A Neutrosophic Proposed Model for Evaluation Blockchain Technology in Secure Enterprise Distributed Applications

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Abstract

Applications that are enabled by blockchain technology have been infused with a decentralized system without the need for intermediate entities. Blockchain technology indicates opportunities with various technologies and applications. Recently, a meteoric rise in the amount of interest has been indicated by academics in blockchain technology. Nevertheless, the acceptance of this blockchain technology paradigm in corporate distributed systems is not exactly promising. Executives and technocrats in a business are required to engage in multiple-criteria decision-making (MCDM) with operating uncertainty factors for the acceptance of new technologies. The proposed model aims to develop a model to identify and keep track of major elements that contribute to the sluggish pace for blockchain technology to be adopted by the general public. The study applied the Evaluation Based on the Distance from Average Solution (EDAS) approach to its interval-valued neutrosophic variant, which has the benefit of concurrently with the consideration of a decision maker's truthiness, falsity, and indeterminacy. The EDAS considers the distances of alternatives from the actual solutions considered by each criterion. In addition, the proposed model illustrated the use of neutrosophic theory with the EDAS method to rank blockchain technology in enterprise-distributed applications in uncertain conditions to aid decision-makers in optimal solutions. A numerical case study is illustrated to show the effectiveness of the proposed model in aiding decision-makers to achieve optimal solutions in uncertain conditions.

Keywords: Blockchain Technology; Enterprises; Secure Distributed Applications; Uncertainty; EDAS; MCDM; Neutrosophic Sets.

1. Introduction

The adaptation of new technologies is a vital aspect for organizations and enterprises that will have a direct impact on the performance operations of the business. The consideration of novel technologies and innovation strategies is suggested in the current competitive environment. Recently, technology has been changing the world such that the availability of services everywhere and at the exact time [1]. A poll was conducted in forty different nations, and the results showed that 67% of individuals are utilizing the Internet [2]. The use of smartphones has also seen an increase in popularity. In addition, the manufacturing industry, service industry, and even recreational activities have profited from technological advancements. The utilization of the current technological aspects increases the influence and quality of not only enterprises but also daily routine activities.

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Evaluating the prospective value of innovations, as well as their advantages for an organization's effectiveness and profitability, is an important part of the technology selection process [3].

As a consequence of advancements in technology, the use of blockchain technology (BT), a decentralized digital current, has grown more widespread in business in recent years [4], [5]. BT is a method for the creation of distributed databases that use a decentralized processing system for transactions. Blocks in Bitcoin are linked together, and every block may include a few transactions. Before being submitted to the system as a freshly produced block, a recently completed transaction has to have its legitimacy checked to ensure a genuine state [6], [7]. The sequence of transactions can be as a Blockchain's representation. The Bitcoin transactions are open to the public. Therefore, the growing need of companies and governments to conduct transactions more securely, the BT was developed.

The anticipation of the widespread adoption of BT will have a significant effect on businesses in the foreseeable future. The information about the transactions is termed the public ledger and is stored on various nodes of the blockchain. Any user who accesses the distributed ledger has the capability of entering the shared ledger network. Therefore, the potential to provide a trustworthy environment while eliminating reliance on outside parties. The technology reduces the likelihood of a system failure and any other hazards associated with the chain. The BT may serve as a reliable location for the storage of certain essential data. Users can keep track of all of their prior transactions using BT[8], [9].

Secure distributed enterprise applications have software components are located on more than one machine inside a network at same time. The architectures of distributed corporate applications have gone through a significant stage of innovation, mainframe computers were used in the construction of the first generation of corporate applications. As the storage capacities of personal computers improved, an increasing number of programmers and tasks were transferred to the computers of individual users to more effectively meet the requirements of businesses or processing tasks. Consequently, in the 1980s a two-tier client/server architecture was used in the development of the first generation of distributed corporate systems. In a client-server design with two tiers, the client is responsible for displaying the program to the user, while the server is in control of managing the data and storing it. In the middle to late 1990s, as the complexity of operations and the volumes of data continued to grow, a 3-tier design became common in the development of corporate applications. Therefore, the quantity of data also continued to expand. The display layer, the app layer, and the database layer are the three levels into which software parts are broken down in a design with three tiers[10], [11].

The decision-making process is based on several criteria prioritizing various elements and components considered to be contradicting problems [12]. Therefore, MCDM is concerned with the process of selecting the option that is most favored among a pool of possible alternatives. The MCDM considered various restrictions under the criteria of a specific ranking issue[13]. By comparing each possible option to the predetermined standards. MCDM has effective methods to achieve effective choices. The current competitive condition in distributed applications and uncertainty conditions leads to many contradictions for decision-makers that have a direct impact on the enterprise's decisions. The uncertain measurements for secure distributed enterprise factors either criteria or alternatives can be handled with neutrosophic theory [14].To extend the capabilities of intuitionistic fuzzy sets, Smarandache came up with the concept of neutrosophic logic and neutrosophic sets (NSs)[15], [16]. The neutrosophic set is defined as the situation in which every component of the cosmos has a degree of truthiness, indeterminacy, and falsity that falls within the range of [-0, 1+[the non-standard unit interval[13]. In the neutrosophic sets, ambiguity is expressed as truth and falsity numbers, and degrees of acceptance and belonging and non-belongingness and indeterminacy number is where the element that was included as the percent of hesitation[17]–[19]. The neutrosophic sets are used to assess the degree of uncertainty associated with a system or a group of experts, but it also allows for the addition of indecision resulting from conflicting information. The membership and non-membership values as the truth value and the falsehood value, respectively, while the indeterminacy value represents reluctance. Neutrosophic sets have all of these features,

