined formula:

$$s_p(w) = \sum_{i=1}^{n} w_i w_j s_i s_j$$

The formula is described as:

$$\begin{aligned} s_p(w) = {} & w_1^2(s_{11}) + 2w_1w_2(s_{12}) + 2w_1w_3(s_{13}) + 2w_1w_4(s_{14}) + 2w_1w_5(s_{15}) + w_2^2(s_{22}) + 2w_2w_3(s_{23}) \\ & + 2w_2w_4(s_{24}) + 2w_2w_5(s_{25}) + w_3^2(s_{33}) + 2w_3w_4(s_{34}) + 2w_3w_5(s_{35}) + w_4^2(s_{44}) \\ & + 2w_4w_5(s_{45}) + w_5^2(s_{55}) \end{aligned}$$

The S_{ij} value is substituted based on the previously obtained value, the S_{ij} value is the covariance value between assets i and j. The results of the substitution are presented in **Table 4**.

Table 4. Variance Calculation $s_p(w)$

	a(min)	b(av2)	c(av2)	d(max)
w_1^2	−0.005940011	−0.0011861367	0.002497573	0.006149464
$2w_1w_2$	−0.004020425	−0.0012446863	0.001436647	0.004528873
$2w_1w_3$	−0.004491071	−0.0014642200	0.001565413	0.004528873

	a(min)	b(av2)	c(av2)	d(max)
$2w_1w_4$	-0.004558908	-0.0012999399	0.001625401	0.004599416
…	…	…	…	…
$2w_4w_5$	-0.003188317	-0.0010098793	$.001143688$	0.003221729
w_5^2	-0.002899658	-0.0006589798	0.001319511	0.002970141

The table shows how each combination can affect the risk in an investment portfolio. Where: a, b, c, d (Minimum, average, and maximum values), w_i (Weight of Asset i), andS_{ij} (Covariance) between returns of assets i and j.

3.2 Finding Weights to Maximize Returns and Minimize Variance

The next step is to find the value of the combination of weights to find the optimum combination that allows maximizing returns and minimizing risks. In finding the ideal weight, the following formula will be used:

$$\text{Min}\{\sigma_P^2(w)|l'w = 1, w \geq 0\}$$

And tangency is used to increase the portfolio's Sharpe ratio, with the formula:

$$\text{Max}\left\{\frac{\mu p(w)}{\sqrt{\sigma^2 p(w)}}|l'w = 1, w \geq 0\right\}$$

Where $\frac{\mu p(w)}{\sqrt{\sigma^2 p(w)}}$ is the Sharpe ratio portfolio and μ_p is the expected return of the portfolio.

First, find the equation value $\mu p(w) = E[r_p(w)]$ and $\sigma^2(w) = E[s_p(w)]$ searched using the values of return and covariance. The calculation results from the equation $\mu p(w) = E[r_p(w)]$ presented in Table 5.

Table 5. Equation Value $E[r_p(w)]$

Variable	Equation
a	$-0.03551909w_1 - 0.02591934w_2 - 0.02868648w_3 - 0.02898465w_4 - 0.02504700w_5$
b	$-0.01843868w_1 - 0.01421090w_2 - 0.01565489w_3 - 0.01483295w_4 - 0.01383858w_5$
c	$0.01643326w_1 + 0.01288688w_2 + 0.01504654w_3 + 0.01374839w_4 + 0.01210850w_5$
d	$0.03746333w_1 + 0.02682805w_2 + 0.02995334w_3 + 0.03021291w_4 + 0.02599338w_5$

The calculation results from the equation. $\sigma^2(w) = E[s_p(w)]$ presented in Table 6.

Table 6. Expected Value Variance $E[s_p(w)]$

Variable	Equation
a	$-0.005940011w_1^2 - 0.00804085w_1w_2 - 0.008982142w_1w_3 - 0.009117816w_1w_4 - 0.007749588w_1w_5 - 0.002995633w_2^2 - 0.006504768w_2w_3 - 0.006555168w_2w_4 - 0.005658986w_2w_5 - 0.003846242w_3^2 - 0.007280878w_3w_4 - 0.00634401w_3w_5 - 0.003856894w_4^2 - 0.006376634w_4w_5 - 0.002899658w_5^2$
b	… ..
c	… ..
d	$0.006149464w_1^2 + 0.008096918w_1w_2 + 0.009057746w_1w_3 + 0.009198832w_1w_4 + 0.007800388w_1w_5 + 0.003047681w_2^2 + 0.006563734w_2w_3 + 0.006605788w_2w_4 + 0.005706138w_2w_5 + 0.003958748w_3^2 + 0.007339866w_3w_4 + 0.006407632w_3w_5 + 0.003958567w_4^2 + 0.006443458w_4w_5 + 0.002970141w_5^2$

To find the w_i value, use the formula:

$$E(A) = \frac{a + 2b + 2c + d}{b}$$

Where $A = (a, b, c, d)$ trapezoidal fuzzy numbers.

