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UNLOCKING THE POTENTIAL OF BLOCKCHAIN THROUGH MULTI-CRITERIA DECISION MAKING IN PLATFORM SELECTION

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ABSTRACT

Purpose: The purpose of this paper is to introduce a methodology that can help organizations choose the best Blockchain platform for their specific business case. With numerous options available, it's important to carefully consider the capabilities of a Blockchain before selecting it. This methodology is intended to provide a structured approach to aid in the decision-making process, taking into account the various characteristics of Blockchain that are needed.

Theoretical Framework: The theoretical framework for this paper is based on Multi Criteria Decision Making (MCDM) and ISO/IEC 25010. MCDM is a decision-making technique that considers multiple criteria when making a choice, which is useful for selecting the best Blockchain platform. ISO/IEC 25010 is a standard that provides a framework for evaluating software quality characteristics, which is relevant for evaluating the quality of the Blockchain platform.

Design/Methodology/Approach: The methodology presented in this paper involves a structured approach to selecting the best Blockchain platform for a specific business case. The approach is based on a combination of MCDM and ISO/IEC 25010, and involves several steps. First, the relevant criteria for selecting the Blockchain platform are identified. Next, a weighting system is developed to determine the importance of each criterion. Then, each Blockchain platform is evaluated based on the criteria and weights, and a score is assigned. Finally, the scores are aggregated to determine the best Blockchain platform for the specific business case.

Findings: The main finding of this paper is the methodology for selecting the best Blockchain platform for a specific business case. This methodology can aid organizations in making an informed decision when choosing a Blockchain platform, taking into account the various characteristics of Blockchain that are needed. The paper also highlights the importance of careful consideration when selecting a Blockchain platform, as the wrong choice could have negative consequences.

Research, Practical & Social Implications: The research implications of this paper are significant, as it provides a structured approach for selecting the best Blockchain platform for a specific business case. This methodology can be used across industries and could have a significant impact on the adoption of Blockchain technology. From a practical perspective, this methodology can aid organizations in making informed decisions when selecting a Blockchain platform, which can save time and resources. From a social perspective, the adoption of Blockchain technology has the potential to revolutionize business operations and improve transparency and accountability.

Originality/Value: The originality of this paper lies in the development of a methodology for selecting the best Blockchain platform for a specific business case. This methodology is based on a combination of MCDM and ISO/IEC 25010 and is not specific to any one industry. The value of this paper is in providing a structured approach to aid organizations in making an informed decision when selecting a

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Blockchain platform, taking into account the various characteristics of Blockchain that are needed.

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DESBLOQUEANDO O POTENCIAL DO BLOCKCHAIN ATRAVÉS DA TOMADA DE DECISÕES MULTI-CRITÉRIOS NA SELEÇÃO DA PLATAFORMA

RESUMO

Objetivo: O objetivo deste artigo é apresentar uma metodologia que pode ajudar as organizações a escolher a melhor plataforma Blockchain para seu caso de negócios específico. Com inúmeras opções disponíveis, é importante considerar cuidadosamente os recursos de um Blockchain antes de selecioná-lo. Esta metodologia pretende fornecer uma abordagem estruturada para auxiliar no processo de tomada de decisão, levando em consideração as diversas características do Blockchain que são necessárias.

Referencial Teórico: O referencial teórico deste artigo é baseado no Multi Criteria Decision Making (MCDM) e ISO/IEC 25010. O MCDM é uma técnica de tomada de decisão que considera múltiplos critérios ao fazer uma escolha, o que é útil para selecionar a melhor plataforma Blockchain . ISO/IEC 25010 é um padrão que fornece uma estrutura para avaliar as características de qualidade do software, o que é relevante para avaliar a qualidade da plataforma Blockchain.

Design/Metodologia/Abordagem: A metodologia apresentada neste artigo envolve uma abordagem estruturada para selecionar a melhor plataforma Blockchain para um caso de negócios específico. A abordagem é baseada em uma combinação de MCDM e ISO/IEC 25010 e envolve várias etapas. Primeiro, são identificados os critérios relevantes para selecionar a plataforma Blockchain. Em seguida, um sistema de ponderação é desenvolvido para determinar a importância de cada critério. Em seguida, cada plataforma Blockchain é avaliada com base nos critérios e pesos, e uma pontuação é atribuída. Por fim, as pontuações são agregadas para determinar a melhor plataforma Blockchain para o caso de negócios específico.

Descobertas: A principal descoberta deste artigo é a metodologia para selecionar a melhor plataforma Blockchain para um caso de negócios específico. Esta metodologia pode auxiliar as organizações na tomada de decisão informada ao escolher uma plataforma Blockchain, levando em consideração as diversas características do Blockchain que são necessárias. O documento também destaca a importância de uma consideração cuidadosa ao selecionar uma plataforma Blockchain, pois a escolha errada pode ter consequências negativas.

Implicações de pesquisa, práticas e sociais: As implicações de pesquisa deste artigo são significativas, pois fornecem uma abordagem estruturada para selecionar a melhor plataforma Blockchain para um caso de negócios específico. Essa metodologia pode ser usada em vários setores e pode ter um impacto significativo na adoção da tecnologia Blockchain. Do ponto de vista prático, essa metodologia pode ajudar as organizações a tomar decisões informadas ao selecionar uma plataforma Blockchain, o que pode economizar tempo e recursos. Do ponto de vista social, a adoção da tecnologia Blockchain tem o potencial de revolucionar as operações comerciais e melhorar a transparência e a responsabilidade.

Originalidade/Valor: A originalidade deste artigo está no desenvolvimento de uma metodologia para selecionar a melhor plataforma Blockchain para um caso de negócio específico. Essa metodologia é baseada em uma combinação de MCDM e ISO/IEC 25010 e não é específica para nenhuma indústria. O valor deste documento está em fornecer uma abordagem estruturada para ajudar as organizações a tomar uma decisão informada ao selecionar uma plataforma Blockchain, levando em consideração as várias características do Blockchain necessárias.

