An Efficient decision-making model of consensus protocols for blockchains: An exploratory study

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Abstract

In addition to being a game-changer for the cryptocurrency business, Blockchain was also a catalyst for the fast rise of certain Distributed Ledger Technologies (DLTs). An important aspect of a DLT system's design is a consensus mechanism, which ensures that almost all interviewees agreed on the integrity of the data. As a result, a broad variety of consensus protocols have been developed, each with a distinct notion and property (e.g., reduced energy usage, greater scalability). When moving from one blockchain network to another, the main criteria for consensus mechanisms typically vary dramatically, so there is no universal protocol. As a result, choosing the best consensus mechanism for a certain DLT system is critical, but also difficult, since experts must balance competing demands. MCDM approaches are used in this research to provide an approach for choosing the best consensus procedures based on criteria, objectives, and other needs. A genuine bike-rental application is used to show the technology's potential, as well as the preferred consensus mechanisms for 3 of the most popular kinds of current blockchain systems. To top it all off, the information and technologies gathered are openly accessible for anybody to use, allowing for maximum replication and future improvement.

Keywords: Blockchain; MCDM; VIKOR; Distributed Ledger Technologies

1. Introduction

Among the most significant innovations presented in Bitcoin [1] is the blockchain, which has lately received many attention from the practitioners and academicians [2]–[5]. Beyond cryptocurrencies, blockchain technology has already been used in a variety of unique ways [6]–[8]. Distributed ledger technologies (DLTs) include a much larger space than blockchain alone[9]. However, although distributed ledgers have been around before, Bitcoin is unique in that it allows data to be exchanged, stored, and maintained without the involvement of a third party while also combining several current systems (such as timestamping, P2P systems, data encryption, and the communicating of computing capabilities[2].

As a result, blockchains are distinct from typical database systems in that they do not depend on a centralized third party. Consensus protocols are the foundation of this technology[10]. It may therefore be seen as a P2P DLT comprised of blocks, in which the consensus mechanism maintains data dependability and consistency throughout the network of nodes. Encryption, on the other hand, provides safe data transfer and enables data preservation in a decentralized system.

Blockchain and DLT in particular lack standards, hence it is difficult to classify all current DLTs. Blockchains are often divided into three types based on how they operate: general populace, consortium

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(or federated), and secret. According to [2], [11]–[13] Measurements (e.g., energy usage, flexibility level, time lag, higher the ratio, fault detection capabilities) must be taken into account for every group.

Choosing the right consensus protocol is critical to the overall measurements of a particular DLT system. Nodes in a blockchain network must all accept the same transaction information without the aid of a trusted central institution[14]. Various blockchain consensus systems with various ideas and attributes have been developed since the Nakamoto protocol was introduced in Bitcoin [14], [15]Therefore, choosing the best consensus protocol for a given DLT system is critical. Experts must balance competing demands and face a high level of ambiguity, which makes their job difficult.

In the studies, consensus procedure choice challenges [16]–[19] are often mentioned [13], [20], [21]. But the most popular strategy is to examine and classify consensus mechanisms given a set of blockchain attributes and give insights and suggestions related to the performance data. As a result, more organized and complex research techniques are required to make a sensible decision, as the consensus may greatly affect the efficiency and availability of a blockchain system.

In a variety of sectors and applications, MCDM approaches are employed to solve main choice (or ranking) issues [22]. Numerous papers have been published, particularly for platform selection in the blockchain area, using MCDM techniques[23], the most essential factors and associated weights for consensus mechanisms are highlighted, highlighting the potential of MCDM approaches for consensus mechanism selection. The choice of a consensus protocol does not have an MCDM-enabled method.

This void is filled by our efforts here. The methodology we offer utilizes an end-to-end MCDM approach to discover the optimal consensus procedure according to the criteria as well as weights and restrictions (if needed). By MCDM[24], we follow all the phases of the problem-solving procedure. We begin by defining the issue and selecting potential solutions, then specify criteria and their relative weights, gather data on the effectiveness of those solutions, and finally arrive at a set of ordered (feasible) consensus procedures. The VIKOR is one of the most widely used state-of-the-art MCDM approaches since each has its advantages for comparing products. By establishing preferred consensuses for the 3 major kinds of blockchain systems general, consortium, and private we illustrate the viability of the concepts we've suggested. We've also used it in a real-world bike-rental system application. Please keep in mind that this process may be used to choose any DLT element or the complete system, in which the factors and associated weights could be reviewed.