The equations obtained are then processed for optimization using the software Lingo 20.0

The optimum value is presented in **Table 7**.

Table 7. Result Value w_i

Stock	Weight
ANTM	0.9382179
ASII	0.0000000
KLBF	0.0617821
PTBA	0.0000000
UNVR	0.0000000

The weight value (w_i) with a value of 0 is not included in the optimal portfolio, then weights with high values will be prioritized because they have the potential to get maximum returns and risks that are still acceptable.

3.3 Calculating Expected Return and Portfolio Risk

The results of portfolio analysis with fuzzy optimization in investment performance show the potential for profit and risk for each investment choice. Expected Return and Risk values for investment performance are presented in **Table 8**.

Table 8. Expected Return Value and Portfolio Risk

Expected Return	0.000910
Risk	0.000421

The analysis results obtained the portfolio weight of ANTM shares is 93.82% and KLBF is 6.17% while ASII, PTBA, and UNVR shares weight 0. This finding indicates that ANTM shares have the largest contribution, while KLBF is used as a diversification with a smaller allocation level. The expected return on the portfolio approach shows a return of 0.0910% which shows the opportunity for financial gain even though the value is relatively low but still shows a consistent tendency. On the other hand, the risk level of 0.0421% shows a relatively low fluctuation value, in other words, the potential for loss is relatively limited. These results illustrate the advantages of investment stability, especially for investors who place their main attention on risk management. The recommended investment strategy is to divide capital between ANTM and KLBF by giving the largest proportion to ANTM shares at 93.82% and the remaining 6.17% to KLBF. The combination of greater profit opportunities compared to the existing risk level makes this strategy a good choice to increase investment value while maintaining risk at an acceptable level. As an illustration, if an investor has funds of 1 billion rupiah, around 930 million rupiah, the investment will be focused on ANTM shares, while 6.7 million rupiah is allocated to KLBF shares. This strategy provides a combination that includes growth potential and controlled risk.

4. CONCLUSIONS

Portfolios with a fuzzy multi-objective approach are expected to be able to overcome multi-objective problems in investment portfolios. By considering returns, risks, and liquidity, it is expected to be able to be passed without obstacles and optimally. The strategy is not only adaptive and flexible but also optimal, along with the dynamic Islamic capital market in Indonesia. Point-to-point stock distribution, such as ANTM and KLBF, emphasizes the importance of realistic and stable fundamental stock analysis, which has the potential to generate sustainable profits with acceptable risks. This approach also increases competitiveness in the financial sector in Indonesia, especially the Sharia market, increases foreign investment, and has stricter regulations.

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REFERENCES

[1] P. Nurokhmawati, "INDEKS SAHAM SYARIAH INDONESIA SAAT PANDEMI COVID'19," *J. Ilm. Ekon. Islam*, vol. 8, no. 1, p. 888, 2022, doi: 10.29040/jiei.v8i1.3623.

[2] A. S. Utomo, "STUDI KOMPARATIF KINERJA SAHAM SYARIAH DAN KONVESIONAL DI INDONESIA DENGAN PENDEKATAN STOCHASTIC DOMINANCE," *SEGMEN J. Manaj. dan Bisnis*, vol. 17, no. 2, 2021, doi: 10.37729/sjmb.v17i2.7177.

[3] F. Jawadi, N. Jawadi, and W. Louhichi, "CONVENTIONAL AND ISLAMIC STOCK PRICE PERFORMANCE: AN EMPIRICAL INVESTIGATION," *Int. Econ.*, vol. 137, pp. 73–87, 2014, doi: 10.1016/j.inteco.2013.11.002.

[4] K. Guesmi and F. Teulon, "THE DETERMINANTS OF REGIONAL STOCK MARKET INTEGRATION IN MIDDLE EAST: A CONDITIONAL ICAPM APPROACH," *Int. Econ.*, vol. 137, pp. 22–31, 2014, doi: 10.1016/j.inteco.2013.10.006.

[5] Iqramuddin, M. Saputra, and M. A. Djalil, "THE EFFECT OF LIQUIDITY , FINANCIAL LEVERAGE , PROFITABILITY AND COMPANY SIZE ON ISLAMIC SOCIAL REPORTING (ISR) DISCLOSURE AND ITS IMPACT ON COMPANY VALUE IN SHARIA COMMERCIAL BANKS IN INDONESIA," *East African Sch. J. Econ. Bus. Manag.*, vol. 3, no. 6, pp. 500–510, 2020, doi: 10.36349/EASJEBM.2020.v03i06.005.