Palavras-chave: Sistema de Apoio Executivo, Tomada de Decisão Multicritério (MCDM), Blockchain, Fuzzy Analytical Hierarchy Processing (FAHP), Técnica Fuzzy para Ordem de Preferência por Similaridade à Solução Ideal (Fuzzy TOPSIS), Sistema de Apoio à Decisão.

DESBLOQUEANDO EL POTENCIAL DE BLOCKCHAIN A TRAVÉS DE LA TOMA DE DECISIONES MULTICRITERIOS EN LA SELECCIÓN DE PLATAFORMA

RESUMEN

Propósito: El propósito de este documento es presentar una metodología que pueda ayudar a las organizaciones a elegir la mejor plataforma Blockchain para su caso de negocios específico. Con numerosas opciones disponibles, es importante considerar cuidadosamente las capacidades de una cadena de bloques antes de seleccionarla. Esta metodología tiene como objetivo proporcionar un enfoque estructurado para ayudar en el proceso de toma de decisiones, teniendo en cuenta las diversas características de Blockchain que se necesitan.

Marco teórico: el marco teórico de este documento se basa en la toma de decisiones de criterios múltiples (MCDM) y la norma ISO/IEC 25010. MCDM es una técnica de toma de decisiones que considera múltiples criterios al hacer una elección, lo cual es útil para seleccionar la mejor plataforma Blockchain. . ISO/IEC 25010 es un estándar que proporciona un marco para evaluar las características de calidad del software, lo cual es relevante para evaluar la calidad de la plataforma Blockchain.
Diseño/Metodología/Enfoque: La metodología presentada en este documento implica un enfoque estructurado para seleccionar la mejor plataforma Blockchain para un caso de negocios específico. El enfoque se basa en una combinación de MCDM e ISO/IEC 25010 e implica varios pasos. Primero, se identifican los criterios relevantes para seleccionar la plataforma Blockchain. A continuación, se desarrolla un sistema de ponderación para determinar la importancia de cada criterio. Luego, cada plataforma Blockchain se evalúa en función de los criterios y pesos, y se asigna un puntaje. Finalmente, los puntajes se agregan para determinar la mejor plataforma Blockchain para el caso de negocios específico.
Hallazgos: El principal hallazgo de este documento es la metodología para seleccionar la mejor plataforma Blockchain para un caso de negocio específico. Esta metodología puede ayudar a las organizaciones a tomar una decisión informada al elegir una plataforma Blockchain, teniendo en cuenta las diversas características de Blockchain que se necesitan. El documento también destaca la importancia de una consideración cuidadosa al seleccionar una plataforma Blockchain, ya que la elección incorrecta podría tener consecuencias negativas.
Implicaciones de investigación, prácticas y sociales: Las implicaciones de investigación de este documento son significativas, ya que proporciona un enfoque estructurado para seleccionar la mejor plataforma Blockchain para un caso comercial específico. Esta metodología se puede utilizar en todas las industrias y podría tener un impacto significativo en la adopción de la tecnología Blockchain. Desde una perspectiva práctica, esta metodología puede ayudar a las organizaciones a tomar decisiones informadas al seleccionar una plataforma Blockchain, lo que puede ahorrar tiempo y recursos. Desde una perspectiva social, la adopción de la tecnología Blockchain tiene el potencial de revolucionar las operaciones comerciales y mejorar la transparencia y la responsabilidad.
Originalidad/Valor: La originalidad de este artículo radica en el desarrollo de una metodología para seleccionar la mejor plataforma Blockchain para un caso de negocio específico. Esta metodología se basa en una combinación de MCDM e ISO/IEC 25010 y no es específica de ninguna industria. El valor de este documento es proporcionar un enfoque estructurado para ayudar a las organizaciones a tomar una decisión informada al seleccionar una plataforma Blockchain, teniendo en cuenta las diversas características de Blockchain que se necesitan.

Palabras clave: Sistema de Soporte Ejecutivo, Toma de Decisiones Multicriterio (MCDM), Blockchain, Procesamiento Jerárquico Analítico Fuzzy (FAHP), Técnica Fuzzy para Orden de Preferencia por Similitud a la Solución Ideal (Fuzzy TOPSIS), Sistema de Soporte de Decisiones.

INTRODUCTION

Blockchain technology has expanded from its initial development for Bitcoin to various fields, such as supply chain management, document safekeeping, and real estate, due to its inherent properties of security and auditability. As the number of adopters of Blockchain technology grows, so do the offerings and capabilities of the Blockchain platform, including decentralized applications, smart contracts, and different types of NFTs. However, with so many options available, selecting the appropriate platform can be challenging. Currently, there is no widely accepted scientific technique for selecting Blockchain platforms, and the existing techniques are often tailored to specific business needs and have limitations in handling complex relationships between criteria or scaling with multiple attributes and high uncertainty.

To address this issue, a generic solution that can cater to different Blockchain applications is needed.

Multi-Criteria Decision Making (MCDM) methods have been used in various selection problems and can help choose among competing alternatives. Studies done by Lee et al. (2001), Murtaza (2003), Pahl et al. (2018), Shaw et al. (2012), Sun (2010) and Xia & Wu (2007) have utilized fuzzy TOPSIS or fuzzy AHP methods for diverse selection problems. Studies have also suggested integrating different MCDM approach for selection problems to offset the limitations of one MCDM method. Fuzzy Logic is an interesting addition for solving selection problems as it uses linguistic terms to describe criteria, making it easy to adopt. Fuzzy TOPSIS and Fuzzy AHP methods are proven MCDM methods that can be employed for selection problems.