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which is the solution to the question of why we are using neutrosophic sets in this research[20]–[22]. This allows for the development and use of deneutrosophication and subtraction functions for the interval-valued Neutrosophic (IVNSs) EDAS [23]–[25]. This paper employed IVNSs with the EDAS method to evaluate the BT in enterprise-distributed apps.
The following is the organizational scheme for the remaining parts of this paper: Section 2 presents a literature review about the MCDM, secure enterprise distributed applications, and blockchain technologies. in addition, introduce the methods to achieve the most appropriate platforms. In Section 3, discusses the suggested approach that will be used to construct IVNSs with the EDAS method. Section 4 illustrates a numerical application and results. presents the overall conclusions. Section 5 mentions the managerial implications. Section 6 shows the blockchain applications. Section 7 summarizes study conclusions and future work.

2. literature review

This section mentions a related work of MCDM methods, enterprise distributed applications and blockchain technologies to achieve to evaluated blockchain technologies that aid decision makers to achieve to the most appropriate decisions.

Filatovas et al. [6] incorporated MCDM methods into a framework for picking the most appropriate consensus protocols based on the criteria, priorities, and other defined parameters to achieve to the most appropriate protocols. The study determined the most advantageous consensuses for the three most popular kinds of blockchain systems that use knowledge in a real-world application for renting bikes. In addition, the data and tools gathered and publicly accessible, ensures the findings may be replicated, reused, and further developed.

Faruk et al. [26] illustrated the most suitable blockchain platform in the logistics business to handle extraordinarily intricate interactions and linkages between many stakeholders. Due to lacking in sufficient solutions, the study established a revolutionary, resilient, practical, and powerful decision-making method. The proposed method is very complicated uncertainties to select the best practicable blockchain technology for the logistics business. Erol et al. [5] presented an example that discussed the process of selecting the BP that would be the most viable for a healthcare organization. The study suggested a paradigm for MCDM that merges the rough Analytic Hierarchy Process (RAHP-E) with the rough Compromise Programming (RCP)

A unique paradigm in enterprise-distributed applications implemented by Siddiqui and Haroon[11]. As a new technology in industry, managers and technocrats need to use MCDM methods in fuzzy environment. The study proposed a model for a system that could be used to identify and to keep track of major elements that were responsible for the blockchain technology's relatively modest pace of adoption. The MULTIMOORA technique for group decision-making, which is a common approach to MCDM, has been further developed by incorporating the information entropy weight–fuzzy comprehensive evaluation model (IEW-FCEM) for an uncertain environment. Therefore, the proposed method is suitable for use in situations with the lack of clarity on the relevant information .Zafar et al. [7]used an MCDM technique to rank the public blockchain platforms and to identify the appropriate platform. The study introduced ECWM, a novel weight assignment approach defined as a hybrid of the entropy method and CRITIC method. The study introduced ECWM for a varied dataset and selected 16 characteristics (indicators indicating various parameters for blockchain adoption) from 30 distinct public blockchain systems. The dataset was used to test ECWM.

2.1 Blockchain

The data is stored over a distributed network of nodes that make up the blockchain. This is a fantastic technological solution for ensuring the privacy of sensitive information stored inside the network. This technology enables the safe and secret communication of vital data while also helping to share it. It is the ideal device for safely storing all the papers that are relevant to the topic in a single area. Also, the use of a unified patient database to look for candidates who meet certain trial requirements may be sped up using blockchain

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technology. A decentralized peer-to-peer (P2P) network of desktop computers known as nodes is what makes up the Blockchain. This network is responsible for the upkeep, storage, and recording of data on past transactions or historical events. It enables trustworthy cooperation by storing the information, allowing all nodes on the network to share and interchange it, and maintaining a continuous record of both past and present events. This technology has the capability of integrating different networks to give insights into the significance of individual therapy. As a result, immutability and security may both be attributed to blockchain technology. The three primary concepts that underpin Blockchain are blocks, nodes, and miners. Blockchain technology prevents any of its data from being stored in a centralized place. In its place, the Blockchain is replicated and dispersed throughout a network of computers. Each computer connected to the internet is responsible for updating its copy of the blockchain whenever there is a new block added to the chain[27], [28].