[6] P. Jana, D. Rosadi, and E. D. Supandi, "THE FORMATION OF PORTFOLIO WITH FUZZY APPROACH AND MULTI-OBJECTIVE METHOD: A CASE STUDY ON STOCKS INCORPORATED IN LQ45," *Electron. J. Appl. Stat. Anal.*, vol. 16, no. 3, pp. 541–563, 2023, doi: 10.1285/i20705948v16n3p541.

[7] P. Jana, D. Rosadi, and E. D. Supandi, "FUZZY PORTFOLIO WITH MULTI-OBJECTIVE APPROACH USING THE TREYNOR RATIO," *IAENG Int. J. Comput. Sci.*, vol. 51, no. 8, pp. 1086–1093, 2024.

[8] N. S. M. Mussafi and Z. Ismail, "QUADRATIC PROGRAMMING FOR OPTIMIZING THE DIVERSIFIED SHARIAH STOCK PORTFOLIO," vol. 474, no. Isstec 2019, pp. 139–147, 2020, doi: 10.2991/assehr.k.201010.021.

[9] S. L. Ng, W. C. Chin, and L. L. Chong, "REALIZED VOLATILITY TRANSMISSION WITHIN ISLAMIC STOCK MARKETS: A MULTIVARIATE HAR-GARCH-TYPE WITH NEAREST NEIGHBOR TRUNCATION ESTIMATOR," *Borsa Istanbul Rev.*, vol. 20, pp. S26–S39, 2020, doi: 10.1016/j.bir.2020.10.001.

[10] V. Cavieze, S. Gambirasi, and S. O. Lozza, "RISK PROFILE USING PCM and RSM," *Electron. J. Appl. Stat. Anal.*, vol. 5, no. 3, pp. 327–332, 2012, doi: 10.1285/i20705948v5n3p327.

[11] M. F. Amin *et al.*, "ANALISIS PEMBENTUKKAN PORTOFOLIO OPTIMAL SAHAM MENGGUNAKAN PENDEKATAN SINGLE INDEX MODEL (STUDI PADA PERUSAHAAN YANG TERDAFTAR DI IDX SHARIA GROWTH)," vol. 2, no. 2, 2024.

[12] P. Studi Matematika Fakultas Sains dan Teknologi *et al.*, "ANALISIS PORTOFOLIO OPTIMAL SAHAM SYARIAH MENGGUNAKAN MULTI INDEX MODELS) MULAT ARJA'I DAN MOHAMMAD FARHAN QUDRATULLAH BY USING COMPOSITE STOCK PRICE INDEX (IHSG), INDEX DOW JONES INDUSTRIAL AVERAGE (DJIA) AND INDEX THE," vol. 2, no. 2, pp. 105–111, 2013, [Online]. Available: www.fourier.or.id.

[13] H. Bilir, "DETERMINATION OF OPTIMAL PORTFOLIO BY USING TANGENCY PORTFOLIO AND SHARPE RATIO," *Res. J. Financ. Account.*, vol. 7, no. 5, pp. 53–59, 2016.

[14] M. Mustika, T. Mulyawati, D. K. Apriyanto, A. Sausan, and Rofikah, "APPLICATION OF PASCOLETTI-SERAFINI SCALARIZATION MODIFICATION METHOD TO SOLVE MULTI-OBJECTIVE OPTIMIZATION PROBLEMS FOR STOCK PORTFOLIO," *J. Phys. Conf. Ser.*, vol. 1821, no. 1, 2021, doi: 10.1088/1742-6596/1821/1/012058.

[15] A. Bilbao-Terol, M. Arenas-Parra, and V. Cañal-Fernández, "A FUZZY MULTI-OBJECTIVE APPROACH FOR SUSTAINABLE INVESTMENTS," *Expert Syst. Appl.*, vol. 39, no. 12, pp. 10904–10915, 2012, doi: 10.1016/j.eswa.2012.03.034.

[16] D. A. Wood, "ASSET PORTFOLIO MULTI-OBJECTIVE OPTIMIZATION TOOLS PROVIDE INSIGHT TO VALUE, RISK AND STRATEGY FOR GAS AND OIL DECISION MAKERS," *J. Nat. Gas Sci. Eng.*, vol. 33, pp. 196–216, 2016, doi: 10.1016/j.jngse.2016.03.103.

[17] G. F. Yu, D. F. Li, D. C. Liang, and G. X. Li, "AN INTUITIONISTIC FUZZY MULTI-OBJECTIVE GOAL PROGRAMMING APPROACH TO PORTFOLIO SELECTION," *Int. J. Inf. Technol. Decis. Mak.*, vol. 20, no. 5, pp. 1477–1497, 2021, doi: 10.1142/S0219622021500395.

[18] R. A. Wardani, S. Surono, and G. K. Wen, "OPTIMIZATION OF PORTFOLIO USING FUZZY SELECTION,"

BAREKENG J. Ilmu Mat. dan Terap., vol. 16, no. 4, pp. 1325–1336, 2022, doi: 10.30598/barekengvol16iss4pp1325-1336.