This study proposes an integrated Fuzzy MCDM approach that combines Fuzzy AHP and Fuzzy TOPSIS with ISO/IEC 25010 to effectively and efficiently solve the problem of Blockchain selection. The contribution of this research is the development of a generic solution that can effectively and efficiently solve the Blockchain selection problem. Employing this solution can help businesses and projects choose the right Blockchain platform that meets their specific needs, leading to improved project outcomes and increased efficiency.

LITERATURE REVIEW

Snowballing method was employed to identify similar research. The literature review includes studies on various decision-making methods, such as fuzzy analytic hierarchy process (FAHP), rough set theory, and satisficing, for supplier selection and evaluation in green supply chain management. Other studies focused on decision-making methods for platform selection, such as FAHP and artificial neural network (ANN) for convenience store location selection and a decision framework for Blockchain platforms for the Internet of Things (IoT) and edge computing. Specifically, Farshidi et al. (2020) developed a decision support system for Blockchain platform selection using a case study approach. They used criteria such as functionality, scalability, security, and performance to evaluate three different Blockchain platforms. Jasti, Varalakshmi (2023) did a study which aims to measure the acceptance of selected financial technology (fintech) products and services by users. The authors used the Technology Acceptance Model (TAM) to develop a questionnaire and collected data from 450 respondents. The study found that perceived usefulness and perceived ease of use significantly influence users' acceptance of fintech products and services. The study provides valuable insights on how technology selection improves products and services and increase user acceptance. Study did by Tam & Thuy (2023) examines the impact of technology on the service quality of commercial banks in Vietnam. The authors used a survey to collect data from 400 bank customers and conducted a regression analysis to analyse the data. The study found that technology has a significant positive impact on service quality. However, the study also found that technology cannot completely replace human interactions, and therefore, a balance between technology and human interactions is necessary to provide high-quality services to customers. Mascena, Santos & Stocker (2021) proposed a method for prioritizing stakeholders in project management using the Analytic Hierarchy Process (AHP) method. The authors used a case study to illustrate the proposed method and compared the results with those obtained using the traditional approach of prioritizing stakeholders based on their power and interest. The study found that the proposed method provides a more comprehensive and accurate prioritization of stakeholders and can help project managers make better decisions. The study proves the effectiveness of AHP in prioritization problems.

Based on the literature reviews the problem statement can be elaborated as below

1. The absence of a widely accepted scientific technique for selecting Blockchain platforms may suggest that the field is still in its early stages of development, and researchers are still exploring various approaches. It also highlights the need for further research and development in this area to provide a more robust framework for selecting Blockchain platforms.
2. The stereotyped approach to selecting Blockchain platforms may limit the effectiveness of the technique, as it may overlook important criteria or fail to capture the unique needs of a specific business. However, it is also important to have some standard criteria for selecting Blockchain platforms to ensure that they meet certain minimum requirements.
3. The tailoring of selection techniques to a particular business need can be a strength if it allows for the identification of the most appropriate Blockchain platform for that specific use case. However, it may limit the applicability of the technique to other businesses or use cases.
4. The limitations of the BDD, SMART, and CBR techniques in handling complex relationships between criteria or scaling when there are multiple attributes and high uncertainty suggest that there is a need for more advanced techniques that can better address these issues. This highlights the importance of ongoing research and

development in this area to improve the effectiveness of Blockchain platform selection techniques.

MATERIAL AND METHODOLOGY

Software Quality Requirements

Software quality requirements are the specific needs and expectations that must be met by a software system to satisfy the stakeholders' needs. The quality requirements specify the performance, functionality, reliability, security, usability, and other non-functional aspects of the software. The quality of the software is critical to the success of any software project, as poor quality can lead to increased costs, missed deadlines, and unsatisfied customers.

ISO/IEC 25010 is an international standard that provides a framework for software quality requirements and evaluation. It defines a set of quality characteristics and sub-characteristics that are used to evaluate the quality of a software product. The standard provides guidance on how to specify quality requirements, measure quality, and evaluate the quality of software systems. It provides a structured approach to defining quality requirements and evaluating the quality of the software. By using the standard, software developers can ensure that their software systems meet the quality requirements of stakeholders. Fig. 1 shows the software quality requirements as outlined by ISO/IEC 25010.

Fig. 1. Software Quality Requirements

Source: Prepared by the authors (2023)

Fuzzy AHP Procedure

Fuzzy AHP generates intuitive decisions by prioritizing Blockchain selection criteria and balancing the ambiguity of their representation. The References section has references to articles and researches which provide explanation on the approaches for selecting alternatives and also for justification for using fuzzy set theory and hierarchical structure analysis. Previous studies have shown that decision makers find it more natural to express quality traits as intervals than fixed absolute values. This work is built upon the fuzzy AHP approach introduced by Chang (1992). He advocated the usage of "triangular fuzzy numbers (TFN)" for pair-wise comparison scales. Synthetic Extent cardinal values corresponding to the pairwise comparisons were obtained from the "Extent Analysis" method. Kahraman et al., (2003, 2004) showed in their research how to employ fuzzy AHP procedures based on the extent analysis method for dealing with problems involving selection. The basic idea of the fuzzy sets and extent analysis method for fuzzy AHP is that, a fuzzy number is a special fuzzy set $F = \{(x, (x)), x \in R\}$, where x takes its values on the real line, $R: -\infty \leq x \leq \infty$ and (x) is a continuous mapping from R to the closed interval. Each TFN represents the relative weight of each pair of elements at the corresponding level and can be expressed as $M = (l, m, u)$, where $l \leq m \leq u$.

