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# MULTI-CRITERIA INVESTMENT DECISION MAKING FOR PROOF-OF-WORK COINS: IQRBOW-BASED VIKOR APPROACH

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## Abstract

This study examines a multi-criteria investment decision-making process for Proof of Work (PoW) cryptocurrencies using the IQRBOW-based Vikor method. The aim of the study is to evaluate the performance of the investment choice generated through multi-criteria decision-making methodologies. The results obtained with the proposed methodology from October 1, 2023, to October 1, 2024 are compared with some other investment choices, showing significant improvements. The motivation for the research stems from the need to manage the significant volatility in the cryptocurrency market and identify optimal portfolio strategies. The fact that the IQRBOW method offers an objective perspective in criteria weighting and also provides the advantage of easy applicability plays an important role in its choice for the study. The findings of the study show that the IQRBOW-based Vikor method is competent in making more balanced investment decisions with significant earning potential, especially in volatile market environments. These findings provide valuable insights for researchers and investors interested in formulating innovative strategies in portfolio management.

**Keywords:** *IQRBOW, Proof-of-Work Coins, Decision Making, MCDM*

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# İŞ KANITI COINLER İÇİN ÇOK KRİTERLİ YATIRIM KARARI: IQRBOW TABANLI VIKOR YAKLAŞIMI


## Öz

Bu çalışma, IQRBOW tabanlı Vikor yöntemini kullanarak Proof of Work (PoW) kripto para birimleri için çok kriterli bir yatırım karar verme sürecini incelemektedir. Çalışmanın amacı, Çok Kriterli Karar Verme metodolojileri aracılığıyla oluşturulan yatırım tercihinin performansını değerlendirmektir. Önerilen yöntemle 1 Ekim 2023'ten 1 Ekim 2024'e kadar elde edilen sonuçlar, diğer bazı yatırım tercihleriyle karşılaştırılarak kayda değer iyileştirmeler ortaya konmuştur. Araştırmanın motivasyonu, kripto para piyasasındaki önemli dalgalanmayı yönetme ve en uygun portföy stratejilerini belirleme ihtiyacından kaynaklanmaktadır. IQRBOW yönteminin, kriter ağırlıklandırmada objektif bir bakış açısı sunması ve aynı zamanda kolay uygulanabilirlik avantajı sağlaması, çalışma için tercih edilmesinde önemli bir rol oynamaktadır. Çalışmanın bulguları, IQRBOW tabanlı Vikor yönteminin, özellikle değişken piyasa ortamlarında önemli kazanç potansiyeline sahip daha dengeli yatırım kararı vermede yetkin olduğunu göstermektedir. Bu bulgular, portföy yönetiminde yenilikçi stratejiler formüle etmek isteyen araştırmacılar ve yatırımcılar için değerli bilgiler sunmaktadır.



**Anahtar Kelimeler:** *IQRBOW, İş Kanıtı Koinler, Karar Verme, ÇKKV*

## 1. INTRODUCTION

In recent years, the significance of cryptocurrencies in financial markets has been rapidly increasing. These digital assets present new opportunities for investors and institutions, yet also carry substantial risks. Cryptocurrencies, with their higher volatility compared to traditional financial instruments, introduce unique challenges for portfolio management strategies (Charfeddine et al., 2020: 207). This volatility is particularly evident in Proof of Work (PoW)-based cryptocurrencies, which exhibit heightened sensitivity to market uncertainties (Hashimoto and Noda, 2019: 6). The energy-intensive mining processes and limited supply, fundamental characteristics of PoW cryptocurrencies, render their market values susceptible to sudden and unpredictable fluctuations.

The increasing role of cryptocurrencies in financial markets necessitates the development of new strategies for investment decisions and portfolio management approaches. However, within this comprehensive framework, Proof of Work (PoW) based cryptocurrencies stand out due to their unique features such as transaction security and energy consumption. The main reason for focusing on PoW-based cryptocurrencies in this study is that such assets contain decisive factors that affect investment decisions under conditions of high volatility and uncertainty. Therefore, performance analysis of PoW-based cryptocurrencies is an area that needs to be analyzed in depth for both financial decision-makers and the literature. The volatile nature of cryptocurrency markets necessitates that investors focus not only on optimizing short-term gains but also on strategies aimed at minimizing risks. Traditional investment approaches struggle to fully adapt to the inherently high volatility of the cryptocurrency market, leading investors to increasingly adopt Multi-Criteria Decision-Making (MCDM) methods, particularly innovative techniques like VIKOR (Tekletsadik, 2024: 2; Maghsoodi, 2023: 2; Fidan, 2022: 527). Such methodologies facilitate the development of more balanced, risk-management-focused investment strategies by considering multiple criteria.

MCDM methods are powerful tools employed in complex decision-making processes, balancing various objectives and constraints (Sahoo and Goswami, 2023: 26). In cryptocurrency portfolio management, investors need to consider not only returns but also factors like liquidity, volatility, and market value. In this context, the VIKOR method enables more informed investment decisions by accounting for the multidimensional nature of cryptocurrencies. This approach aids investors in optimizing the risk-return balance, helping to build portfolios that are more resilient to market fluctuations. The main reason why the VIKOR method is preferred in this study is that it facilitates reaching the optimal solution by taking into account the different priorities of decision makers in the MCDM processes. VIKOR stands out, especially with its capacity to reconcile conflicting criteria. On the other hand, the use of the IQRBOW method in the criteria weighting stage allows the weights between criteria to be determined in a completely objective manner. IQRBOW has an important role in this study as it provides consistent results regardless of outliers in the data set and is an easily applicable method in the social sciences. The combination of these two methods provides a powerful methodological framework for developing an efficient portfolio management approach in highly volatile markets.