A system known as blockchain operates on top of the internet, on a peer-to-peer distributed network that all runs the procedure and has an exact duplicate of the blockchain system. This enables peer-to-peer value transactions to take place without the need for an intermediary, which is achieved using machine consensus. There are several distinct varieties of Blockchain technology available today, including public, private, hybrid, and consortium blockchains. Every Blockchain network comes with its own unique set of benefits and drawbacks, both of which significantly impact the kinds of applications that can make the most use of the technology [29].

2.2 Blockchain Technologies

After the internet, many people consider blockchain technology (BT) to be one of the most significant innovations ever developed. There are several significant ways in which BT and the existing Internet technology do not compare. Only the knowledge and duplicates of things can be moved across the Internet; the discovered knowledge cannot be moved at all. When using BT, the valuation of the items being traded is recorded in a way that is both secure and time-stamped in a shared ledger [3], [30]. The blockchain technology that underpins BT is distributed ledger technology. BT is IT. Because of this advancement in technology, there is no longer any requirement to depend on a third party. When a transaction is completed in BT, the transaction should be verified. After ensuring that everyone is on the same page, the transaction can then be authorized. After that, the details of the transaction are recorded on a brand-new block, and the brand-new block is appended to the end of the chain after all of the other blocks. After the information has been validated and included in the chain, it can no longer be removed from the chain. The application of Bitcoin helped BT gain popularity, but it has also begun to be used in other fields, such as medicine, the economy, and the IoT, among other places. Even though BT presents many advantages to businesses, the only way it can add value to the items is if the procedures are designed to accommodate the execution of BT. For instance, if there is a requirement for the irreversibility or openness of data, BT will be advantageous. On the other hand, if the speed of the payment is essential, BT will not be suitable [10], [31].

3. The proposed model

This section introduces the steps of the proposed model. Figure 1 shows the steps of the neutrosophic EDAS method. 1.Build the decision matrix, 2: Compute the weights of the criteria, 3: Compute the distance average from the positive am negative criteria, 4: Compute the weighted sum, 5: Normalize the $\boldsymbol{SumP}$ $\boldsymbol{and}$ $\boldsymbol{SumN}$, 6. Compute the score of appraisals and rank the alternatives. The details are described on the following the Neutrosophic EDAS Method

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Figure 1: The steps of the proposed method.

The Neutrosophic EDAS Method

In this part, we employ the EDAS technique's interval-valued neutrosophic sets to overcome the imperfection, indeterminacy, and irregularity of the system's data. The following is a list of the stages involved in the expanded method [32]:

Build the decision matrix by the experts

Let experts use linguistic terms to evaluate the criteria and alternatives. The experts used the scale of interval-valued neutrosophic numbers (IVNNs) [32].

$$IVNNs = ([T^L, T^U], [I^L, I^U], [F^L, F^U])$$

Compute the weights of the criteria

The weights of criteria are computed using the average of values which experts evaluated.

Build the matrix using the mean weights of the criterion.

Determine the beneficial distance from average (PDA) and the non-beneficial distance from average (NDA) based on the criterion of benefit and cost, respectively.

$$PDA = \begin{cases} \frac{\max(x_{mn} - mean_n)}{mean_n} & for\ positive\ criteria \\ \frac{\max(mean_n - x_{mn})}{mean_n} & for\ negative\ criteria \end{cases} \quad (1)$$

$$NDA = \begin{cases} \frac{\max(mean_n - x_{mn})}{mean_n} & for\ positive\ criteria \\ \frac{\max(x_{mn} - mean_n)}{mean_n} & for\ negative\ criteria \end{cases} \quad (2)$$

Follow the steps below to compute the weighted sum of the beneficial and non-beneficial distances for each of the available options:

$$SumP = \sum_{n=1}^{i} (w_j * PDA_{mn}) \quad (3)$$

$$SumN = \sum_{n=1}^{i} (w_j * NDA_{mn}) \quad (4)$$

Normalize the $\boldsymbol{SumP\ and\ SumN}$ values

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$$NSumP = \frac{SumP}{\max(SumP)} \quad (5)$$

$$NSumN = 1 - \frac{SumN}{\max(SumN)} \quad (6)$$

Compute the score of the appraisal

$$SumA = \frac{1}{2} * (NSumN + NSumP) \quad (7)$$

Rank the alternatives
The alternatives are ranked according to the minimum value of the appraisal score.

4. The Application

The goal of the experiment that is being provided here is to serve as an illustration of the effectiveness of the suggested approach. Customers have the option of either increasing the number of factors and variables or decreasing the number of factors and parameters. We have recognized factors that are responsible for the slow-increasing adoption of blockchain technology in enterprise-distributed apps with the assistance of a literature review and inputs chosen to take from industry and academic specialists, in general. These inputs were taken from individuals all over the world. To show that the suggested approach is effective, we conducted empirical research in which we employed ten characteristics. Extensibility, range, adaptation, price, efficiency, effort, speed of operation, verification of components, maintainability, and assessment system are the abbreviations for these characteristics.
In addition to this, we have uncovered five application domains in which blockchain technology is already being used for certain apps. The abbreviations for these industries are as follows: financial technology, e-commerce, healthcare, supply chain, and social media. For this investigation, all of the data were gathered utilizing evaluation forms submitted by three specialists who had between 5 and 12 years of experience working in both academia and industry and at least 5 years of experience conducting study and development on blockchain-enabled business apps.