"l" indicates least possible value,

"m" indicates most promising value

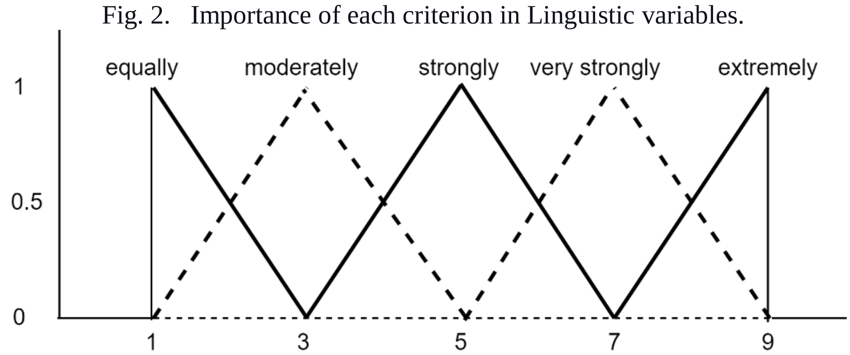
"u" indicates utmost (largest) possible value

in a fuzzy event. Triangular type membership function of M fuzzy number can be described as shown in Eq. (4.1).

$$\mu_M(x) = \begin{cases} 0 & \text{if } x < l \\ (x-l)/(m-l) & \text{if } l \leq x \leq m \\ (u-x)/(u-m) & \text{if } m \leq x \leq u \\ 0 & \text{if } x > 0 \end{cases} \quad (4.1)$$

Linguistic variables employ linguistic colloquial expressions to represent values. Zimmermann (1991) as well as Kaufman and Gupta (1991) proved in their research that the concept of linguistic variables is useful when dealing with situations that are too complex or cannot be adequately described by traditional quantitative terms. Linguistic variables depict positive TFNs for each criterion in this model (Refer to Fig. 2)

Fig. 2. Importance of each criterion in Linguistic variables.



Source: Prepared by the authors (2023)

The below table (*Table 1*) describes linguistic variables, their matching TFNs, and the related membership functions. The table uses what is known as the "Likert Scale" of fuzzy numbers starting from 1 through 9

Table 1. Linguistic Variable Fuzzy Scale.

Degree of Importance	**Linguistic scale for importance**	**Membership function**	**Domain**	**Triangular fuzzy scale (l, m, u)**	**Description**
-	Just Equal	-	-	(1.0, 1.0, 1.0)	
1	Equal Importance	$_M(x)=(3-x)/(3-1)$	$1 \leq x \leq 3$	(1.0, 1.0, 3.0)	Two factors make a contribution similarly to the property
3	Weak importance of one over another	$_M(x)=(x-1)/(3-1)$	$1 \leq x \leq 3$	(1.0, 3.0, 5.0)	Experience and judgment slightly favour one over the other
5	Essential or strong importance	$_M(x)=(5-x)/(5-3)$ $_M(x)=(x-3)/(5-3)$	$3 \leq x \leq 5$	(3.0, 5.0, 7.0)	Experience and judgment strongly favour one over another
7	Very strong importance	$_M(x)=(7-x)/(7-5)$ $_M(x)=(x-5)/(7-5)$	$5 \leq x \leq 7$	(5.0, 7.0, 9.0)	An element is strongly favoured and its dominance is demonstrated in practice.
9	Extremely preferred	$_M(x)=(9-x)/(9-7)$ $_M(x)=(x-7)/(9-7)$	$7 \leq x \leq 9$	(7.0, 9.0, 9.0)	Evidence favours one factor over another is one of the highest possible affirmative orders
Reciprocals	When activity '*i*' compared to '*j*' is assigned one of the above numbers, the activity '*j*' compared to '*i*' is assigned its reciprocal			Reciprocals of the above $M^{-1}(1/u,1/m,1/l)$	
Rational	Ratios arising from forcing consistency of judgments				

Source: Prepared by the authors (2023)

Table 1 Maps AHP scale to its corresponding fuzzy AHP comparison scale, based on the linguistic variables that describe the importance of criteria. These criteria help evaluate the alternatives being compared (in this case, Blockchain). This is to improve the scaling scheme for the judgment matrices. Employing TFNs via pairwise comparison, the fuzzy judgment matrix A(a_{ij}) is mathematically expressed as shown in Eq. (4.2)

$$A = \begin{Bmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1(n-1)} & a_{1n} \\ a_{21} & 1 & a_{23} & \cdots & a_{2(n-1)} & a_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{(n-1)1} & a_{(n-1)2} & a_{(n-1)3} & \cdots & 1 & a_{(n-1)n} \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{n(n-1)} & 1 \end{Bmatrix} \quad (4.2)$$

The judgment matrix A is an "nXn" fuzzy matrix which constitutes fuzzy numbers "a_{ij}".

$$a_{ij} = \begin{cases} 1 & \text{if } i = j \\ 1,3,5,7,9\ (or)\ 1^{-1}, 3^{-1}, 5^{-1}, 7^{-1}, 9^{-1} & \text{if } i \neq j \end{cases} \quad (4.3)$$

Let's consider

$X = \{x_1, x_2, x_3, \ \dots \ x_n\}$ as an object set and

$U = \{u_1, u_2, u_3, \ \dots \ u_n\}$ as its corresponding goal set.

Fuzzy extent analysis methods can be performed with respect to each object for each corresponding goal "g_i" resulting in "m" extent analysis values for each object. This can be mathematically represented as

$$M_{g_i}^1, \ M_{g_i}^2, \ \dots, \ M_{g_i}^{(m-1)}, \ M_{g_i}^m$$

$M_{g_i}^j$, $(j = 1,2 \dots, m)$ are TFN, which represent the performance of the object x_i with respect to the goal u_j.