The following are the paper's key contributions:

I. It examines the many methods used to choose the best consensus mechanism for a particular blockchain system or app.
II. In an accessible data repository, it gathers and combines statistical and qualitative information representing the characteristics and system performance of 18 current consensus procedures.
III. For the first time, academics and practitioners have a methodology for selecting the best consensus mechanism (or other DLT system elements) for particular blockchain apps, thanks to this approach.
IV. An example of a general populace, consortium, and private blockchain built using the newly proposed architecture.
V. It is based on a real-world bicycle rental scheme.

As for the rest of the study, it's structured as follows: a literature study of the topic of MCDM-based consensus protocol selection is introduced in Section 2. Section 3 provides the methodology and framework. Using three different kinds of blockchains, Section 4 demonstrates and proves the proposed framework's efficacy by the application and provides results. The last section of our report is Section 5 provides the conclusion.

2. Related Work

It is the purpose of this part to evaluate the literature on blockchain consensus mechanisms. The major strategy we used to find relevant material was a backward forward and overextending (Wohlin, 2014) method. Exception of generic blockchain surveys in which evaluations of current consensus mechanisms gained substantial attention, we rigorously evaluated only studies whose major emphasis was on

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consensus mechanisms in our evaluation. Because of this, papers that concentrated more on blockchain system choice than consensus mechanisms were removed.

Most typically, benchmarking is used to assess consensus mechanism, which involves comparing and measuring the performance of two or more protocols against a predetermined set of standards. The first section of this chapter reviews research that used benchmarking as the major method for determining blockchain consensuses, as stated above. MCDM approaches have been used to solve consensus assessment and selection issues in the second half of this paper. Reviewing consensus mechanism, criteria, and a decision-making strategy for blockchain technology comparisons and selection are the primary goals of this research (if any).

Utilizing 7 criteria, [25]compared the five most prevalent consensus model types. On the basis of this, the authors argued that consensus should be obtained among a significant number of untrusted peers for permissionless systems (for example, utilizing robust computationally or storage difficulty), compromising transaction permanence and performance in the process. It is less scalable, but quicker transaction closure and greater throughput make the public blockchain collaboration from blockchains more desirable. When deciding on a consensus model for business, the size of the network, the relationships between members, and both functional and non-functional characteristics must all be taken into account (e.g., performance and confidentiality).

It was found that [12]compared the performance of five consensus mechanisms based on 5 different criteria. The authors of this study provided technical advice on appropriate consensus processes for three distinct circumstances, according to their research (public, private, and permissioned blockchains).
Distributed Proof of Stake (DPoS) and Proof of Work (PoW) consensuses are popular options for public blockchains since they are completely open and decentralized and do not need any central authority. Due to the confined nature of private blockchains, solving crash faults is more critical than resolving Byzantine faults. Crush-tolerant consensus techniques such as PBFT and RAFT show promise in this regard. Permissions are semi-private networks developed by many businesses. Certain nodes may turn become malevolent nodes if there are disagreements between various companies in the network. PBFT seems to be a viable alternative in this situation.

There were two independent comparisons of consensuses given by[26]. Before doing this, they conducted a comparison of three primary groups based on six different variables. Second, a comparison of Vote-based and Proof-based consensus methods was made using eight criteria. Each category's benefits and downsides were discussed by the writers. Vote-based consensus mechanisms, as opposed to Proof-based consensus mechanisms, have a lot of promise in the newly formed consortium and private blockchain, according to the study's findings. Rather than evaluating individual techniques, the authors in this study evaluated their broad categories. However, the findings of every category were combined using a huge variety of particular consensus techniques.

MCDM techniques have previously been employed in the blockchain area in various papers. There are a lot of them dedicated to choosing a blockchain platform. For a comprehensive review of previous work including MCDM approaches for blockchain system choice, see Section III in[24]. Our focus here is on examining papers in which MCDM approaches were used to analyze blockchain consensus.