The aim of this study is to determine the criteria weights used in portfolio management for PoW cryptocurrencies using the InterQuartile Range-Based Objective Weighting (IQRBOW) method. Additionally, the effectiveness of these weights in portfolio management is examined through the VIKOR method. By employing the IQRBOW-based VIKOR method (Fidan, 2024: 4), the performance of portfolios was analyzed using data from October 1, 2023, to October 1, 2024, and significant improvements were achieved by comparing the results with other potential portfolio strategies. The IQRBOW-based VIKOR method used in this study builds upon and extends existing multi-criteria decision-making approaches in the field of cryptocurrency portfolio management. Previous studies, such as those by Ecer, Böyükaslan, and Hashemkhani Zolfani (2022), have highlighted the importance of objective weighting techniques for balancing risk and return in volatile markets. Similarly, research by Fang et al. (2022) emphasized the need for innovative strategies to address the unique dynamics of cryptocurrency investments. Unlike these studies, which often rely on traditional or hybrid weighting methods, this study provides a novel framework by integrating the robust outlier management capabilities of the IQRBOW method with the compromise-seeking features of the VIKOR method. This integration offers a systematic and scalable approach to evaluating portfolio performance in high-volatility environments, contributing to the literature by introducing a methodology that enhances both theoretical and practical understanding of cryptocurrency portfolio management. The findings of this study demonstrate that volatility in cryptocurrency markets can be effectively managed, indicating that such innovative strategies offer substantial advantages to investors.

In this context, the remainder of the paper will examine in detail the structure of cryptocurrency markets, the role of MCDM methods in portfolio management, and the advantages offered by the IQRBOW-based VIKOR method.

## 2. LITERATURE REVIEW

### 2.1. Proof of Work Blockchain Based Cryptocurrencies

PoW, commonly used as a consensus algorithm in blockchain-based cryptocurrencies, was developed to ensure security in distributed systems and secure the transaction verification process (Mingxiao et al., 2017: 2568). In PoW-based systems, miners in the network must solve specific mathematical problems to verify transactions between users. In this system, each transaction is recorded as a block on the network and must be verified before being added to the chain. Consequently, networks operating under this algorithm provide a high level of security in a decentralized structure, ensuring transaction verification and block creation without reliance on a central authority (Gemeliarana and Sari, 2018: 127).

The core principle of the PoW algorithm is that network participants must expend effort and energy to contribute to system security (Gervais et al., 2016: 4). This structure aims to prevent malicious actors within the system from creating fraudulent transactions or engaging in “double-spending” (Akbar, et al., 2021: 2). Many cryptocurrencies, most notably Bitcoin, adopt the PoW algorithm to ensure transaction security within the network and maintain a decentralized structure. Bitcoin, the most recognized example of a PoW-based cryptocurrency, has secured a significant position in the digital asset market today due to the security and decentralization that this algorithm provides (Werth et al., 2023: 147; Watters, 2023: 356).

In addition to Bitcoin, cryptocurrencies such as Ethereum, Litecoin, and Monero also stand out among those using the PoW algorithm. While Bitcoin is widely recognized in the markets as the oldest and most popular example of a PoW system, Litecoin aims to address Bitcoin’s limitations by offering faster transaction confirmation times (Singh et al., 2023: 2). Monero, on the other hand, is known for its focus on user privacy, providing fully anonymous transactions and ensuring security through the PoW algorithm (Biryukov and Tikhomirov, 2019: 2). All PoW-based coins rely on an energy- and labor-intensive process for transaction verification and security, aiming to foster a trust-based ecosystem among users. These digital assets hold a significant place in the cryptocurrency market due to their decentralized structure and security priorities, yet challenges related to energy consumption and scalability are highlighted in the literature as primary factors impacting their development (Nakamoto, 2008: 9; Ghosh et al., 2020: 8).

## 2.2. Portfolio Management in Cryptocurrencies

The volatile and uncertain nature of cryptocurrencies presents both opportunities and various challenges for investors (Charfeddine et al., 2020: 207). These digital assets exhibit much more dynamic price fluctuations compared to traditional investment instruments, directly impacting portfolio management strategies. The uncertainty and high volatility in cryptocurrency markets necessitate that investors adopt more balanced and risk-sensitive strategies.

Previous studies on cryptocurrency portfolio management highlight that the unique characteristics of these markets necessitate more innovative approaches compared to traditional investment strategies. Classical methods often fall short in adequately managing the high volatility of cryptocurrencies (Fang et al., 2022: 9). Qarni and Gulzar (2021) note that cryptocurrency markets have a lower correlation with traditional financial markets, thus offering potential for diversification strategies for investors. Moreover, employing Multi-Criteria Decision-Making (MCDM) methodologies to balance returns and risks in cryptocurrencies provides advantages to investors in this volatile environment (Ecer et al., 2022: 2).

## 2.3. VIKOR Method and Applications

MCDM methods are powerful tools that enable the simultaneous evaluation of multiple criteria, allowing investors to balance various risk-return scenarios. Among these methods, the VIKOR method stands out, offering decision-makers a compromise solution to help identify the optimal alternative. Developed by Opricovic and Tzeng (2004), VIKOR brings clarity to decision-making in MCDM problems by balancing conflicting criteria. Unlike other MCDM methods, VIKOR ranks the performance of alternatives between the worst and best scenarios, providing decision-makers with the most balanced solution.