Kahraman (2003) has detailed out the extent analysis of Chang (1992) as follows

- ***Step 1***

Fuzzy synthetic extent value for the i^{th} element is calculator as

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \quad (4.4)$$

The factor($\sum_{j=1}^{m} M_{g_i}^{j}$), can be computed by performing fuzzy addition ("m range analysis") operations for a particular matrix. The “m extent analysis” values for given matrix will be,

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j ,\ \sum_{j=1}^{m} m_j ,\ \sum_{j=1}^{m} u_j\right) \qquad (4.5)$$

Similarly, the factor ($\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} - 1$), is computed by doing the fuzzy addition operation on $M_{g_i}^{j}$(j = 1, 2, 3 . . . m) values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i ,\ \sum_{i=1}^{n} m_i ,\ \sum_{i=1}^{n} u_i\right) \qquad (4.6)$$

Also, compute the inverse of the values as below

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left[\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right] \qquad (4.7)$$

- ***Step 2***

The degree of possibility for $M_2 \geq M_1$ is represented as

$$V(M_2 \geq M_1) = \sup\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right], \quad y \geq x \qquad (4.8)$$

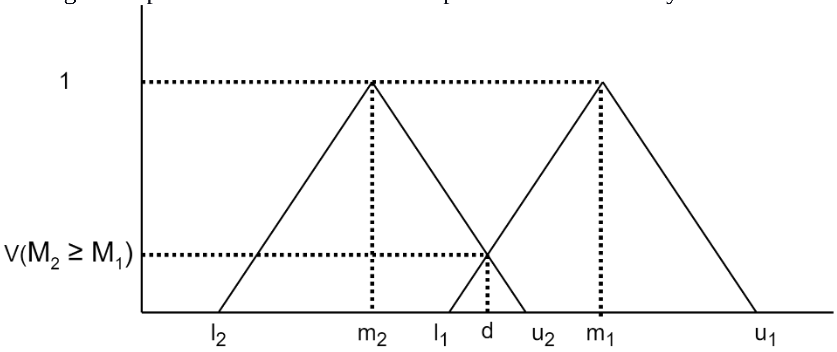
And x and y are values on the axis of the membership function of each criterion. Therefore, this can be defined as follows.

$$V(M_2 \geq M_1) = hgt(M_2 \cap M_1) = \mu_{M_2}(d)$$

$$= \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \qquad (4.9)$$

Where “d” is the value at the highest intersection point D between μ_{M_1} and μ_{M_2}. To evaluate M1 and M2 both values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$ are computed. Refer to the image (Fig. 3)

Fig. 3. Representation of intersection point between 2 fuzzy numbers.



Source: Prepared by the authors (2023)

- ***Step 3***

Compare the degree of possibility among the criteria. The comparison between degrees of possibility between M_i $(i = 1, 2, 3, 4, 5 \ldots k)$ can be defined by:

$$V(M \geq M_1, M_2 \ldots M_k) = V((M \geq M_1), (M \geq M_1) \ldots (M \geq M_k)) \text{ and } V(M > M_i), (i = 1, 2, 3, \cdots, k) \quad (4.10)$$

If we consider that the

$$d'(A_i) = \min(S_i \geq S_k) \ for \ k = 1, 2, \cdots, n \ and \ k \neq i \quad (4.11)$$

Then the weight vector is given by

$$W' = \left(d'(A_1), d'(A_2), \cdots, d'(A_n)\right)^T \quad (4.12)$$

Where A_i ranges from 1 to n

- ***Step 4***

The normalized weight vector is given by

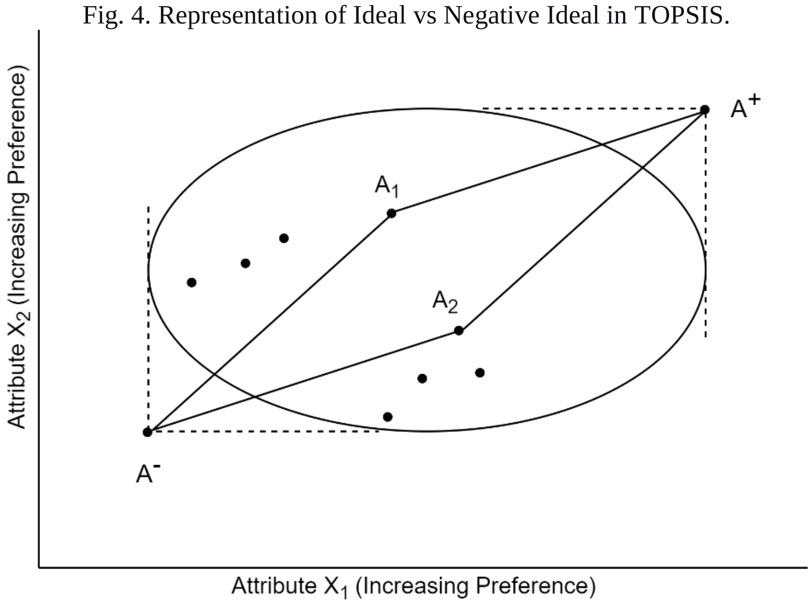
$$W = \left(d(A_1), d(A_2), \cdots, d(A_n)\right)^T \quad (4.13)$$

Where “W” is a non-fuzzy number of the weight vector

Fuzzy TOPSIS Procedure

Yoon and Hwang (1981) developed TOPSIS. Basic concept of TOPSIS is that the distance between the selected alternative and the ideal solution will be minimal and farthest from most unlikely solution (refer to Fig. 4). Here A- represents the negative ideal solution (most unlikely solution) and A+ represents the ideal solution.

Fig. 4. Representation of Ideal vs Negative Ideal in TOPSIS.