An algorithm choice formalization method that uses MCDM was developed by[15]. The first step was to do a thorough assessment of the research on blockchain consensus. They found a wide range of criteria for analyzing blockchain consensuses, all of which were implemented and employed. Some of the studies we looked at weren't included since they were more centered on blockchain than consensus procedures. The most significant factors and subcriteria that impact the effectiveness of consensus methods were highlighted in this study. Before this, criteria were evaluated using a comparison matrix approach[27]. A performance assessment methodology for blockchain consensus algorithms was created as a result. For this purpose, the standard benchmarking approach was used. There were seven criteria used in the first phase, and ten criteria used in the second part, to compare 10 consensus methods based on their represented currencies. To sum up, this research can only serve as a starting point for the creation of a full-scale MCDM method. It's still necessary to specify the specific criterion values for each option, choose and apply the relevant MCDM approaches, evaluate the findings, and summarise the useful information for operators.

Researchers have developed a 4-category (origin, architecture, effectiveness, and safety) categorization system for 28 novel consensus mechanisms, which incorporates information from past studies as well as

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new features. They compared 28 treatments utilizing 22 different criteria in this framework. Organizations seeking guidance in selecting an appropriate consensus for their app were given a methodology based on the Boolean Decision Tree (BDT) approach, which the authors described in the last section. To take benefit of the reasoning and goals underlying an organization's decisions, the process was created "manually." Starting with the blockchain's accessibility (i.e., does the business want a permissioned or permissionless environment?) and moving on to considerations of design, performance, and security is the suggested decision process. As a result, the organization's newly proposed flowchart will show a reasonable consensus based on its goals for a particular application.

3. Research Methodology

To assist decision-makers being unable to make precise choices, Wang and Tzeng [28] developed the VIKOR technique. A mechanism like VIKOR must be used to handle the particular conflicts in this paper's decision criteria system, like the charging range of a ship and the power system distance. This approach normalizes the outcomes, increases community benefit while reducing individual regret, and ultimately leads to a workable compromise. The options are ranked using this technique. Figure 1 shows the framework of the study.

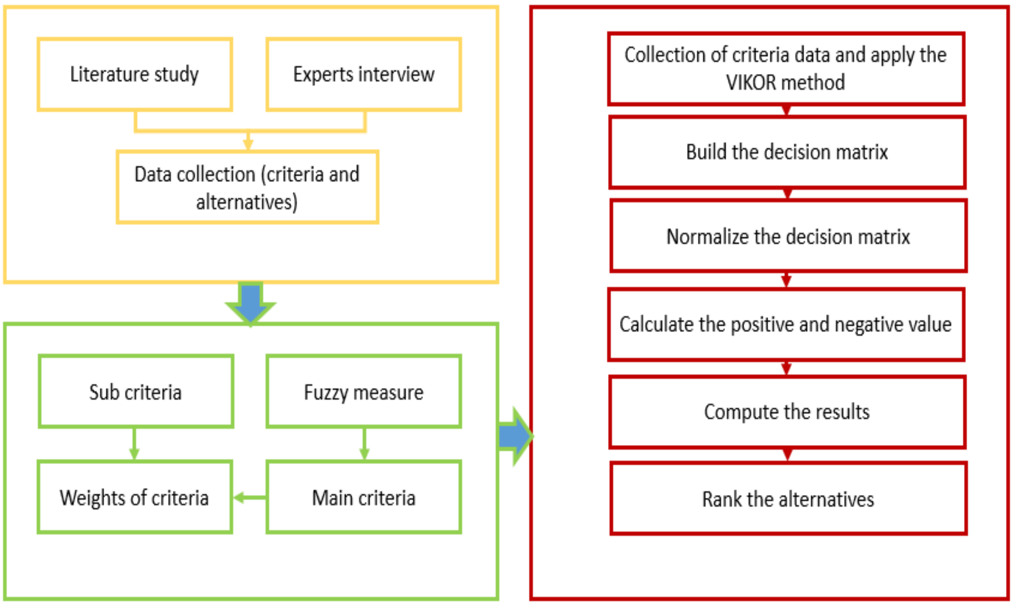

Figure 1. The framework of the study

$$R_k = \sum_{i=1}^{n} \sum_{j=1}^{m} w_j w_{ij} \frac{t_{ij}^{+} - t_{kij}}{t_{ij}^{+} - t_{ij}^{-}}$$

$$U_k = \max \left[w_j w_{ij} \frac{t_{ij}^{+} - t_{kij}}{t_{ij}^{+} - t_{ij}^{-}} \right]$$

$$V_k = \lambda \frac{R_k - {R_k}^{+}}{{R_k}^{-} - {R_k}^{+}} + (1 - \lambda) \frac{U_k - {U_k}^{+}}{{U_k}^{-} - {U_k}^{+}}$$