The VIKOR method has been successfully applied across various fields in financial markets. İç et al. (2022) demonstrated its use in measuring financial performance, achieving a compromise among different investment strategies. In cryptocurrency markets, VIKOR allows investors to balance both return and risk factors in portfolio selection. This method accelerates the process of identifying the optimal option in environments where alternative investment choices are evaluated based on numerous criteria, bringing flexibility to investment decisions. VIKOR's particular suitability for volatile markets stems from its ability to provide the most balanced solution despite market fluctuations, offering a significant advantage in helping investors manage uncertainties in cryptocurrency markets. However, the literature reveals a limited number of studies focusing on the development of MCDM methods specifically tailored for PoW-based cryptocurrencies. This gap underscores the importance and originality of our study, which aims to fill this void by applying the IQRBOW-based VIKOR method to PoW cryptocurrencies.

## 3. METHOD

### 3.1. Data Collection and Ethics

The dataset used in this study is based on secondary data obtained from investing.com. It includes daily open, high, and low price data for cryptocurrencies. The use of secondary data sources eliminates the need to apply to an ethics committee for data collection. Therefore, it has been assumed that this study does not require ethics committee approval.

### 3.2. Data Set and Timeframe

The analysis process of this study is based on data collected from October 1, 2023, to October 1, 2024. This one-year timeframe provides an adequate period for analyzing cryptocurrency market volatility and evaluating performance across different periods. The dataset includes the top ten cryptocurrencies by market capitalization that operate on the PoW (Proof of Work) algorithm. The daily price data forms a crucial foundation, enabling investors to conduct accurate volatility, return, and risk analyses.

### 3.3. IQRBOW-Based VIKOR Method

The IQRBOW-based VIKOR method is a powerful tool for evaluating alternatives in MCDM problems. This method aims to use the Interquartile Range (IQR) to weight alternatives, thereby reducing the influence of outliers and creating a more balanced decision-making process. The classic version of the VIKOR method ranks the performance of alternatives between the best and worst values, offering the most suitable compromise to the decision-maker (Opricovic and Tzeng, 2004). IQRBOW enhances this process by making it more precise, as it minimizes the influence of human decision-maker bias on the decision (Fidan, 2024). This method provides a more balanced assessment against the high volatility in cryptocurrency markets, reduces subjectivity in portfolio management, and offers ease of use in social sciences due to its mathematical simplicity.

### 3.3.1. Criteria Selection

The criteria used in this study were selected to evaluate the performance of cryptocurrencies from a multidimensional perspective. These criteria include:

- **Liquidity:** The trading volume (TV) of a cryptocurrency indicates how easily it can be bought or sold in the market, affecting the ability to quickly convert assets in the portfolio into cash.
- **Risk:** When forming a cryptocurrency portfolio, the coefficient of variation (CV) has been calculated to determine the level of risk associated with each alternative (Eq. 1). This calculation analyzes the potential deviations around the average return of each alternative in the portfolio, allowing a clearer assessment of the relationship between risk and return.

$$CV = \frac{\sigma_i}{\bar{x}_i} \tag{1}$$

- **Volatility:** Price fluctuations of a cryptocurrency indicate the level of risk for investors. High volatility can imply high risk and potentially high returns. To determine volatility, the annual change rate (CR) has been calculated from the data (Eq. 2).

$$CR = \frac{x_{(i)max} - x_{(i)min}}{x_{(i)min}} \tag{2}$$

- **Return Rates:** The annual return (AR) represents the returns provided by a cryptocurrency over a specific period, assisting investors in optimizing their portfolio strategies. AR is calculated using Equation 3.

$$AR = \alpha(1 + \frac{x_{end(n)} - x_{end(1)}}{x_{end(1)}}) \tag{3}$$

The mathematical modeling process consists of the following four steps:

1. **Normalization of Criteria:** The performance values of alternatives are normalized to make them comparable.

The best ($f_j^*$) and worst ($f_j^-$) values for each criterion in the decision matrix are determined using Equation 4.

$$j \in B => \begin{cases} f_j^* = \max x_{ij} \\ f_j^- = \min x_{ij} \end{cases}$$

(4)

$$j \in B' => \begin{cases} f_j^* = \min x_{ij} \\ f_j^- = \max x_{ij} \end{cases}$$

In this notation, the symbol $B$ represents benefit-based criteria, while $B'$ denotes cost-based criteria. Higher values are considered favorable for benefit-based criteria, whereas lower values are preferred for cost-based criteria, creating a more positive impact on the decision-making process. This distinction provides clarity in evaluating the performance of alternatives according to the relevant criteria.

Equation 5 is used for normalizing the decision matrix. In this equation, $N_{ij}$, v represents the normalized values of the data, while $f_j^*$and $f_j^-$, indicate the best or worst values determined based on whether the criterion is benefit- or cost-based. Here, $x_{ij}$ represents the raw value of the i-th alternative for the j-th criterion.

$$N_{ij} = \frac{f_j^* - x_{ij}}{f_j^* - f_j^-} \qquad (5)$$

2. **Weighting Using Interquartile Range (IQR):** The weights of the criteria are determined using the Interquartile Range (IQR). This approach provides objective weighting to prevent bias and balances the effect of outliers. The normalization of data according to benefit or cost criteria is conducted using Equation 6.

$$N_{ij}^{x} = \begin{cases} \dfrac{x_{ij}}{\max\limits_{k} x_{kj}} & if \quad j \in \mathcal{B} \\ 1 - \dfrac{x_{ij}}{\max\limits_{k} x_{kj}} & if \quad j \in \mathcal{B}' \end{cases} \qquad (6)$$