Source: Prepared by the authors (2023)

It is difficult for someone to assign a precise rating to an alternative for the criteria under consideration. The merit of using a fuzzy approach lies in its ability to accommodate the relative importance of criteria using fuzzy numbers instead of precise numbers. In the fuzzy environment, various criteria scales used for comparison are normalized. According to Chen (1992), the procedure of fuzzy TOPSIS can be expressed in a series of steps.

- ***Step 1:***

The linear scale transformation can be expressed as below

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j}, \frac{b_{ij}}{c_j}, \frac{c_{ij}}{c_j}\right), \quad c_{ij} = \max_i c_{ij} \qquad (5.1)$$

Jahanshahloo et al. formula for "r_{ij}" is

$$\widetilde{r_{ij}} = \left(\frac{a_{ij}}{\sqrt{\left(\sum_{i=1}^{n}\left[(a_{ij})^2 + (c_{ij})^2\right]\right)}}, \frac{b_{ij}}{\sqrt{\left(\sum_{i=1}^{n}(2a_{ij})\right)}}, \frac{c_{ij}}{\sqrt{\left(\sum_{i=1}^{n}\left[(a_{ij})^2 + (c_{ij})^2\right]\right)}} \right) \quad (5.2)$$

Where $\widetilde{X} = (a_{ij}, b_{ij}, c_{ij})$ repesents the elements of the decision matrix. The decision matrix is as below

$$\widetilde{X} = \begin{Bmatrix} \widetilde{x} & \widetilde{x}_{12} & \widetilde{x}_{13} & \cdots & \widetilde{x}_{1(n-1)} & \widetilde{x}_{1n} \\ \widetilde{x}_{21} & \widetilde{x}_{22} & \widetilde{x}_{23} & \cdots & \widetilde{x}_{2(n-1)} & \widetilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \widetilde{x}_{(j-1)1} & \widetilde{x}_{(j-1)2} & \widetilde{x}_{(j-1)3} & \cdots & \widetilde{x}_{(j-1)n} & a_{(n-1)n} \\ a_{j1} & a_{j2} & a_{j3} & \cdots & a_{j(n-1)} & \widetilde{x}_{jn} \end{Bmatrix} \quad (5.3)$$

- ***Step 2:***

Construct the weighted normalized decision matrix.

$$\widetilde{v_{ij}} = \widetilde{w_j} \cdot \widetilde{r_{ij}}, \; i = 1, 2, \cdots, m \; and \; j = 1, 2, \cdots, n \quad (5.4)$$

- ***Step 3:***

Determine the fuzzy ideal and fuzzy negative-ideal solutions.

$$A^+ = \{\widetilde{v_1^+}, \widetilde{v_2^+}, \cdots, \widetilde{v_m^+}\}, \quad \widetilde{v_j^+} = \{1, 1, 1\}, \quad j = 1, 2, 3, \cdots, m \quad (5.5)$$
$$A^- = \{\widetilde{v_1^-}, \widetilde{v_2^-}, \cdots, \widetilde{v_m^-}\}, \quad \widetilde{v_j^-} = \{0, 0, 0\}, \quad j = 1, 2, 3, \cdots, m \quad (5.6)$$

- ***Step 4:***

Calculate the separation measure:

➔ Ideal separation can be calculated as follows

$$S_i^+ = \sum_{j=1}^{m} s\left(\widetilde{v_{ij}}, \widetilde{v_j^+}\right), \; i = 1, 2, \cdots, n \quad (5.7)$$

➔ Negative-ideal separation is represented by

$$S_i^- = \sum_{j=1}^{m} s\left(\widetilde{v_{ij}}, \widetilde{v_j^-}\right), \; i = 1, 2, \cdots, n \quad (5.8)$$

Where $s\left(\widetilde{v_{ij}}, \widetilde{v_j^-}\right)$ *and* $s\left(\widetilde{v_{ij}}, \widetilde{v_j^+}\right)$ are distance measurements calculated with the vertex method

$$d(\widetilde{x_{ij}}, \widetilde{y_{ij}}) = \sqrt{\left(\frac{1}{3}\left[\left(x_{ij}^{1} - y_{ij}^{1}\right)^{2} + \left(x_{ij}^{2} - y_{ij}^{2}\right)^{2} + \left(x_{ij}^{3} - y_{ij}^{3}\right)^{2}\right]\right)}$$
$$\widetilde{x_{ij}} = \left(x_{ij}^{1}, x_{ij}^{2}, x_{ij}^{3}\right) \text{ and } \widetilde{y_{ij}} = \left(y_{ij}^{1}, y_{ij}^{2}, y_{ij}^{3}\right) \qquad (6.9)$$

- ***Step 5:***

Calculate the relative closeness to the Ideal Solution.

$$c_i^{*} = \frac{s_i^{-}}{(s_i^{+} + s_i^{-})}, \quad 0 < c_i^{*} < 1 \text{ and } i = 1, 2, \cdots, n$$
$$c_i^{*} = 1 \text{ if } A_i = A^{+} \text{ and } c_i^{*} = 0 \text{ if } A_i = A^{-} \qquad (6.10)$$

- ***Step 6:***

Arrange in order of preference

a) Prioritise alternatives in descending order of c_i^{*}

b) The utility of each criterion in the decision matrix will be monotonically increasing or decreasing.