$$R^{+} = \min_k R_k$$

$$R^{-} = \max_k R_k$$

$$U^{+} = \min_k U_k$$

$$U^{-} = \max_k U_k$$

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$$\lambda = 0.5$$

This article uses both quantitative and qualitative criteria to assess its findings. Specific data may be gathered for quantitative criteria such as yearly direct and diffuse irradiance and average yearly temperature. Because of their ambiguity and uncertainty, precise statistics cannot be collected for qualitative factors such as environmental formations, the influence on the local economy, and support from the public. Expert rating and the use of set-valued stats may instead be used to quantify features.

The triangular intuitionistic fuzzy numbers can be defined as:

$$e = < (a, b, c); h, p >$$

The x and y can be defined as:

$$h_e(x) = \begin{cases} \dfrac{x-b}{b-a} & a \le x \le b \\ w_e & x = b \\ \dfrac{c-x}{c-a^{w_e}} & b \le x \le c \\ 0 & x \le x \text{ or } a \le c \end{cases}$$

$$p_e(x) = \begin{cases} \dfrac{b-x+(x-a)p_e(x)}{b-a} & a \le x \le b \\ p_e(x) & x = b \\ \dfrac{x-b+(c-x)p_e(x)}{c-b} & b \le x \le c \\ 1 & x \le x \text{ or } a \le c \end{cases}$$

Defuzzification formula

$$F = \frac{1}{12}(a + 4 * b + c)(1 - h + p)$$

4. Results and Discussion

Using a real bike rental app, this part shows the structure suggested in the preceding section. In this study, we used five main criteria, 12 sub-criteria, and ten alternatives as below

Key criteria	Sub criteria	alternatives
Throughput	Transactions per second	BCA1
	Transaction latency	BCA2
	Finalization	BCA3
Decentralization	Number of consensus nodes	BCA4
	Number of network nodes	BCA5
Incentivization	fees	BCA6
	Reward	BCA7
Sustainability	Power consumption	BCA8
	Hardware dependency	BCA9
Security	Fault-tolerance	BCA10
	attack	
	Double spending	

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A consensus procedure for renting a bike was determined by following the architecture presented in the paper, which describes how the weights for the various criteria and groupings of criteria representing bike rental system needs were calculated. The results are displayed in figure 2.

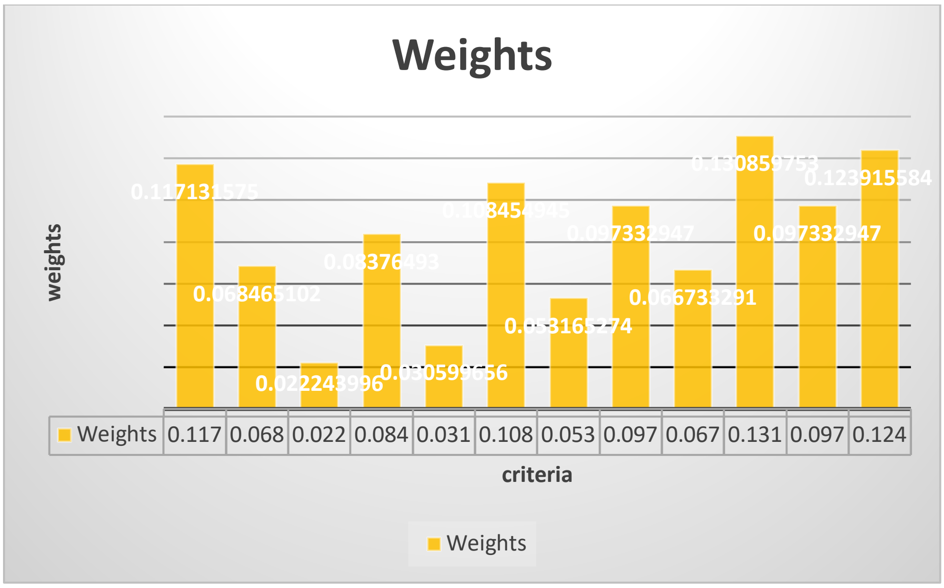

Figure 2. The weights of criteria.

Let three decision-makers build the decision matrix. Tables 1,2,3 show the decision matrix. Then aggregate the opinions of experts in table 4.