As visually described in Figure 1, Build the decision matrix. Then compute the weights of criteria by the average method. Eqs. (1,2) are used to compute the distance average from the positive and negative criteria. Then compute the weighted sum of the positive and negative criteria by using Eqs. (3,4). Then normalize the weighted sum by using Eqs. (5,6). Then compute the score of appraisals by using Eq. (7). Finally rank the alternatives.

First starting with building the decision matrix with three experts, five alternatives, and ten criteria. The decision matrix is shown in Table 1. Then compute the weights of the criteria. Experts evaluate the 10 criteria, then compute the weights of criteria as $w1 = 0.134914958, w2 = 0.10695173, w3 = 0.115840089, w4 = 0.07776983, w5 = 0.094023208, w6 = 0.074948339$, $w7 = 0.115840089, w8 = 0.058231336, w9 = 0.122357336, w10 = 0.099123086$ and mentioned in Figure 2.

Table 1: The evaluation of criteria and alternatives.

	BTC_1	TC_2	TC_3	TC_4	TC_5	TC_6	TC_7	TC_8	TC_9	TC_{10}
TA_1	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.3, 0.4], [0.4, 0.5], [0.6, 0.7]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>
TA_2	<[0.3, 0.4], [0.4, 0.5],	<[0.6, 0.7], [0.4, 0.5],	<[0.4, 0.5], [0.3, 0.4],	<[0.3, 0.4], [0.4, 0.5],	<[0.1, 0.2], [0.6, 0.7],	<[0.4, 0.5], [0.3, 0.4],	<[0.4, 0.5], [0.3, 0.4],	<[0.2, 0.3], [0.5, 0.6],	<[0.6, 0.7], [0.4, 0.5],	<[0.2, 0.3], [0.5, 0.6],

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	[0.6, 0.7]>	[0.3, 0.4]>	[0.5, 0.6]>	[0.6, 0.7]>	[0.8, 0.9]>	[0.5, 0.6]>	[0.5, 0.6]>	[0.7, 0.8]>	[0.3, 0.4]>	[0.7, 0.8]>
TA_3	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>
TA_4	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>
TA_5	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>
	BTC_1	TC_2	TC_3	TC_4	TC_5	TC_6	TC_7	TC_8	TC_9	TC_{10}
TA_1	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.3, 0.4], [0.4, 0.5], [0.6, 0.7]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>
TA_2	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.3, 0.4], [0.4, 0.5], [0.6, 0.7]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>
TA_3	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>
TA_4	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>
TA_5	<[0.8, 0.9], [0.6, 0.7],	<[0.6, 0.7], [0.4, 0.5],	<[0.8, 0.9], [0.6, 0.7],	<[0.1, 0.2], [0.6, 0.7],	<[0.6, 0.7], [0.4, 0.5],	<[0.7, 0.8], [0.5, 0.6],	<[0.1, 0.2], [0.6, 0.7],	<[0.6, 0.7], [0.4, 0.5],	<[0.8, 0.9], [0.6, 0.7],	<[0.8, 0.9], [0.6, 0.7],

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	[0.1, 0.2]>	[0.3, 0.4]>	[0.1, 0.2]>	[0.8, 0.9]>	[0.3, 0.4]>	[0.2, 0.3]>	[0.8, 0.9]>	[0.3, 0.4]>	[0.1, 0.2]>	[0.1, 0.2]>
	BTC$_1$	TC$_2$	TC$_3$	TC$_4$	TC$_5$	TC$_6$	TC$_7$	TC$_8$	TC$_9$	TC$_{10}$
TA$_1$	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.3, 0.4], [0.4, 0.5], [0.6, 0.7]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>
TA$_2$	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.3, 0.4], [0.4, 0.5], [0.6, 0.7]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>
TA$_3$	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>
TA$_4$	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.8, 0.9], [0.6, 0.7], [0.1, 0.2]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.2, 0.3], [0.5, 0.6], [0.7, 0.8]>
TA$_5$	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.6, 0.7], [0.4, 0.5], [0.3, 0.4]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.1, 0.2], [0.6, 0.7], [0.8, 0.9]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>	<[0.4, 0.5], [0.3, 0.4], [0.5, 0.6]>	<[0.7, 0.8], [0.5, 0.6], [0.2, 0.3]>