[19] Z. A. Zain, N. Saif, M. Mussafi, and E. D. Supandi, "CLUSTER ANALYSIS OF K-MEANS AND WARD METHOD IN FORMING A ROBUST PORTFOLIO : AN EMPIRICAL STUDY OF JAKARTA ISLAMIC INDEX," vol. 19, no. 1, pp. 537–546, 2025.

[20] J. Aryento, F. Kusnadi, and D. Lesmono, "CALCULATION OF CREDITED INTEREST RATE WITH INVESTMENT YEAR METHOD AND PORTFOLIO METHOD," *BAREKENG J. Ilmu Mat. dan Terap.*, vol. 16, no. 3, pp. 787–796, 2022, doi: 10.30598/barekengvol16iss3pp787-796.

[21] I. A. Yuri, N. O. Lisadi, and M. R. Sari, "ANALISIS KINERJA PORTOFOLIO SAHAM PERUSAHAAN PADA SEKTOR JASA PENERBANGAN DI BEBERAPA NEGARA ASEAN," *J. Ilm. Akunt. Kesatuan*, vol. 9, no. 3, pp. 563–574, 2022, doi: 10.37641/jiakes.v9i3.905.

[22] A. W. Nugraha, "PERLINDUNGAN HUKUM TERHADAP INVESTOR ATAS TINDAKAN FORCED DELISTING PERUSAHAAN TERCATAT OLEH BURSA EFEK INDONESIA," *Lex Libr. J. Ilmu Huk.*, vol. 7, no. 2, p. 99, 2021, doi: 10.46839/lljih.v7i2.207.

[23] R. S. Aminda, "ASSESMENT OF PORTFOLIO RETURN PERFORMANCE IN THE INDONESIAN CAPITAL MARKET," vol. 143, no. Isbest 2019, pp. 285–290, 2020, doi: 10.2991/aebmr.k.200522.053.

[24] M. D. Saifullah, U. Sa'adah, K. Andawaningtyas, and E. W. Handamari, "VALUE AT RISK ESTIMATION FOR STOCK PORTFOLIO USING THE ARCHIMEDEAN COPULA APPROACH," *BAREKENG J. Ilmu Mat. dan Terap.*, vol. 18, no. 3, pp. 1779–1790, 2024, doi: 10.30598/barekengvol18iss3pp1779-1790.

[25] F. Pérez, T. Gómez, R. Caballero, and V. Liern, "PROJECT PORTFOLIO SELECTION AND PLANNING WITH FUZZY CONSTRAINTS," *Technol. Forecast. Soc. Change*, vol. 131, no. June, pp. 117–129, 2018, doi: 10.1016/j.techfore.2017.07.012.

[26] E. Vercher, J. D. Bermúdez, and J. V. Segura, "Fuzzy Portfolio Optimization Under Downside Risk Measures," *Fuzzy Sets Syst.*, vol. 158, no. 7, pp. 769–782, 2007, doi: 10.1016/j.fss.2006.10.026.

[27] A. N. Pratama, N. Satyahadewi, and E. Sulistianingsih, "ANALYSIS OF OPTIMAL PORTFOLIO FORMATION ON IDX30 INDEXED STOCK WITH THE MEAN ABSOLUTE DEVIATION METHOD," *BAREKENG J. Ilmu Mat. dan Terap.*, vol. 18, no. 3, pp. 1753–1764, 2024, doi: 10.30598/barekengvol18iss3pp1753-1764.

[28] T. Ardhitha, E. Sulistianingsih, and N. Satyahadewi, "VALUE AT RISK ANALYSIS ON BLUE CHIP STOCKS PORTFOLIO WITH GAUSSIAN COPULA," *BAREKENG J. Ilmu Mat. dan Terap.*, vol. 17, no. 3, pp. 1739–1748, 2023, doi: 10.30598/barekengvol17iss3pp1739-1748.

[29] N. Nurwahidah, "QUADRATIC PROGRAMMING: AN OPTIMIZATION TOOL FOR BUILDING GLOBAL MINIMUM VARIANCE PORTFOLIO WITH NO SHORT SALE," *BAREKENG J. Ilmu Mat. dan Terap.*, vol. 15, no. 2, pp. 305–314, 2021, doi: 10.30598/barekengvol15iss2pp305-314.

[30] T. T. Nguyen, L. Gordon-Brown, A. Khosravi, D. Creighton, and S. Nahavandi, "FUZZY PORTFOLIO ALLOCATION MODELS THROUGH A NEW RISK MEASURE AND FUZZY SHARPE RATIO," *IEEE Trans. Fuzzy Syst.*, vol. 23, no. 3, pp. 656–676, 2015, doi: 10.1109/TFUZZ.2014.2321614.