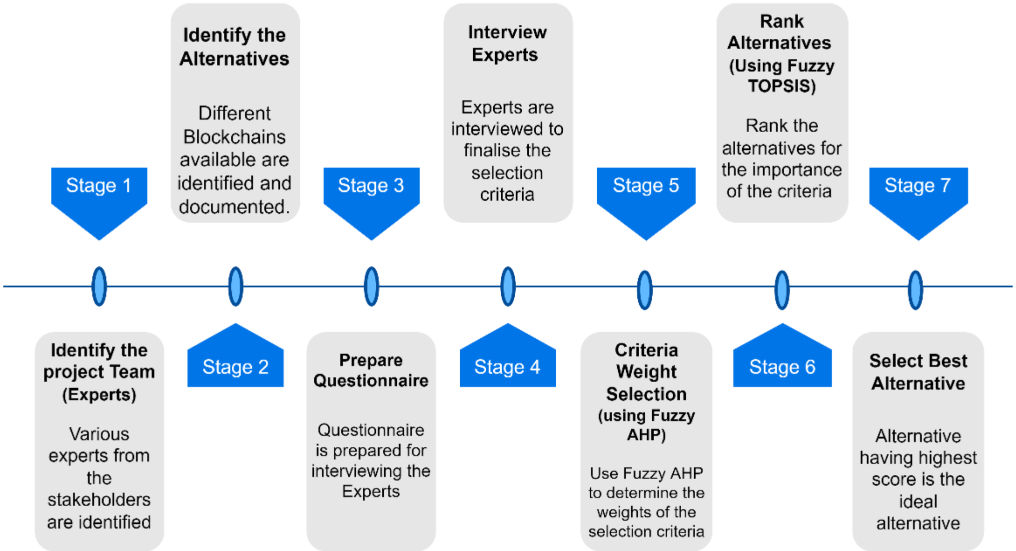
c) It is required to have a decision matrix of m criteria, n alternatives and a set of weights for the criteria.

d) Quantify non-numerical outcomes using appropriate scaling technique.

Framework for Blockchain Selection: An Executive Support System

An Executive Support System was devised based on the research conducted and the studies done to identify the suitable Blockchain for a particular application. Essentially, this system has seven stages, as shown in the below diagram (*Fig. 5*)

Fig. 5. Executive Support System Process Flow.



Source: Prepared by the authors (2023)

Stage 1 - Identify the Project Team:

The Project Team is the "Expert" team responsible for providing input for selecting the Blockchain platform. This team should consist of various stakeholders in the project. These people must be well versed in their area. Meaning, Blockchain solutions developed for a Marketing should have knowledgeable people from marketing domain. It would be nice if these people have some prior knowledge in Blockchain, though it is not mandatory. These people can do some self-learning or internal brainstorming to acquire some fundamental knowledge in Blockchain.

Stage 2 - Identify Alternatives:

Conduct a survey to identify the various alternatives. The alternatives are determined by surveying the technical market or by discussing with vendors or Blockchain consultants. Remember that the consultant may be savvy in the Blockchain, but may not be well equipped to solve the particular problem of the organization.

Stage 3 - Prepare a Questionnaire to Interview the experts:

Prepare a questionnaire based on the ISO/IEC 25010 to identify the import traits of the Blockchain which is necessary to solve the problem at hand. Subsequent steps use this questionnaire to discuss with the experts. ISO/IEC 25010 being generic, it may describe some characteristics which may seem irrelevant to the problem at hand. But don't worry at this stage about it. Subsequent steps will clear it

Stage 4 - Interview Experts to finalize the criteria:

Interview Experts using the Delphi technique. The interview has to be structured to identify the essential criteria, making a particular Blockchain fit for use. The rationale behind using Delphi is because it has the below fundamental characteristics:

(1) anonymous response

(2) controlled feedback

(3) iterative

(4) statistical group responses.

Because of these characteristics, Delphi is ideal for interviewing experts. Propagate responses incrementally to build a knowledge base that is acceptable to everyone. Experts may have to answer the question more than once. After each round of answering, collate the responses, and share the summary of responses anonymously. The experts are free to revise their answers. Repeat the process to achieve a stable, acceptable result. Two sets of inputs are available at the end of this stage

(1) Alternatives on the Blockchain platform

(2) The criteria that were necessary to select the Blockchain.

The subsequent steps combine these two inputs to identify a suitable Blockchain platform.

Stage 5 - Employ Fuzzy AHP to finalize criteria:

Once we have the final list of criteria, Fuzzy AHP is employed to calculate the weights of each criterion. It is not always possible to rate the criteria as an absolute crisp number. There will always be vagueness in evaluation criteria. So, to accommodate this vagueness and human's natural ways of expressing and thinking, we recommend using fuzzy AHP to calculate the weights.

Stage 6 - Employ Fuzzy TOPSIS to rank alternatives based on the Criteria:

Compute distance from positive ideal solution and the negative ideal solution. Also compute the closeness coefficient. Rank the Blockchain using the closeness coefficient.

Stage 7 – Select Best Alternative

The Blockchain which has the highest closeness coefficient in the TOPSIS output is the ideal solution. This is the Blockchain which address the business problem at hand more optimally than other alternatives.

Case Study

The validity of the solution is tested on an exploratory theory-testing case study. The above-formulated methodology was applied to a real-world problem to test its efficacy. The selected company is a mid-sized manufacturing enterprise, which manufactures wiring harnesses for automobiles. It manufactures a wide range of wiring harnesses for a wide variety of automobiles. The company procures various parts of the harness from different vendors and assembles it into a finished product based on the specifications provided by the automobile companies. The company has implemented a limited supply chain management solution to its manufacturing process. The company has a strong reputation because of its quality. As a part of the company's Industry 5.0 transformation, the company plans to provide an auditable, fool-proof mechanism for its end customers to verify its quality standards. As part of this transformation, they are sharing some of the company's supply chain and quality data in a verifiable manner. To do this, the company plans to employ Blockchain to store data that is of interest to other organizations in the supply chain. The company had to select one of the many Blockchain platforms available in the market. A hybrid fuzzy MCDM approach described earlier was employed to tackle the Blockchain platform selection problem.

Stage 1 - Identify the Project Team:

A project team consisting of four engineers and two managers working for the company was established. Detailed interviews were conducted to ascertain the Blockchain features needed for the company.