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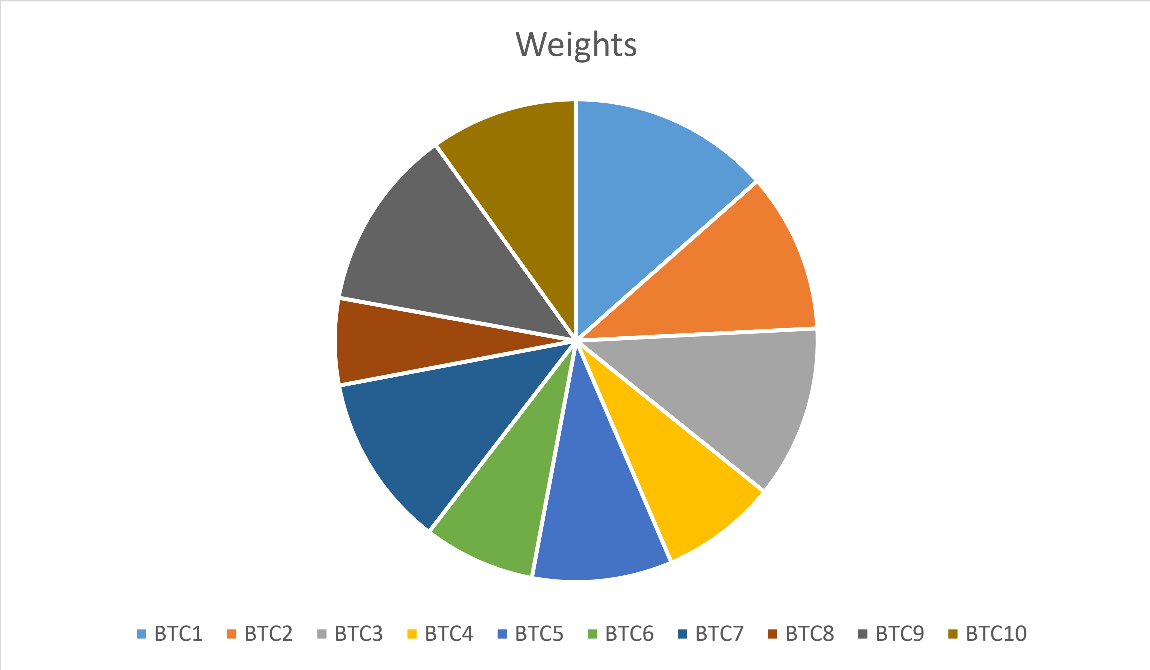

Figure 2: The weights of criteria.

Compute the PDA and NDA values as shown in Tables 2, 3.

Table 2: The PDA matrix.

	BTC_1	TC_2	TC_3	TC_4	TC_5	TC_6	TC_7	TC_8	TC_9	TC_{10}
TA_1	0.266406	0	0.329792	0	0	0.012074	0.472072	0	0.030575	0.387917
TA_2	0	0	0.023293	0	0	0.040124	0.099799	0	0.084612	0
TA_3	0.266406	0.094656	0	0.773031	0.571565	0	0.575894	0.184558	0	0.387917
TA_4	0.161607	0.094656	0	0.773031	0	0.450194	0	0.748258	0.053034	0
TA_5	0	0	0.409548	0	0.39489	0.366044	0	0.551718	0	0.387917

Table 3: The NDA matrix.

	BTC_1	TC_2	TC_3	TC_4	TC_5	TC_6	TC_7	TC_8	TC_9	TC_{10}
TA_1	0	0.188992	0	0.353457	0.262282	0	0	0.841395	0	0
TA_2	0.432255	0.00016	0	0.353457	0.411492	0	0	0.643139	0	0.581875
TA_3	0	0	0.422562	0	0	0.868436	0	0	0.001003	0
TA_4	0	0	0.340071	0	0.29268	0	0.290732	0	0	0.581875
TA_5	0.262163	0.00016	0	0.839148	0	0	0.857032	0	0.167218	0

Then compute the weighted sum of the PDA and NDA matrix to compute the matrices of $SumP$ and $SumN$ as shown in tables 4, and 5.

Table 4: The $SumP$ matrix.

	BTC_1	TC_2	TC_3	TC_4	TC_5	TC_6	TC_7	TC_8	TC_9	TC_{10}
TA_1	0.035942	0	0.038203	0	0	0.000905	0.054685	0	0.003741	0.038452
TA_2	0	0	0.002698	0	0	0.003007	0.011561	0	0.010353	0
TA_3	0.035942	0.010124	0	0.060118	0.05374	0	0.066712	0.010747	0	0.038452
TA_4	0.021803	0.010124	0	0.060118	0	0.033741	0	0.043572	0.006489	0
TA_5	0	0	0.047442	0	0.037129	0.027434	0	0.032127	0	0.038452

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Table 5: The $SumN$ matrix.

	BTC_1	TC_2	TC_3	TC_4	TC_5	TC_6	TC_7	TC_8	TC_9	TC_{10}
TA_1	0	0.020213	0	0.027488	0.024661	0	0	0.048996	0	0
TA_2	0.058318	1.71E-05	0	0.027488	0.03869	0	0	0.037451	0	0.057677
TA_3	0	0	0.04895	0	0	0.065088	0	0	0.000123	0
TA_4	0	0	0.039394	0	0.027519	0	0.033678	0	0	0.057677
TA_5	0.03537	1.71E-05	0	0.06526	0	0	0.099279	0	0.02046	0

Then normalize the values of SumP and SumN. Then compute the value of the appraisal score. Then rank the alternatives based on the minimum value of appraisal as shown in Figure 3. From Figure 3 application 2 is the highest score and application 5 is the lowest score. The results are illustrated in Figure 3.