Table 1. The opinions of experts 1.

	BCC_1	BCC_2	BCC_3	BCC_4	BCC_5	BCC_6	BCC_7	BCC_8	BCC_9	BCC_{10}	BCC_{11}	BCC_{12}
BCA_1	0.1515	0.1515	0.10025	0.21583	0.1515	0.083167	0.21583	0.175	0.1515	0.083167	0.175	0.21583
BCA_2	0.21583	0.21583	0.10025	0.21583	0.175	0.10025	0.21583	0.175	0.10025	0.1515	0.175	0.10025
BCA_3	0.10025	0.175	0.083167	0.1515	0.175	0.175	0.175	0.10025	0.10025	0.21583	0.10025	0.175

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BCA4	0.10025	0.21583	0.21583	0.10025	0.175	0.21583	0.1515	0.083167	0.1515	0.175	0.083167	0.10025
BCA5	0.21583	0.1515	0.175	0.083167	0.1515	0.10025	0.175	0.083167	0.175	0.10025	0.083167	0.175
BCA6	0.1515	0.1515	0.083167	0.083167	0.21583	0.1515	0.1515	0.083167	0.1515	0.21583	0.1515	0.083167
BCA7	0.21583	0.175	0.175	0.175	0.175	0.175	0.1515	0.10025	0.175	0.175	0.10025	0.175
BCA8	0.1515	0.10025	0.21583	0.10025	0.175	0.1515	0.175	0.21583	0.21583	0.10025	0.1515	0.175
BCA9	0.175	0.175	0.10025	0.175	0.10025	0.1515	0.21583	0.10025	0.1515	0.10025	0.175	0.175
BCA10	0.175	0.10025	0.1515	0.21583	0.175	0.21583	0.10025	0.1515	0.083167	0.21583	0.10025	0.083167

Table 2. The opinions of experts 2.

	BCC1	BCC2	BCC3	BCC4	BCC5	BCC6	BCC7	BCC8	BCC9	BCC10	BCC11	BCC12

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BCA_1	0.083167	0.175	0.083167	0.21583	0.21583	0.1515	0.21583	0.1515	0.175	0.21583	0.175	0.21583
BCA_2	0.1515	0.1515	0.10025	0.1515	0.10025	0.083167	0.1515	0.175	0.21583	0.10025	0.175	0.10025
BCA_3	0.21583	0.175	0.10025	0.175	0.1515	0.175	0.175	0.21583	0.10025	0.1515	0.10025	0.175
BCA_4	0.175	0.10025	0.21583	0.10025	0.21583	0.175	0.21583	0.21583	0.083167	0.10025	0.083167	0.10025
BCA_5	0.1515	0.10025	0.175	0.1515	0.1515	0.21583	0.175	0.21583	0.1515	0.1515	0.083167	0.175
BCA_6	0.10025	0.083167	0.10025	0.175	0.10025	0.175	0.083167	0.1515	0.10025	0.175	0.1515	0.083167
BCA_7	0.175	0.1515	0.175	0.175	0.175	0.10025	0.1515	0.1515	0.21583	0.1515	0.10025	0.175
BCA_8	0.1515	0.1515	0.21583	0.1515	0.1515	0.1515	0.10025	0.083167	0.1515	0.21583	0.1515	0.175

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BCA_9	0.1515	0.175	0.175	0.21583	0.175	0.175	0.21583	0.10025	0.175	0.21583	0.175	0.175
BCA_{10}	0.175	0.21583	0.1515	0.21583	0.1515	0.1515	0.21583	0.175	0.1515	0.175	0.10025	0.083167

Table 3. The opinions of experts 3.

	BCC_1	BCC_2	BCC_3	BCC_4	BCC_5	BCC_6	BCC_7	BCC_8	BCC_9	BCC_{10}	BCC_{11}	BCC_{12}
BCA_1	0.10025	0.21583	0.175	0.10025	0.083167	0.175	0.083167	0.10025	0.175	0.21583	0.21583	0.1515
BCA_2	0.21583	0.21583	0.1515	0.10025	0.1515	0.175	0.21583	0.175	0.1515	0.1515	0.083167	0.175
BCA_3	0.175	0.10025	0.21583	0.10025	0.083167	0.21583	0.1515	0.21583	0.10025	0.175	0.21583	0.1515
BCA_4	0.21583	0.10025	0.1515	0.083167	0.1515	0.21583	0.175	0.1515	0.175	0.10025	0.175	0.1515
BCA_5	0.10025	0.1515	0.083167	0.1515	0.10025	0.1515	0.175	0.1515	0.21583	0.1515	0.175	0.21583