In the normalized data matrix, the $Q_3$ and $Q_1$ values of each criterion are determined to calculate the interquartile range (IQR), as shown in Equation 7.

$$\underset{N^*}{Iqrbow}\, C_j = Q_{3\,(cj)} - Q_{1\,(cj)} \quad (7)$$

The weights of each criterion are calculated using the IQRBOW value obtained for each criterion, as shown in Equation 8.

$$w_j = \begin{cases} \frac{1}{m} & , \quad if\ all\ Iqrbow_{Cj}'s\ are\ zero \\ \frac{Iqrbow_{Cj}}{\sum_{j=1}^{m} Iqrbow_{Cj}} & , \quad others \end{cases} \quad (8)$$

**Calculation of VIKOR Scores:** The VIKOR scores of the alternatives are calculated based on the best and worst performance values for each criterion (Opricovic and Tzeng, 2004).

Equation 9 is used to create the weighted normalized decision matrix.

$$V_{ij} = N_{ij} \,.\, w_j \quad (9)$$

Calculation of $S_j$ and $R_j$ Values: The calculation of $S_j$ and $R_j$ values is a critical step in the VIKOR method, essential for determining the $Q$ value. These two values represent the total and maximum distances of the alternatives across all criteria. $S_j$ and $R_j$ values are calculated using Equation 10, providing an objective measure of each alternative's relative closeness to the best and worst solutions.

$$S_j = \sum_{j=1}^{n} v_{ij}$$

$$R_j = \max v_{ij} \quad (10)$$

3. **Determination of the Compromise Solution:** The results are ranked to identify the best compromise solution, which is then presented to the investor.

The calculated $Q_j$ value (Equation 11) forms the final ranking based on a weighted combination of $S_j$ and $R_j$ values, contributing to the attainment of the optimal solution in the VIKOR method.

$$Q_j = q.\frac{S_j - S^*}{S^- - S^*} + (1-q).\frac{R_j - R^*}{R^- - R^*} \quad (11)$$

### 3.3.2. Determination of Alternatives

In selecting the cryptocurrencies for the portfolio, the top ten cryptocurrencies by market capitalization operating on the PoW algorithm have been identified: Bitcoin ($A_1$), Bitcoin Cash ($A_2$), Doge ($A_3$), Ethereum ($A_4$), Ethereum Classic ($A_5$), Litecoin ($A_6$), Zcash ($A_7$), Kaspa ($A_8$), Monero ($A_9$), and Bitcoin SV ($A_{10}$). These cryptocurrencies are considered suitable alternatives for portfolio management due to their high trading volumes in the market. The selected cryptocurrencies enable investors to develop more balanced and risk-focused strategies among PoW-based assets.

## 4. RESULTS

In this study, a summary analysis was conducted using various statistical measures to compare the performance of alternatives. Key statistical metrics, including maximum value (max), third quartile ($Q_3$), median, first quartile ($Q_1$), minimum value (min), standard deviation (standard dev.), and arithmetic mean (mean), were used to evaluate the overall performance levels of the alternatives. These measures provide a meaningful summary for the decision-maker by reflecting the distribution structure, central tendency, and dispersion characteristics of the alternatives in detail (Table 1).

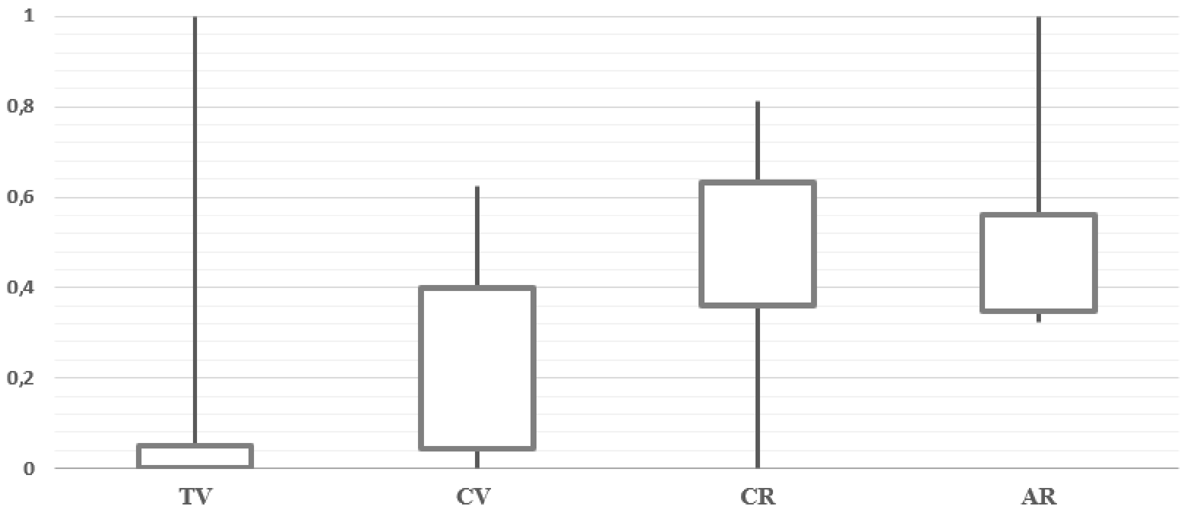
**Table 1.** Summary of Statistics for Alternatives

| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ | $A_9$ | $A_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| max | 73066,30 | 694,39 | 0,22 | 4065,02 | 38,05 | 108,91 | 43,64 | 0,21 | 180,55 | 115,84 |
| $Q_3$ | 65015,30 | 429,78 | 0,14 | 3333,51 | 26,97 | 80,08 | 30,08 | 0,16 | 167,52 | 73,50 |
| median | 59016,00 | 332,91 | 0,10 | 2657,87 | 22,92 | 71,28 | 27,66 | 0,14 | 157,19 | 51,16 |
| $Q_1$ | 42678,45 | 243,54 | 0,08 | 2278,39 | 19,20 | 66,96 | 23,24 | 0,11 | 135,42 | 45,62 |
| min | 26761,10 | 212,20 | 0,06 | 1539,70 | 14,79 | 55,94 | 18,29 | 0,04 | 104,52 | 32,47 |
| standard dev. | 13023,29 | 110,36 | 0,04 | 644,42 | 5,37 | 9,80 | 5,03 | 0,04 | 18,48 | 19,47 |
| mean | 54133,62 | 346,41 | 0,11 | 2762,01 | 23,54 | 73,89 | 27,46 | 0,13 | 151,64 | 60,49 |

Examining the findings presented in Table 1 reveals that the numerical data for the alternatives spans a wide range of values, underscoring the necessity for normalization. This normalization process transforms the values of alternatives into a compatible scale, enabling more consistent and meaningful comparisons. By normalizing the data, the impact of extreme values on the analysis results is reduced, allowing for a clearer evaluation of the relative performance of the alternatives.

A comprehensive visualization has been prepared for the comparative analysis of the criterion weights for TV, CV, CR, and AR criteria using minimum (min), maximum (max), first quartile ($Q_1$), and third quartile ($Q_3$) values. This visualization, presented in Figure 1, is designed to reveal each criterion's weight distribution and performance boundaries in detail. In the figure, the graphical representation of statistical measures for each criterion allows for a detailed comparison of the spread, trends, and distribution of criterion weights based on quartile values. This analysis visualizes the relative importance levels of the criteria in the decision-making process, enabling decision-makers to evaluate inter-criterion differences more clearly.

**Figure 1.** Determinants of Criterion Weights




Based on the statistical values obtained for each criterion, the IQRBOW method was applied to calculate criterion weights, and the results are presented in Table 2. This calculation aims to determine the relative importance of each criterion in the decision-making process by considering the distribution structure and dispersion characteristics of the criteria. The use of the IQRBOW method provides an objective weighting framework within the interquartile range (IQR), and the level of contribution of each criterion to the overall evaluation is comprehensively shown in Table 2.

**Table 2.** Criteria weights

| | **TV** | **CV** | **CR** | **AR** |
|---|---|---|---|---|
| $w_j$ | 0,0529 | 0,4005 | 0,3060 | 0,2406 |

The criterion weights determined by the IQRBOW method are summarized in Table 2. The calculated weight values for the TV, CV, CR, and AR criteria reflect the relative importance of each criterion in the decision-making process. Notably, the CV criterion holds the highest weight at 0.4005, exerting the most significant influence in the decision process.

This is followed by the CR criterion with a weight of 0.3060 and the AR criterion at 0.2406. The TV criterion, with the lowest weight of 0.0529, carries relatively less importance. This weighting objectively demonstrates each criterion's contribution level in the decision process, indicating their relative ranking.

The combined use of the IQRBOW-based VIKOR method in this study offers several unique advantages. The IQRBOW method minimises the influence of outliers in data, ensuring that extreme values do not disproportionately affect decision-making. This provides a more stable and reliable framework for weighting criteria. Additionally, the VIKOR method facilitates compromise solutions by balancing conflicting criteria, which is particularly useful in volatile environments like cryptocurrency markets. Together, these methods reduce subjectivity in the decision-making process and offer practical usability in fields such as social sciences, where mathematical simplicity is a significant advantage.

The raw values each alternative obtained for each criterion, along with the normalized results from the normalization process, are presented in Table 3. In this table, the relative performance of each alternative in the context of relevant criteria has been made comparable on a consistent scale. The normalization process aims to enable direct comparisons between criteria and to provide a coherent assessment in the analysis. Consequently, the performance differences of the alternatives on a criterion basis are presented in a clearer and more comprehensible manner.

**Table 3.** The Values of the Alternatives for Each Criterion

| | **Calculated Values** | | | | **Normalized Values** | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternatives** | **TV** | **CV** | **CR** | **AR** | **TV** | **CV** | **CR** | **AR** |
| **$A_1$** | 4086,15 | 0,24 | 1,73 | 2,17 | 1,0000 | 0,2576 | 0,5559 | 0,7526 |
| **$A_2$** | 40,66 | 0,32 | 2,27 | 1,31 | 0,0100 | 0,0169 | 0,4168 | 0,4546 |
| **$A_3$** | 256,65 | 0,32 | 2,80 | 1,69 | 0,0628 | 0,0000 | 0,2808 | 0,5856 |
| **$A_4$** | 975,86 | 0,23 | 1,64 | 1,41 | 0,2388 | 0,2800 | 0,5791 | 0,4893 |
| **$A_5$** | 26,88 | 0,23 | 1,57 | 1,10 | 0,0066 | 0,2961 | 0,5964 | 0,3819 |
| **$A_6$** | 52,92 | 0,13 | 0,95 | 0,93 | 0,0130 | 0,5905 | 0,7570 | 0,3222 |
| **$A_7$** | 9,13 | 0,18 | 1,39 | 0,95 | 0,0022 | 0,4351 | 0,6443 | 0,3286 |
| **$A_8$** | 12,80 | 0,28 | 3,90 | 2,89 | 0,0031 | 0,1248 | 0,0000 | 1,0000 |
| **$A_9$** | 14,23 | 0,12 | 0,73 | 0,97 | 0,0035 | 0,6239 | 0,8133 | 0,3359 |
| **$A_{10}$** | 12,35 | 0,32 | 2,57 | 1,39 | 0,0030 | 0,0065 | 0,3411 | 0,4815 |