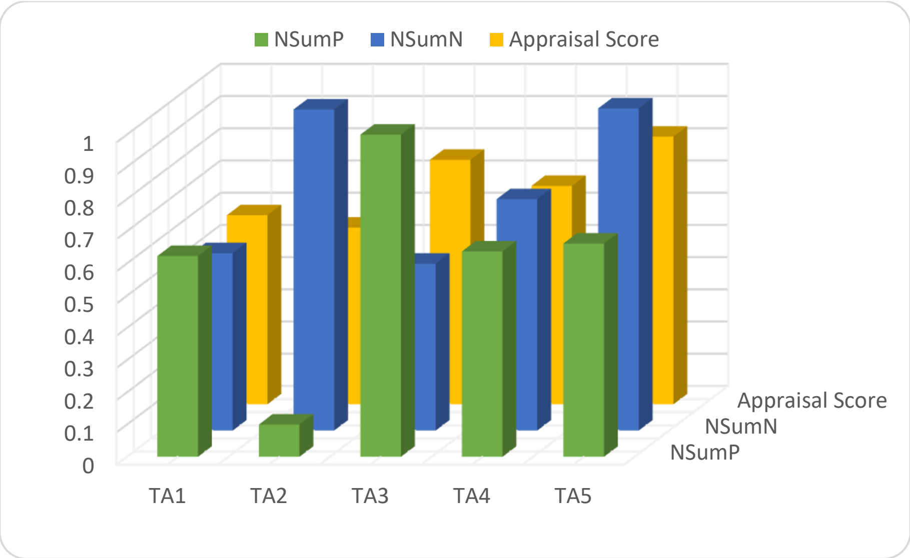

Figure 3: The rank of five Blockchain applications.

5. Managerial Implications

The mathematical model that was presented for use in this research might provide managers with assistance in decision-making by assisting in identifying business-specific aspects that could influence blockchain adoption. It would be helpful for managers to anticipate the dangers and challenges that are linked with the use of blockchain technology. The results of this research provided managers with the ability to prioritize and assess their difficulties to more effectively address them. In this piece of writing, a manager's quick reference is provided in the form of empirical research. In this study, an improved version of EDAS-Neutrosophic called Neutrosophic-EDAS is provided. Using this technology, managers will be able to make better decisions in uncertain environments. Policymakers and managers are tasked with the responsibility of determining the most advantageous route for blockchain implementation inside their organization.

6. Blockchain Applications

Many applications used Blockchain technology in enterprise-distributed applications like

A. Healthcare

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The development of information and communication technology (ICT) has ushered in a new age for the whole globe, one in which all the necessary things may be obtained with only the touch of a button. These new control systems and technologies play an important part in almost every facet of human existence, including but not limited to agriculture, smart cities, industrial automation, smart homes, and healthcare, amongst other domains. The field of medicine, which addresses one of the fundamental requirements for human existence, ranks highest among these applications in terms of importance. Control systems and electronic health records (also known as EHRs) are the two primary components that make up the use of advanced technologies, such as the Internet of Things (IoT), in the healthcare industry. Control systems contribute to the provision of control methods, while electronic health record systems play an important part in making medical services more user-friendly and cost-effective while also improving their timeliness of delivery. Implanting tracking and sensing devices into a patient's body enables smart healthcare systems to monitor and diagnose vital biomedical parameters, such as a patient's heart rate, blood sugar level, electroencephalogram (EEG), electrocardiograph (RCG), and other essential biomedical signals. These metrics include things like the patient's pulse rate and sugar level.

B. Financial Technology

Blockchain technology was first created as the distributed ledgers for Bitcoin. It is classified as a kind of financial technology known as FinTech. Blockchain technology was obscured for some time by the craze around Bitcoin; nevertheless, in recent years it has begun to garner attention on its own merits and is quickly becoming an essential component of the family of technologies known as FinTech.

C. E-Commerce

To ensure the continued viability of both technology and online business, numerous e-commerce items, including medications, electronics, home security equipment, food products, and many more, are being explored for inclusion in a distributed and transparent ledger system.

D. Supply Chain

The use of blockchain technology offers some interesting prospects for the construction of decentralized transaction records for supply chains. In general, blockchain is regarded to be an immutable digital ledger of data that has been organized in data blocks linked to each other. These data blocks have been connected by cryptographic hashes.

E. Social Media

individuals utilize services that are based on the Internet called social media to develop social networks or links with other individuals who have similar personal interests, hobbies, backgrounds, or connections in real life. Since the introduction of smartphones and tablets, using them to communicate with other people has unquestionably become an extremely common activity. However, the rapid expansion of social media is also associated with the emergence of a variety of unintended consequences in our society. Because there is such a wide variety of free software that generates content, it is currently simpler than it has ever been to fabricate and forge false information.