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BCA_6	0.175	0.21583	0.1515	0.21583	0.1515	0.1515	0.21583	0.175	0.1515	0.175	0.1515	0.175
BCA_7	0.21583	0.1515	0.175	0.10025	0.1515	0.083167	0.21583	0.175	0.21583	0.10025	0.10025	0.175
BCA_8	0.175	0.10025	0.10025	0.083167	0.21583	0.1515	0.1515	0.1515	0.10025	0.1515	0.175	0.21583
BCA_9	0.175	0.21583	0.1515	0.21583	0.175	0.21583	0.10025	0.10025	0.175	0.175	0.175	0.175
BCA_{10}	0.21583	0.1515	0.1515	0.1515	0.175	0.083167	0.1515	0.1515	0.083167	0.083167	0.1515	0.175

Table 4. The combined opinions of experts.

	BCC_1	BCC_2	BCC_3	BCC_4	BCC_5	BCC_6	BCC_7	BCC_8	BCC_9	BCC_{10}	BCC_{11}	BCC_{12}
BCA_1	0.111639	0.180777	0.119472	0.177303	0.150166	0.136556	0.171609	0.14225	0.167167	0.171609	0.188861	0.194387
BCA_2	0.194387	0.194387	0.117333	0.15586	0.14225	0.119472	0.194387	0.175	0.15586	0.134417	0.144389	0.125167

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BCA_3	0.163693	0.150083	0.133082	0.14225	0.136556	0.18861	0.167167	0.177303	0.10025	0.180777	0.138777	0.167167
BCA_4	0.163693	0.138777	0.194387	0.094556	0.180777	0.20222	0.180777	0.150166	0.136556	0.125167	0.113778	0.117333
BCA_5	0.15586	0.134417	0.144389	0.128722	0.134417	0.15586	0.175	0.150166	0.180777	0.134417	0.113778	0.18861
BCA_6	0.14225	0.150166	0.111639	0.157999	0.15586	0.159333	0.150166	0.136556	0.134417	0.18861	0.1515	0.113778
BCA_7	0.20222	0.159333	0.175	0.150083	0.167167	0.119472	0.172943	0.14225	0.20222	0.14225	0.10025	0.175
BCA_8	0.159333	0.117333	0.177303	0.111639	0.180777	0.1515	0.14225	0.150166	0.15586	0.15586	0.159333	0.18861
BCA_9	0.167167	0.18861	0.14225	0.20222	0.150083	0.180777	0.177303	0.10025	0.167167	0.163693	0.175	0.175
BCA_{10}	0.18861	0.15586	0.1515	0.194387	0.167167	0.150166	0.15586	0.159333	0.105945	0.157999	0.117333	0.113778

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Normalize the decision matrix in table 5. Then compute the positive and negative values. Then rank the alternative base on the lowest value of V_k. Figure 3. Shows the rank of alternatives. From figure 3. The BCA_3 is the highest rank and BCA_4 is the lowest rank.

Table 5. The normalization combined the opinions of experts.

	BCC_1	BCC_2	BCC_3	BCC_4	BCC_5	BCC_6	BCC_7	BCC_8	BCC_9	BCC_{10}	BCC_{11}	BCC_{12}
BCA_1	0.117132	0.012093	0.020138	0.019386	0.020205	0.086064	0.023227	0.044279	0.02294	0.035067	0	0
BCA_2	0.010129	0	0.020713	0.036069	0.025429	0.108455	0	0.00291	0.03034	0.11178	0.048712	0.106408
BCA_3	0.049819	0.039365	0.01648	0.046658	0.029188	0.017838	0.027757	0	0.066733	0.016157	0.054894	0.041844
BCA_4	0.049819	0.049412	0	0.083765	0	0	0.013879	0.03428	0.042973	0.13086	0.082431	0.11845
BCA_5	0.059949	0.053286	0.01344	0.057183	0.03306	0.060763	0.019769	0.03428	0.014033	0.11178	0.082431	0.00888
BCA_6	0.077548	0.039292	0.022244	0.034405	0.016446	0.05621	0.045093	0.051472	0.044373	0	0.040879	0.123916
BCA_7	0	0.031146	0.005211	0.040563	0.008983	0.108455	0.021866	0.044279	0	0.095623	0.097333	0.029802