The calculated criterion weights and the resulting Sj, Rj and Qj values obtained through the application of the VIKOR methodology are presented in Table 4 to comprehensively evaluate the relative performances of the alternatives. These values determine each alternative's proximity to the optimal solution and allow for comparisons among the alternatives. The Sj value represents the total distance of each alternative across all criteria, while the Rj value shows the maximum distance relative to the worst case. The Qj value, calculated as a combined performance metric, incorporates both Sj and Rj values to rank each alternative. The results presented in Table 4 serve as a crucial reference for assessing the superiority of alternatives in the decision-making process. The Sj value represents the total deviation of an alternative from the ideal solution across all criteria. Simply put, it represents the total distance of an alternative from the optimal scenario. The Rj value, on the other hand, gives insight into the most important shortcoming for a given alternative by showing the maximum deviation across all criteria. Finally, the Qj value combines the information from Sj and Rj to produce a single score that ranks the alternatives, taking into account both their overall performance and their weakest points. Collectively, these values guide decision-makers in selecting the best alternative by providing a clear and quantitative comparison.

**Table 4.** Ranking for S, R and Q values

| $\mathbf{S_j}$ | $\mathbf{R_j}$ | $\mathbf{Q_j}$ (q=0) | $\mathbf{Q_j}$ (q=0,25) | $\mathbf{Q_j}$ (q=0,50) | $\mathbf{Q_j}$ (q=0,75) | $\mathbf{Q_j}$ (q=1) |
|---|---|---|---|---|---|---|
| $A_{10}$ | $A_{10}$ | $A_{10}$ | $A_{10}$ | $A_{10}$ | $A_{10}$ | $A_{10}$ |
| $A_3$ | $A_2$ | $A_2$ | $A_2$ | $A_2$ | $A_3$ | $A_3$ |
| $A_2$ | $A_3$ | $A_3$ | $A_3$ | $A_3$ | $A_2$ | $A_2$ |
| $A_8$ | $A_4$ | $A_4$ | $A_4$ | $A_5$ | $A_8$ | $A_8$ |
| $A_5$ | $A_1$ | $A_1$ | $A_5$ | $A_4$ | $A_5$ | $A_5$ |
| $A_4$ | $A_5$ | $A_5$ | $A_1$ | $A_8$ | $A_4$ | $A_4$ |
| $A_7$ | $A_7$ | $A_7$ | $A_7$ | $A_7$ | $A_7$ | $A_7$ |
| $A_1$ | $A_6$ | $A_6$ | $A_8$ | $A_1$ | $A_1$ | $A_1$ |
| $A_6$ | $A_8$ | $A_8$ | $A_6$ | $A_6$ | $A_6$ | $A_6$ |
| $A_9$ | $A_9$ | $A_9$ | $A_9$ | $A_9$ | $A_9$ | $A_9$ |

One of the distinctive features of the VIKOR methodology is the acceptable advantage principle. This principle suggests that when no single alternative stands out as significantly better than the others, multiple alternatives that are close to the best solution should be considered together. In this study, this principle has been applied to ensure a balanced evaluation, preventing the exclusion of alternatives that might offer valuable benefits under certain criteria. By integrating this principle, the study provides a more flexible and inclusive approach to portfolio management, reflecting real-world decision-making scenarios where trade-offs between multiple factors are unavoidable.

The acceptable advantage principle, a strong feature of the VIKOR methodology, plays a crucial role in identifying the best solution. According to this principle, when there is no significant difference among the top-ranked solutions, it is recommended that the decision-maker consider alternatives that fall within a certain proximity together. In this study, based on the results obtained through the VIKOR methodology, alternatives $A_{10}$, $A_3$, and $A_2$ have been identified as the best solutions without any distinct advantage over one another. These three alternatives are proposed as the recommended portfolio according to the acceptable advantage principle and are deemed suitable for joint consideration in the decision-making process.

The performances of alternatives $A_{10}$, $A_3$, and $A_2$, determined to be included in the portfolio, have been calculated for each criterion and compared with a single investment strategy for each cryptocurrency. This analysis was conducted to evaluate the advantages and disadvantages of the proposed portfolio structure relative to alternative investment strategies. The potential performance levels each alternative offers in light of the specified criteria provide in-depth insights into investment decision-making processes. The findings, presented in Table 5, clearly illustrate how the portfolio's performance compares to single investment strategies.