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7. Conclusions

Blockchain provides opportunities with a wide variety of technologies and application areas. Academics provoke a precipitous surge in the amount of interest in blockchain technology. Despite, there is not much cause for optimism regarding the adoption of this blockchain technology paradigm within corporate distributed systems. The process of making decisions based on various criteria, abbreviated MCDM, should be expected of company executives and technocrats. The neutrosophic MCDM approach, considers both qualitative and quantitative characteristics, is used to construct the detection and monitoring of the important variables driving the adoption of blockchain technology. Also, a model has been suggested to identify and to monitor major elements that are contributing to the delayed adoption rate of blockchain technology. The current study adopted the use of MCDM, EDAS that are a widespread application. In the interval-valued neutrosophic EDAS that has been presented, the degrees of truthiness, falsehood, and indeterminacy are aspects of the same notion. The proposed model is used to achieve the most appropriate blockchain technology to aid decision makers in uncertain conditions. The study used an application with numerical evidence to show that application 2 is the optimum solution and application 5 is the lowest solution. In future work, the proposed model can be applied to various MCDM problems like personnel selection, material selection, risks assessment, energy selection, etc. This kind of problem can be applied to various MCDM methods like AHP, TOPSIS, and VIKOR.

References

[1] I. Erol, I. M. Ar, I. Peker, and C. Searcy, "Alleviating the impact of the barriers to circular economy adoption through blockchain: an investigation using an integrated MCDM-based QFD with hesitant fuzzy linguistic term sets," *Comput. Ind. Eng.*, vol. 165, p. 107962, 2022.

[2] S. Çıkmak, B. Kantoğlu, and G. Kırbaç, "Evaluation of the effects of blockchain technology characteristics on SCOR model supply chain performance measurement attributes using an integrated fuzzy MCDM methodology," *Int. J. Logist. Res. Appl.*, pp. 1–31, 2023.

[3] Z. H. Munim, S. Balasubramaniyan, M. Kouhizadeh, and N. U. I. Hossain, "Assessing blockchain technology adoption in the Norwegian oil and gas industry using Bayesian Best Worst Method," *J. Ind. Inf. Integr.*, vol. 28, p. 100346, 2022.

[4] B. Özkan, İ. Kaya, M. Erdoğan, and A. Karaşan, "Evaluating blockchain risks by using a MCDM methodology based on pythagorean fuzzy sets," in *Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making: Proceedings of the INFUS 2019 Conference, Istanbul, Turkey, July 23-25, 2019*, Springer, 2020, pp. 935–943.

[5] I. Erol, A. Oztel, C. Searcy, and İ. T. Medeni, "Selecting the most suitable blockchain platform: A case study on the healthcare industry using a novel rough MCDM framework," *Technol. Forecast. Soc. Change*, vol. 186, p. 122132, 2023.

[6] E. Filatovas, M. Marcozzi, L. Mostarda, and R. Paulavičius, "A MCDM-based framework for blockchain consensus protocol selection," *Expert Syst. Appl.*, vol. 204, p. 117609, 2022.

[7] S. Zafar, Z. Alamgir, and M. H. Rehman, "An effective blockchain evaluation system based on entropy-CRITIC weight method and MCDM techniques," *Peer-to-Peer Netw. Appl.*, vol. 14, no. 5, pp. 3110–3123, 2021.

[8] M. Kaska and A. C. Tolga, "Blockchain software selection for a maritime organization with MCDM method," in *Intelligent and Fuzzy Techniques: Smart and Innovative Solutions: Proceedings of the INFUS 2020 Conference, Istanbul, Turkey, July 21-23, 2020*, Springer, 2021, pp. 543–549.

[9] I. Peker, I. M. AR, I. Erol, and C. Searcy, "Leveraging blockchain in response to a pandemic through

Doi : https://doi.org/10.54216/JCIM.110101
Received: October 15, 2022 Revised: December 24, 2022 Accepted: January 03, 2023

disaster risk management: an IF-MCDM framework," *Oper. Manag. Res.*, pp. 1–26, 2022.

[10] M. Çolak, I. Kaya, B. Özkan, A. Budak, and A. Karaşan, "A multi-criteria evaluation model based on hesitant fuzzy sets for blockchain technology in supply chain management," *J. Intell. Fuzzy Syst.*, vol. 38, no. 1, pp. 935–946, 2020.

[11] Z. A. Siddiqui and M. Haroon, "Research on significant factors affecting adoption of blockchain technology for enterprise distributed applications based on integrated MCDM FCEM-MULTIMOORA-FG method," *Eng. Appl. Artif. Intell.*, vol. 118, p. 105699, 2023.

[12] N. A. Nabeeh, M. Abdel-Basset, and G. Soliman, "A model for evaluating green credit rating and its impact on sustainability performance," *J. Clean. Prod.*, vol. 280, p. 124299, 2021.

[13] M. Abdel-Basset, V. Chang, and N. A. Nabeeh, "An intelligent framework using disruptive technologies for COVID-19 analysis," *Technol. Forecast. Soc. Change*, vol. 163, p. 120431, 2021.