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BCA8	0.0554457	0.0684465	0.0045992	0.0704474	0	0.0664777	0.0531665	0.034428	0.030334	0.0675551	0.032225	0.00888
BCA9	0.0453328	0.0051333	0.0140155	0	0.0202259	0.0281005	0.017442	0.097333	0.022994	0.0513944	0.0149992	0.0298002
BCA10	0.0175999	0.0342333	0.0115229	0.0060994	0.0089883	0.0682226	0.0392887	0.02277	0.0630006	0.0631339	0.0785155	0.1239916

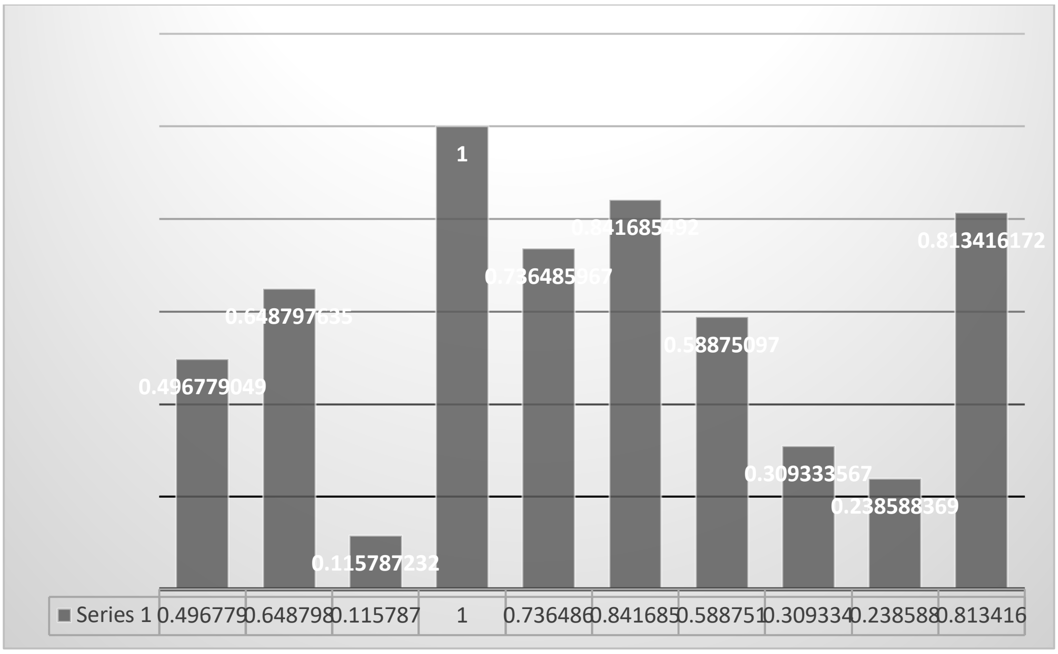

Figure 3. The rank of alternatives

5. Conclusion

The number of consensus mechanisms is outpacing the worldwide interest in blockchain technology. When reviewing related work in detail, it was discovered that all of the studies try to classify current consensus procedures including a set of operational assessment criteria, and provide suggestions based on the gathered data. For the most part, MCDM approaches have not been used in the choice of a comprehensive consensus mechanism, which would have made the process considerably more effective. As a result, we devised a new MCDM methodology to help blockchain systems choose the best consensus mechanism for their needs. Decision-makers evaluate a collection of alternatives (protocols) in light of the decision matrix (features) and prioritize them based on the weights (priorities) they've assigned to them. The consensus mechanism ranking method was patterned after this MCDM dilemma (experts). All of the relevant quantitative and qualitative information on 18 current consensus mechanisms' features and performance measures was gathered from multiple sources in an accessible data repository. The platform's promise has been proved by discovering the best consensuses for the 3 major kinds of blockchain systems,

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consortium, and secret. In addition, a blockchain-based bike rental business used the framework to find the best consensus process. Because the data and technologies are openly accessible, they can be easily replicated, repurposed, and improved upon in the future. The proposed MCDM-based systematic functional may be an efficient consensus evaluation tool for constructing different real-world blockchain systems based on expert opinions and system needs to give worldwide interest in the bitcoin blockchain.

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