**Table 5.** Performance Assessment

| | TV | CV | CR | AR |
|---|---|---|---|---|
| Bitcoin | -0,7474 | 0,9685 | 0,3772 | -0,3261 |
| Bitcoin Cash | 24,3859 | 0,5182 | 0,1694 | 0,1157 |
| Doge | 3,0218 | -7,1256 | -0,2331 | -0,1338 |
| Ethereum | 0,0578 | 0,9710 | 0,4021 | 0,0367 |
| Ethereum Classic | 37,4040 | 0,9726 | 0,4195 | 0,3283 |
| Litecoin | 18,5038 | 0,9862 | 0,5426 | 0,5742 |
| Zcash | 112,1028 | 0,9813 | 0,4626 | 0,5437 |
| Kaspa | 79,6305 | 0,9349 | -345,2239 | -0,4928 |
| Monero | 71,5298 | 0,9870 | 0,5743 | 0,5102 |
| Bitcoin SV | 82,5757 | -0,2475 | -0,0151 | 0,0535 |

The criterion-based performance values presented in Table 5 were obtained by comparing the constructed portfolio with single investment vehicles. Positive values indicate that the portfolio outperformed the single investment in the respective criterion, while negative values represent lower performance. During the analyzed period, the low trading volume of Zcash and the minimal movement of Kaspa are considered the primary reasons for the varied performance values observed in the table.

On the other hand, when comparing the constructed portfolio with Bitcoin, which is known for its dominant influence in the market, Bitcoin maintains its dominant position in terms of trading volume. However, in terms of risk and volatility, the portfolio exhibits a lower risk level, making it a safer investment choice. These results indicate that, despite Bitcoin's high volume, the portfolio offers a more stable and lower-volatility investment option.

When examining annual return rates, the constructed portfolio demonstrates superior performance compared to all cryptocurrencies except Bitcoin, Doge, and Kaspa. Considering that the investment process involves a decision framework balancing both gains and risks, it is advisable for investors to make their choices based on their flexibility concerning these two critical variables. This approach allows investors to adopt a more informed and strategic stance in portfolio selection, aligning with their risk tolerance and targeted return rates. The constructed portfolio presents a noteworthy option for investors seeking to balance security and gain potential in their investment process.

## 5. CONCLUSION

The findings of this study demonstrate that evaluating a portfolio of PoW-based cryptocurrencies using the IQRBOW-based VIKOR method offers meaningful advantages for investors. The analyses compare the performance levels of alternatives across various criteria, highlighting each alternative's advantages and disadvantages under market conditions. Using VIKOR, one of the MCDM methods, an optimal portfolio strategy was determined, with Bitcoin SV, Bitcoin Cash, and Doge selected as suitable components for the recommended portfolio. This portfolio, established in line with the acceptable advantage principle, presents a structure capable of maintaining stability in the volatile cryptocurrency market while offering a reliable potential for returns. This study provides an innovative contribution to areas such as volatility management and objective weighting in PoW-based cryptocurrencies. By integrating the IQRBOW method with the VIKOR approach, the study offers a novel methodology for constructing balanced and reliable portfolios in highly volatile environments. These contributions not only enhance the literature on cryptocurrency portfolio management but also provide practical insights for investors navigating the complex dynamics of PoW-based assets.

The IQRBOW method used in this study provides an objective weighting mechanism in the decision-making process, creating a structure unaffected by biases from human decision-makers. This objective nature of IQRBOW contributes to a more balanced decision-making process, particularly when outliers are present in the dataset. Additionally, the simplicity of its calculation process allows for quick and practical application in investment decision-making, making it easily applicable even on large datasets. Another advantage of the IQRBOW method is its flexibility to integrate with various MCDM methods. In this study, its successful integration with the VIKOR method facilitated an objective and multi-criteria decision-making process. These features make IQRBOW especially suitable for financial environments that require fast, reliable, and systematic analysis.

Comparing the performance values of cryptocurrencies in the portfolio based on TV, CV, CR, and AR criteria with single investment strategies reveals that the proposed portfolio offers a more balanced risk-return profile against Bitcoin, the market's dominant player in terms of trading volume. While Bitcoin maintains its dominant market position, its high volatility and risk level pose potential risks for investors. The constructed portfolio, with its lower volatility compared to Bitcoin, stands out as a strategy that provides reliability for long-term investment processes. In terms of annual return rates, the proposed portfolio demonstrates superior performance over all cryptocurrencies except Bitcoin, Doge, and Kaspa. These results present a structure that enables investors to manage both gain and risk factors in volatile market conditions.

Within the portfolio strategy, each alternative has demonstrated a decision framework that balances gains and risks across each criterion. In this context, it is crucial for investors to adopt a more flexible and strategic approach to portfolio selection, tailored to their risk tolerance and expected return levels. Given the high volatility in the cryptocurrency market, the criterion weights provided by the IQRBOW-based VIKOR method in the portfolio construction process have contributed to a more balanced investment profile by minimizing the impact of outliers. Consequently, this portfolio, which allows investors to enhance their gain potential while optimizing risk levels, is considered a reliable investment alternative against volatile market conditions.

Future research could explore the application of the IQRBOW-based VIKOR method to other consensus algorithms beyond PoW, such as Proof of Stake (PoS) or hybrid models, to evaluate its adaptability and effectiveness in different contexts. Additionally, examining the integration of more dynamic criteria, such as real-time market sentiment or macroeconomic indicators, could provide deeper insights into cryptocurrency portfolio management. For practitioners, the findings of this study underscore the importance of using objective and systematic approaches in portfolio construction to mitigate risks and optimize returns in volatile markets. Investors are encouraged to adopt strategies that leverage such methodologies to maintain a balanced risk-return profile, particularly in emerging financial ecosystems like cryptocurrencies.