[14] A. Abdel-Monem, A. A. Gawad, and H. Rashad, *Blockchain Risk Evaluation on Enterprise Systems using an Intelligent MCDM based model*, vol. 38. Infinite Study, 2020.

[15] S. Broumi, A. Bakali, and A. Bahnasse, "Neutrosophic sets: An overview," 2018.

[16] M. Abdel-Basset, M. Mohamed, M. Elhoseny, F. Chiclana, and A. E.-N. H. Zaied, "Cosine similarity measures of bipolar neutrosophic set for diagnosis of bipolar disorder diseases," *Artif. Intell. Med.*, vol. 101, p. 101735, 2019.

[17] A. Ur Rahman, M. Saeed, S. S. Alodhaibi, and H. A. El-Wahed Khaifa, "Decision making algorithmic approaches based on parameterization of neutrosophic set under hypersoft set environment with fuzzy, intuitionistic fuzzy and neutrosophic settings," *Comput. Model. Eng. Sci.*, vol. 128, no. 2, pp. 743–777, 2021.

[18] M. Abdel-Basset, A. Gamal, G. Manogaran, L. H. Son, and H. V. Long, "A novel group decision making model based on neutrosophic sets for heart disease diagnosis," *Multimed. Tools Appl.*, vol. 79, no. 15, pp. 9977–10002, 2020.

[19] X. Peng and J. Dai, "A bibliometric analysis of neutrosophic set: two decades review from 1998 to 2017," *Artif. Intell. Rev.*, vol. 53, no. 1, pp. 199–255, 2020.

[20] A. Karaşan, C. Kahraman, and E. Boltürk, "Interval-valued neutrosophic EDAS method: an application to prioritization of social responsibility projects," in *Fuzzy Multi-criteria Decision-Making Using Neutrosophic Sets*, Springer, 2019, pp. 455–485.

[21] I. Irvanizam *et al.*, "An improved EDAS method based on bipolar neutrosophic set and its application in group decision-making," *Appl. Comput. Intell. Soft Comput.*, vol. 2021, pp. 1–16, 2021.

[22] S. Ashraf, S. Ahmad, M. Naeem, M. Riaz, and M. Alam, "Novel EDAS methodology based on single-valued neutrosophic Aczel-Alsina aggregation information and their application in complex decision-making," *Complexity*, vol. 2022, 2022.

[23] A. Karaşan and C. Kahraman, "A novel interval-valued neutrosophic EDAS method: prioritization of the United Nations national sustainable development goals," *Soft Comput.*, vol. 22, pp. 4891–4906, 2018.

[24] D. Stanujkić *et al.*, "A single-valued neutrosophic extension of the EDAS method," *Axioms*, vol. 10, no. 4, p. 245, 2021.

[25] D. Xu, X. Cui, and H. Xian, "An extended EDAS method with a single-valued complex neutrosophic

Doi : https://doi.org/10.54216/JCIM.110101
Received: October 15, 2022 Revised: December 24, 2022 Accepted: January 03, 2023

set and its application in green supplier selection," *Mathematics*, vol. 8, no. 2, p. 282, 2020.

[26] Ö. F. Görçün, D. Pamucar, and S. Biswas, "The blockchain technology selection in the logistics industry using a novel MCDM framework based on Fermatean fuzzy sets and Dombi aggregation," *Inf. Sci. (Ny).*, vol. 635, pp. 345–374, 2023.

[27] S. Farshidi, S. Jansen, S. España, and J. Verkleij, "Decision support for blockchain platform selection: Three industry case studies," *IEEE Trans. Eng. Manag.*, vol. 67, no. 4, pp. 1109–1128, 2020.

[28] M. Krstić, G. P. Agnusdei, P. P. Miglietta, and S. Tadić, "Evaluation of the smart reverse logistics development scenarios using a novel MCDM model," *Clean. Environ. Syst.*, vol. 7, p. 100099, 2022.

[29] N. Van Thanh, "Blockchain Development Services Provider Assessment Model for a Logistics Organizations," *Processes*, vol. 10, no. 6, p. 1209, 2022.

[30] N. A. Nabeeh *et al.*, "A Neutrosophic Evaluation Model for Blockchain Technology in Supply Chain Management," in *2022 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)*, IEEE, 2022, pp. 1–8.

[31] N. A. Nabeeh, M. Abdel-Basset, A. Gamal, and V. Chang, "Evaluation of production of digital twins based on blockchain technology," *Electronics*, vol. 11, no. 8, p. 1268, 2022.

[32] A. Karaşan and C. Kahraman, "Interval-valued neutrosophic extension of EDAS method," in *Advances in Fuzzy Logic and Technology 2017: Proceedings of: EUSFLAT-2017–The 10th Conference of the European Society for Fuzzy Logic and Technology, September 11-15, 2017, Warsaw, Poland IWIFSGN'2017–The Sixteenth International Workshop on Intuitionistic Fuzzy Sets and Generalized Nets, September 13-15, 2017, Warsaw, Poland, Volume 2 10*, Springer, 2018, pp. 343–357.

Doi : https://doi.org/10.54216/JCIM.110101
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