Stage 2 - Identify Alternatives:

Market scanning was done to identify the Blockchain platforms available. After a series of discussion with vendors, the following platforms were shortlisted (represented by A1 through A5 for convenience) - Ethereum (*A1*), Corda (*A2*), IBM Blockchain (*A3*), Hyperledger fabric (*A4*), Quorum (*A5*). The features of the Blockchain were documented for further use in the next steps.

Stage 3 - Prepare a Questionnaire to Interview the experts:

An elaborate questionnaire describing the qualitative and quantitative criteria for the Blockchain was created using the ISO/IEC 25010.

Stage 4 - Interview Experts to finalize the criteria:

A series of interviews were conducted, and ten criteria were determined as needed for the Blockchain platform. The criteria are Accountability, Integrity, Authenticity, Accessibility, Learnability, Maturity, Time Behaviour (*performance*), cost, Functionality compliance (*Smart contracts*), and Maintainability.

During the initial research, it was observed that all the alternatives had the same characteristics in terms of Accountability, Integrity, Authenticity, Accessibility, and Learnability. So, these criteria were excluded from the decision-making process. The criteria which were considered for decision making were reduced to five, namely - Maturity [*C1*], Time Behaviour (*performance*) [*C2*], cost [*C3*], Functionality compliance (*Smart contracts*) [*C4*], and Maintainability [*C5*].

Stage 5 - Employ Fuzzy AHP to finalize criteria:

Five experts selected from different departments were assigned the tasks of rating the above-selected criteria based on their opinion using the five-point scale described in Table 1. Based on the preferences provided by the Experts, Weights of the criteria were computed using Fuzzy AHP. The computed weights and their ranks are shown in Table 2. As shown in the table, Functionality compliance (Smart contracts) [C4] is the foremost important criteria. Next priorities are assigned to Maturity [C1], Time Behaviour (performance) [C2], Cost [C3] and Maintainability [C5] according to the obtained weights.

Table 2. Calculated Ranking of Criteria.

Rank	Criterion name	Criterion weight
2	Maturity [C1]	0.203
3	Time Behaviour(performance) [C2]	0.2
4	Cost [C3]	0.195
1	Functionality compliance (Smart contracts) [C4]	0.213
5	Maintainability [C5]	0.189

Source: Prepared by the authors (2023)

Stage 6 - Employ Fuzzy TOPSIS to rank alternatives based on the Criteria:

The experts were requested to rank the alternatives based on the criteria. The experts again used the five-point scale in Table 1 for this step. Based on the data provided by the experts, the below table (table 3) was computed. It shows the geometrical spatial distance of each alternative from the ideal solution.

Table 3. Calculated Geometrical Spatial Distance.

Alternatives	*Distance from positive ideal*	*Distance from negative ideal*
Ethereum(A1)	1.112	4.324
Corda(A2)	1.127	4.315
IBM Blockchain(A3)	1.892	3.58
Hyperledger fabric(A4)	1.039	4.44
Quorum(A5)	5.025	0.411

Source: Prepared by the authors (2023)

The closeness coefficient is also calculated, and the alternatives are ranked based on this coefficient as shown in table 4.

Table 4. Calculated Closeness Coefficient.

Alternatives	*Ci*	*Rank*
Ethereum(A1)	0.795	2
Corda(A2)	0.793	3
IBM Blockchain(A3)	0.654	4
Hyperledger fabric(A4)	0.81	1
Quorum(A5)	0.076	5

Source: Prepared by the authors (2023)

RESULTS AND DISCUSSION

Based on the above results, Hyperledger fabric (*A4*) is the ideal platform for the company. This choice is also in conformity with almost all the expert decisions. On the other hand, Quorum, which ranked fifth, was the least preferred one. The reason for this is the fact that Quorum is more inclined towards the financial industry. It was deduced during the analysis that Quorum is basically a permissioned version of Ethereum without a cryptographic token or mining-based consensus-mechanism. Its strength does not lie in the supply chain management nor in the manufacturing segment. Experts in the organization were not very inclined towards the Support (quality of Maintainability). They had it covered by other means. IBM Blockchain lost its charm because of this. Corda Was another attractive alternative to consider, but this is again more inclined towards the financial industry. Even though it seems like a good choice currently, there is no guarantee that it will be a good fit for Manufacturing and SCM-related operations. It scores less in Maturity when compared to Hyperledger. Ethereum seems like an amicable solution, but it is behind Hyperledger in terms of performance. It can be inferred that the Hyperledger is the right choice for the company for which this case study was carried out.

CONCLUSION

A comprehensive framework for Blockchain selection was developed using ISO/IEC 25010 and integrated MCDM. The solution was designed to be industry-agnostic, making it applicable to any business problem that could be solved using Blockchain. To test the framework's applicability, it was implemented in a manufacturing ancillary unit. The framework successfully helped decision makers identify which aspects of their business problem could be solved using Blockchain. This was made possible because of using ISO/IEC 25010 to express Blockchain's capabilities. Despite having multiple functional and non-functional requirements, Fuzzy AHP was able to help decision makers prioritize their needs, while Fuzzy TOPSIS helped them select the most suitable Blockchain platform without ambiguity. Fuzzy variants of MCDM employed in developing the framework, aided decision makers to express the business needs in natural language without any constrains

The framework's effectiveness was evaluated over an extended period, and its applicability was established. However, future implementations of the framework could consider the following factors for improvement:

1. Updating the framework to include new software quality standards as they become available or when the ISO/IEC 25010:2011 is updated.
2. Exploring other combinations of MCDM to enhance the framework's versatility.
3. Building an automated solution using software tools to streamline the selection process further.
4. Implementing the framework across various industries and use cases to validate its adaptability.

By considering these factors, the framework can be further enhanced to address the ever-evolving needs of businesses and industries.

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