## REFERENCES

Akbar, N. A., Muneer, A., ElHakim, N., & Fati, S. M. (2021). Distributed hybrid double-spending attack prevention mechanism for proof-of-work and proof-of-stake blockchain consensuses. *Future Internet, 13*(11), 285. https://doi.org/10.3390/fi13110285

Biryukov, A., & Tikhomirov, S. (2019). Security and privacy of mobile wallet users in Bitcoin, Dash, Monero, and Zcash. *Pervasive and Mobile Computing, 59,* 101030. https://doi.org/10.1016/j.pmcj.2019.101030

Charfeddine, L., Benlagha, N., & Maouchi, Y. (2020). Investigating the dynamic relationship between cryptocurrencies and conventional assets: Implications for financial investors. *Economic Modelling, 85,* 198-217. https://doi.org/10.1016/j.econmod.2019.05.016

Ecer, F., Böyükaslan, A., & Hashemkhani Zolfani, S. (2022). Evaluation of cryptocurrencies for investment decisions in the era of Industry 4.0: A borda count-based intuitionistic fuzzy set extensions EDAS-MAIRCA-MARCOS multi-criteria methodology. *Axioms, 11*(8), 404. https://doi.org/10.3390/axioms11080404

Fang, F., Ventre, C., Basios, M., Kanthan, L., Martinez-Rego, D., Wu, F., & Li, L. (2022). Cryptocurrency trading: A comprehensive survey. *Financial Innovation, 8*, 13. https://doi.org/10.1186/s40854-021-00321-6

Fidan, Ü. (2022). Portföy çeşitlendirme kararı için Bitcoin bir alternatif olabilir mi? MEREC tabanlı VIKOR yaklaşımı. *Akademik Yaklaşımlar Dergisi, 13*(2), 526-545. https://doi.org/10.54688/ayd.1182620

Fidan, Ü. (2024). Basic statistical methods in determining criteria weights. *International Journal of Information Technology and Decision Making*. https://doi.org/10.1142/s0219622024500093

Gemeliarana, I. G. A. K., & Sari, R. F. (2018). Evaluation of proof of work (POW) blockchains security network on selfish mining. In *2018 International seminar on research of information technology and intelligent systems (ISRITI)* (pp. 126-130). IEEE. https://doi.org/10.1109/ISRITI.2018.8864381

Gervais, A., Karame, G. O., Wüst, K., Glykantzis, V., Ritzdorf, H., & Capkun, S. (2016). On the security and performance of proof of work blockchains. In *Proceedings of the 2016 ACM SIGSAC conference on computer and communications security* (pp. 3-16). https://doi.org/10.1145/2976749.2978341

Ghosh, A., Gupta, S., Dua, A., & Kumar, N. (2020). Security of Cryptocurrencies in blockchain technology: State-of-art, challenges and future prospects. *Journal of Network and Computer Applications, 163,* 102635. https://doi.org/10.1016/j.jnca.2020.102635

Hashimoto, Y., & Noda, S. (2019). Pricing of mining ASIC and its implication to the high volatility of cryptocurrency prices. *Available at SSRN 3368286*. http://dx.doi.org/10.2139/ssrn.3368286

İç, Y. T., Çelik, B., Kavak, S., & Baki, B. (2022). An integrated AHP-modified VIKOR model for financial performance modeling in retail and wholesale trade companies. *Decision Analytics Journal, 3,* 100077. https://doi.org/10.1016/j.dajour.2022.100077

Investing.com. (2024). *Geçmiş veriler*. https://tr.investing.com/crypto/bitcoin/historical-data (Accessed Date: 10th October 2024).

Maghsoodi, A. I. (2023). Cryptocurrency portfolio allocation using a novel hybrid and predictive big data decision support system. *Omega, 115,* 102787. https://doi.org/10.1016/j.omega.2022.102787

Mingxiao, D., Xiaofeng, M., Zhe, Z., Xiangwei, W., & Qijun, C. (2017). A review on consensus algorithm of blockchain. In *2017 IEEE international conference on systems, man, and cybernetics (SMC)* (pp. 2567-2572). IEEE. https://doi.org/10.1109/SMC.2017.8123011

Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. https://bitcoin.org/bitcoin.pdf (Accessed Date: 25th October 2024).

Opricovic, S., & Tzeng, G. H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research, 156*(2), 445-455. https://doi.org/10.1016/S0377-2217(03)00020-1

Qarni, M. O., & Gulzar, S. (2021). Portfolio diversification benefits of alternative currency investment in Bitcoin and foreign exchange markets. *Financial Innovation, 7,* 17. https://doi.org/10.1186/s40854-021-00233-5

Sahoo, S. K., & Goswami, S. S. (2023). A comprehensive review of multiple criteria decision-making (MCDM) methods: advancements, applications, and future directions. *Decision Making Advances, 1*(1), 25-48. https://doi.org/10.31181/dma1120237

Singh, J., Sharma, A., & Kaur, S. (2023). Analysis of secured hash algorithm-256 in a blockchain-based money transaction system. In *2023 International conference on innovative computing, intelligent communication and smart electrical systems (ICSES)* (pp. 1-6). IEEE. https://doi.org/10.1109/ICSES60034.2023.10465578

Tekletsadik, S. E. (2024). Application of TOPSIS, VIKOR and COPRAS for ideal investment decisions. *Accounting, 10*, 1-10. https://doi.org/10.5267/j.ac.2023.9.002

Watters, C. (2023). Digital gold or digital security? Unravelling the legal fabric of decentralised digital assets. *Commodities*, *2*(4), 355-366. https://doi.org/10.3390/commodities2040020

Werth, J., Berenjestanaki, M. H., Barzegar, H. R., El Ioini, N., & Pahl, C. (2023). A Review of Blockchain platforms based on the scalability, security and decentralization trilemma. *ICEIS*, (1), 146-155. https://doi.org/10.5220/0011837200003467

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